BER EVALUATION OF MULTICHANNEL OPTICAL FIBER TRANSMISSION SYSTEM WITH PSK MODULATION

A thesis report is submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

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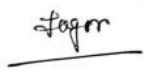
SEPTEMBER, 2024

DECLARATION

I hereby declare that this project "**BER evaluation of multichannel optical fiber transmission system with psk modulation**" represents my own work which has been done in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications. I have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical and safety approval (where applicable), and acknowledged my obligations and the rights of the participants.

Signature of the candidates



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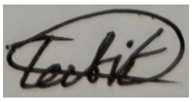

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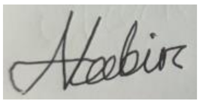

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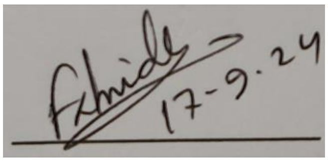
APPROVAL

The project entitled **"BER evaluation of multichannel optical fiber transmission system with psk modulation"** submitted by **Name: Md Sabbir Hossain Sagor ID: 201-33-1177, Name: Shah Imtiaz Jahan ID:201-33-1168, Name: Md Toufik Hasan ID:201-33-1173 & Name: Nasrul Islam Neebir ID:201-33-1081** has been done under my supervision and accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** in **September, 2024.**

Signed



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Dedicated

To

My Parents

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LIST OF SYMBOLS

Symbol	
P	Input Power
L	Fiber Length

LIST OF ABBREVIATIONS

OFC	Optical Fiber Communication
PSK	Phase-Shift Keying
SOA	Semiconductor Optical Amplifiers
EDFA	Erbium Doped Fiber Amplifier
BER	Bit Error Rate
SNR	Signal to Noise Ratio
OSNR	Optical signal-to-noise ratio
Q-Factor	Quality factor
DRA	Distributed Raman amplification
NESC	National Electrical Safety Code
ITU	International Telecommunication Union
NEC	National Electrical Code

ACKNOWLEDGEMENT

First of all, we want to give thanks to **Almighty Allah**. With his blessing we are able to complete our work with best effort.

We want to pay our utmost respect to our Supervisor **Name: Dr. Fahmida Hossain Tithi Designation: Associate Professor** of the **Department of EEE, Daffodil International University** for who has given us the chance to work on an impactful idea and taken care of every issue of development of this concept. Then we would like to take this opportunity to express gratitude to our supervisor for being dedicated in supporting, motivating and guiding us throughout this project. This project can't be done without his useful advice and help. Also thank him very much for giving us the opportunity to work with this project.

ABSTRACT

The rapid growth of data traffic, fueled by internet services, streaming media, and cloud computing, necessitates highly efficient and dependable communication networks. Optical Fiber Communication (OFC) systems are critical due to their high bandwidth and low attenuation, with Phase Shift Keying (PSK) being the preferred modulation technique due to its spectral efficiency and noise immunity. However, signal distortion, phase noise, nonlinear effects, and interference degrade PSK performance. Erbium-Doped Fiber Amplifiers (EDFA) and Semiconductor Optical Amplifiers (SOA) are used to achieve amplification, which is required to maintain signal strength across long distances. While EDFAs provide high gain and low noise, and SOAs provide compactness and fast gain dynamics, integrating these amplifiers with PSK introduces additional complexities, such as noise accumulation, nonlinear interactions, gain saturation, There are also wavelength-dependent gain variations. This study looks into the integration of PSK, EDFA, and SOA in OFC systems, with the goal of improving performance by characterizing amplifier impact, mitigating signal distortion and nonlinear effects, optimizing amplifier configurations, and improving system robustness and efficiency using advanced signal processing, hybrid modulation schemes, and error correction methods. The findings are intended to significantly advance high-performance OFC systems capable of meeting the growing demands of modern telecommunication networks.

Key words

1. Phase-Shift Keying
2. Semiconductor Optical Amplifiers
3. Erbium Doped Fiber Amplifier
4. Optical Fiber Communication
5. Distributed Raman Amplifier
6. Bandwidth

CHAPTER 1

INTRODUCTION

1.1 Introduction

Optical fibers, constructed of glass or plastic, are essential in modern telecommunications as they allow for long-distance data transfer with little signal deterioration and high bandwidth. These fibers use complete internal reflection to efficiently transmit light information through their cores. Their extensive acceptance is due to their low attenuation, immunity to electromagnetic interference, and reliable data-carrying characteristics, making them essential in modern communication infrastructure. [1,2]

Distributed Raman Amplification (DRA) uses Raman scattering within transmission fibers to constantly enhance optical signals over their length. DRA, unlike traditional systems that use individual amplifiers at intervals, provides consistent amplification throughout the fiber span, preventing signal loss in optical communication networks, particularly over long distances. [3,4]

SOAs are active devices that use semiconductor materials to magnify optical signals. SOAs are integrated into optical systems, providing high gain and fast response times. Injecting current into semiconductor material causes stimulated emission, which amplifies optical signals traveling through. SOAs have multiple applications, including wavelength conversion, signal amplification, and optical switching in optical communication systems. [5,6]

Erbium-doped fiber amplifiers (EDFAs) improve signal strength in optical communication systems using erbium-doped fibers. EDFAs use erbium ions to increase light signals near 1550 nm, coinciding with optical fibers' best transmission range. Amplifiers play a crucial role in expanding communication networks by providing high-quality signal amplification with low noise. [7]

PSK, the carrier phase information is varied in accordance with the digital information to be transmitted, by advancing or delaying the phase of the carrier.[20]

In this paper we are evaluate the BER of multichannel optical fiber transmission system with PSK modulation.

1.2 Problem Statement and Proposed solution(s)

Problem Statement:

1. The quality of the transmitted signal can be lowered by signal distortion caused by chromatic dispersion and polarization mode dispersion in optical fibers.
2. The transmitted signal may be distorted and lose some of its integrity due to nonlinear processes as self-phase modulation, cross-phase modulation, and four-wave mixing in optical fibers.
3. The integration of Erbium-Doped Fiber Amplifiers (EDFA) and Semiconductor Optical Amplifiers (SOA) with PSK introduces complexities such as noise accumulation

Proposed Solutions:

1. Combining PSK with other modulation techniques improve data rates and robustness.
2. Adjust EDFA settings to balance amplification and signal integrity.
3. Optimize SOA configurations to reduce gain saturation and wavelength-dependent variations.

1.3 Objectives

1. Characterize Amplifier Impact: Evaluate noise and distortion introduced by EDFAs and SOAs on PSK signals.
2. BER Analysis: Evaluate and compare the BER performance of DRA+SOA and EDFA+SOA hybrid amplifiers across different PSK formats and varying data rates.
3. Optimize Amplifier Configurations: Investigate optimal settings for EDFAs and SOAs to balance amplification and signal integrity.
4. Enhance System Robustness: Propose solutions for error correction, dynamic channel allocation, and nonlinearity mitigation.
5. Advance Modulation Techniques: Implement hybrid modulation schemes and PSK to improve data rates and phase noise resilience.
6. Eye Diagram Analysis: Generate and analyze eye diagrams for WDM systems using hybrid amplifiers with PSK modulation.

1.4 Brief Methodology / Technologies/ Procedures

- **Optisystem**: OptiSystem is a comprehensive software tool designed by Optiwave Systems Inc. for the design, simulation, and analysis of optical communication systems. It is widely used in research and development, academic environments, and by industry professionals to model, simulate, and optimize various components and systems used in optical fiber communications (OFC).
- **System Configuration**: Creating a baseline system configuration for optical fiber transmission,which includes the type of optical fiber, transmitter, receiver, and starting amplifier setup.
- **Amplifier Implementation**: Incorporating hybrid amplifiers DRA-SOA-EDFA into the optical fiber transmission system. This involves setting up the amplifiers, choosing the best location along the transmission line, and making sure the new components work with the old ones.
- **Performance Evaluation**: Conducting performance assessments with and without DRA-SOA hybrid amplifiers in various circumstances. This entails evaluating gain, signal-to-noise ratio, and Bit Error Rate (BER) under different situations.
- **Data Collection and Analysis**: Collecting simulation data and analyzing the findings to determine the effectiveness of the DRA-SOA hybrid amplifiers.

- **Matlab**: After gathering the data, we used MATLAB to create charts that allowed for a better understanding. Using these charts, examining the results for different combinations and lengths becomes much easier.
- **Comparison with Existing Work**: Comparing the performance of the DRA-SOA hybrid amplifier-based system to earlier research on optical amplifiers and hybrid amplifier technologies. This enables the validation of outcomes and the discovery of any improvements or developments.
- **Discussion of Findings**: Discussing the findings' ramifications, such as the practicality and prospective applications of DRA-SOA hybrid amplifiers in optical fiber transmission networks. This includes considerations like cost-effectiveness, scalability, and compatibility with existing infrastructure.

By following these methods, you can properly assess the performance of DRA-SOA-EDFA hybrid amplifier-based optical fiber transmission systems and give valuable insights to the field of optical communication.

