UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ANALYSIS AND SIMULATION OF HIGH QUALITY PERFORMANCE OF OPTICAL REPEATER FOR FIBER OPTIC COMMUNICATION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology Electronic (Telecommunication) (Hons.)

by

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DECLARATION

"I hereby declare that this report is result of my own effort except for works that have been cited clearly in the references."

Signature : ……………………………….

Name : ...…………………………….

Date : ……………………………….

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology Electronic (Telecommunication) (Hons.). The member of the supervisory is as follow:

……………………………….

(Project Supervisor)

ABSTRACT

Optical repeater is a device that based on 3R Regeneration used to re-amplified, to re-shape and to re-timing the weak signal in order to ensure the information can be caught and understand at the receiver. Currently, its application can be used for long distance communication, it may reach ten to hundred thousand km. There are several methods that required for signal processing in optical repeater regeneration such by using non-linear gates, synchronization modulation and WDM regeneration. Thus the overall methods are potentially to improve the performance quality of optical repeater for future high bit rate systems and more capability and reliable systems.

ABSTRAK

Pengulangan optik adalah alat yang menggunakan “3R Regeneration” untuk membesarkan semula, membentuk semula dan melaraskan semula masa isyarat yang lemah bagi memastikan maklumat yang boleh diterima dan difahami oleh penerima. Pada masa ini, aplikasi ini boleh digunakan untuk komunikasi yang berjarak jauh, ia boleh mencapai antara 10-100,000 km. Terdapat beberapa kaedah yang diperlukan untuk pemprosesan isyarat dalam pengulangan optik seperti dengan menggunakan pintu pagar bukan linear, modulasi penyegerakan dan pertumbuhan semula WDM. Oleh itu, keseluruhan kaedah ini berpotensi untuk meningkatkan kualiti prestasi pengulangan optik untuk sistem kadar bit tinggi pada masa hadapan dengan lebih keupayaan dan sistem yang boleh dipercayai.

DEDICATION

To my beloved mother, my siblings and all my supportive friends, thank you for your help and support.

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LIST OF SYMBOLS AND ABBREVIATIONS

DCA	=	Digital Communication Analyzer
DWDM	=	Dense Wavelength Division Multiplexing
EDFA	=	Erbium-Doped Fiber Amplifier
GUI	=	Graphic User Interface
HNLF	=	Highly Non-linear Fiber
LED	=	Light Emitting Diode
OEO	=	Optical Electrical Optical
OOK	=	On-Off Keying
OBPF	=	Optical Band Pass Filter
PDFA	=	Praseodymium-Doped Fiber Amplifier
PM	=	Phase Modulator
RZ	=	Return to Zero
SBS	=	Stimulated Brillouin Scattering
SNR	=	Signal Noise to Ratio
SP	=	Self-Pulsating
SP-DFBL	=	Self-Pulsating Distributed Feedback Laser
TDM	=	Time Division Multiplexing
TOD	=	Tuneable Optical Delay
WAN	=	Wide Area Network
WDM	=	Wavelength Division Multiplexing
1 R	=	1 Regeneration

CHAPTER 1

INTRODUCTION

1.1 Background

In digital communication systems, a repeater is a device that receives a digital signal on an electromagnetic or optical transmission medium and regenerates the signal along the next leg of the medium and repeaters also remove the unwanted noise in an incoming signal. Optical repeater also a device that based on 3R Regeneration used to re-amplified, to re-shape and to re-timing the weak signal in order to ensure the information can be caught and understand at the receiver. This project will design and analyze the optical repeater parameter from the theoretical and simulation aspect. The parameter such as power loss, delay, signal-to-noise ratio (SNR) and other parameter will be affected.

1.2 Statement of Purpose

Generally, To support this communication of course need device to re-amplify, to re-shape and to re-timing to ensure the information can be caught and understand by receiver. This system required several optical devices such as WDM (Wavelength Division Multiplexing), Circulator, amplifier, synchronizer and etc. All these devices are possibly recover the weak signals along the transmission distance and thus enhance the transmission bit rates. Thus, the overall methods are potentially to improve the performance quality of optical repeater for future high bit rate systems and more capability and reliable systems. The development of the proposed techniques applied in order to achieve high quality performance of optical repeater for fiber communication.

1.3 Objectives

The objective of this project is to design and analyze the high quality performance of optical repeater by calculation, animation and simulation aspects. Since the fiber optic is one of the new fields in Malaysia, so the exploration in the optical repeater's works is very important for the future. Plus there are more exploration should be done in this project to learn on how to make an animation of optical repeater for fiber optic communication.

1.4 Scope of Works

This project is to design and analyze the high quality performance of optical repeater for fiber Optic communication. After identifying the project title, next thing to do is to study and do some research through reference materials from the internet, books and information from the industry to understands and learn more how optical repeaters function simultaneously achieving the best quality performances.

