PERFORMANCE EVALUATION OF OPTICAL AMPLIFIER IN WDM SYSTEM

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DEDICATION

Special dedicated to my beloved father, Peh Kim Pong and my mother, Tee Siew Ching.

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ABSTRACT

This report explores on how to evaluate the performance of optical amplifier which are Erbium-Doped Fiber Amplifier (EDFA), Raman Amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifier (HFAs) which are technologies for future dense wavelength-division-multiplexing (DWDM) multiterabit systems. After that, the best optical amplifier will be chosen among all of these amplifiers. This report will be explained the fundamental knowledge, the characteristic of these three types of amplifier and the simulation process involved in completing the project. The methods used to achieve the objectives are also clarified throughout the report.

ABSTRAK

Laporan ini menghuraikan tentang bagaimana untuk menilai prestasi penguat optic "*Erbium-Doped Fiber Amplifier (EDFA), Raman Amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifier (HFAs)*" yang merupakan teknologi "*wavelength-division-multiplexing (WDM)*" sistem multiterabit untuk masa depan. Peguat optic yang terbaik akan dipilih dikalangan ketiga-tiga jenis peguat tersebut. Laporan ini akan menerangkan pegetahuan asas, cirri-ciri ketiga-tiga jenis peguat dan proses simulasi yang terlibat dalam menyiapkan projek ini. Kaedah-kaedah yang digunakan untik mencapai objektif juga dijelaskan sepanjang laporan ini.

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LIST OF ABBREVIATIONS

ASE	-	Amplified Spontaneous Emission
BER	-	Bit Error Rate
DMux	-	Demultiplexer
DRA	-	Distributed Raman Amplifier
EDFA	-	Erbium-Doped Fiber Amplifier
HFAs	-	Hybrid Fiber Amplifiers
Mux	-	Multiplexer
NF	-	Noise Figure
OSA	-	Optical Spectrum Analyzer
OSNR	-	Optical Signal-to-Noise Ratio
P_H	-	Power High
P_M	-	Power Medium
SNR	-	Signal-to-Noise Ratio
SOAs	-	Semiconductor Optical Amplifiers
WDM	-	Wavelength-Division-Multiplexing

CHAPTER I

INTRODUCTION

In optical fiber network, amplifiers are used to regenerate an optical signal, amplify and then retransmitting an optical signal. In a long-haul optical systems, the amplifiers are needed to compensate the attenuation occurred.

The main purpose of this project is to investigate and determine the characteristic of Erbium-Doped Fiber Amplifier (EDFA), Raman Amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifier (HFAs) and its performance in telecommunication by using the Optisystem software. After that, the best optical amplifier will be chosen among these amplifiers. Since the performance of the amplifier is influenced by the parameter of gain, Noise Figure (NF), Bit Error Rate (BER), and Optical-Signal-to-Noise Ratio (OSNR), the problem encounter in this project is to find the best design parameter for maximum reachable transmission distance.

Optisystem software is used as the simulation tools for the whole project. Optisystem software is based on the realistic modeling for the fiber optic communication systems and serves a wide range of applications, thus it is an ideal simulation tools for this project. Since the simulation would not give the significant result in this project without understanding the calculation in this aspect, therefore this project also will explore the theoretical.

1.1 Objectives of Project

The objectives of this project are:

1) To identify the best optical amplifier that can be used in the WDM system.
2) To suggest a new design of optical WDM transmission by using the best optical amplifier characteristic.
3) To analyze the simulated data obtained from the Optisystem software.

1.2 Scopes of Works

This project will be focused primarily on the simulation of Erbium-Doped Fiber Amplifier (EDFA), Raman Amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifier (HFAs) by using the Optisystem software. The performance of the amplifiers will be evaluated depend on the amplifier's gain, Noise Figure (NF), Bit Error Rate (BER), Optical Signal-to-Noise Ratio (OSNR), and eye-pattern. After that, comparison of result between the simulation result and theoretical result will be analyzed.

1.3 Problems Statement

Optical amplifiers have become a necessary component in long-haul fiber optic systems due to the demand for longer transmission lengths. The effect of dispersion and attenuation can be minimized in long-haul optical systems due to the invention of Erbium-Doped Fiber Amplifier (EDFA), Raman Amplifier, and Semiconductor Optical Amplifier (SOAs).

In order to have a high capacity transmission system, there are several ways such as by using the WDM technique, increase the power of output transmission system, reduce the losses in transmission system and etc. by increase the number of optical amplifier in long-haul transmission system is able to increase the output power of transmission system but this will increase the costs. Thus, the best solution is to evaluate the best performance of optical amplifier.

1.4 Methodology

This project will starts with the searching of source and information regarding to the EDFA, Raman amplifier, and HFA. The source and information are acquired from journal, reference books, e-Books, and internet. The circuit schematic diagrams of these amplifiers are determined from the journal and simulate by using the Optisystem software. All the parameters such as gain, Noise Figure (NF), Bit Error Rate (BER), Optical Signal-to-Noise Ratio (OSNR), and eye-pattern that determine the performance of these amplifiers are analyzed.

1.5 Thesis Outlines

Chapter 1: The first chapter will provide a general inspiration for the project. It includes the objectives of the project, scopes of works, problems statement and the methodology.

