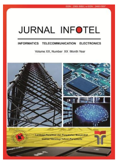

JURNAL INFOTEL
Informatics - Telecommunication - Electronics
Website Jurnal : http://ejournal.st3telkom.ac.id/index.php/infotel
ISSN : 2085-3688; e-ISSN : 2460-0997

Comparative Analysis of Erbium Doped Fiber Amplifier (EDFA) and Raman Optical Amplifier (ROA) in Nonlinear-CWDM System

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Received 15 July 2018, Revised 08 August 2018, Accepted 28 August 2018

Abstract — The massive demands for high-rate application drove the telecommunication service to use large bandwidth capacity. The Coarse Wavelength Division Multiplexing (CWDM), common use in Metro-WDM, can be a solution to provide large bandwidth in optical communications. In a communications system, there are attenuation and nonlinear effect decreasing the system performance. To overcome the limitation imposed by electrical regeneration to maintain system performance, a means of optical amplification was sought. In this paper presents the comparison of two competing technologies emerged: Erbium Doped Fiber Amplifier (EDFA) and Raman Optical Amplifier (ROA) to overcome the attenuation in the nonlinear system. We designed the CWDM system using 8 channels with 20 nm channel spacing and 60 km length. The result was conducted by varying the optical power launch using -8, -6, -4, -2, 0, 2, 4, and 6 dBm. Based on the result of the research, Raman amplification can maintain the BER and the Q-factor that meet the ITU-T standard for all optical power launch value, but EDFA can maintain those for optical power launch more than 0 dBm. In addition, the received power in Raman amplification larger than that received in EDFA. In conclusion, a CWDM system using ROA amplifier prefer to use for the system than using the EDFA amplifier.

Keywords – CWDM, EDFA, ROA, BER, Q-factor

I. INTRODUCTION

The world of telecommunications continues to grow in line with the increasing public demand for high-rate application services, such as video on demand, streaming media, virtual private circuits, high-resolution image transfer, and online entertainment. Those services require large bandwidth [1] [2]. Optical communication systems are one of the most appropriated transmission systems with high bit rate communication [3] [4]. In addition to the reliable speed of optical transmission is resistant to noise and interference [3] such as dispersion [4]. Fiber optic had better performance compared to cooper as the transmission media and using wireless because it provides high-speed communications [5]. Coarse Wavelength Division Multiplexing (CWDM) provides large bandwidth utilization that is useful for sending much information through one transmission using wavelength. In the nonlinear CWDM system, attenuation and nonlinear effects could affect the performance of a WDM network [8]. The nonlinear effect results in the reduction of the information signal power that transmitted through the optical fiber that made, an interruption to the signal propagation, but to overcome these problems are using an amplifier to amplify the lightwaves [7]. The appropriated amplifier is using Erbium Doped Fiber Amplifier (EDFA) and Raman Optical Amplifier (ROA) [8]. Before the improvement of pump laser technology, EDFA emerged as the preferred approach than ROA [9]. Today, implementation ROA to amplify the optical signal in fiber optical communication system more common, especially to reduce the non-linear effects

This paper based on previous research conducted in [10] that analyses the nonlinear effect on CWDM network using eight channels. By comparing the linear networks and the nonlinear ones of different length. The results obtained that the system needed an EDFA amplifier in transmission length more than 40 km. In addition, the system using a nonlinear effect is decreased the system performance compared to the linear system. In [10], a system using EDFA can be implemented either in linear or non-linear optical link. In [11] analyzed the hybrid SOA-EDFA amplifier using boosters schemes in CWDM networks with wavelengths from 1470 nm to 1610 nm and 0 dBm input power for 80 Km of fiber length. It obtained that hybrid booster has more advantage because it is more stable. In [12] compare EDFA amplifier and a Raman amplifier by observing the BER value for length variation. The result obtains that the Raman amplifier has better performance than an EDFA amplifier. Because the EDFA amplifier output power will increase, but then will decrease again while the pump power runs out, but for Raman amplifier did not decrease. In [13] compare the CWDM and DWDM system by the number of wavelengths, channel spacing, application, and maximum link distance obtained that DWDM results have better performance than CWDM because it has greater bandwidth, and longer transmission distance. In CWDM has fewer channels but CWDM requires less power compared to DWDM.