This system required several optical devices such as WDM, circulator, amplifier, synchronizer and etc. Next stage is to make an animation that shows how the optical repeater work and the processes involved in producing a better signal. After animation process, calculation involving parameters such as power loss, delay, SNR and other parameters that will be affected. Then, the next process is for the designing optical repeater system for long-distance transmission. In this application, re-amplify, re-timing and re-shape must be done to make sure the information can be caught and understand by receiver.

Three aspects are divided in this process such as calculations, simulations and measurements, where all three aspects need to achieve a certain specification before it is implemented. After all aspects of designing had reached specification, the process of analyzing the collected data implemented. Lastly, when all the process is completed, all information is arranged and starts writing a final report.

CHAPTER 2

LITERATURE REVIEW

2.1 Background Study

Fiber optic communication has revolutionized the telecommunication industry. It has also made its presence widely felt within the data networking community as well. Using fiber optic cable, optical communications have enabled telecommunications links to be made over much greater distances and with much lower levels of loss in the transmission medium and possibly most important of all, fiber optical communication has enabled much higher data rates to be accommodated.

Fiber optics had many benefits over other methods of transmitting data. The glass fibers do not conduct electricity, so they are unaffected by electromagnetic disturbances or lighting storms. In addition, the amount of information that a single fiber-optic wire can carry is greater than copper wire or wireless links.

2.1.1 Fiber-Optic Communication Systems

The development of lasers in the 1960s and low loss fibers in the early 1970s made possible the first fiber optic communication system in 1978. These systems were able to transmit signals at 100 Mb/s using multimode fibers operating near 0.85 um. Although the repeater spacing was less than 10 km, it was sufficiently large than the repeater spacing an attractive alternative for the future, thus the first generation of fiber optic system was born.(Zhi,2001)

The desire to reduce the number of regeneration units by increasing the repeater spacing of the first generation system quickly lead to the second generation system in the early 1080s. the second generation system allowed for increased repeater spacing by operating the system at the lower loss regime near 1.3 um. Additional improvements were also made in optical fiber technology by the introduction of the single mode fiber, this soon propelled the system capacity to Gb/s with repeater spacing in excess of 50 km. The system operation wavelength was further moved to 1.55 um to take advantage of the lowest fiber loss for third generation system introduced in the late 1980s. the increased propagation distance allowed by lower fiber loss and the larger fiber dispersion problem was eventually solved by using dispersion-shifted fibers and single longitudinal mode lasers to reduce the spreading of the transmitted pulse. Such systems can operate in excess of 10Gb/s with repeater spacings as large as 100km. (Zhi,2001)

The early generations of fiber-optic system on repeaters to compensate fiber loss through electrical amplification. These regeneration stations consisted of decoders to transform the information from an optical domain to an electrical domain, electronic amplifiers to reboost the signal, and transmitter to re-transform the information from the electrical domain back to the optical signal. This process was an expensive necessity. (Zhi,2001)

Optical amplifiers have paved the way to another ground-breaking technology-WDM. The WDM technique offered the ability to scale the system capacity via the same fiber by simply adding data channels using different wave-length. (Zhi,2001)

2.1.2 Chronological Development of Optical Fiber Communication

The visible optical carrier waves or light has been commonly used for communication purpose for many years. Alexander Graham Bell transmitted a speech information using a light beam for the first time in 1880. Just after four years of the invention of the telephone Bell proposed his photophone which was capable of providing a speech transmission over a distance of 200m. In the year 1910 Hondros and

Debye carried out a theoretical study and in 1920 Schriever reported an experimental work. Although in the early part of twentieth century optical communication was going through some research work but it was being used only in the low capacity communication links due to severe affect of disturbances in the atmosphere and lack of suitable optical sources. However, low frequency (longer wavelength) electromagnetic waves like radio and microwaves proved to be much more useful for information transfer in atmosphere, being far less affected by the atmospheric disturbances. The relative frequencies and their corresponding wavelengths can be known from the electromagnetic spectrum and it is understandable that optical frequencies offer an increase in the potential usable bandwidth by a factor of around 10000 over high frequency microwave transmission. With the LASER coming into the picture the research interest of optical communication got a stimulation. A powerful coherent light beam together with the possibility of modulation at high frequencies was the key feature of LASER. Kao and Hockham proposed the transmission of information via dielectric waveguides or optical fiber cables fabricated from glass almost simultaneously in 1966. In the earlier stage optical fibers exhibited very high attenuation (almost 1000 dB/km) which was incomparable with coaxial cables having attenuation of around 5 to 10dB/km. Nevertheless, within ten years optical fiber losses were reduced to below 5dB/km and suitable low loss jointing techniques were perfected as well. Parallely with the development of the optical fibers other essential optical components like semiconductor optical sources (i.e. injection LASERs and LEDs) and detectors (i.e. photodiodes and phototransistors) were also going through rigorous research process. Primarily the semiconductor LASERs exhibited very short lifetime of at most a few hours but by 1973 and 1977 lifetimes greater than 1000 hr and 7000 hr respectively were obtained through advanced device structure. (Prasenjit,2000)