Chapter 2: In this chapter, the research of background related to the project will be discussed. The concept and theory of the circuit schematic diagram of Erbium-Doped Fiber Amplifier (EDFA), Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifier (HFA) that is used in the simulation will be explained.

Chapter 3: The third chapter is the methodology. In this chapter, the procedure and project flow of this project will be shown.

Chapter 4: This chapter will present all the simulation result from the Optisystem software. All the graphs and tables obtained from the simulation will be compared with the theoretical results.

Chapter 5: The last chapter of this thesis is the conclusion and recommendation. The results will be evaluated based on the objectives of the project. It’s followed by some recommendation for the future study about this project.

CHAPTER II

LITERATURE REVIEW

2.1 Fiber Optic is Green Technology

For instance, when a solar company improves energy conversion rate by a couple of percents, it is a market-breaking result! Slow improvements seem to be characteristic of energy production. But it is time we use technology innovation and put the best minds to work in order to improve energy efficiency across the board. It is possible. One example: first experiments in emitting diodes started in early nineties with very small efficiency. Fifteen years later, semiconductor lights are surpassing incandescent lights thanks to improvements typical of the semiconductor industry (performance doubling roughly every 2 years aka. as Moore's law).

But it is fair to say that performance increase cannot always go hand-to-hand with energy efficiency. If we continue to take the semiconductor analogy, Moore's law is possible thanks to the ability to integrate more and more transistors and reduce the resolution of printed circuit boards. This comes with a cost though: power consumption. As distances get finer, power dissipation increases too. This explains why personal computers feel hotter on our laps, or why servers require fancier cooling systems. Heat dissipation is a real problem in today's processors. Actually, if we continue to increase integrated circuit speed, their power density would reach the mark of a nuclear reactor within 10 years.

In contrast, fiber optics is a very "green" technology compared to semiconductor electronics. It dissipates a lot less energy than copper based cables and it saves a lot of materials: one single strand of glass can carry as much data as many thousands of copper cables and it can do over a longer distance without using electronic equipment to regenerate it. The oceans for example are a lot less crowded with more efficient fiber-optic submarine cables while supporting an ever growing need for international communications. In the other hand, fiber optics does not create any environmental polluting waste or byproducts or do not emit any harmful radiations etc.

2.2 Wavelengths-Division-Multiplexing (WDM)

Wavelengths-division-multiplexing (WDM) is the basic technology of optical networking. It is a technique for using a fiber (or optical device) to carry many separate and independent optical channels as shown in Figure 1. The wavelength division multiplexing (WDM) is one of the most efficient techniques for increasing the information carrying capacity of an optical fiber communication system. The number of multiplexed channels is increased by reducing the channel spacing. The reduction in channel spacing increases the crosstalk and hence the performance of the system degrades considerably. There is continuous effort in scientific community to devise methods to decrease it [1].

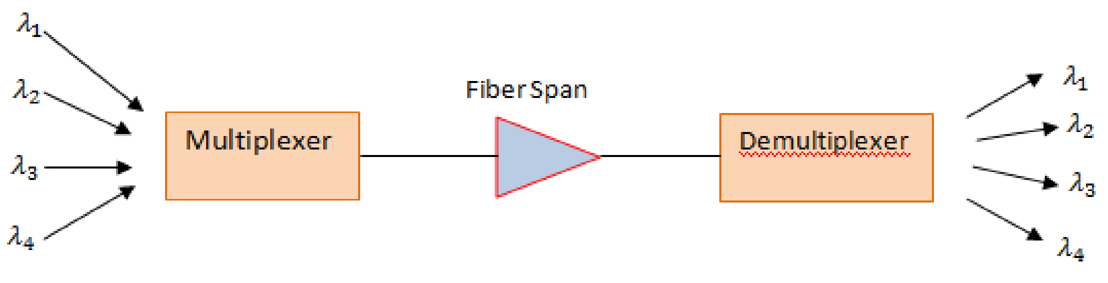

Figure 2.1: Wavelength-Division-Multiplexing (WDM)

Wavelength selective couplers are used both to mix (multiplex) and to separate (demultiplex) the signals. The distinguishing characteristic is very wide separation of wavelength used (different band rather than different wavelengths in the same band). Some systems are using a single fiber bidirectional for each direction. Each channel is allocated its own wavelength or rather range wavelength. A typical optical channel might be separate in 1nm wide. This channel is really a wavelength range within which the signal must stay. Normally, it's much wider the signal itself. The width of the channel depends on many things such as the modulated line width of the transmitter, its stability and the tolerances of the other components in the system. Table 2.1 shows the transmission windows for different wavelength bands.

Table 2.1: Transmission windows (wavelength bands)

Bands	Description	Wavelength Range (nm)
O band	Original	1260-1360
E band	Extended	1360-1460
S band	Short Wavelength	1460-1530
C band	Conventional ("erbium window")	1530-1565
L band	Long Wavelength	1565-1625
U band	Ultra-long Wavelength	1625- 1675

In most of telecommunication system, C band is chosen because C band has the lowest attenuation losses and achieves the longest range, compatible with fiber amplifiers.

There is some specification of the WDM such as conventional single-mode fibers transmit wavelengths in the 1300nm and 1550nm ranges and absorb wavelengths in the 1340-1440nm ranges. Therefore, WDM use wavelengths in the two regions of 1310nm and 1550nm. The other specifications for use in WDM are as shown in Table 2.2.