

**PERFORMANCE EVALUATION OF HYBRID RAMAN AND ERBIUM DOPED  
FIBER AMPLIFIERS (HFAs)**

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**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**  
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**BORANG PENGESAHAN STATUS LAPORAN  
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**Tajuk Projek** : Performance Evaluation of Hybrid Raman and Erbium Doped Fiber Amplifiers (HFAs)

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*Dedicated to my father, Chai Ming Aon and my beloved late mother, Loh Siew Kim.*

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## **ABSTRACT**

This report explores how to evaluate the performance of Hybrid Raman and Erbium Doped Fiber Amplifiers (HFAs) which are a technology for future dense wavelength-division-multiplexing (DWDM) multiterabit systems. The fundamental objective is to provide a design parameter for maximum reachable transmission distance in optical transmission system using the Hybrid Raman and Erbium Doped Fiber Amplifiers. All the basic parameter and fundamental theory are described in detail. The simulation result will be revealed and discussed.

## ABSTRAK

Laporan ini menghuraikan bagaimana prestasi penguat “*Hybrid Raman dan Erbium Doped Fiber*” dapat dinilai. Ianya merupakan teknologi “*dense wavelength-division-multiplexing (DWDM)*” sistem multiterabit untuk masa depan. Tujuan utama projek ini adalah untuk mereka bentuk parameter untuk mendapatkan jarak penghantaran maksimum dapat dicapai bagi sistem penghantaran optik yang menggunakan penguat “*Hybrid Raman dan Erbium Doped Fiber*”. Semua parameter dan teori asas dijelaskan secara terperinci. Keputusan simulasi juga dinyatakan dan dibahas.



## CONTENTS

CHAPTER	TITLE	PAGES
	<b>PROJECT TITLE</b>	
	<b>STATUS REPORT FORM</b>	ii
	<b>STUDENT DECLARATION</b>	iii
	<b>SUPERVISOR DECLARATION</b>	iv
	<b>DEDICATION</b>	v
	<b>ACKNOWLEDGEMENT</b>	vi
	<b>ABSTRACT</b>	vii
	<b>ABSTRAK</b>	viii
	<b>CONTENT</b>	ix
	<b>LIST OF TABLE</b>	xiii
	<b>LIST OF FIGURE</b>	xi
	<b>LIST OF ABBREVIATIONS</b>	xi
<b>I</b>	<b>INTRODUCTION</b>	
	1.1 Overview of Project	1
	1.2 Objectives	2
	1.3 Problem Statement	2
	1.4 Scope	3
	1.5 Project Outcomes	4
	1.6 Methodology	4
	1.7 Thesis Structure	5

## **II LITERATURE REVIEW**

2.1 Optical Amplifiers	6
2.1.1 Semiconductor Optical Amplifiers	7
2.1.2 Erbium Doped Fiber Amplifiers(EDFA)	8
2.1.3 Raman Optical Amplifier	10
2.1.4 Hybrid Raman and Erbium-Doped Fiber Amplifier (HFAs)	11
2.2 Performance of optical amplifier	12
2.2.1 Gain	12
2.2.2 Noise	13
2.2.3 Signal-to-Noise Ratio	13
2.2.4 Bit Error Rate	14
2.2.5 Eye-Pattern	14
2.3 Optical fiber	15
2.3.1 Single Mode Fiber (SMF)	16
2.3.2 Chromatic Dispersion	16
2.3.3 Dispersion-compensating fiber (DCF)	17
2.3.4 Multimode Fiber vs. Single-mode Fiber	17

