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Raman amplifier performance in pre-amplifier use for optical fiber communication systems

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Abstract

The development of telecommunications networks is currently dominated by fiber optics. The fiber optic has become a waveguide medium transmitting information with high frequency bands, high capacity and high speed. An optical amplifier is required to maintain electromagnetic signals when they propagate in far distance. One of the amplifiers, Fiber Raman Amplifiers (FRA) which is the light scattering from the light that comes with the phonon in the lattice of amplification medium produces photons that are coherent with the incoming photons. Many amplifiers are commonly used but the problems not only come from the amplifier but also the component circuit and system. By simulation method, FRA circuit is designed and operated in the form of pre-amplifiers to maintain a better signal from material interference and geometry. The simulation results show that the lowest BER value and the highest Q-factor are found at a distance of 10 km depicted by eye diagram.

Keywords*: fiber optics, fiber Raman amplifiers, optical amplifiers, optics*

1. Introduction

The use of copper wire as a transmission medium in a communication system cannot allow it to be used in long distance data transmission with large capacity and high speed. In order to overcome this obstacle, it is commonly used a fiber optic as transmission media. Fiber optics can serve as optical sensors to determine efficient optical system in a variety of criteria such as reach, functional, the sensitivity and accuracy of the optical system [1-4]. Transmission of light signals on optical fiber, Single Mode Fiber (SMF) can transmit signals in one mode and can avoid inaccuracies in data distribution. During the propagation process in light, the fiber optics weakens and widens the signal due to the impurity of fiber materials that absorb and spread light so that the signal power will be reduced [5-7]. The right optical amplifier can overcome this and can maximize the work of optical transmission media.

Transmission of light signals on optical fiber SMF transmits signals in one mode and can avoid inaccuracies in data distribution. This SMF clutch has become the most important fiber optic device in telecommunications with a coupling ratio in the range of 1% to 75% [8, 9]. During the process of propagation of light on SMF optical fiber will experience a reduction in power from the electromagnetic wave. This is due to the absorption of light in optical fiber materials and scattering of light, the magnitude of this reduction in power depends on the transmission distance and the characteristics of the optical fiber material. The power reduced during the propagation process causes the power reaching the detector to be smaller than the power sent by the source. So, an optical amplifier is needed to maintain the power [10-12].

Fiber Raman Amplifier (FRA) is used and expected to be able to generate a weak signal with a large gain factor and data can be transmitted at high bit rates. The FRA circuit is used in the form of a pre amplifier that can amplify light signals sent via optical fiber before the light signal is received by the photo detector so that the weakening of the signal to noise ratio caused by thermal noise in the photo detector can be suppressed [13, 14]. Increment of

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power can increase the sensitivity of the photo detector so that it can increase the power link budget [15, 16].

FRA optical amplifier can work using pumping and generating signals with large gain factors and data transmitted at high bit rates. Bromage introduces a shutter amplifier used in fiber optic communication systems [17]. Raman amplifiers can be used in inline amplifier use with high transmission distances and low attenuation [18, 19]. In this case, analysis of FRA performance in the use of pre amplifiers will be carried out, namely the optical amplifier is placed after the optical fiber or before the detector. Th value of gain FRA gain can be calculated as given [20]:

$$G_{FRA} = \frac{P_S(L)}{P_{s,in}} = \left[\exp\left(\frac{g_R}{a_p}\; P_{p,in}\, L_{eff} - \alpha_s L\right)\right] \tag{1}$$

$$L_{eff} = \left[\frac{1-\exp(-\alpha_p L)}{\alpha_p}\right] \tag{2}$$

gain is in decible unit and can be written as follows,

$$G(\text{dB}) = 10\log G_{FRA} \tag{3}$$

where G_{FRA} is the magnitude of gain of Raman amplifier which is the ratio $P_s(L)$ and $P_{s\,,in}$. $P_s(L)$ is the output signal power when the total optical fiber length L (m) in Watt and $P_{s\,,in}$ is the input signal power (Watt). The parameter of $P_{p,in}$ is the laser pump power (Watt), α_s and α_p are the signal and pump attenuation coefficient, g_R is Raman gaincoefficient and $L_{eff}$is the effective length of optical fiber (m).