This paper compared the system performance using EDFA amplifier and ROA amplifier in CWDM system using eight channels number with 10 Gbps bitrate and 60 km fiber length. The result was conducted by the value of Bit Error Rate (BER), Q-factor, and received power parameters for each amplifier. The rest of the paper is formed as follows. Section II presents the method and describes the system design, while section III confers some experimental results used to evaluate the system that discusses in section IV. In the end, section V concludes the paper.

II. RESEARCH METHOD

A. System Scheme

System design can be seen in Fig.1 that is divided into three blocks. The transmitter block is used to send the signal; the bit signal is derived from Pseudo Random Bit Sequence (PRBS) and then changes to an electrical signal which is encoded by NRZ Generator. The laser provides optical wave input as a light source using power -8, -6, -4, -2, 0, 2, 4, and six dBm. The signal will be modulated in Mach-Zehnder Modulator in each channel. After modulation, before transmitting a signal from 8 channels for wavelength 1471-1611 nm will be combined in the multiplexer. The optical signal is transmitted using optical fiber with 60 km length, then to overcome the attenuation of the waveform and fiber loss at the time of transmission is using an amplifier. In this design, there are two types of an optical amplifier that are used. In the receiver block, the signal will be separated into eight channels according to their respective wavelengths using WDM demultiplexer and then received by photo-detector. The system parameters designed in this works show in Table 1.

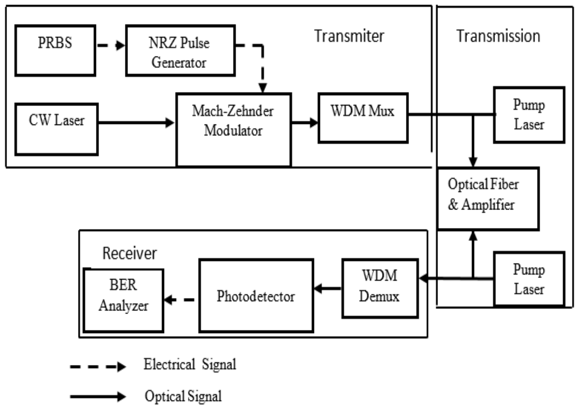

Fig.1. Block Diagram System

Table 1. System Design Parameters

Parameters	Value
Wavelength	1471-1611 nm
Number of Wavelengths	8 Channel
Optical CW Launch Power	-8, -6, -4, -2, 0, 2, 4, 6 dBm
Channel spacing	20 nm
Bit rate	10 Gb/s
Fiber Length	60 km
Fiber Attenuation	0.2 dB/km
EDFA Gain	10 dB
Responsitivity PIN	1 A/W
PIN Gain	3 dB

Table 1 shows the specifications of the system from the transmitter to the receiver. The transmitter block used eight channels with 10 Gbps bit rate. The wavelength used from 1471-1611 nm with 20 nm channel spacing. The system performance is using power variation from the CW Laser for -8, -6, -4, -2, 0, 2, 4, and six dBm. The transmission block is used single-mode fiber with 60 Km length and has fiber losses for 0.2 dB/km. EDFA amplifier is used with 10 dB of gain. The optical detector used a PIN with responsivities 1 A/W and 3 dB of gain.

III. RESULT

The simulation system for CWDM nonlinear system in 10 Gbps bitrate using a different optical amplifier for EDFA and ROA amplifier by variate the optical input power has done. The results are obtained from BER and Q Factor parameters that simulated in OptiSystem software. Table 2 describe the BER results from the average of the eight channel in the system using different input power from -8 dBm to 6 dBm. Table 3 describes the Q Factor results from the average of eight channel in the system using different input power from -8 dBm to 6 dBm. Table 4 describes the

Received Power results from eight channel in the system using different input power from -8 dBm to 6 dBm.