1.5 Implementation Schedule

1. Research and gather information on Phase-Shift Keying (PSK) and performance -2 weeks
2. Determine signal specifications and design parameters - 2 weeks
3. Procure necessary materials and components for the PSK - 4 weeks
4. Simulation the PSK and perform initial testing - 3 weeks
5. Analyze the performance of PSK with DRA and make necessary adjustments - 2 weeks
6. Again Analyze the performance of PSK with DRA,EDFA, and SOA and make necessary adjustments - 3 weeks
7. Finalize the design and test the Improvement- 2 weeks
8. Document the design process and results in the thesis paper - 2 weeks

Total Time: 20 Weeks

1.6 Organization

Our thesis topic, " **BER evaluation of multichannel optical fiber transmission system with psk modulation**", follows a systematic framework with several key chapters. Chapter 1 is the introduction, presenting a summary of our project's aims. Chapter 2 includes a thorough literature review in which we examine related research and perform a comparative analysis. Chapter 3 focuses on materials and processes, including design requirements and implementation details. The fourth chapter, Results and debate, shows our findings and allows for substantial debate. Chapter 5 focuses on project timelines and milestones. In Chapter 6, Impact Assessment, we assess the project's social, economic, and worldwide repercussions. Finally, Chapter 7 discusses impact in terms of social, economic, and global ramifications. And lastly, in the last Chapter7.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Recent research has concentrated heavily on hybrid optical amplifiers to improve transmission capacity in optical fiber communication networks. Scholars have investigated several amplification approaches, such as Distributed Raman Amplification (DRA) and Semiconductor Optical Amplification (SOA), with the goal of improving system performance, particularly in PSK-based configurations. Studies have assessed the advantages of hybrid amplification architectures, such as DRA-SOA, and compared them to traditional amplifiers such as Erbium-Doped Fiber Amplifiers (EDFAs). Notable findings include DRA's ability to compensate for chromatic dispersion and the potential of unique hybrid configurations for obtaining flat gain characteristics in Phase-Shift Keying (PSK) systems. These research pave the way for more informed design decisions in optical network designs.

2.2 Related Research/ Works

Optical fiber amplifiers are critical for increased transmission capacity in optical fiber transmission systems [1-3]. Recent research has focused on hybrid optical amplifiers to assess the performance of optical fiber transmission systems [4-7].

The uses and characteristics of several types of optical amplifiers and hybrid amplifiers for both wired and wireless communication systems are described in ref. [8].

A discrete Raman amplifier's performance in a coherent transmission system was evaluated experimentally while taking the chromatic dispersion effect into account. The results showed that positive dispersion >10ps/nm/km and that a nonlinear coefficient of about 4W-1km-1 is an appropriate gain option for this system [9].

In their research, V. Mikhailov et al. examined a range of amplification devices, including Raman and doped fiber amplifiers. They also showcased a bismuth doped fiber amplifier, which has an output of 18 dBm and can enhance signals. power, 5.5 dB noise figure throughout the 3-dB bandwidth larger than 60 nm, and 20 dB gain [10].

For WDM systems with 0.4 and 0.8 nm channel spacing at 10 Gbps, performance analyses of various hybrid optical amplifier types are provided in [11]. Comparative analysis is also displayed taking into account various values of parameters like dispersion, but error rate (BER), fiber length, etc.[12] reports on the performance evaluation of star, tree, and mesh optical network topologies using an optimized Raman - EDFA Hybrid Optical Amplifier, taking into account the number of carriers at varying signal powers at 0.1 THz channel spacing and 1 MHz line width.For DWDM systems, a hybrid DRA-EDFA with a new flat gain is suggested [13].

This system demonstrates competent gain variations between 2.01 and 1.15 dB.A study comparing the noise figure (NF) and gain of different single-pump dispersion-compensating Raman/EDFA hybrid amplifier topologies has been conducted experimentally [14].

PSK modulation increases the impact of phase noise on transmissions, making it difficult for eavesdroppers to retrieve data [15-16]. The accuracy of in the amplitude and phase is very important characteristics of a PSK modulator [17]. phase-shift keying (PSK) has recently attracted renewed attention for use in ultra-long-haul optical wavelength-division multiplexed (WDM) systems [18-19]. PSK waveform parameters exhibit significant freedom and inter-parameter coupling, affecting composite waveform performance and potentially elevating sidelobe levels without proper optimization [20-21]. Optical transmitter for RF-signal generation and distribution is an important component for the emerging radio-over-fibber (RoF) systems. The transmitter is required to modulate the data, such as PSK signal, to the generated RF carrier. Different schemes have been developed in [22-24] to directly modulate the phase of a RF-signal in the optical domain, where an expensive high-frequency oscillator is indispensable.

In this research, we investigate the BER of a multichannel optical fiber transmission system using PSK modulation.

2.3 Summary

Research has focused heavily on hybrid optical amplifiers to enhance transmission capacity in optical fiber networks. Approaches like Distributed Raman Amplification (DRA) and Semiconductor Optical Amplification (SOA) have been explored, particularly for PSK-based systems. Studies highlight DRA's dispersion compensation and the potential of hybrids like DRA-SOA for achieving flat gain in PSK. Experimental findings on discrete Raman amplifiers show optimal conditions for positive dispersion and nonlinear coefficients. Research on bismuth doped fiber amplifiers and performance analyses of WDM systems at various channel spacings provide crucial insights. Hybrid DRA-EDFA systems for DWDM exhibit promising flat gain characteristics.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

In this paper, we discuss our findings on the performance of DRA-SOA and EDFA-SOA hybrid amplifier-based optical fiber transmission systems. Our study will look at how different power levels, fiber lengths, and the number of wavelength-division multiplexing (WDM) channels affect system performance. In addition, we compare the gain and bit error rate (BER) performance with and without DRA-SOA and EDFA-SOA hybrid amplification under various WDM channel count and fiber length situations.

The DRA-SOA hybrid amplifiers are made up of erbium-doped fiber amplifiers (EDFAs) that have been merged with semiconductor optical amplifiers (SOAs). We alter the pump power levels applied to the amplifiers to see how they affect system performance. Fiber lengths are also varied to test signal propagation properties and integrity over various distances. Furthermore, we adjust the number of WDM channels to test the system's capacity and spectral efficiency under different traffic loads.

Performance is evaluated using simulations and experimental observations. The gain and BER performance parameters are compared for DRA-SOA hybrid amplifier-based systems and those without such amplification. Our research sheds light on the effectiveness of DRA-SOA hybrid amplification in increasing system performance, namely in terms of signal amplification, noise reduction, and error rate reduction in optical fiber transmission systems.

3.2 Methods and Materials or System Design and Components

In this research investigates the performance evaluation of optical fiber transmission systems based on DRA-SOA hybrid amplifiers under different situations. Erbium-doped fiber amplifiers (EDFAs), semiconductor optical amplifiers (SOAs), and wavelength-division multiplexing (WDM) apparatus were among the essential elements of the experimental setup.

1. **DRA-SOA and EDFA-SOA Hybrid Amplifier Setup:** The DRA-SOA hybrid amplifiers were developed by integrating semiconductor optical amplifiers (SOAs) with erbium-doped fiber amplifiers (EDFAs). The impact of varying the pump power levels applied to the amplifiers on system performance were evaluated.

2. **Fiber Length and WDM Channel Manipulation:** In order to examine the properties and integrity of signal propagation over various distances, fiber lengths were changed. To examine the system's capacity and spectral efficiency under various traffic loads, the number of WDM channels was changed.

3. **Performance Evaluation:** Performance parameters for gain and bit error rate (BER) were assessed for systems based on DRA-SOA hybrid amplifiers as well as systems not requiring such amplification. A combination of experimental data and simulations were used to assess performance.

4. **Data Analysis:** Variations in power, fiber length, and WDM channel count were examined for their effects on system performance using BER data from simulations and experiments. To find out how well DRA-SOA and EDFA-SOA hybrid amplification improves system performance, comparative analysis was done. This study's setup and data analysis approach were designed to offer thorough insights into the performance traits of DRA-SOA and EDFA-SOA hybrid amplifier-based optical fiber transmission systems under various operating scenarios.

3.3 Design Specifications. Standards and Constraints

Fig 3.1: **Block Diagram (PSK with DRA+SOA)**

Fig. 3.1 show our model's block diagram. Our research complies with optical communication standards, guaranteeing compatibility and interoperability with current systems. We are aware of the shortcomings of the simulation program (OptiSystem) that we employed for this research. Although OptiSystem offers a complete framework for simulating optical systems, accuracy and modeling complexity may be limited. The parameters and constraints of the optical components we used, such as WDM transmitters, amplifiers (DRA and SOA), demultiplexers, and receivers, affect how well our simulated system performs. To guarantee accurate simulation results, we take these parameters into account in our study. A number of fiber optic transmission limitations, including signal attenuation, dispersion, and nonlinear effects, could affect our system's performance. These limitations may affect the achievable system performance, which is why we took them into account in our analysis.

Our research complies with the power budget limitations and signal quality specifications meant for optical communication systems. These limitations guarantee that the signals that are transmitted fulfill the necessary dependability and quality of service standards.

Although the majority of our study's research is simulation-based, we recognize that experimental validation is crucial to ensuring the precision and dependability of our conclusions. Our goal is to verify the outcomes of our simulations through experimental value, taking into account the limitations of actual implementation.

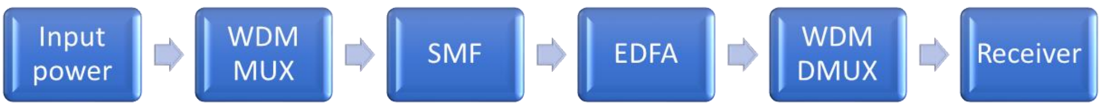


Fig 3.2: **Block Diagram (PSK with EDFA)**

A PSK (Phase Shift Keying) system with an EDFA (Erbium-Doped Fiber Amplifier) is designed to efficiently transmit data over long distances. The block diagram consists of a data source, PSK modulator, multiplexer (MUX), EDFA, demultiplexer (DEMUX), and receiver. The data source generates a binary data stream that the PSK modulator converts into a phase-modulated signal. This signal is then multiplexed with other signals for efficient bandwidth use. The EDFA boosts the signal strength to counteract transmission losses, ensuring signal integrity over long distances. At the receiving end, the demultiplexer splits the combined signal back into individual signals, and the receiver demodulates the PSK signal to retrieve the original data.
Design specifications include the data rate (10 Gbps), operating wavelength (around 1550 nm), and required Signal-to-Noise Ratio (SNR). This system ensures reliable, high-speed data transmission by addressing these design specifications, standards, and constraints.