2. Research Method

The design of the network amplifier is designed and operated by a simulation process. The optical fiber communication system consists of a block of transmitters that function to convert electrical signals into light signals, optical fiber transmission medium and detectors as sensors of visible or invisible light signals and convert them into electrical signals [21]. This simulation uses information sources in the form of data in the binary of 0 and 1 bits generated by Pseudo-Random Bit Sequence (PRBS) with a data rate (bit rate) of 5 bits/s and is coded with a Non-Return to Zero Pulse Generator (NRZ) coding technique. This input signal is modulated with an output signal from Continuous Wave (CW) Laser by Mach-Zehnder Modulator (MZM) which has an extinction ratio of 30 dB. The continuous laser input signal has a wavelength of 1350 nm.

The output signal from the modulator is transmitted by SMF optical fiber having a small dispersion and large transmission capability. SMF is operated with attenuation of 0.2 dB/km with optical fiber length of 50 km. In order the signal arrives at the detector with a large capacity, FRA with attenuation value of 0.2 dB/km is used at room temperature of 300 K with a distance varied by 5 iterations and each iteration is 10 km. FRA works with a Laser Pump power of 0.1 Watt and a wavelength source of 980 nm.

Photo detector Avalanche Photo Diode (APD) has a faster response to detect signals. This photo detector is used having a response value of 1 A/W, an ionization ratio of 0.9, gain of 3 and a current of 10 nA. The light signal will be converted into an electrical signal and will be filtered by a Low Pass Bessel Filterthat has a cutoff frequency of 5 Hz and only passes signals with low frequencies and blocks signals with high frequency. BER Analyzer is used to measure the bit rate of error and Q factor of the network circuit [22]. The series of FRA pre-amplifier optical fiber amplifier systems can be seen in Figure 1.

3. Results and Discussion

This simulation is carried out by applying a continuous laser wavelength of 1350 nm and pump power from a raman amplifier with a value of 0.1Watt by varying the distance. The iterations are set from 1 until 5 corresponding a distance from 10 km until 50 km. At a distance 50 km the BER value is 4.4424×10^{-15} resulting Q factor is 7.7438. The BER value and

Q factor meet the International Telecommunications Union (ITU) standard, for BER value to be less than 10^{-12} [23]. The BER value is sufficient for standard second-generation forward-error correction [24]. FRA's eye diagram for a distance of 50 km can be seen in Figure 2.

Figure 2 looks like a lot of power losses are produced. The large slope of the eye diagram indicates that the sensitivity of the time error (jitter) of the eye diagram is large. Inaddition, the amount of noise that can be tolerated is small, meaning that a lot of noise occursin the image and the distortion is large too [25]. If the distance is reduced to 10km with a BER value of 1.8606×10^{-22} and Q factor 9.6696 the eye diagram is shown in Figure 3.

Compared to a distance of 50 km, it can be seen that at a distance of 10 km, the eye diagram formed has eyes wider than that of 50 km, this means that the BER value for 10 km is lower. The formed eye diagram is smoother, less powerand the amount of noise that can be tolerated is large. The slope formed is small so that the sensitivity of the time error (jitter) that occurs is smaller. The comparison value of Q factor and BER for various distances for FRA can be depicted in Table 1. Table 1 shows that the larger the FRA distance the greater the BER value and the Q factor obtains smaller to the minimum value. The best distance is at a 10 km with a very small BER value and the Q factor value is far from the minimum value.