Table 2. BER Result of The System For ROA And EDFA Amplifier Using Different Input Power

Power (dBm)	ROA	EDFA
-8	4.924×10^{-36}	6.484×10^{-02}
-6	1.914×10^{-41}	6.026×10^{-07}
-4	2.010×10^{-42}	6.688×10^{-07}
-2	7.991×10^{-43}	3.790×10^{-07}
0	5.646×10^{-43}	2.110×10^{-12}
2	5.036×10^{-43}	2.128×10^{-15}
4	4.648×10^{-43}	1.225×10^{-22}
6	4.273×10^{-43}	1.257×10^{-39}

Table 3. Q Factor Result of The System for ROA and EDFA Amplifier Using Different Input Power

Power (dBm)	ROA	EDFA
-8	13.351	7.530
-6	14.432	7.878
-4	14.697	8.019
-2	14.815	8.514
0	14.863	9.426
2	14.882	10.616
4	14.888	12.851
6	14.738	16.734

Table 4. Received Power Result of The System for ROA and EDFA Amplifier Using Different Input Power

Power (dBm)	ROA	EDFA
-8	-11.669	-13.808
-6	-9.807	-11.808
-4	-7.807	-9.695
-2	-5.807	-7.806
0	-3.807	-5.795
2	-1.852	-3.812
4	0.469	-1.828
6	2.323	0.117

IV. DISCUSSION

In this section discuss the comparison for performance results of the system with EDFA amplifiers and ROA amplifiers for BER, Q-factor and power receiver parameters using different input power.

A. Input power effect to BER using EDFA and ROA amplifier

From Fig.2 shows the result of BER values that obtained by varying the input power from -8 dBm to 6 dBm for the CWDM Nonlinear system using EDFA and ROA amplifier. For the system using the EDFA amplifier, the bit error decreases as the input power increase. It gives a better result for 2, 4, and six dBm. But for -8 to 0 dBm input power gives result below-standard of maximum BER value.

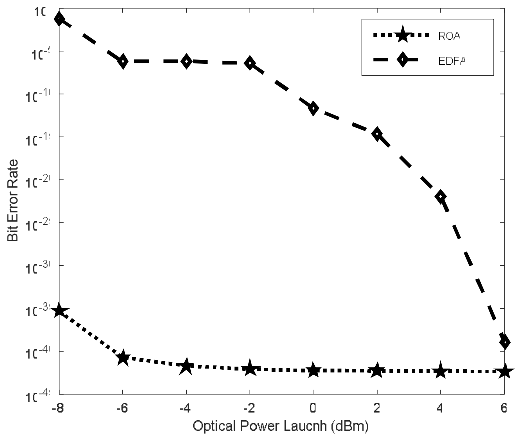

Fig.2. Input Power Effect to BER Using EDFA and ROA Amplifier

The system using ROA amplifier had stabile Min BER value because this component used the fiber nonlinearity to amplify the signal. It gave above standard Min BER value for -8 dBm to 6 dBm. As can be seen in Table 2, the results obtained that greatest power for the system using EDFA amplifier gave the minimum BER value $1{,}257 \times 10^{-39}$ for six dBm-optical power launch and the maximum BER value $6{,}484 \times 10^{-02}$ for -8 dBm-optical power launch. The smallest BER for the system using ROA amplifier was $4{,}273 \times 10^{-43}$ for six dBm input power and $4{,}924 \times 10^{-36}$ for -8 dBm input power as the biggest BER value. System performance of ROA amplifier reached the standard minimum BER that was smaller than 10^{-12}, but system performance of EDFA amplifier was not worked properly for input power less than 0 dBm. As this comparison, the system using ROA amplifier gave better performance than the system using EDFA amplifier because the system using ROA amplifier has bigger value than using EDFA Amplifier in -8 dBm to 6 dBm input power.

