Analysis of Attenuation Compensation Using Erbium Doped Fiber Amplifiers on Wavelength Division Multiplexing Networks as Optical Amplifiers in Communication Systems

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Abstract. Communication technology is currently very rapidly growing that causes the need for data flow speed increase significantly. These needs could be met through the technology of a fiber optic. The addition of use wavelength division multiplexing (WDM) networks can increase the bandwidth value because this network system can enter several wavelengths in a block diagram that is a multiplexer. This paper will discuss concerning a WDM that uses optical amplifier EDFA to strengthen a transmitted signal with input signal is sent two channel in one axis a fiber optic. Approach was used in the study simulations with three types of variation. The results of the simulation showed the variations of this type of circuit, the circuit is a form of consumption preline most excellent attenuation coefficient has 0.593 dBm/km, the variation of the value of the bandwidth on the value of 200 GHz is the value that best has a attenuation coefficient dBm 0.026/km and variations of long fiber optics at a distance 1 km that is the distance transmission of maximum.

1. Introduction

Transmission media greatly affects the performance of a communication system. The work of optical transmission media should be maintained continuously so that it can be transmitted for long distances, with an optical amplifier. Optical amplifier is a device that functions to strengthen the optical signal that is received directly without requiring the conversion of optical signals to electrical signals or vice versa [1-3].

The presence of a WDM system can meet this need even though this communication still experiences several obstacles such as dispersion. Dispersion causes loss when sending data [4,5]. Ikhsan et al. [6] have conducted a study of dispersion compensation using Raman Amplifiers if placed as a Preline Amplifier with the results in the eye diagram showing little noise. The optical signal that passes through Erbium doping fibers serves as a trigger so that emissions emit photon energy. The energy is coherent and causes optical signal amplification [7-10]. The information spectrum of absorption cross section and emission cross section in an EDF is very important to explain the properties of EDF where cross sections can be determined from measurements of gain with maximum
gain [7,11]. The WDM system uses a multiplexer at the transmitter to combine several signals and demultiplex at the receiver to share them with the right parts so that it is possible to have a device that does both simultaneously, and can function as an optical add drop multiplexer [12].

2. Methodology
The research is conducted computationally by designing several optical network using Optisystem. There are three networks which simulating for different bandwidth and different length transmission. The basic design follow diagram in Fig. 1 for each network.

Diagram block in Fig. 1 show components for simulation. Non-Return-to-Zero Pulse Generator (NRZ) is one type of digital coding technique or modulation type. Mach-Zehnder Modulator (MZM) is an external modulator that will modulate information signals before they are transmitted into optical fibers. Laser is a light source that functions to convert electrical signals into light signals. Optical Amplifier (OA) is a device that functions as an amplifier. The amplifier that will be used is EDFA. Fiber Optic (FO) functions as a transmission medium. Photo Detector (PD) is a device that converts light signals into electrical signals. Filters are devices used to select signals. The filter used is a low pass filter. Single Mode Fiber (SMF) is a type of optical fiber commonly used to transmit longer distances. This is one of two types of optical fiber, the other is multi-mode fiber. Single-mode fiber is a single glass fiber strand that is used to transmit one mode or light beam. WDM multiplexer (WDM Mux) is the one is a function for multiplexing or combining several information signals to be transmitted in a single optical fiber [13].

Simulation procedure
This stage of the procedure begins with the initial simulation process which aims to determine the maximum transmission propagation distance of the signal on optical fibers without any reinforcement as a comparison, then simulations are carried out with three types of variations with different parameter values. The parameter values of the three types of variations are adjusted to the type of circuit so that the system can work properly, from the three types of parameters will be measured.

The length of optical fiber greatly affects the performance of a fiber optic communication system. In determining the maximum transmission distance, the parameters that play an important role in this case are the Bit Error Rate (BER) and Q factor. According to ITU-T Recommendation rules, BER requirements for optical communication systems must be better than 10^{-12}, meaning that the minimum BER system must be less than 10^{-12}. Q-factor is a quality factor that will determine whether or not the quality of a link is good. In optical fiber communication systems, a minimum Q-factor size of 6 is good [6]. The attenuation coefficient will be measured using Optical Power Meter and Electrical Power Meter found in the circuit, then it will also be seen the effect of wavelength on the optical power of the signal using the Optical Spectrum Analyzer (OSA).
3. Results and Discussion
BER and Q-Factor values for each variation, namely variation of circuit configuration, variation in bandwidth values and length variation of the fiber optics are depicted in Fig. 3 to Fig. 4, Figure 5, Figure 6, Figure 7 and Figure 8. BER requirements for optical communication systems should be better than $10^{-9}$ - $10^{-12}$, meaning the minimum BER system value must be smaller than $10^{-12}$ [6].

![Figure 3. BER vs transmission distance.](image-url)
Figure 4. Q-Factor vs transmission distance.