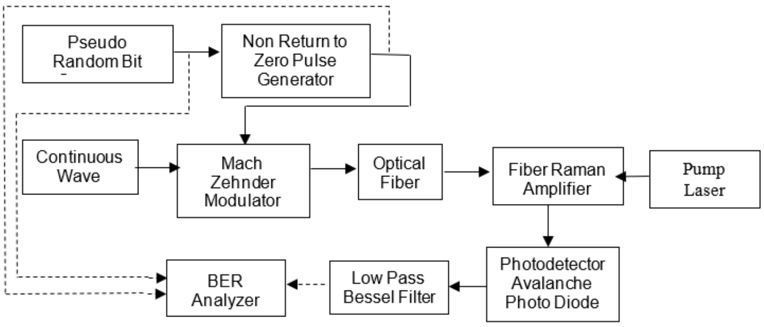

Figure 1. Raman amplifier circuit with pre-amplifier

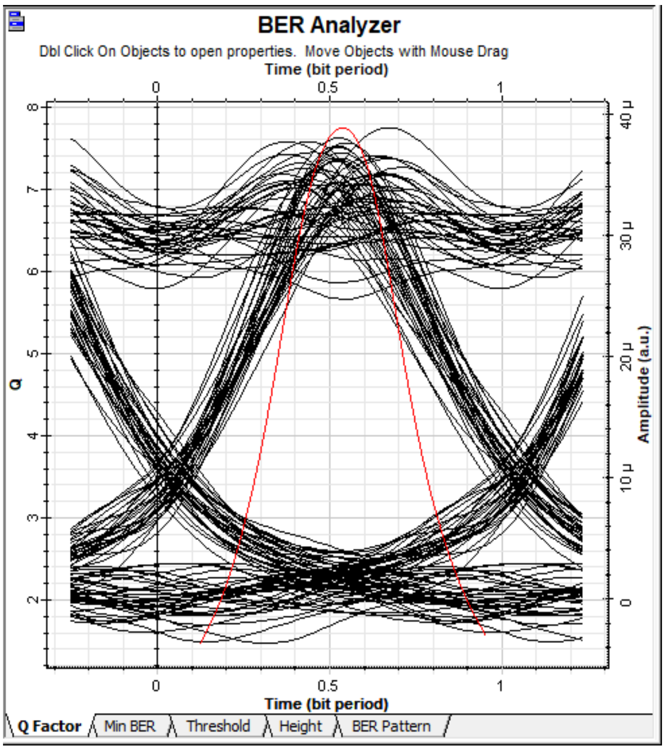

Figure 2. Raman amplifier diagram at a distance of 50 km

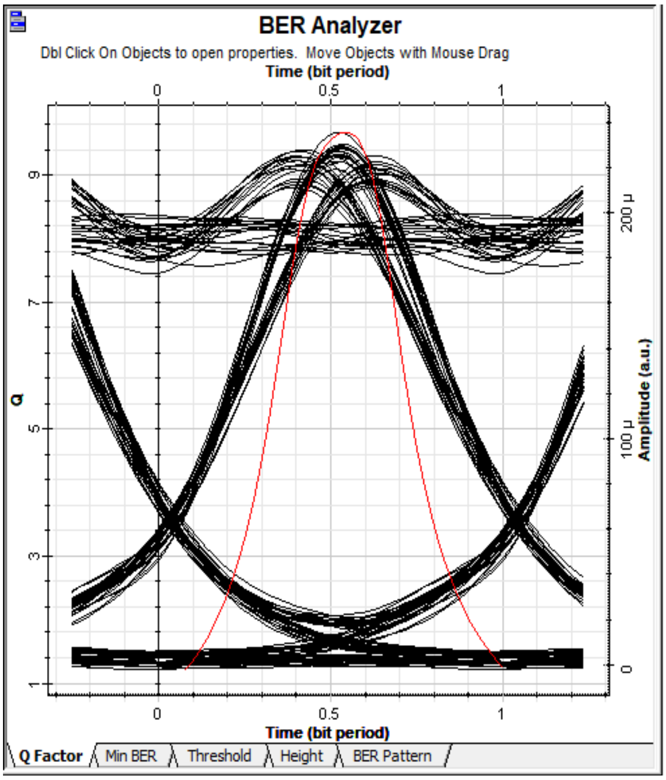

Figure 3. Raman's eye diagram with a distance of 10 km

Table 1. BER Values and Q Factor for FRA

No.	Distance(km)	Q factor	BER
1.	10	9.6696	1.8606×10^{-22}
2.	20	9.6364	2.5827×10^{-22}
3.	30	9.5105	8.7867×10^{-22}
4.	40	8.4764	1.0689×10^{-17}
5.	50	7.7438	4.4424×10^{-15}