Fig 3.3: **Block Diagram (PSK with EDFA+SOA)**

A PSK (Phase Shift Keying) system with both an EDFA (Erbium-Doped Fiber Amplifier) and an SOA (Semiconductor Optical Amplifier) is designed to efficiently transmit data over long distances. The block diagram consists of a data source, PSK modulator, multiplexer (MUX), EDFA, SOA, demultiplexer (DEMUX), and receiver. The data source generates a binary data stream that the PSK modulator converts into a phase-modulated signal. This signal is multiplexed with other signals for efficient bandwidth use. The EDFA first boosts the signal strength to counteract transmission losses, and the SOA provides additional amplification, offering benefits like faster response times and integration with semiconductor devices. At the receiving end, the demultiplexer splits the combined signal back into individual signals, and the receiver demodulates the PSK signal to retrieve the original data.
The operational wavelength (around 1550 nm) and data rate (10 Gbps) are included in the design parameters.Fiber attenuation the requirement to strike a balance between performance and cost and power economy are some of the constraints to take into account. These design requirements, guidelines, and limitations are addressed by this system to guarantee dependable, fast data transfer.

3.4 System Analysis or Design Analysis

1. **WDM Transmitter:** It is possible to send many data streams across a single optical fiber at the same time with the WDM transmitter. It generates signals at various wavelengths using lasers or LEDs, then combines them into a single

composite signal for transmission.This technology multiplexes data streams into a shared media, increasing the capacity and efficiency of optical networks.

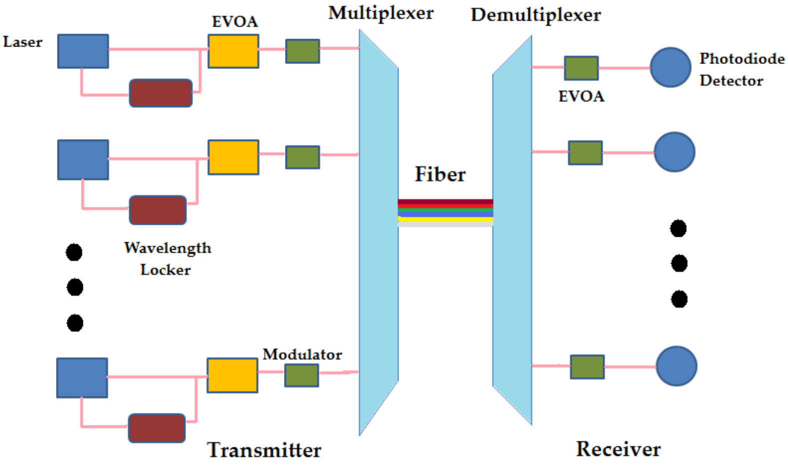


Fig.3.4 WDM Transmitter

2. **WDM Mux (Wavelength Division Multiplexer):** WDM technology uses different light colors or wavelengths to combine many signals onto a single optical cable, thereby revolutionizing fiber optic communications. These various light wavelengths are efficiently combined by a WDM Mux into a single fiber strand transmission that is coherent.

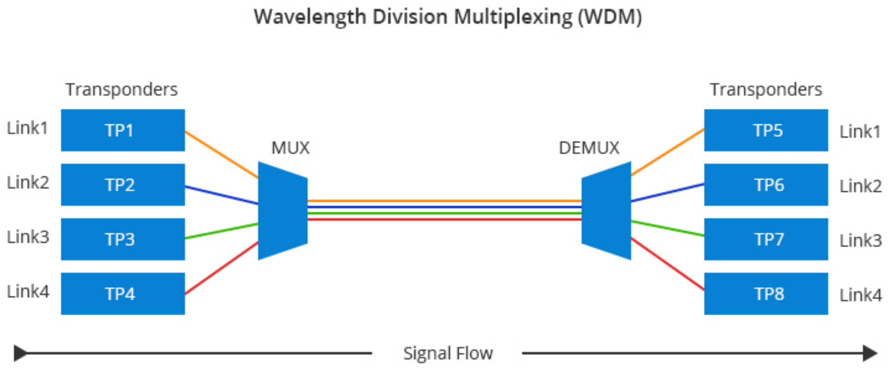


Fig.3.5 WDM Mux (Wavelength Division Multiplexer)

3. **SMF (Single Mode Fiber):** SMF stands for single-mode fiber, an optical fiber designed to transport a single mode of light and a crucial component in telecommunications. SMFs are the ideal option for long-distance communication because of their reputation for minimizing signal attenuation, which guarantees effective data transmission over great distances.

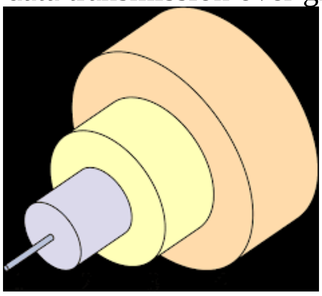


Fig.3.6 SMF (Single Mode Amplifier)

4. **DRA (Distributed Raman Amplifier):** In order to achieve effective amplification in fiber-optic communication systems, distributed Raman amplifiers (DRAs) require optimizing pump configurations, regulating signal power for best performance, and taking nonlinear effects into consideration.

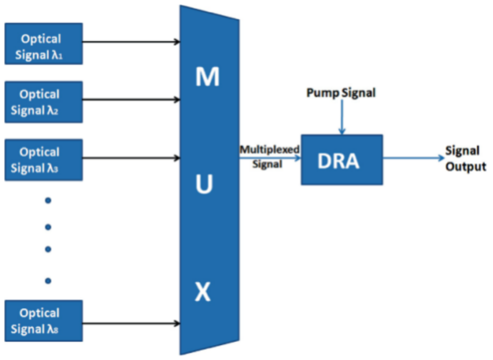


Fig.3.7 DRA (Distributed Raman Amplifier)

5. **SOA (Semiconductor Optical Amplifier):** The quick signal amplification capabilities provided by SOA, a semiconductor-based optical amplifier, are essential for fiber optic communications. It is a cornerstone technology that increases signal strength and facilitates effective data transfer via optical networks thanks to its quick response time and increased gain.

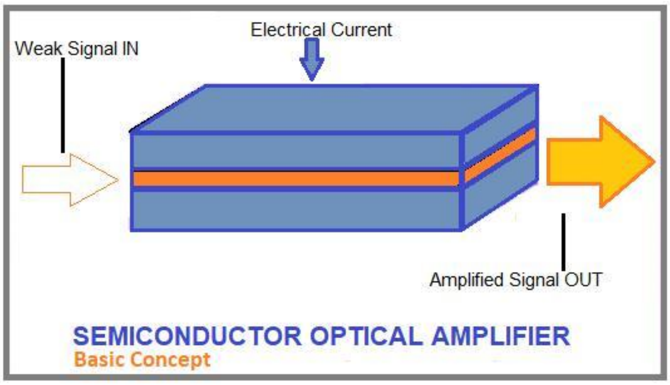


Fig.3.8 SOA (Semiconductor Optical Amplifier)

6. **WDM Demux (Wavelength Division Demultiplexer):** In fiber optic communications systems, the Wavelength Division Demultiplexer (WDM Demux) is an essential component. Its purpose is to return mixed optical signals—which are each sent at a distinct wavelength—to their respective original channels. Effective signal reception and decoding at the receiving end of the communication channel are made possible by this demultiplexing procedure. The WDM Dmux is an essential component that allows several data

streams to be transmitted simultaneously over a single optical fiber, increasing the flexibility and capacity of optical communication networks.

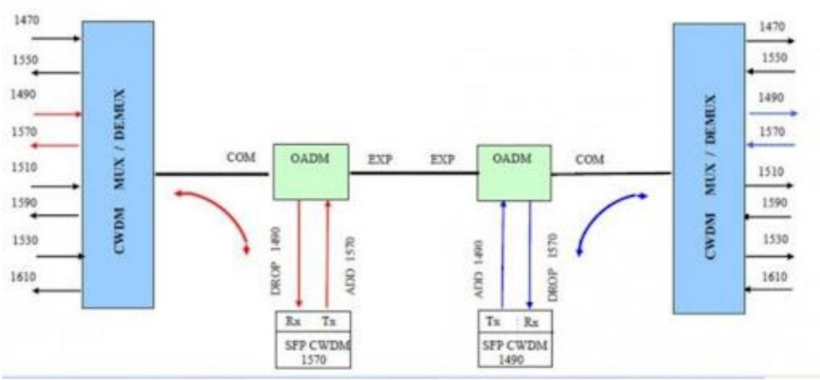


Fig.3.9 WDM Demux (Wavelength Division Demultiplexer)

7. **Receiver:** One of the most important components of the fiber optic communication ecosystem is the receiver, which is responsible for receiving and processing transmitted signals. The receiver skillfully transforms optical impulses back into electrical signals for further processing and use, whether it is via photodetectors or more advanced devices.