The first generation optical fiber links operated at around 850 nm range. Existing GaAs based optical sources, silicon photo detectors, and multimode fibers were used in these links and quiet understandably they suffered from intermodal dispersion and fiber losses. With the advent of optical sources and photo detectors capable of operating at

1300 nm, a shift in transmission wavelength from 850nm to 1300nm was possible which in turn resulted in a substantial increase in the repeater less transmission distance for long haul telephone trunks. Systems operating at 1550nm provided lowest attenuation and these links routinely carry traffic at around 2.5Gb/s over 90 km repeater less distance. The introduction of optical amplifiers like Erbium-doped fiber amplifiers (EDFA) and Praseodymium-doped fiber amplifiers (PDFA) had a major thrust to fiber transmission capacity. The use of Wavelength Division Multiplexing along with EDFA proved to be a real boost in fiber capacity. Hence developments in fiber technology have been carried out rapidly over recent years. Glass material for even longer wavelength operation in the mid-infrared (2000 to 5000nm) and far-infrared (8000 to 12000nm) regions have been developed. Furthermore, the implementation of active optoelectronic devices and associated fiber components (i.e. splices, connectors, couplers etc.) has also accelerated ahead with such speed that optical fiber communication technology would seem to have reached a stage of maturity within its developmental path. (Prasenjit,2000)

2.1.3 A to Z Optical Fibers

Optical fiber is a dielectric waveguide or medium in which information (voice, data or video) is transmitted through a glass or plastic fiber, in the form of light. The basic structure of an optical fiber is shown in figure 2.1. It consists of a transparent core with a refractive index n1 surrounded by a transparent cladding of a slightly less refractive index n2. The refractive index of cladding is less than 1%, lower than that of core. Typical values for example are a core refractive index of 1.47 and a cladding index of 1.46. The cladding supports the waveguide structure, protects the core from absorbing surface contaminants and when adequately thick, substantially reduces the radiation loss to the surrounding air. Glass core fibers tend to have low loss in comparison with plastic core fibers. Additionally, most of the fibers are encapsulated in an elastic, abrasion-resistant plastic material which mechanically isolates the fibers from small geometrical irregularities and distortions. (Prasenjit,2000)

A set of guided electromagnetic waves, also called the modes of the waveguide, can be describes the propagation of light along the waveguide. Only a certain number of modes are capable of propagating through the waveguide