## **III METHODOLOGY**

3.1 Project Flow Chart	20
3.2 Project Block Diagram	20

## VI RESULT AND DISCUSSION

4.1 Design parameter choosing for Erbium Doped Fiber Amplifier (EDFA)	22
4.2 Design parameter choosing for Raman Amplifier	24
4.3 Gain, Noise Figure, and Output OSNR comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with 0dBm, -10dBm, and -20dBm input signal	27
4.3.1 Gain comparison between EDFA, Raman, and Hybrid Raman and Erbium-Doped Fiber amplifiers with 0dBm input signal	27
4.3.2 Gain comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber amplifiers with -10dBm input signal	29
4.3.3 Gain comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber amplifiers with -20dBm input signal	32
4.3.4 BER comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber amplifiers with 0dBm input signal	34
4.3.5 BER comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber amplifiers with -10dBm input signal	37
4.3.6 BER comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber amplifiers with -20dBm input signal	39

4.3.7 OSNR comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber amplifiers with 0dBm input signal	41
4.3.8 OSNR comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber amplifiers with -10dBm input signal	42
4.3.9 OSNR comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber amplifiers with -20dBm input signal	43
4.4 Hybrid Raman and Erbium-Doped Fiber amplifiers amplifier's gain with -20dBm, -10dBm, and 0dBm input signal power	44
4.5 Hybrid Raman and Erbium-Doped Fiber amplifiers amplifier's BER with -20dBm, -10dBm, and 0dBm input signal power	45
4.6 Hybrid Raman and Erbium-Doped Fiber amplifiers amplifier's OSNR with -20dBm, -10dBm, and 0dBm input signal power	46
4.7 Different wavelength of pump power for EDFA and Raman amplifier in Hybrid Raman and Erbium-Doped Fiber amplifiers	47
4.7.1 All pump power with wavelength 980nm	47
4.7.2 All pump power with wavelength 1480nm	48
4.7.3 EDFA with pump power of wavelength 1480nm and Raman amplifier with pump power of wavelength 980nm	50
4.8 Raman amplifier followed by EDFA in Hybrid	51

Raman and Erbium-Doped Fiber amplifiers with -  
10dBm input signal

<b>V</b>	<b>CONCLUSION &amp; RECOMMENDATION</b>	
	5.1 Conclusion	53
	5.2 Recommendation	54
	<b>REFERENCES</b>	56
	<b>APPENDIX</b>	58

## LIST OF TABLES

<b>TABLE</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Multimode Fiber vs. Single-mode Fiber	18
4.1	Gain, Noise Figure, and Output OSNR for EDFA from 1m to 10m with -10dBm input signal	24
4.2	Gain, Noise Figure, and Output OSNR for Raman amplifier from 1km to 25km with -10dBm input signal	26
4.3	Gain comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with 0dBm input signal	28
4.4	Gain comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with -10dBm input signal	30
4.5	Gain comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with -20dBm input signal	32
4.6	BER comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with 0dBm input signal	35
4.7	BER comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with -10dBm input signal	37
4.8	BER comparison between EDFA, Raman amplifier, and	39

	Hybrid Raman and Erbium-Doped Fiber Amplifiers with - 20dBm input signal	
4.9	Gain, Noise Figure, Output OSNR and BER for all pump power with wavelength 980nm with -10dBm input signal in Hybrid Raman and Erbium-Doped Fiber amplifiers	47
4.10	Gain, Noise Figure, Output OSNR, and BER for all pump power with wavelength 1480nm with -10dBm input signal in Hybrid Raman and Erbium-Doped Fiber amplifiers	49
4.11	Gain, Noise Figure, Output OSNR and BER for EDFA with pump power of wavelength 1480nm and Raman amplifier with pump power of wavelength 980nm with - 10dBm input signal in Hybrid Raman and Erbium-Doped Fiber amplifiers	50
4.12	Gain, Noise Figure, Output OSNR and BER for Raman amplifier followed by EDFA in Hybrid Raman and Erbium-Doped Fiber amplifiers with -10dBm input signal	52

## LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	Semiconductor Optical Amplifier [1]	8
2.2	Simplified energy level of Er <sup>3+</sup> ions in Erbium-doped fiber [2]	8
2.3	Experimental configurations for the three types of single pump, hybrid Raman and Erbium Doped Fiber Amplifier (HFAs) [6]	11
2.4	Example of eye pattern at receiver [8]	15
2.5	Light Transmitted through Single-Mode Fiber [8]	16
2.6	Output Wavelengths of Laser Source [9]	17
3.1	Project Flow Chart	20
3.2	Project block diagram	21
4.1	The schematic diagram of single EDFA with -10dBm input signal	23
4.2	The schematic diagram of single Raman amplifier with -10dBm input signal	25
4.3	Gain comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with 0dBm input signal	29
4.4	Gain comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with -10dBm input signal	31
4.5	Gain comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with -20dBm input signal	33



4.6	The schematic diagram of Hybrid Raman and Erbium Doped Fiber Amplifiers with 0dBm input signal	34
4.7	BER comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with 0dBm input signal	36
4.8	BER comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with -10dBm input signal	38
4.9	BER comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with -20dBm input signal	40
4.10	OSNR comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with 0dBm input signal	41
4.11	OSNR comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with -10dBm input signal	42
4.12	OSNR comparison between EDFA, Raman amplifier, and Hybrid Raman and Erbium-Doped Fiber Amplifiers with -20dBm input signal	43
4.13	Hybrid Raman and Erbium-Doped Fiber amplifiers amplifier's gain with -20dBm, -10dBm, and 0dBm input signal power	44
4.14	Hybrid Raman and Erbium-Doped Fiber amplifiers amplifier's BER with -20dBm, -10dBm, and 0dBm input signal power	45
4.15	Hybrid Raman and Erbium-Doped Fiber amplifiers amplifier's OSNR with -20dBm, -10dBm, and 0dBm input signal power	46

## LIST OF ABBREVIATIONS

<b>ASE</b>	- Amplified Spontaneous Emission
<b>BER</b>	- Bit Error Rate
<b>DCF</b>	- Dispersion Compensation Fiber
<b>DFB</b>	- Distributed Feedback Laser
<b>DWDM</b>	- Dense Wavelength Division Multiplexing
<b>EDFA</b>	- Erbium Doped Fiber Amplifier
<b>FP</b>	- Fabry-Perot Laser
<b>HFAs</b>	- Hybrid Raman and Erbium Doped Fiber Amplifiers
<b>MMF</b>	- Multimode Fiber
<b>NF</b>	- Noise Figure
<b>OSNR</b>	- Optical Signal Noise Ratio
<b>SMF</b>	- Single Mode Fiber

- SNR** - Signal Noise Ratio
- SOA** - Semiconductor Optical Amplifier
- VSCSEL** - Vertical-Cavity Surface-Emitting Laser
- WDM** - Wavelength Division Multiplexing

## CHAPTER 1

### INTRODUCTION

#### 1.1 Overview of Project

Hybrid Raman and Erbium Doped Fiber Amplifiers (HFAs) are a technology for future dense wavelength-division-multiplexing (DWDM) multiterabit systems. HFAs are designed in order to maximize the transmission length and to minimize the impairments of fiber nonlinearities, and to enhance the bandwidth of Erbium Doped Fiber Amplifiers (EDFAs).

This project simulates and evaluates the performance of hybrid Raman and Erbium-Doped Fiber Amplifiers in optical transmission systems using Optisystem software. Since the performance of the amplifier is influenced by the parameter of Optical Signal-to-Noise Ratio (OSNR), Bit Error Rate (BER), and Noise Figure (NF), the problem encounter in this project is to find the best design parameter for maximum reachable transmission distance using the hybrid amplifiers.

Optisystem software is used as the simulation tools for the whole project. Optisystem software is based on realistic modeling of fiber optic

communications systems and serves a wide range of applications, thus it is an ideal simulation tools for this project.

## 1.2 Objectives

The objectives of the project are:

- 1) to design hybrid Raman and Erbium Doped Fiber Amplifiers using Optisystem software.
- 2) to provide a design parameter for maximum reachable transmission distance in optical transmission system using the hybrid Raman and Erbium Doped Fiber Amplifiers.
- 3) to evaluate the performance of the Hybrid Raman and Erbium Doped Fiber Amplifiers based on the amplifier's gain, Optical Signal-to-Noise Ratio (OSNR), Bit Error Rate (BER), Noise Figure (NF), and etc.
- 4) to analyze the simulated data obtained from Optisystem software.