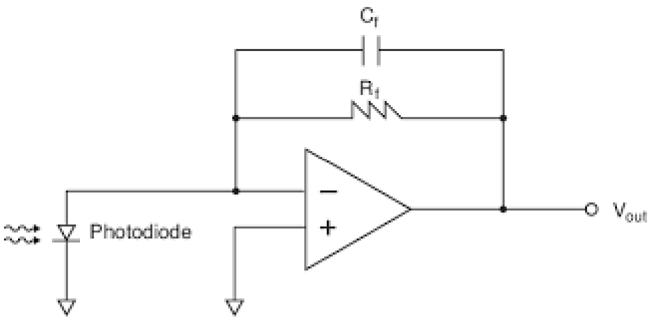


Fig.3.10 Optical Receiver

3.5 Simulation

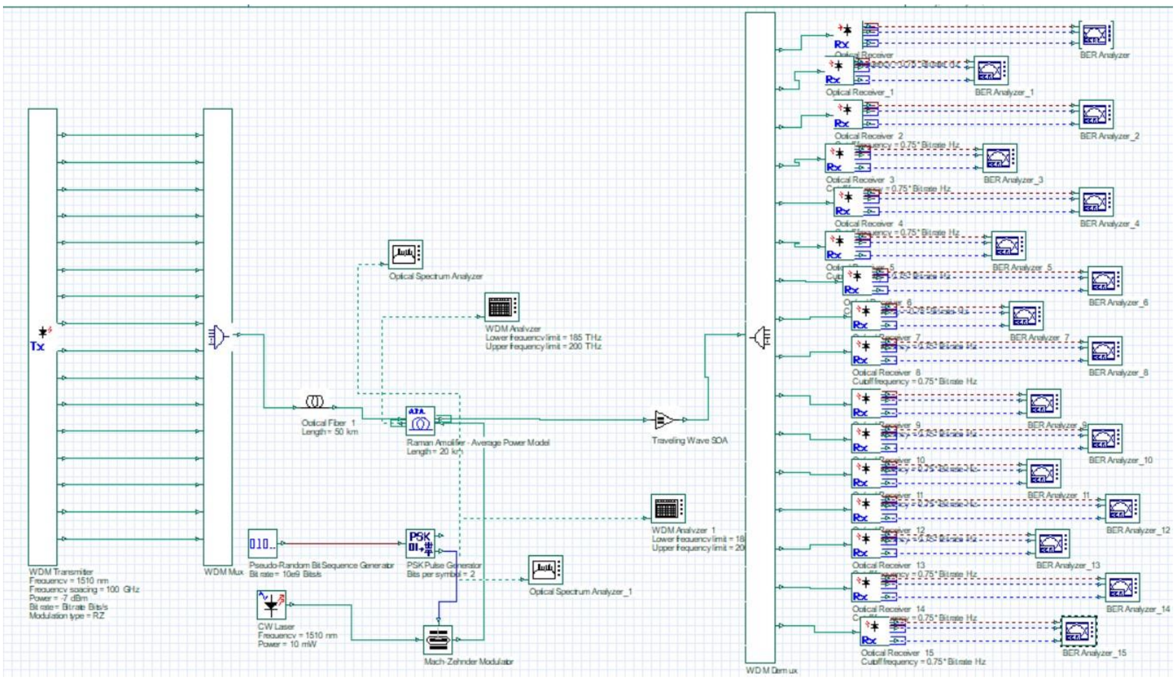


Fig.3.11 Simulation setup for DRA-SOA hybrid amplifier based optical transmission system with PSK modulation.

First, we used OptiSystem software in our simulation, and the main input was the WDM transmitter. With 16 channels for data transmission, the transmitter ran at a frequency of 1510 nm. Using a WDM Mux, multiplexing was accomplished before transmission via a single mode fiber (SMF). Different SMF lengths were used to examine signal performance at various distances. The multiplexed signal was passed via a Distributed Raman Amplifier (DRA), and its effects were measured using WDM and optical spectrum analyzers placed before and after the DRA. The DRA was amplified by applying pump power to it. Then, a Semiconductor Optical Amplifier (SOA) was used to amplify the signal. A WDM Demux was then used to de multiplex the SOA's output into 16 channels. For thorough examination, an optical receiver, BER analyzer, and electrical carrier analyzer were installed on each channel. To determine the influence of the SOA, comparative simulations were run both with and without it. To see how the DRA affected variables including Bit Error Rate (BER), Signal-to-Noise Ratio (SNR), Gain, and Optical Signal-to-Noise Ratio, simulations were run both with and without the DRA. An in-depth comprehension of the contributions made by the DRA and SOA to system performance was made possible by this exhaustive analysis.

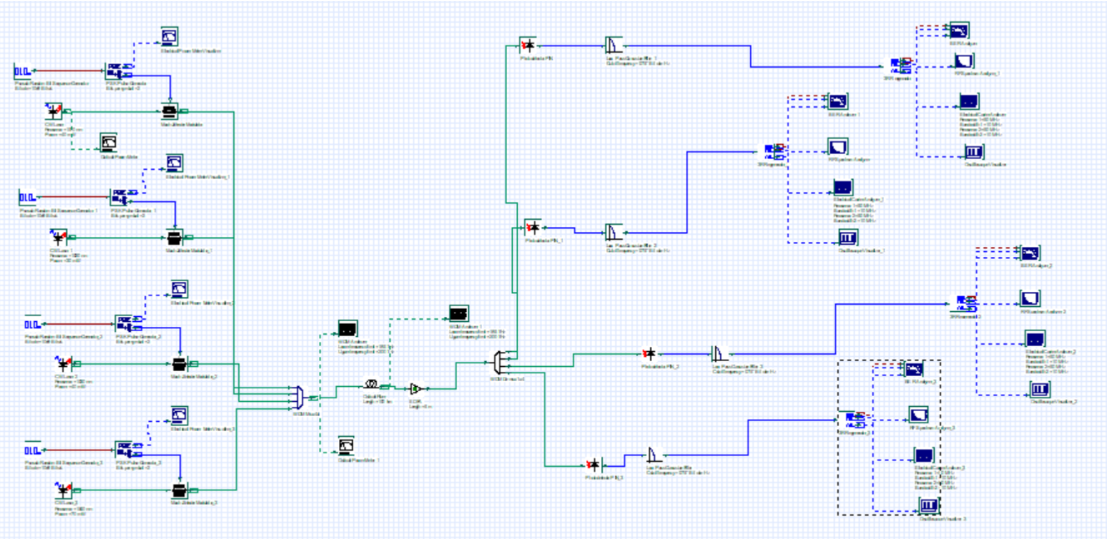


Fig.3.12 Simulation setup for EDFA hybrid amplifier based
optical transmission system considering PSK modulation.

To set up a simulation for an Erbium-Doped Fiber Amplifier (EDFA) hybrid amplifier-based optical transmission system, Firstly need several key components: an optical transmitter, optical fiber, EDFA, hybrid amplifier, and an optical receiver. The optical transmitter consists of a laser source and a modulator, which generates and modulates continuous wave light, respectively. The signal is then transmitted through single-mode fiber (SMF), where fiber loss, dispersion, and nonlinearity are considered. The EDFA uses a pump laser to provide energy to the erbium-doped fiber, amplifying the signal. A hybrid amplifier, such as a Raman amplifier, complements the EDFA to improve performance over long distances. The optical receiver, consisting of a photodetector pin and receiver electronics, converts the optical signal back into an electrical signal and processes it to extract the transmitted data.

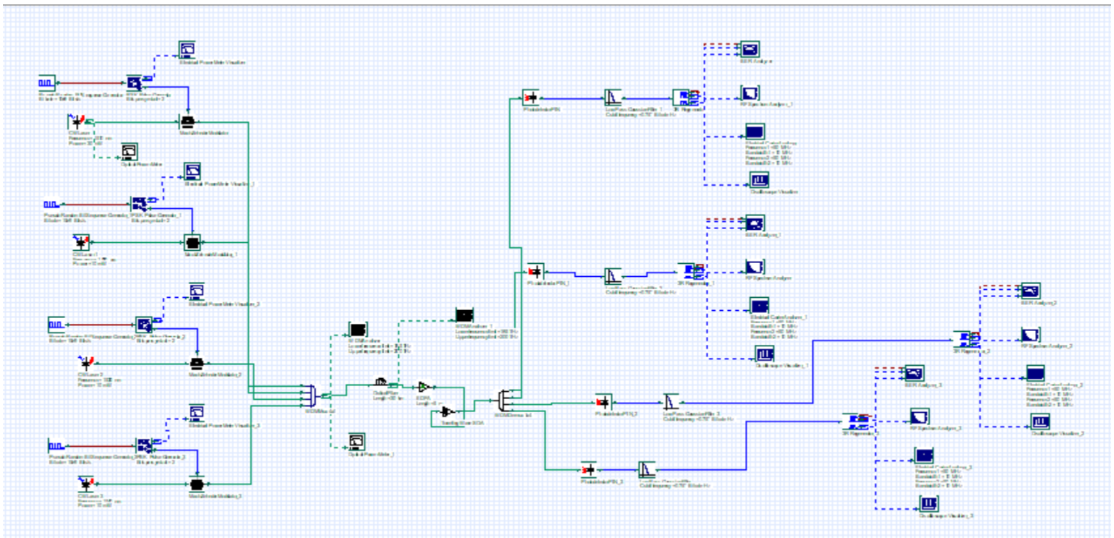


Fig.3.13 Simulation setup for EDFA-SOA hybrid amplifier based
optical transmission system considering PSk modulation.

