

Comparative Analysis of Fiber Optic Voice Link Using Intensity Modulation in Commercially Available Optical Fibers

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Abstract— Communication is the method by which two persons can share any meaningful information with each other at an instant. It requires a sender who wants to communicate, message which is to be conveyed & receiver who receives this message at the receiver end. Now a days due to the advancements and technology, digital communication is receiving wide attention among researchers. Digital communication is achieved by sending digital messages in form of pulses 0 & 1 through modem. Modem is mediator to transfer the message which consists of both modulator & demodulator. The communication can only be possible with modulation. In this paper, the digital communication link is established using the fiber optic voice link technique which uses intensity modulation in different optical fibers such as step index, graded index & glass optical fibers. Intensity modulation is basically the modulation in which output power of the source varies in accordance with modulating signal. In FM optical communication system, even if an electrical base band signal is used to modulate the frequency of electrical carrier, it is still the parameter which works i.e. intensity of light wave varies with the electrical FM carrier. The purpose of this paper is to study the switched faults in fiber optic voice link in different fibers using intensity modulation with the help of ST-2502. The switched faults are basically used to find out the fault conditions in FM modulation system.

Keywords— Intensity Modulation, Frequency Modulation, Fiber Optic Cables

I. INTRODUCTION

Communication may be defined as - "A process by which facts, ideas, opinions, thoughts and information can be shared through speech, writing, gestures or symbols between two or more persons". . Modulation is the method in which the instantaneous frequency of a sine wave carrier is caused to depart from the center frequency by an amount proportional to the instantaneous value of the modulating signal. There are different types of modulation such as frequency modulation, intensity modulation, and pulse width modulation. Here we are considering only FM modulation. In the traditional form of FM the carrier frequency is changed or modulated by the amplitude of the analog signal. In a fiber optic

system. Intensity modulation (IM) [5] is a form of modulation in which the intensity of the light wave varies or modulated by the electrical FM carrier. In this paper, the comparative analyses of available optical fibers through fiber optic voice link using intensity modulation is done by finding the switched faults in FM modulation system. Flexible transparent fiber devices, sometimes called light guides are used for either image or information transmission. In these devices light is propagated by total internal reflection. The three basic elements of fiber optic cable are core, cladding and coating over the fiber. The first element is Core, light transmission area of the fiber, either glass or plastic. The larger the core, the more light will be transmitted into the fiber. The next element is the Cladding. The function of the cladding is to provide a lower refractive index at the core interface in order to cause the reflection within the core so that the light wave transmitted over the fiber.

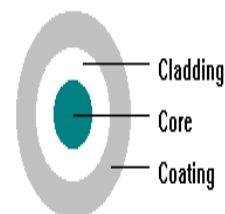


Figure 1. Elements of optical fiber

Coatings are usually multi-layers of plastics applied to preserve fiber strength, absorb shock and provide extra fiber protection. There are three basic types of optical fibers. Propagation in these light guides is most easily done only by ray optics. In a multimode, stepped-refractive-index-profile fiber, the number of rays or modes of light are guided, core size will determine the amount of light power coupled into the light guide and thus the core-cladding refractive index difference can be found out. Refractive Index profiles of a multimode, stepped-refractive-index fiber as shown in figure 3. Such fibers, used for conventional image transfer, are limited to short distances for information transmission due to pulse broadening. An initially sharp pulse made up of many modes broadens as it travels long distances in the fiber, since high-angle modes have a longer distance to travel relative to the low-angle modes.