Figure 5. BER value vs transmission distance

Graph of BER values for transmission distance in simulation of variations in circuit type Figure 5, simulation of variation in bandwidth values Figure 5, and simulation of fiber optic length variation Figure 7 shows that the bit value error is directly proportional to the transmission distance, the greater the distance traveled there are also many bit values that have errors [14]. So is the case with the Q-factor graph of the transmission distance. The Q-factor value is inversely proportional to the distance traveled, when the distance traveled is greater, the Q-factor value will be smaller [15-17], but at the same transmission distance when the BER value decreases, the Q-factor value increases for the increase transmission distance.
Figure 6. Three configuration of WDM for 100 km transmission length. (a) Postline, (b) Inline and, (c) Preline.

Figure 7. Eye diagram of bandwidth variation at 200 GHz.
The eye diagram on an optical system is a tool used to analyze the bit error rate and the quality of the link or signal received. Simulations carried out on several variations show several differences in BER values and Q-factors as shown in the eye pattern. Fig. 7 and 8 show eye diagrams of the three variations in 10th iteration. It can be seen from the eye diagram on the variation of bandwidth values is the appearance of the most subtle eye patterns from other variations. Optical Spectrum Analyzer (OSA) is a system of measuring optical power as a function of wavelengths. A good indication of optical spectrum analysis for its ability to solve signal amplitude equations has filter selection from 0.08 nm to 0.1 nm, which makes it possible to choose sufficient resolutions for most measurements. The following is a display of the response from OSA on a circuit without amplifier and with an amplifier with a bandwidth value of 20 GHz.

As shown in Fig. 9, power output for network without amplifier and with amplifier at a bandwidth of 20 GHz on the channel with a frequency of 193.1 THz there is an increase in power.
power for without amplifier circuit has a value of -28 dBm, when added the amplifier increases to 29.9 dBm.

4. Conclusion
All three variations have their advantages and disadvantages. Variations in the type of circuit found that the preline circuit has the best BER and Q-factor values, the variation in bandwidth values at a constant value, the variation of optical fiber length at 1 km is the maximum transmission distance but has attenuation that matches the parameters can maintain the signal passed on the waveguide path, some amplifiers still have deficiencies. So it can be concluded that EDFA can be used as attenuation compensation because even with short distances attenuation is not large.

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References
[1]. Wang X, Zhuang X, Yang S, Chen Y, Zhang Q, Zhu X, Zhou H, Guo P, Liang J, Huang Y, Pan A and Duan X 2015 Phys. Rev. Lett. 115 027403.
[2]. Tahir B A, Ali J, Saktioto, Fadhali M, Rahman R A and Ahmed A 2008 J. Optoelectron. Adv. Mater. 10 2564-68.
[3]. Shiryaev V S, Smetanin S V, Ovchinnikov D K, Churbanov M F, Kryukova E B and Plotnichenko V G 2005 Inorg. Mater. 41 308–14.
[4]. Syahputra R F, Saktioto, Meri R, Syamsudhuha and Okfalisa 2017 Profile of single mode fiber coupler combining with Bragg grating. Telkomnika.; 15(3): 1103-1107.
[5]. Mhareb M H A, Hashim S, Ghoshal S K, Alajerami Y S M, Bqoor M J, Hamdan A I, Saleh M A and Abdul Karim M K B 2016 J. Lumin. 177 366-72.
[6]. Ikhsan R, Syahputra R F, Saktioto, and Okfalisa 2018 Proc. SNPD (Busan) pp. 32-6.
[7]. Bujari S S 2012 World J. Scie. Technol. 2 39-43
[8]. Saktioto, Ali J, Fadhali M, Rahman R A and Zainal J 2008 Proc. SPIE. 7155 71551P.
[9]. Chaundary K T, Qindeel R, Saktioto, Hussain M S, Ali J and Yupapin P P 2010 Proc. Eng. 8 432-27.
[10]. Ivaniga P and Ivaniga T 2017 Rzegład Elektrotechniczny 93 193-6.
[11]. Zhou P, Zhan W, Mukaikubo M, Nakano Y, and Tanemura T 2017 Opt. Express 25 28547-55.
[12]. Zhang L, Xiao S, Bi M, Liu L, and Zhou Z 2016 Opt. Commun. 364 129-33.
[13]. Cruz E R, Salgado I R, Herrera D E C and Castrejon R G 2018 Proceedings of 20th ICTON (1-5 July, Bucharest, Romania) Th.B4.4 (1-4).
[14]. Bromage J 2004 IEEE J Lightwave Technol. 22 79-93.
[15]. Eliasson H, Olsson S L I, Karlsson M and Andrekson P A 2016 Opt. Express 24 888-900.
[16]. Stephens M F C, Tan M, Gordienko V, Harper P and Doran N J 2017 Opt. Express 25 24312-25.
[17]. Khare R P 2004 Fiber Optics and Optoelectronics (New Delhi: Oxford University Press) p. 262-4.