In order to simulate an optical transmission system employing an EDFA (Erbium-Doped Fiber Amplifier) + SOA (Semiconductor Optical Amplifier) hybrid amplifier, an optical source must be used, such as a continuous wave (CW) laser or modulated laser around 1550 nm, and modulating the signal with a Mach-Zehnder modulator. The signal is transmitted through single-mode fiber with specific attenuation and dispersion. The hybrid amplifier consists of an EDFA, which amplifies the 1550 nm signal with low noise, and an SOA, which provides wide bandwidth and fast switching. At the receiver end, a photodetector converts the optical signal back to electrical, followed by amplification and filtering. Measurement instruments like an Optical Spectrum Analyzer (OSA), Bit Error Rate (BER) tester, and oscilloscope are used to evaluate performance. The simulation defines parameters like wavelength, input power, and fiber length, creates the schematic layout, configures the EDFA and SOA, and runs the simulation to analyze signal spectrum, eye diagrams, and BER. The hybrid approach extends transmission distance, enhances gain, provides wider bandwidth, and offers system flexibility, improving the performance and reliability of optical communication systems.

3.6 Summary

We looked into covered a comprehensive overview of hybrid amplifier systems in optical fiber transmission. These systems indeed leverage the strengths of different amplifier technologies like EDFAs, SOAs, and DRAs to optimize performance across various types of optical communication networks.

An Erbium-Doped Fiber Amplifier (EDFA) and Semiconductor Optical Amplifier (SOA) hybrid system combines the strengths of both technologies in optical communication networks. EDFAs utilize erbium-doped fibers to achieve high gain and low noise amplification across multiple wavelength channels, ideal for long-haul and metro networks. SOAs, employing semiconductor materials, offer compact size, fast response times, and signal processing capabilities like switching and wavelength conversion, suited for access networks and integrated applications. By integrating EDFAs' superior noise performance with SOAs' flexibility and processing speed, hybrid systems extend reach, improve signal quality, and enable innovative network designs and configurations, enhancing overall efficiency and performance in modern optical communications. A DRA-SOA hybrid amplifier system combines the strengths of both Distributed Raman Amplifiers (DRAs) and Semiconductor Optical Amplifiers (SOAs) in optical fiber communication networks. DRAs utilize Raman scattering for signal amplification over long distances, making them ideal for long-haul applications. SOAs, on the other hand, employ semiconductor materials to amplify optical signals and are typically used in shorter-range networks and access points due to their compact size and integration ease. By integrating both DRA and SOA technologies, hybrid amplifier systems can enhance signal amplification across a broad range of optical frequencies and distances. They offer flexibility in network design, supporting both long-distance transmission and local access points effectively in telecommunications and data transmission networks.

CHAPTER 4

RESULTS AND DISCUSSIONS

Table 4.1 contains the values of parameters used in our simulation. Table 4.2 is about frequencies and wavelengths, which are the basic inputs of our simulation. Table 2 also contains some analytical results before and after DRA.

TABLE 4.1 VALUES OF PARAMETERS

Parameter	Value
Operating wavelength	1510 nm
Channel spacing	100 GHz
Max. Power	100 mW
Attenuation	0.25 dB/km
Dispersion slop(ps/nm2/km)	0.08
Fiber Dispersion(ps/nm/km)	17
Bandwidth	10 GHz
Fiber Length (Km)	30~100
DRA	20 Km

TABLE 4.2 WDM analyzer before and after amplification

Before DRA			After DRA			
OSNR (dB)	Signal Power (dBm)	Noise Power (dBm)	OSNR (dB)	Signal Power (dBm)	Noise Power (dBm)	Frequency (THz)
37.866609	-100	-58.960488	-41.039512	-20.941113	-58.807722	198.53805
37.845702	-100	-59.033422	-40.966578	-21.034934	-58.880636	198.53805
37.905806	-100	-59.033422	-40.966578	-20.97483	-58.880636	198.63805
37.88308	-100	-59.110279	-40.889721	-21.074405	-58.957485	198.73805
38.030754	-100	-59.180324	-40.819676	-20.996767	-59.027521	198.83805
38.085245	-100	-59.254155	-40.745845	-21.016097	-59.101342	198.93805
38.14586	-100	-59.32327	-40.67673	-21.024571	-59.170431	199.03805
38.055111	-100	-59.32327	-40.67673	-21.11532	-59.170431	199.13805
38.119249	-100	-59.387222	-40.612778	-21.115122	-59.234372	199.23805
38.2338	-100	-59.443463	-40.556537	-21.056799	-59.290599	199.33805
38.180469	-100	-59.488814	-40.511186	-21.155468	-59.335936	199.43805
38.217637	-100	-59.520333	-40.479667	-21.149786	-59.367423	199.53805
38.269357	-100	-59.520333	-40.479667	-21.098066	-59.367423	199.63805
38.299675	-100	-59.535636	-40.464364	-21.083035	-59.38271	199.73805
38.22458	-100	-59.542265	-40.457735	-21.164741	-59.389321	199.83805
38.207661	-100	-59.53815	-40.46185	-21.177528	-59.385189	199.93805

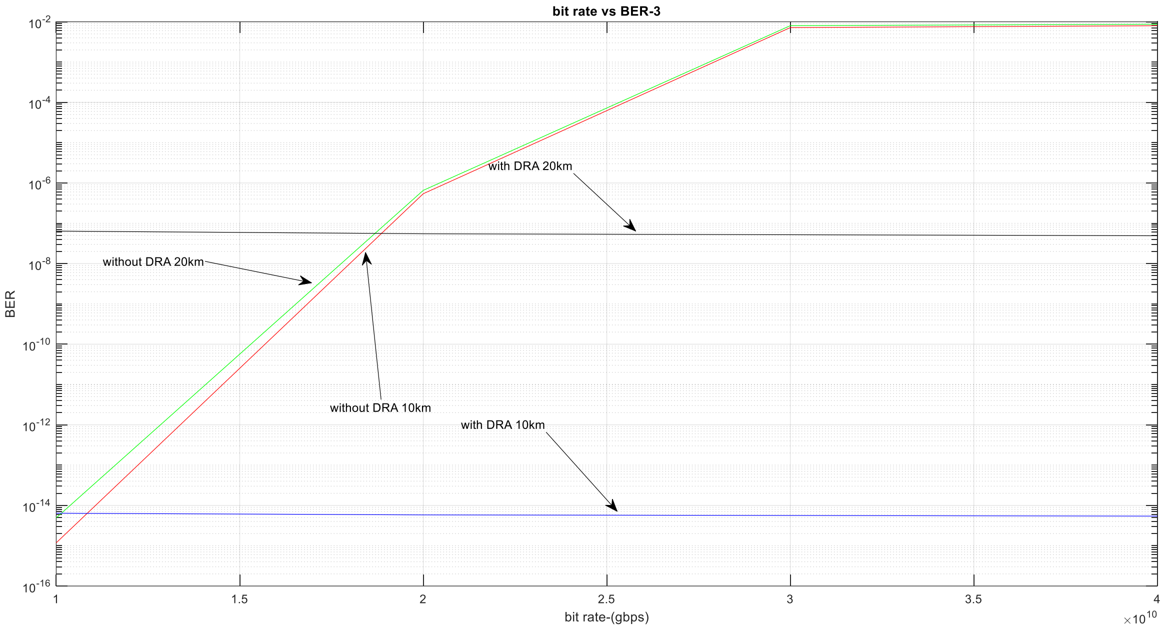


Fig 4.1 Bit rate Vs BER for different fiber length.

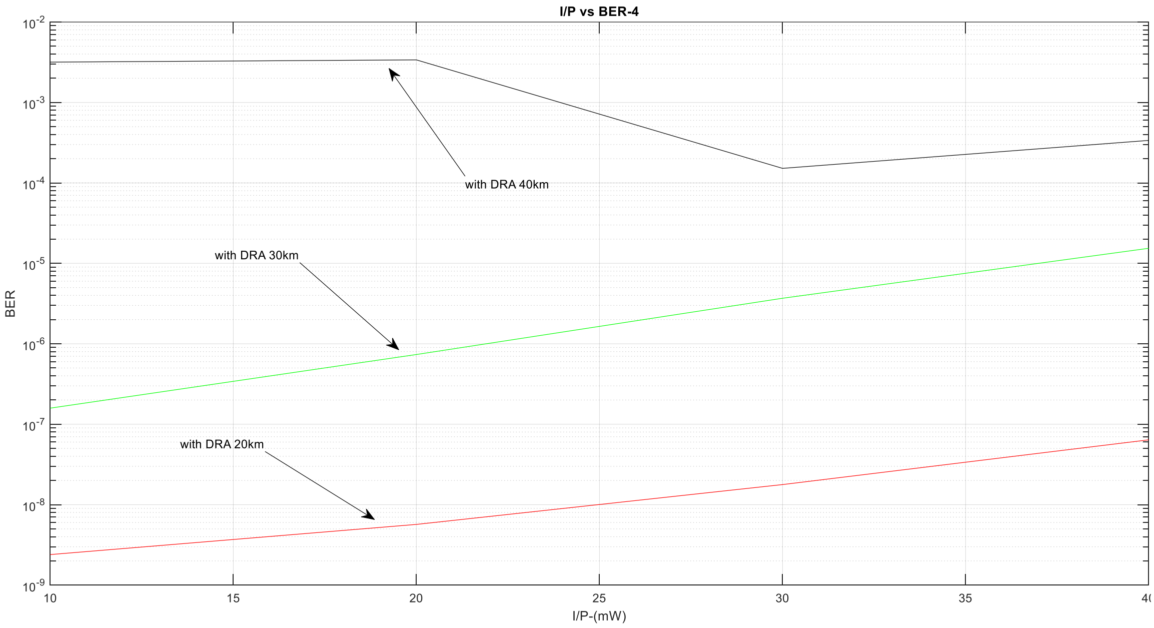


Fig 4.2 Input Vs BER With DRA for different fiber length.