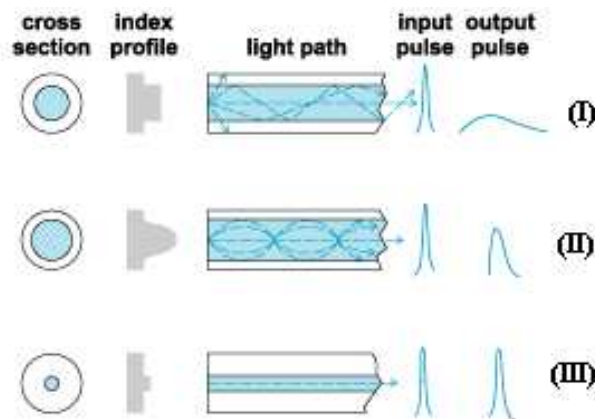


Figure 2 Types of optical fiber designs. (I) Multimode, stepped-refractive-index-profile. (II) Multimode, graded-index-profile. (III) Single-mode, stepped-index.

A graded-index multimode fiber, where the core refractive index varies across the core diameter, is used to minimize pulse broadening due to intermodal dispersion. Refractive Index profile of a graded-index multimode fiber is shown in figure 4. This type of fiber is suitable for intermediate-distance, intermediate-bit-rate transmission systems. Graded

index fibers are commercially available with core diameters of 50, 62.5 and 100 microns. [8] The single mode fiber allows only a single light ray or mode to be transmitted down the core. This virtually eliminates any distortion due to the light.

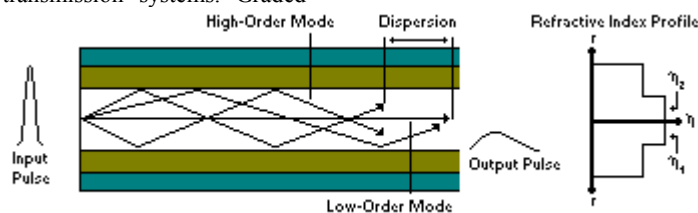


Figure 3. Refractive Index profile of a multimode, stepped-refractive-index fiber

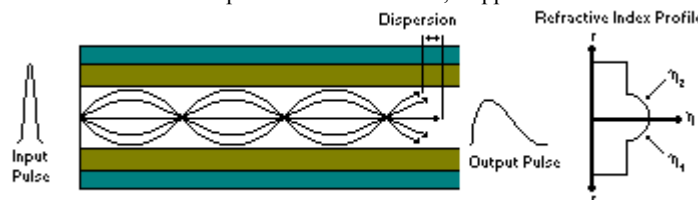


Figure 4. Refractive Index profile of a graded-index multimode fiber

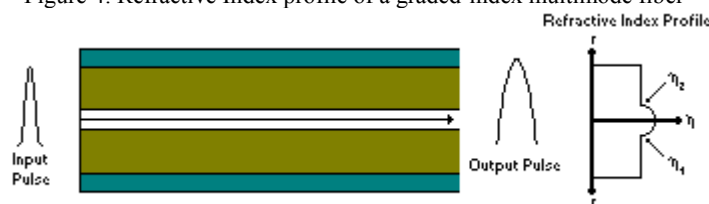


Figure 5. Refractive Index profile of a single-mode fiber

A single-mode fiber is designed with a core diameter and refractive index distribution such that only one fundamental mode is guided, thus eliminating intermodal pulse-broadening effects. [1]Refractive Index profile for a single-mode fiber is shown in figure 5. The core of the single mode fiber is extremely small, approximately five to ten microns.

II. Communication

The way of the Communication is to convey information, messages, opinions, speech and

thoughts via different forms of modern communication media, like, e-mail, telephone and mobile [14] Communication needs sender, who sends the message known as source and the other 'Receiver', who is end point at which message is received & the message which is the subject of communication includes facts, ideas, feelings or thoughts.. After the receiver understands the message and gives the feedback to the source then the process of communication is said to be complete . The feedback is considered to be a very essential element in the process of communication along with

message, sender and receiver. Different mediums can be used to transmit a message from source to destination and getting feedback known as means of communication.