B. Input power effect to Q-factor using EDFA and ROA amplifier

Figure 3 shows the result of Q-factor values that obtained by varying the input power from -8 dBm to 6 dBm for the CWDM Nonlinear system using EDFA and ROA amplifier. In the system using the EDFA amplifier, as the power increase is increasing the Q Factor value. It gives better Q Factor result for -8 dBm to 6 dBm and for the system using ROA amplifier, it gives stable Q Factor values for -8 to 6 dBm and the result has reached the standard. It because this amplifier is used the fiber nonlinearity to amplify the signal in the transmission system. As can be seen in Table 3, the results obtained that greatest power for the system using EDFA amplifier is giving Q Factor value 16.734 for 6 dBm input power and the smallest is -7.530 for -8 dBm input power. Greatest result for the system using ROA amplifier is 14.738 for 6 dBm input power and the smallest result is 13.351 for -8 dBm input power. These results are reached the standard Q Factor to be greater than 7. As this comparison, the system using ROA Amplifier gives better performance than using EDFA amplifier because the system using ROA amplifier has bigger value than using EDFA Amplifier in -8 dBm to 4 dBm input power.

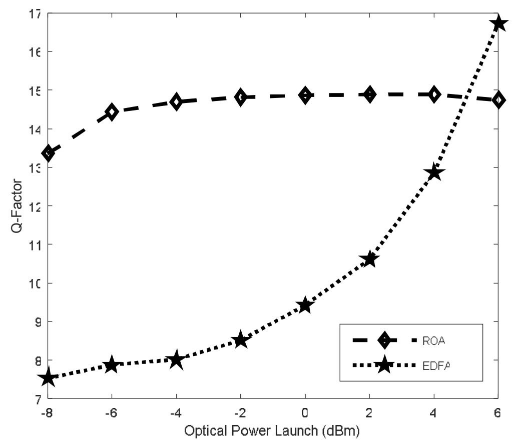

Fig.3. Input Power Effect to Q-Factor Using EDFA and ROA Amplifier

C. Input power effect to Received Power using EDFA and ROA amplifier

Figure 4 shows the results of Received Power values that obtained by varying the input power from -8 to 6 dBm for the CWDM Nonlinear system using EDFA and ROA amplifier. For the system using EDFA amplifier, the received power give better value for -8 to 6 dBm and for the system using ROA amplifier give bigger value than using EDFA amplifier in -8 to 6 dBm. The system reaches the standard received power for above of -28 dBm. As can be seen in Table 4, the results obtained the greatest power for the system using EDFA amplifier 0.117 dBm for six dBm input power and the smallest is -11.808 dBm for -8 dBm input power. Greatest result for the system using ROA amplifier is 2.323 dBm for six dBm input power and the smallest result is -11.669 dBm for -8 dBm input power. These results are reached the standard received power to be greater than -28 dBm. As this comparison, the system using ROA Amplifier gives better performance than using the EDFA amplifier because it has bigger output power in the system than using the EDFA amplifier.

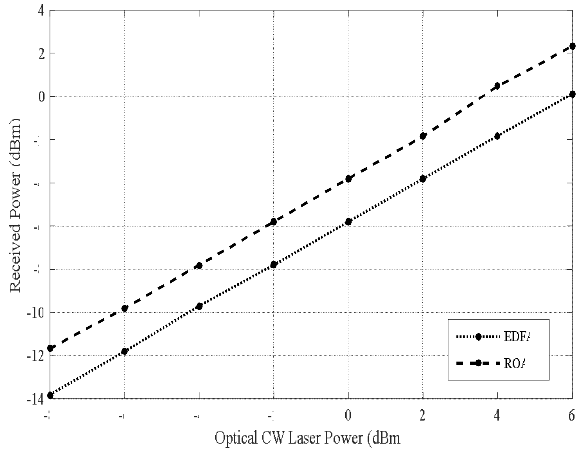

Fig.4. Input Power Effect to Received Power on A System Using EDFA and ROA Amplifier

V. CONCLUSION

Comparison of EDFA and ROA in CWDM Optical Network using BER, Q-factor, and power received had been done. The result obtained the system using EDFA amplifier for -8 to 0 dBm did not reach the standard, but the system using ROA amplifier for -8 to 6 dBm reached the standard. It concluded that the system using Raman Optical Amplifier to overcome the attenuation gave a stable performance when it was used in the Non-Linear CWDM System. It was recommended to use ROA amplifier especially with low power transmission system in Non-Linear CWDM optical network.

ACKNOWLEDGMENT

The authors would like to express their thanks to Kemenristekdikti for their support in developing the system and providing a grant from PKM-PE to carry out and to finish this research project.

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