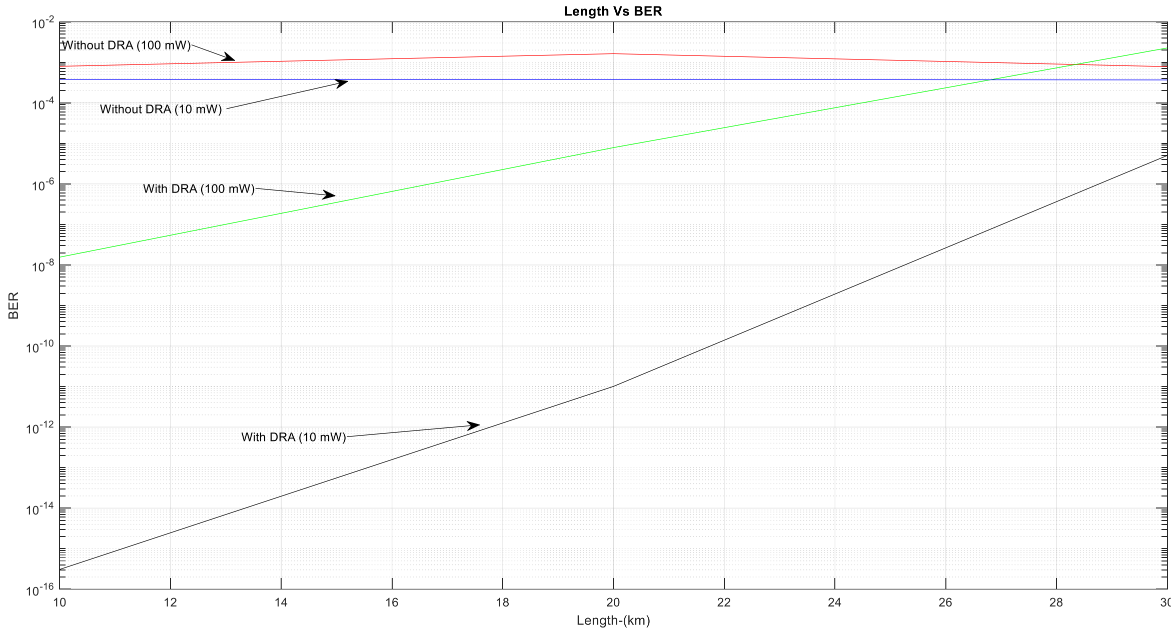


Fig 4.3 Length Vs BER With and without DRA for different input power.

Figure 4.1 shows plots of Bit Rate versus BER with and without DRA. It is apparent that BER is saturated with DRA. After the Raman amplification operation, the BER improves. Figure 4.2 depicts the variation in BER in the wdm channel for different fiber lengths, with varying power. According to Figure 4.2, when the length is increase, the BER varies significantly. Figure 4.3 shows the changes in fiber length vs BER for various hybrid amplifier power levels.

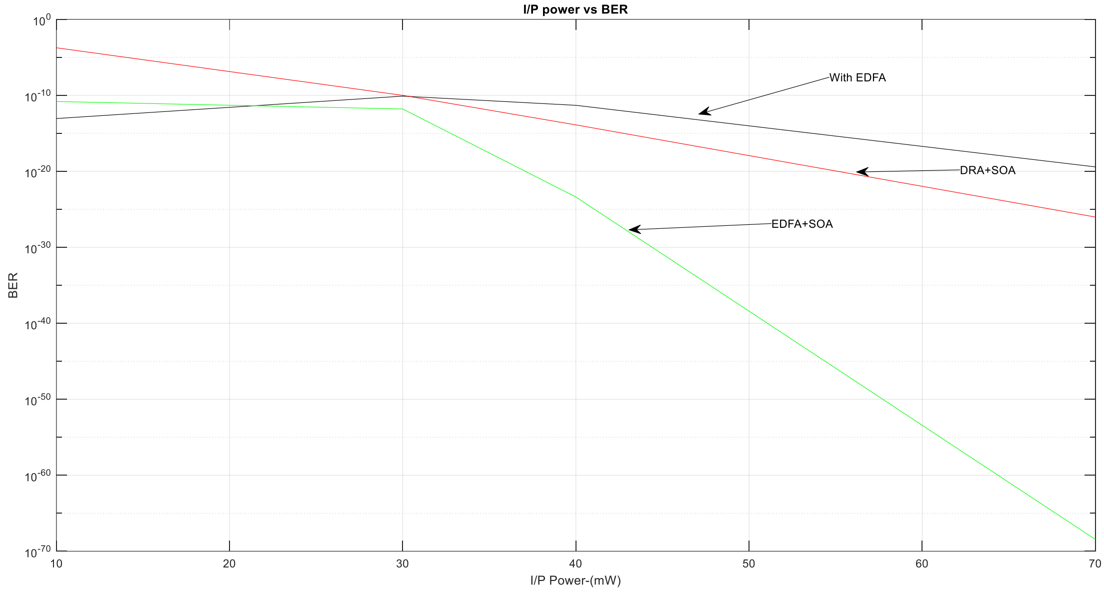


Fig 4.4 Input power Vs BER With EDFA-SOA, DRA-SOA and EDFA for PSk modulation.

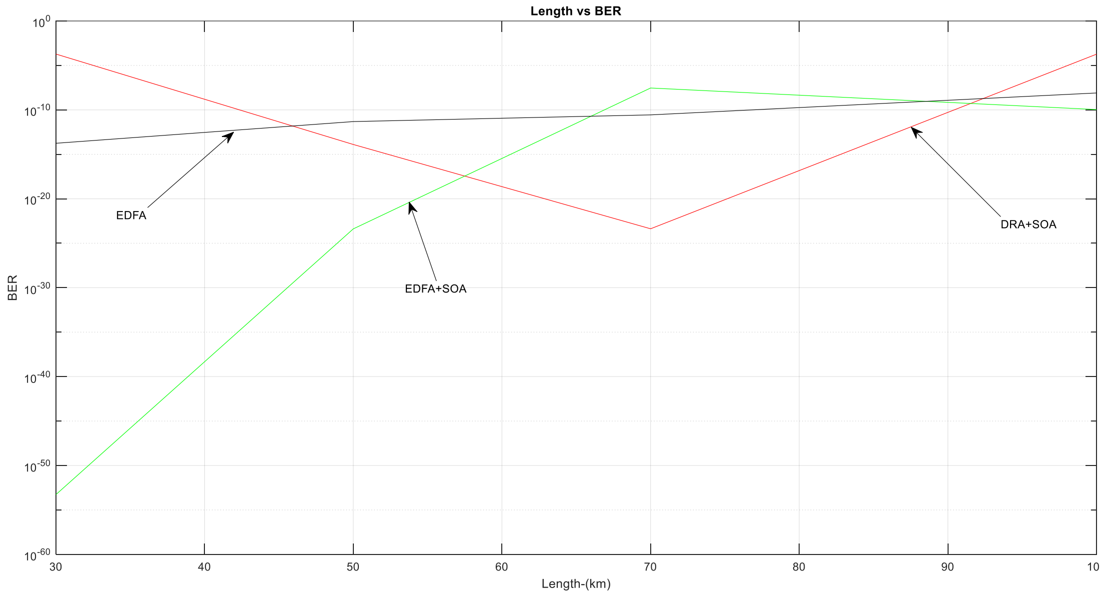
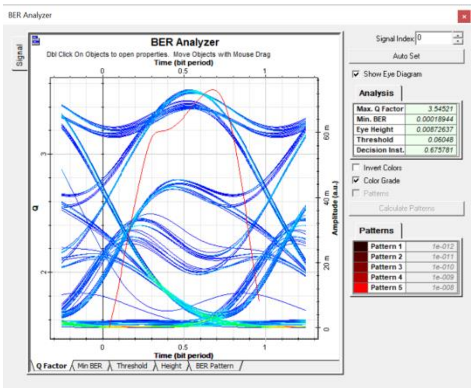
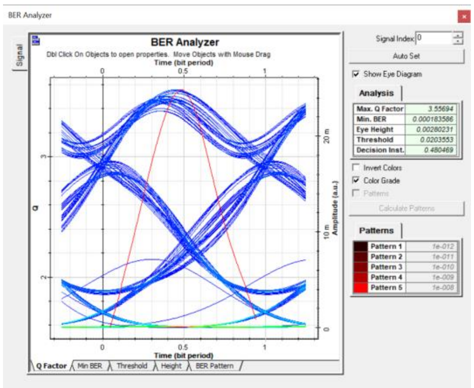


Fig 4.5 Length Vs BER With EDFA-SOA, DRA-SOA and EDFA for PSk modulation.

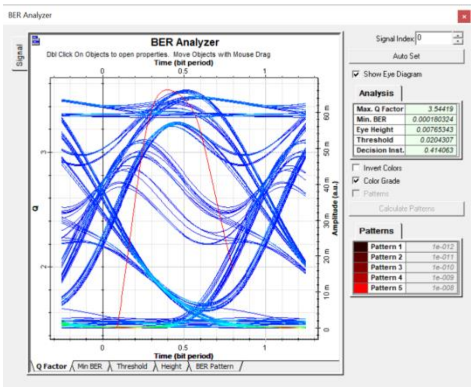
Figure 4.4 shows graphs of input versus BER with EDFA-SOA, DRA-SOA, and EDFA. It is apparent that BER decreases as the input power level increases. After decreasing the input power, the BER improves. The figure depicts the variation in BER across different fiber lengths.4.5, where the power is constant at 40 mW. According to Figure 4.5, when the length is increase, the BER varies significantly. Figure 4.5 shows that BER varies greatly at high lengths. Next, the plot demonstrates that the DRA-SOA is more valuable than the EDFA-SOA.