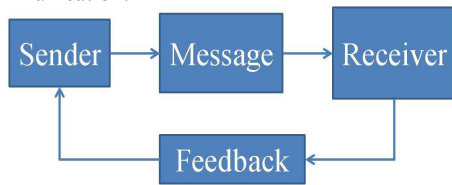


Figure 6. Communication

III. MODULATION

Modulation is the process of varying one or more properties of a high-frequency periodic waveform, called the carrier signal, with a modulating signal which typically contains information to be transmitted. There are three key parameters of a periodic waveform i.e. amplitude ("volume"), its phase ("timing") and its frequency. Any of these properties can be modified in accordance with a low frequency signal to obtain the modulated signal. Modulation of a sine waveform is used to transform a baseband message signal into a pass band signal, for example low-frequency audio signal into a radio-frequency signal (RF signal). [11] A device used to perform modulation is known as a modulator and a device that performs the inverse operation of modulation is known as a demodulator or detector. A device that can do both operations is called modem (modulator-demodulator). There are different types of modulation used analog modulation, digital modulation. Analog modulation is used to transfer the low frequency signal over an analog band pass channel. Common techniques of analog modulation are amplitude modulation & digital modulation. Amplitude modulation in which the amplitude of the carrier signal is varied in accordance to the instantaneous amplitude of the modulating signal. Digital Modulation is used to transfer a digital bit stream over an analog band pass channel of fixed frequency range. For example over the public switched telephone network (where a band pass filter limits the frequency range to between 300 and 3400 Hz), In digital modulation, an analog carrier signal is modulated by a discrete signal. Digital modulation methods can be considered as digital-to-analog conversion, and the corresponding demodulation or detection methods as analog-to-digital conversion.

Analog and digital modulation facilitate frequency division multiplexing (FDM), where several low pass information signals are transferred simultaneously over the same shared physical medium, using separate pass band channels. Pulse modulation methods is used to transfer a narrowband analog signal, for example a phone call over a wideband baseband channel. In music synthesizers, modulation may be used to synthesize waveforms with a desired overtone spectrum. In this case the carrier frequency is typically in the same order or much lower than the modulating waveform. See for example frequency modulation synthesis or ring modulation.

2 INTENSITY MODULATION

Modulation in which the instantaneous frequency of a sine wave carrier is caused to depart from the center frequency by an amount proportional to the instantaneous value of the modulating signal. There are different types of modulation such as frequency modulation, intensity modulation, and pulse width modulation. Here we are considering only FM modulation.

In the traditional form of FM the carrier frequency is changed or modulated by the amplitude of the analog signal. In a fiber optic system, this is not feasible since both are light sources, the LED and the LASER, are fixed frequency devices. In fiber optic systems, FM is achieved by using the original analog input signal to vary the frequency of a train of digital pulses. A circuit called Voltage controlled Oscillator usually abbreviated as VCO achieves this. The digital pulses are communicated through the optic fiber and squared up at the receiver by a comparator in the same way as it was in amplitude modulation system.

At this point we convert the digital train back to the original analog signal by means of the Pulse Locked Loop Detector (PLL). The PLL circuit performs a very simple function. It monitors an incoming signal and produces a DC Voltage increases. If the frequency decreases, the DC voltage decreases. In this way the original analog signal is recovered. The output of the PLL contains many unwanted frequency components. A low pass filter removes these and then finally the signal is amplified to a desired level.