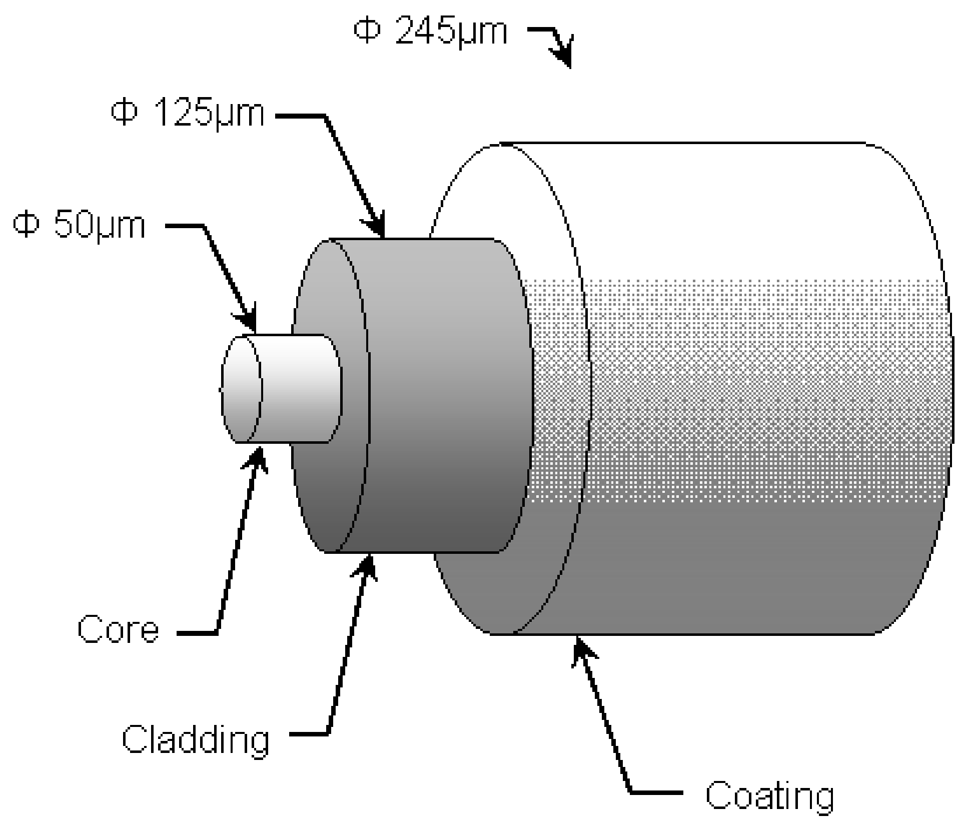

Figure 2.1: Basic Structure of Optical Fiber

2.1.4 Principle of Ray Propagation

This is the most interesting thing about optical fiber cables. Such an indispensable part of modern day communication system works on an extremely simple property of light ray i.e. Total Internal Reflection. As we all know that when light ray is passing from denser (refractive index is higher) dielectric medium to a rarer (refractive index is lower) dielectric medium then from the point of incidence at the interface it bends away from the normal. When the incidence angle is sufficiently high such that the angle of refraction is 90º then it is called critical angle. Now if light ray falls at the interface of the two mediums at an angle greater than the critical angle then the light ray gets reflected back to the originating medium with high efficiency (around 99.9%) i.e. total internal reflection occurs. With the help of innumerable total internal reflections light waves are propagated along the fiber with low loss as shown in figure 2.2. In this context, two parameters are very crucial namely Acceptance Angle and Numerical Aperture.

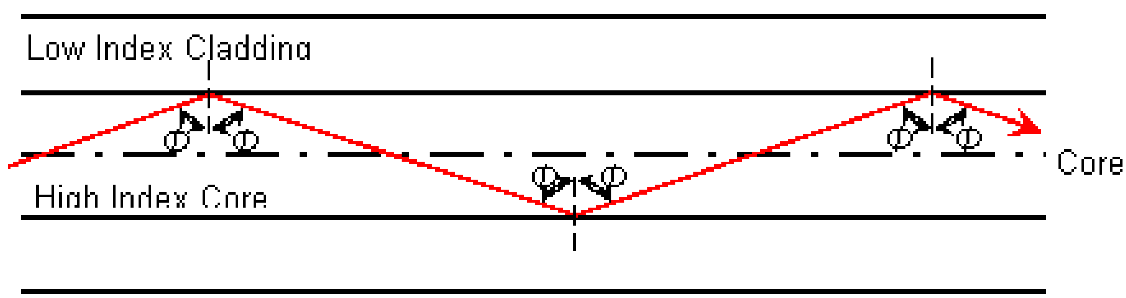

Figure 2.2: Ray Propagation

Acceptance angle is the maximum angle at which light may enter the fiber in order to be propagated and is denoted by θa in figure2.2. The relationship between the acceptance angle and the refractive indices of the three media involved-core, cladding and air, leads to the definition of Numerical Aperture which is given by –

$$NA = (n1^2 - n2^2)^{1/2} = n0 \sin \theta a \ldots\ldots(2.1)$$

where n0 is the refractive index of air.

The light ray shown in figure2.2 is known as a meridional ray as it passes through the axis of the fiber. However, another category of ray exists which is transmitted without passing through the fiber axis and follows a helical path through the fiber.(Prasenjit,2000)

2.2 Optical Communication

Optical communication, also known as optical telecommunication, is communication at a distance using light to carry information. It can be performed visually or by using electronic devices. An optical communication system uses a transmitter, which encodes a message into an optical signal, a channel, which carry the signal to its destination, and a receiver, which reproduce the message from the received optical signal. (IBM,1998)

At the present day a variety of electronic systems optically transmit and receive information carried by pulses of light. Fiber optic communication cables are now employed to send the great majority of the electronic data and long distance telephone calls that are not conveyed by either radio or satellite. (IBM,1998)

Fiber optic transmission devices, also called optical-electronic devices or optoelectronic devices, are coupled with optical fibers for data and signal transmission by converting optical signals into electrical signals, electrical signals into optical signals, or both. Fiber optic communication utilizes optical transmitter, optical receivers and optical fiber, among other component, to transmit light signals through the fiber. (IBM,1998)

Optical fiber is thin transparent fibers of glass or plastic enclosed by material having a lower index of refraction and transmit light throughout their length by internal reflection. The fibers and cladding are typically enclosed in a protective polymer jacket. The transmitter and receivers are often integrated into a single component called a transceiver. Transmitter are light sources, such as lasers or light-emitting diodes. (IBM,1998)