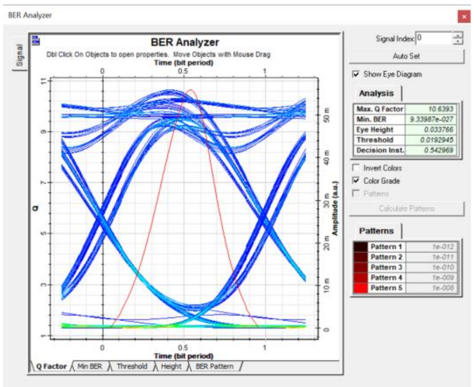
(a)DRA-SOA,L=30km,P= 40mW



(b)DRA-SOA,L= 100km,P= 40mW

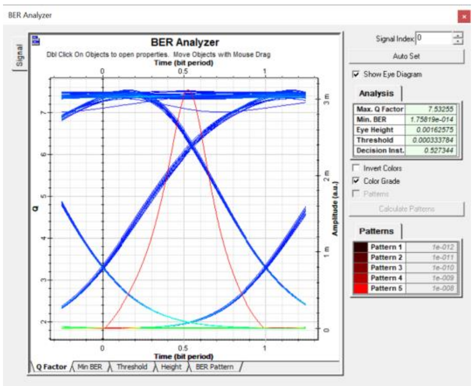


(c)DRA-SOA,L=50 KM, P=10mW

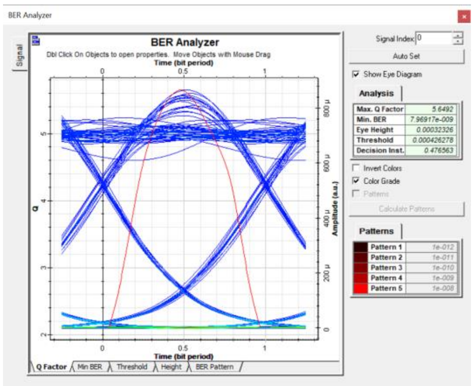


(d)DRA-SOA,L= 50KM, P=70mW

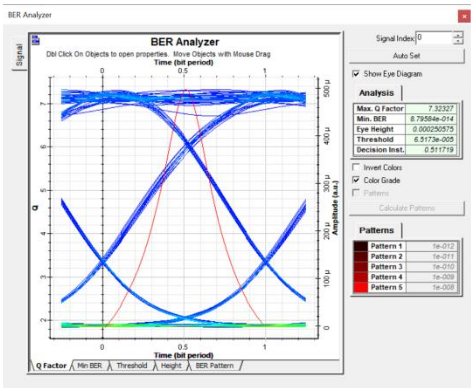
Fig 4.6 Eye diagram of DRA-SOA hybrid optical amplifier based WDM transmission link.

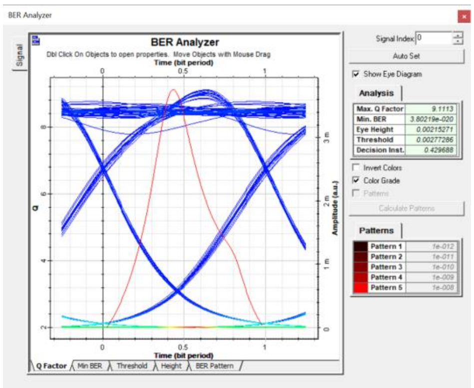


(a)EDFA, L=30Km,P= 40mW



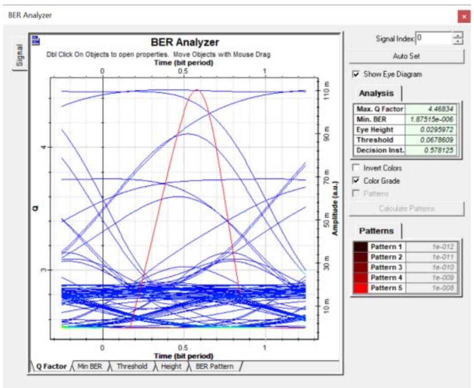
(b)EDFA, L=100Km, P=40mW

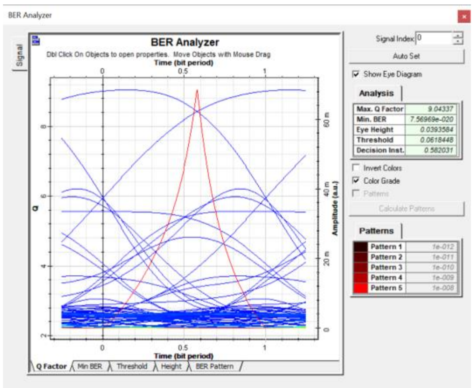




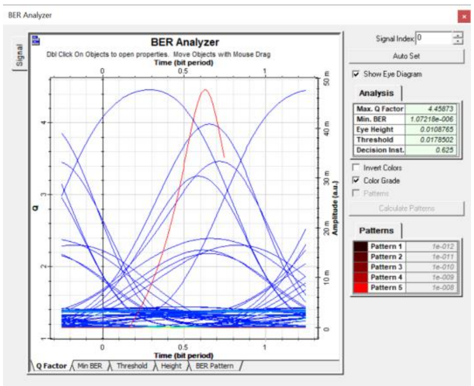
(c)EDFA, L= 50Km, P=10mW (d)EDFA, L=50Km, P=70mW

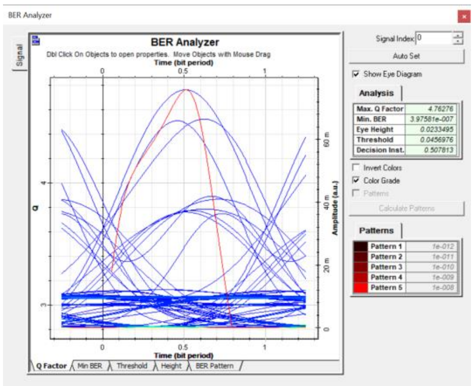
Fig 4.7 Eye diagram of EDFA hybrid optical amplifier.





(a)EDFA-SOA, L=30Km, P=40mW (b)EDFA-SOA, L=100Km, P=40mW





(c)EDFA-SOA, L=50KM, P=10mW (d)EDFA-SOA, L=50Km, P=30mW

Fig 4.8 Eye diagram of EDFA-SOA hybrid optical amplifier based WDM transmission link

The eye diagram of a hybrid optical amplifier-based WDM transmission link visualizes the quality of the transmitted signal. We show the amplitude and temporal characteristics of the optical signal as it travels through the system. Figures 4.6, 4.7, and 4.8 show eye diagrams of DRA-SOA, EDFA, and EDFA-SOA for various channels.

CHAPTER 5
PROJECT MANAGEMENT

5.1 Task, Schedule and Milestones

1. Project Initiation (Week 2):

- Specify the goals, parameters, and deliverables of the project.
- Determine the roles and duties of the project team.
- Create a project management plan that includes a timetable, milestones, and tasks.

2.Literature Review (Week 3):

- Perform an extensive review of the literature on optical fiber transmission systems based on DRA-SOA hybrid amplifiers.
- List pertinent research studies, techniques, and conclusions.
- Highlight important discoveries and gaps in the body of current research.

3. Simulation Setup (Week 3):

- Use the OptiSystem program to set up the simulation.
- Set up the SMF, receivers, amplifiers, and transmitters for WDM.
- Verify the simulation setup by doing preliminary test runs.

4. Data Collection and Analysis (Week 5):

- Run simulations to gather information about system performance.
- Examine the outcomes.
- Examine and compare the effects of changing the parameters.

5. Results Interpretation and Discussion (Week 3):

- Consider data analysis results in light of the project's goals.
- Talk about the results' ramifications and how important they are for the optical communication industry.
- Identify the study's shortcomings and possible research topics.

6. Report Writing (Week 4):

- A study paper draft that includes parts on the approach, results, discussion, and conclusion.
- Go over and edit the draft in light of the project team members' comments.
- Complete the study paper in order to submit it to a conference or peer-reviewed publication.

5.2 Lesson Learned

The following succinct takeaways from the thesis paper:

- How to design a circuit using OptiSystem correctly.
- Learn about analysis of BER, SNR,OSNR and Gain.
- Learn on how to reduce BER.
- Plot is create by MATLAB program.

CHAPTER 6

IMPACT ASSESSMENT OF THE PROJECT

6.1 Economical, Societal and Global Impact

By maximizing amplifier performance and minimizing the need for extra infrastructure, research on DRA-SOA and EDFA-SOA hybrid amplifiers may result in financial savings for optical fiber transmission systems. In terms of society, better optical communication technologies might improve telecommunications and internet access, which would help communities all over the world by promoting connectivity and communication. Progress in optical communication technology fosters economic growth, innovation, and international cooperation by creating a more digitally connected and integrated world.