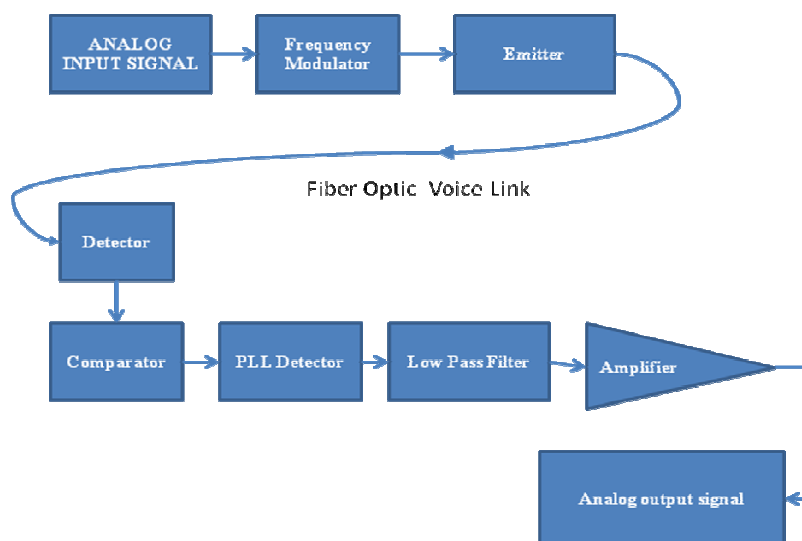


Figure 7. Frequency Modulation System

IV. METHODOLOGY

4.1 INTRODUCTION TO OPTICAL FIBER TRAINER ST-2501

ST2502 is a single board fiber optic transmitter-receiver module providing two independent fiber optic communication links. The module may be configured to establish an analog link also it may be used to provide a full two way serial fiber optic communication link between two micro computers. The module contains following functional blocks such as Two fiber optic emitter circuit each with analog and digital driver, Two fiber optic detector circuits, Frequency modulation circuit, Phase locked loop detector circuit for FM detection, Two receiver low pass filters, Two receiver A.C. Amplifier circuits with adjustable gain, Two receiver voltage comparator circuits, Function generator providing 1 KHz sq. wave and adjustable amplitude sine wave output, RS232 interface, Audio Input Block, Audio Output Block.

4.2. SWITCHED FAULTS IN OPTICAL FIBER TRAINER

The switched faults are basically used to introduce fault conditions within the circuit on the ST2502 board. Each Switch controls single fault condition to provide normal operation. These switched faults are of eight types. It is essential that all the switched faults are set to off.

Switched Fault 1

Removes the bias normally present on emitter 1's LED in analog mode, so that distortion occurs when analog amplitude modulation takes place.

Switched Fault 2

Open circuits the feed back loop of the first stage of detector 2's voltage amplifier so that the final amplifier O/P tp.12 saturates.

Switched Fault 3

Break the input circuit to comparator 1, so that incoming signals can never cause the comparator to switch, irrespective of the bias 1 present position.

Switched Fault 4

This fault affects the phase locked loop detector, by breaking the loop between the voltage controlled oscillator (VCO) and phase comparator (exclusive OR gate). The result is that the phase locked loop no longer follows changes in frequency of the input signal.

Switched Fault 5

If short circuits the output and negative of A.c. amplifier 2, so that amplifier gain is always +1, irrespective of the position of the gain adjust preset.

Switched Fault 6

Change the d.c. bias on the frequency modulators VCO input from +2.5V to 0V, so that VCO no longer oscillates, irrespective of the signal applied to its input.

Switched Fault 7

Switches OFF constant current source to pulse width modulator, so that output level of modulator is permanently high.

Switched Fault 8

This shorts pin 11 'R' of IC9 to junction of R90 & C32.

4.3. GENERATION OF MODULATING FREQUENCY SIGNAL

In this work, Frequency modulation using fiber optic trainer ST2501 is taken up for the study. The following points are to be taken care of during experimentation. All switched faults are should be set to OFF position.

Frequency modulator is given an input of 1 kHz sine wave signal using Function Generator. Frequency modulator output tp2 is given to the emitter1 input at tp5. [10] The optical fiber is connected between the emitter 1 circuit and the detector1 circuit. Detector1 output tp10 is given to comparator 1 input at tp14. Comparator1 output at t p 15 to the PLL detector input at t p 23. PLL detector output at t p 26 to the low pass filter1 input at t p 19. Low Pass Filter1 output t p 20 to AC Amplifier1 input at t.p.27. Switch emitter 1's driver to digital mode.