## 1.3 Problem Statement

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

One of the shortcomings of EDFAs is their non flat-gain characteristics across a given optical spectrum. In particular, the gain level is substantially less at the end of the L-band between about 1600 nm and 1620 nm. Fortunately, the gain level of such amplifiers can be rendered substantially flat across the L-band window by the use of gain flattening filters which are optically coupled between

the coils of erbium doped fiber. However, the use of such filters results in a higher NF in the channels having wavelengths in the 1600-1620 nm range. The substantially higher NF in the 1600-1620 nm range lowers the usable bandwidth available from such EDFA amplifiers.

Raman amplifiers likewise have non-flat gain characteristics. A typical Raman gain level curve has minimum gains at about 1570 nm, 1595 nm, and 1620 nm, and maximums at 1585 nm and 1610 nm. A gain flattening filter can be applied to reduce this variation but will only be optimized at a single operating gain value. Additionally, there is the desire to minimize the number of gain flattening filters in the system and the loss they incur.

Clearly, there is a need to reduce the maximum NF in EDFA gain, as well as to further flatten the gain curve in Raman-type amplifiers in order to reduce signal losses throughout the network.

The invention is a hybrid optical signal amplifier that reduces the maximum NF of an EDFA while flattening the gain of a Raman amplifier without compromising laser pump efficiency.

Therefore, this project simulates and evaluates the performance of hybrid Raman and Erbium Doped Fiber Amplifiers (HFAs) in optical transmission systems to provide a design parameter for maximum reachable transmission distance using the hybrid amplifiers.

## **1.4 Scope**

This project will focus primarily on the simulation of hybrid Raman and Erbium Doped Fiber Amplifiers (HFAs) using Optisystem software. The performance of the amplifier will be evaluated depend on amplifier's gain,

Optical Signal-to-Noise Ratio (OSNR), Bit Error Rate (BER), and Noise Figure (NF) obtained from the simulation of a single mode fiber transmission link. The fabrication or development of hybrid Raman and Erbium Doped Fiber Amplifiers (HFAs) will not be covered in this project.

## **1.5 Project Outcomes**

It is expected that at the end of the project, a design parameter for maximum reachable transmission distance using the hybrid amplifiers can be obtained.

## **1.6 Methodology**

This project starts with the searching of source and information regard hybrid Raman and Erbium Doped Fiber Amplifiers (HFAs). The source and information are acquired from journal, reference books, e-Books, magazine and internet. The circuit schematic diagram of hybrid Raman and Erbium Doped Fiber Amplifiers (HFAs) is determined from the journal and simulate using Optisystem software. All the parameter likes amplifier's gain, Optical Signal-to-Noise Ratio (OSNR), Bit Error Rate (BER), and Noise Figure (NF) that determines the performance of the HFAs is analyzed. The simulation process is repeated until the design parameter for maximum reachable transmission distance using the hybrid amplifiers can be obtained.

## 1.7 Thesis Structure

- Chapter 1: The first chapter provides a general inspiration for the project. It includes the overview of project; the objectives of project, problem statement, scope of the project and project outcomes.
- Chapter 2: Project's background is illustrated in this chapter. Generally, this chapter summaries the literature review that have been studied. The concept and theory of the circuit schematic diagram of hybrid Raman and Erbium Doped Fiber Amplifiers (HFAs) that is used for simulation will be explained in this chapter.
- Chapter 3: The third chapter is discussed about the methodology of the project. The method, materials and procedures used to conduct the project in achieving the objectives of the project is explained in details.
- Chapter 4: The chapter four will present all the simulation result from the Optisystem software. All the graphs and tables obtained from the simulation will be discussed in details.
- Chapter 5: The last chapter will conclude all the findings and results obtained throughout the project. The results will be evaluated based on the findings and the objectives of the project. Recommendations for future studies also will be included in this chapter.