Basically, those eye diagrams have multipath interference effects where an electromagnetic wave from the source delivers to detector through two or more paths, under right condition, the two and more component of the electromagnetic wave can interfere [26]. The modulation is accomplished by the varying the sine and cosine inputs at a precise time. Geometrically both diagrams are in good pattern although it is found there is slightly distortion due to dispersion as shown at the across lines 'left arm' and 'right arm' between the curves. Noise also occurs mainly in lines on top (noise "1") compared lines on bottom (noise "0") [27].

The eye diagram represents the opening of the eye where FRA is wide at the center. Amount of noise can be tolerated by the signal depicted as a vertical length of eye is large and also a horizontal length of eye is wide. The horizontal length explaining the time over the waveform indicates that the sensitivity to timing error is small, meaning the pattern is good. Also, the time jitter is small where it can be seen from the bit period of point 0 and 1. In summary, based on the above geometry analysis, it is found that FRA is good amplifier.

Graphs 4 and 5 describe the value of BER and Q factor for the transmission distance in the FRA series. The BER value of an optical source with a wavelength of 1350 nm is 8.0942×10^{-10} or -90.9 dB at a distance of 90km having a Q factor value of 6.0319. In Figure 4, it can be concluded that the transmission distance is exponentially proportional to the BER value, which is the farther the transmission distance from the optical fiber, the greater BER value of the series. Figure 5 shows the relationship between the distance of optical fiber transmission and Q factor, which is the further the transmission distance, the smaller the Q factor value is obtained.

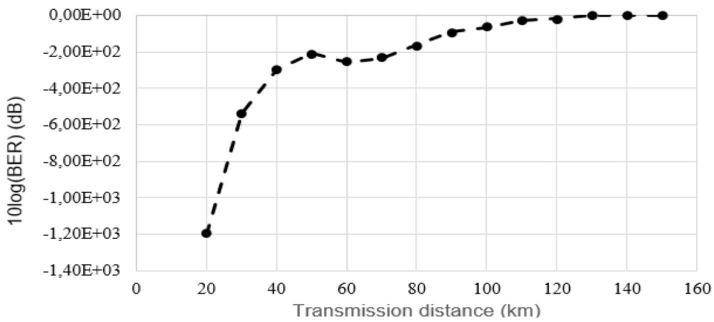

Figure 4. BER of transmission distance on FRA amplifier circuit

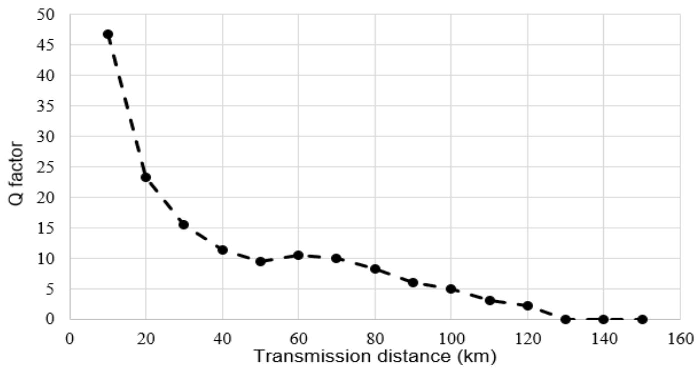

Figure 5. Q factor of transmission distance on FRA amplifier circuit

4. Conclusion

Raman amplifier circuit system has been successfully simulated from 10-50 km with 1350 nm wavelength source, where 0.1 W pump power is run with several iterations corresponding to various distances. At the largest distance of 50 km, there is an eye diagram that shows a lot of widening signals, large noise and more power losses compared to the smallest distance of 10 km.This is due to the shorter the distance from the secure amplifier, the better the circuit will be used.The shorter distance from the amplifier can reduce the occurrence of disturbances in the propagating signal propagating.

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