Initially, the function generator output amplitude is set to zero. Monitor the output of the voltage controlled oscillators (VCO) in the frequency modulator block t p 2. It is noted that the frequency

of this digital signal is constant, since the modulating sine wave has zero amplitude. By examining the output of detector1 (t.p.10), it is found that the transmitted digital pulses are successfully detected at the receiver. The output of the detector is fed to comparator which is examined using the dual trace oscilloscope as shown in figure 8. Now adjusts the bias 1 preset until the bias input at t.p.13 is halfway between the top and the bottom of the square wave on t.p.14. The function of the comparator is to clean up the square wave after its transmission through the fiber optic link.

The output of comparator 1 drives the input of the PLL detector, which produces a signal whose average level is proportional to the frequency of the digital stream. This average level is then extracted by low pass filter 1 and amplified by A.C.Amplifier1 to produce the original analog signal at the amplifier output t p 28. By examining tp28, it is noted that the output voltage is zero. This is expected since there is currently no modulating voltage at the transmitter.

While monitoring the input to the frequency modulator block tp1 and the output from A.C.Amplifier1 t.p.28 turn the 1 KHz preset to its fully clockwise maximum amplitude position. Note that the modulating 1 kHz signal now appears at the amplifiers output. Adjust the amplifiers gains adjust 1 preset until the two-monitored signals are equal in amplitude. The inputs and the outputs of all functional blocks within the system are examined using an oscilloscope to understand the frequency modulation system.

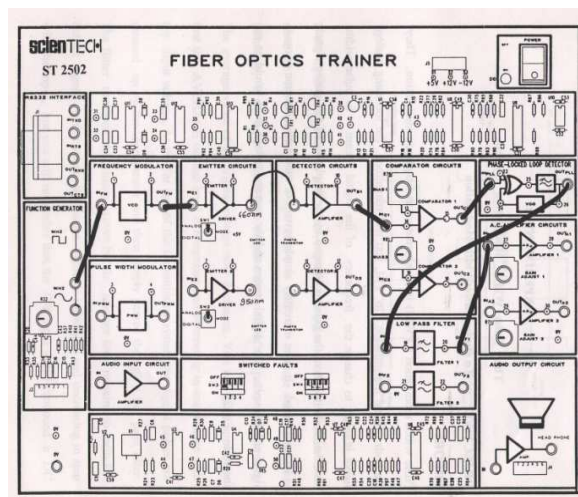


Figure 8. Fibre optic trainer showing connections of FM modulation system

4.4. Voice transmission through optic fiber using Frequency Modulation.

Disconnect the function generator and Plug the Microphone in the input of Audio input block. [12]Attach the output of Audio input block to input of FM block, where the function generator was connected earlier. Output of AC Amp block is connected to input of Audio output block. Switch on the Power supply. Speak in the Microphone and

listen the same in the speaker / Headphone. Hence a voice link is established through different optical fiber cables used connecting between emitter and detector.

4.5. Effect of fault no. 6 & 8 in FM System.

Connect power supply to board and set the emitter to digital mode.3. Again reset the complete FM System as explained above. Switch ON the power. [13]After this check that FM System is operating correctly. The preset in AC Amplifier block is adjusted to give a sinusoidal signal of amplitude same as input. Switch fault 6 is set to be ON. This changes the DC bias on frequency Modulator VCO input from +2.5V to 0V, So that the VCO no longer oscillates irrespective of the signal applied to its input. Observe the system output and the FM block's output. Set the switch fault 6 to OFF and Switch fault 8 to be ON. This will short the R pin 11 of IC 9 to junction of R90 & C32. Observe the output of system and also PLL output. Switch OFF fault 8 and check the operation of FM System.

V. RESULTS \$ DISCUSSION

This paper studies the effects of frequency modulation on different types of cables namely 1M STEP INDEX PMMA, 2M GLASS and 1M GRADED INDEX OPTICAL FIBER cables.