6.2 Environmental and Ethical Issues

In order to address environmental issues, the research evaluates the power consumption of optical communication systems as well as the energy efficiency of DRA-SOA and EDFA-SOA hybrid amplifiers. Ensuring responsible research methods, such as openly disclosing results and adhering to moral standards for the gathering and use of data, are examples of ethical considerations. Minimizing the ecological footprint of the technology also requires assessing the possible effects of amplifier manufacturing and disposal on the environment. Ethical concerns encompass not only the fair allocation of advantages resulting from technical progress but also the resolution of any possible inequalities in the availability of enhanced communication infrastructure.

6.3 Utilization of Existing Standards or Codes

In the developing projects pertaining to optical communication systems, it is imperative to consider many standards, safety considerations, and regulations:

- **National Electrical Safety Code (NESC):** The NESC establishes recommendations for the safe installation, operation, and maintenance of overhead and subsurface electrical networks, including optical fiber cables. Adhering to NESC standards helps to ensure worker and public safety throughout the installation and maintenance of optical communication infrastructure.
- **International Telecommunication Union (ITU) Standards:** Global standards are set by ITU for optical communication technologies as well as networks and services in the telecommunications industry. Global telecommunications infrastructure compatibility and interoperability are guaranteed by adhering to ITU standards.
- **Environmental Regulations:** The disposal of hazardous wastes and the effects of infrastructure development on ecosystems are governed by a number of environmental regulations. To reduce the environmental impact of optical communication projects, including the disposal of optical fiber cables and other components, compliance with environmental rules is required.
- **National Electrical Code (NEC):** The NEC offers guidelines for the secure installation of optical communication system components as well as electrical

wiring and equipment. Following NEC guidelines guarantees the safe operation of optical communication infrastructure and helps prevent electrical dangers.

6.4 Other Concerns

- **Quality Assurance:** Implementing quality control procedures to ensure the durability and effectiveness of optical communication networks.
- **Data Protection:** Putting measures in place to guard data sent across optical communication networks against illegal access and cyber attack.
- **Interference Management:** Addressing any electromagnetic interference sources that could interfere with optical communication systems' ability to perform.
- **Accessibility:** Ensuring that, in compliance with accessibility regulations and rules, the optical communication infrastructure is usable by everyone, including those with disabilities.

By addressing these additional issues, project developers can increase the efficiency and inclusivity of optical communication systems while conforming to relevant standards and regulations.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The study aimed to improve the performance and reliability of optical fiber transmission systems based on DRA-SOA and EDFA-SOA hybrid amplifiers for PSK modulation. Significant progress was made toward meeting the project objectives through a comprehensive series of tasks that included literature review, simulation setup, data collecting and analysis, and findings interpretation. The project's findings have ramifications for a variety of fields, including telecommunications, data centers, internet infrastructure, and medical imaging. By reducing bit error rate (BER) and optimizing system parameters, the initiative helps to improve the efficiency and reliability of optical communication networks in these areas. Finally, the project's accomplishments illustrate its potential to enhance optical communication technology and its applications across multiple industries. The optimized DRA-SOA and EDFA-SOA hybrid amplifier-based optical fiber transmission system has great potential for improving communication networks, promoting digital connectivity, and driving technological innovation. Phase-shift keying (PSK) is a digital modulation technique which transmits information by altering the phase of a stable frequency carrier signal.

7.2 New Skills and Experiences Learned

Here are some of the abilities I've learned to create this paper:

- **Problem solving ability**: Managing the project from start to finish has helped me improve my skills in task scheduling, milestone planning, and team coordination.
- **Matlab Proficiency:** I've learned to use MATLAB for visualization and charting, as well as Visio for building block diagrams.
- **Optical Simulation:** I've learnt how to utilize OptiSystem software to simulate and analyze optical fiber transmission systems, which includes creating simulations, configuring parameters, and evaluating findings.

7.3 Future Recommendations

Certainly! Here are some simple suggestions for future work to improve the project:

1. Explore hybrid amplifier combinations other than DRA-SOA and EDFA-SOA and EDFA-EDFA for different combination of optical amplifier.

2. Optimize optical fiber settings to improve system performance.

3. Create dynamic power management solutions for adaptive control.

4. Connect DRA-SOA and EDFA-SOA amplifiers to wavelength-selective switches.

5. Expand performance evaluation to nonlinear domains and investigate mitigation strategies.

6. Assess system resilience by conducting robustness testing under unfavorable situations.

7. Maximize energy efficiency while meeting performance requirements.

8. Consider real-world deployment factors such as cost-effectiveness and scalability.

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APPENDIX A

TURNITIN REPORT

201-33-1177

ORIGINALITY REPORT

22%	20%	13%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	dspace.daffodilvarsity.edu.bd:8080 Internet Source	9%
2	otip.sjtu.edu.cn Internet Source	2%
3	Mingxia Dong, Jie Zhang, Huibin Zhang, Yongli Zhao, Yajie Li, Chao Lei. "Key Distribution Scheme Based on Uneven PSK Modulation Using Phase Noise", 2020 Opto-Electronics and Communications Conference (OECC), 2020 Publication	1%
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6	Shurong Lv, Siqi Liu, Huili Shi, Jindong Zhang. "Design of low-correlation sidelobe FSK-PSK waveforms with controllable frequency points", Journal of Physics: Conference Series, 2024 Publication	1%

APPENDIX B

COMPLEX ENGINEERING PROBLEM SOLVING AND ENGINEERING ACTIVITIES

Complex Engineering Problems (P) Solving		
	Attributes	Statement from students
P1	Depth of knowledge required	An enormous depth of knowledge was required for the design, which involved an understanding of amplifier analysis, OptiSystem, and MATLAB software.
P2	Range of conflicting requirements	The necessity of paying close attention to every aspect in the planning and implementation of the study is highlighted by the need to navigate conflicting circumstances when generating plots and modeling outcomes.
P3	Depth of analysis required	The design required in-depth investigation, exploring minute intricacies of bit error rates across long distances.
P4	Familiarity of issues	Overcoming unusual challenges in the unique combination of amplification and visual aids emphasizes the need for adaptability and the capacity to traverse new ground when tackling problems.

Complex Engineering Problems (P) Solving		
	Attributes	Statement from students
A1	Range of resources	The project's diverse resource requirements underscore the significance of effective resource allocation and management.
A2	Level of interaction	Comprehending the complexities of design complexity becomes crucial when combining various amplifiers, requiring expertise in areas such as signal manipulation techniques, circuitry design, and electrical engineering principles.
A3	Innovation	Promoting creativity is essential, as it motivates students to look for novel solutions for long-distance transmission lines.

APPENDIX C

PROGRAM CODE

```
clc;
clear all
x=[10 20 30]; % Length without and with DRA
y=[0.000796775 0.001633 0.00078245]; %BER without DRA 100mW
y1=[1.55886e-008 7.86549e-006 0.00226119]; %BER with DRA 100mW
y2=[0.000380649 0.000378328 0.000367607]; %BER without DRA 10mW
y3=[3.07799e-016 1.0085e-011 5.02549e-006]; %BER with DRA 10mW
plot(x,y3,'black')
hold on
grid on

clc;
clear all
x=[10e9 30e9 60e9 70e9]; % bit rate  without and with DRA
y=[0.00355606 0.00121477 0.000376878 6.78398e-005]; %BER without DRA 30km
y1=[0.000900476 0.000856182 0.000836015 0.0008416]; %BER with DRA 30km
%y2=[0.000380649 0.000378328 0.000367607]; %BER without DRA 30km
%y3=[3.07799e-016 1.0085e-011 5.02549e-006]; %BER with DRA  30km
plot(x,y1,'g')
hold on
grid on

clc;
clear all
x=[20 30 40 50]; % i/p  without and with DRA
y=[0.000297349 0.000552307 0.000697835 0.000900474]; %BER with DRA 20km
%y1=[0.000900476 0.000856182 0.000836015 0.0008416]; %BER with DRA 20km
%y2=[0.000380649 0.000378328 0.000367607]; %BER without DRA 30km
%y3=[3.07799e-016 1.0085e-011 5.02549e-006]; %BER with DRA  30km
plot(x,y,'g')
hold on
grid on

clc;
clear all
x=[30 50 70 100]; % I/P without and with DRA
y=[0.00016998 0.00355606 0.000991794 0.000778245]; %BER without DRA 30km
y1=[0.000552307 0.000900476 0.00146734 0.00316048]; %BER with DRA 30km
%y2=[0.000380649 0.000378328 0.000367607]; %BER without DRA 30km
%y3=[3.07799e-016 1.0085e-011 5.02549e-006]; %BER with DRA  30km
plot(x,y1,'g')
hold on
grid on

clc;
clear all
x=[30 50 70 100]; % Length with and without EDFA and DRA SOA
y=[1.75819e-014 4.82932e-012 2.74327e-011 7.96917e-009]; %BER with With EDFA 40mW
y1=[5.42399e-054 4.12371e-024 2.88909e-008 1.08992e-010]; %BER with EDFA+ SOA
40mW
y2=[0.000189498 1.2852e-014 4.22811e-024 0.000184492]; %BER With DRA+ SOA 40mW
plot(x,y2,'r')
hold on
grid on
```

```
clc;
clear all
x=[30 50 70 100]; % Length with and without EDFA and DRA SOA
y=[1.75819e-014 4.82932e-012 2.74327e-011 7.96917e-009]; %BER with With EDFA 40mW
y1=[5.42399e-054 4.12371e-024 2.88909e-008 1.08992e-010]; %BER with EDFA+ SOA
40mW
y2=[0.000189498 1.2852e-014 4.22811e-024 0.000184492]; %BER With DRA+ SOA 40mW
semilogy(x,y,'black')
hold on
semilogy(x,y1,'g')
hold on
semilogy(x,y2,'r')
grid on
```