5.1. TO STUDY THE FREQUENCY MODULATION SYSTEM with INPUT as a SINE WAVE

The frequency modulation reception in the system is done using different types of fiber optic links. From the experimental results it is found that while using 1M STEP INDEX PMMA CABLE, output amplitude decreases from 10.5 V to 6.0 V, and in 1M GLASS CABLE it again decreases from 0 V where as in 1M GRADED INDEX OPTICAL FIBER CABLE, output of A.C. AMPLIFIER increases from 5.24V to 5.29V. Hence it is noted that 1M GRADED INDEX OPTICAL CABLE gives better results for the given operating conditions as compared to 1M STEP INDEX PMMA CABLE and 1M GLASS CABLE. It is also found that output of VCO and comparator is displayed only in case of 1M GRADED INDEX optical fiber, which shows the superiority of 1M graded index optical fiber cable over the other cables used in the present work.

Table 1: Comparison of parameters of different fiber optic cables in Frequency Modulation

1M STEP INDEX PMMA cable	1M GLASS CABLE	1M GRADED INDEX OPTICAL FIBER CABLE
INPUT AMPLITUDE = 10.5 V	INPUT AMPLITUDE = 10.5 V	INPUT AMPLITUDE = 5.24 V
OUTPUT AMPLITUDE AT A.C AMPLIFIER = 6.0 v	OUTPUT AMPLITUDE AT A.C AMPLIFIER = 0.24 V	OUTPUT AMPLITUDE AT A.C AMPLIFIER = 5.29 V
OUTPUT OF VCO=0 V	OUTPUT OF VCO=STRAIGHT LINE	OUTPUT OF VCO=4.7 V
OUTPUT OF COMPARATOR=0V	OUTPUT OF COMPARATOR=0 v	OUTPUT OF COMPARATOR=5.09 V

5.2. To study voice transmission through optic fiber using FM.

After studying the frequency modulation we have to establish a fiber optic voice link using FM. First of all disconnect the 1 KHz sine wave output from input of FM block. Plug the Microphone in the input of Audio input block , Output of Audio input block to

input of FM block and Output of AC Amp block to input of Audio output block. Then Switch on the Power supply. Speak in the Microphone and listen the same in the speaker / Headphone. Hence a voice link is established through different optical fiber cables used connecting between emitter and detector.

5.3. SWITCHED FAULTS IN FREQUENCY MODULATED SYSTEM

Table 2 input at the emitter

INPUT	INPUT AMPLITUDE	TIME
Sine Wave	0.040 mv	2.2 msec

Table 3: output at the A.C. Amplifier

OUTPUT	OUTPUT AMPLITUDE	TIME
Sine wave	4.0 v	2.2m sec

CASE 1: BY MAKING THE SWITCH 6 TO BE IN ON CONDITION.

Table 4: Comparison of parameters of different fiber optic cables in Switched fault no 6 of Frequency Modulation

System

PARAMETERS	USING 1M SI PMMA CABLE	USING 1M GRADED INDEX CABLE	USING 1M GLASS CABLE
Input at the emitter	AMPLITUDE= 0.040 MV TIME= 2MSEC	AMPLITUDE= 4.2 V TIME= 2MSEC	AMPLITUDE= 0.040 V TIME= 2MSEC
Output OF AC Amplifier	DISTORTED	AMPLITUDE= 8.2 V	AMPLITUDE= 2.5 V
Change in output of FM BLOCK with input	Straight Horizontal Line	OUTPUT AMPLITUDE=4.1 V	Straight Horizontal Line

EFFECT OF SWITCH FAULT 6: After establishing a voice link through different optical fibers such as glass, step and graded index optical fibers, Connect power supply to board and set the emitter to digital mode. Again reset the complete FM System using above given points. Now it is needed to study the switched faults which are used to introduce fault conditions within the circuit in ST 2502. At first it is checked that FM System is operating correctly or not. The preset in AC Amplifier block is adjusted to give a sinusoidal signal of amplitude same as input. Switch fault 6 is set to be ON. It is observed that output of FM block decreases by 0.1 V in Case of 1M GRADED INDEX CABLE where it becomes

zero in case of other optical fibers such as 1M SI PMMA CABLE & 1M GLASS CABLE. Secondly it is noted that output of A.C. Amplifier in case of 1M GRADED INDEX CABLE increases more rapidly from 4.2 V to 8.2 V, where in case of 1M GLASS CABLE, it increased from 0.040 V to 2.5 V in amplitude. Hence it is observed that VCO no longer oscillates irrespective of the signal applied to its input. At last in few words it can be said that graded index optical fiber is superior in performance as compared to others optical fibers used.

CASE 2: BY MAKING THE SWITCH 8 TO BE IN ON CONDITION.

Table 4: Comparison of parameters of different fiber optic cables in Switched fault no 8 of Frequency Modulation System

DIFFERENT PARAMETERS	USING 1M SI PMMA CABLE	USING 1M GRADED INDEX CABLE	USING 1M GLASS CABLE
Input at the emitter	AMPLITUDE= 0.040 MV TIME= 2MSEC	AMPLITUDE= 4.2 V TIME= 2MSEC	AMPLITUDE= 0.040 V TIME= 2MSEC
Output OF AC Amplifier	DISTORTED	AMPLITUDE= 7.9 V	DISTORTED
Change in output of PLL BLOCK with input	Straight Horizontal Line	AMPLITUDE=6.3 V	DISTORTED

EFFECT OF SWITCH FAULT 8: The second Switched fault is no 8 which is needed to be studied For this set the switch fault 6 to be OFF and check the operation of FM System. Then set the Switched fault 8 to be ON. It is observed that in case of 1M GRADED INDEX CABLE, output of A.C.Amplifier increases from 4.2 V to 7.9 V& output of PLL block increases up to 6.3 V which results to be good performance in comparison to others. In case of other optical fibers signal becomes zero when the switched fault 8 is set to be in ON condition. This will occur due to the fact that Switched Fault 8 will short the R pin 11 of IC 9 to junction of R90 & C32.

VI. CONCLUSION

This paper discusses the fiber optic voice link using intensity modulation in available optical fibers such as 1M GRADED INDEX, 1M SI PMMA CABLE & 1M GLASS CABLE which concludes that the performance of graded index optical fiber is found to be more better as compared to other optical fibers. Firstly FM modulation system is established through different optical fibers using ST-2502 which shows that using 1M STEP INDEX PMMA CABLE, output amplitude decreases from 10.5 V to 6.0 V, and in 1M GLASS CABLE it again decreases from 0 V where as in 1M GRADED INDEX OPTICAL FIBER CABLE, output of A.C. AMPLIFIER increases from 5.24V to 5.29V.This establishing of FM modulation system helped us to maintaining a voice link in between emitter and detector of ST-2502 which enabled us to easily transmission of voice from microphone or speaker at the input to the head phones at the output of A.C. Amplifier. Once a link is established it is needed to be find out the switched faults in FM modulation system because of which output varies through different optical fibers used. The ON condition of switched fault 6 concludes that output of FM block decreases by 0.1 V in Case of 1M GRADED INDEX CABLE where it becomes zero in case of other optical fibers such as 1M SI PMMA CABLE & 1M GLASS CABLE. Secondly it is noted that output of A.C.Amplifier in case of 1M GRADED INDEX CABLE increases more rapidly from 4.2 V to 8.2 V, where in case of 1M GLASS CABLE, it increased from 0.040 V to 2.5 V in amplitude .Hence it is observed that VCO no longer oscillates irrespective of the signal applied to its input. After this Switched fault 8 is set to be ON

which concludes that in case of 1M GRADED INDEX CABLE, output of A.C.Amplifier increases from 4.2 V to 7.9 V& output of PLL block increases up to 6.3 V which results to be good performance of graded index optical fibers in comparison to others.

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