Designing a WDM-PDM based RoF amplifier using EDFA and Raman amplifier

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Abstract: An RoF system makes use of optical transmission for sending RF signal and takes advantage of immense merits offered by optical communication. Yet, any signal that travels through any medium suffers from attenuation and thus amplifiers are necessary to restore signal to its original form. In this study a radio over fiber amplifier is considered which make use of EDFA and Raman optical amplifiers. The system also employs WDM and PDM multiplexing techniques to increase the bit rate. The optical system is designed in Opti system software which is tailor made of optical networks. The parameters considered in the analysis are Q factor, Bit error rate (BER), Optical SNR and Eye diagram.

Keywords: Bit error rate (BER), Erbium Doped Fiber Amplifier (EDFA), Eye diagram, Radio over fiber (RoF) systems, Signal to noise ratio (SNR), Raman Amplifier, Wavelength Division Multiplexing (WDM).

1. Introduction

In Radio over fiber systems, Radio frequency signals are transmitted through an optical fiber cable [1]. The bandwidth of any optical system can be increased further by increasing the number of channels for transmission by using multiplexing techniques. In wavelength division multiplexing (WDM), multiple channels are created by separating transmission of signal at different wavelengths. Another multiplexing technique known as polarization division multiplexing (PDM), the signals are separated by their polarization states [2].

To enhance a system performance and increase its range of transmission amplifiers can be used. Amplifiers provide necessary boost to any signal to counter the effect of attenuation of signal along the transmission path. For amplification of optical signals, optical amplifiers are used. Optical amplifiers offer great advantage as earlier to amplify optical signal, it needed to be converted to electrical form then again after amplification the electrical signal is converted to optical form, but optical amplifiers amplify the light signal without converting it in electrical form [3]. EDFA and Raman amplifiers are common optical amplifiers.

Raman amplifier works on the principle of Stimulated Raman Scattering (SBS) [4]. In Raman amplifiers when a suitable pump laser is used in a Raman amplifier, energy is transferred from higher-frequency signals to those with lower frequencies [5 -7]. Raman amplifiers can work on wide range of frequencies and it also does not require any doping element for active medium [5]. Raman amplification in optical fibers commonly uses three main pumping techniques. In forward or co-pumping, both the pump and signal travel in the same direction through the fiber. In contrast, counter or backward pumping involves the signal and pump moving in opposite directions. A third approach, known as bidirectional pumping, utilizes two pump sources introduced from opposite ends of the fiber at the same time to enhance amplification [8].

EDFA is another optical amplifier which is extensively used in optical communication systems. It works on the principle of stimulated emission. It uses an optical fiber which is doped with erbium ions. These ions are at higher energy levels and when incident optical signal comes in contact with these ions in the fiber, these erbium ions drop to a lower energy level

releasing photon in the process. Thereby amplification is achieved by EDFAs [9]. Unlike Raman amplifier, EDFA amplifier can only work in L and C optical bands [10].
Using combination of amplifiers along transmission channel known as hybrid amplifier can provide an opportunity to use merits of both the amplifiers and improve performance of the entire optical system.

2. System Description

The transmitter part of the RoF system is shown in figure 1. Transmitter basically multiplexes four input signals. Each input signal has separate wavelength varying from 1550nm to 1551.5nm. At each input a pseudorandom bit generator is used to generate the binary sequence to be transmitted. Then, the bit sequence is changed to NRZ format using an NRZ pulse generator. A laser source is used to modulate the input signal using a MZ modulator. After this another MZ modulator is used to modulate a sine wave. The output of the second MZ modulator is fed to a 2x1 multiplexer where two input optical signals are multiplexed. To 2x1 WDM multiplexers are used to multiplex the four input signal. The outputs of the two WDM multiplexers is then polarization multiplexed by making the second WDM output ninety degrees out of phase with the first WDM output.

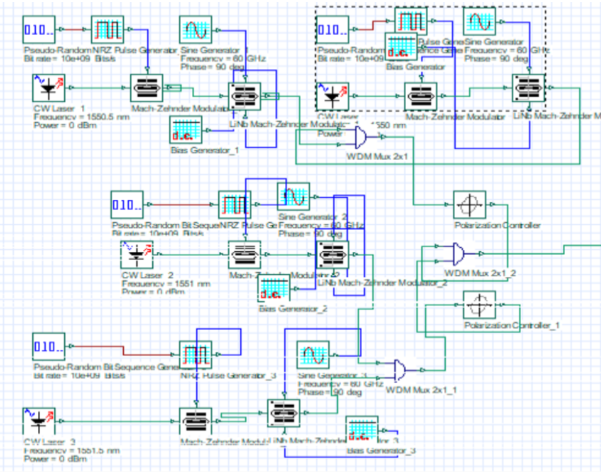

Figure 1: Transmitter

The channel consists of an optical fiber and an EDFA amplifier and a Raman amplifier. The channel for the system is shown in Figure 2.

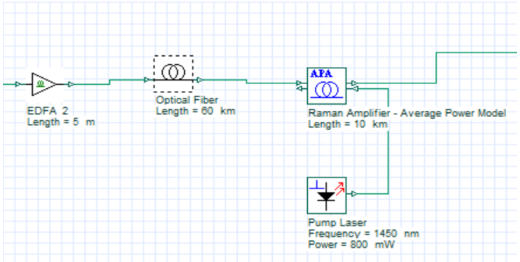

Figure 2: Channel

The receiver part of the system is shown in figure 3. At the receiver, a polarization splitter is used to separate the incoming signal into respective polarizations state. Then two WDM Multiplexers are used to separate the four input signals. A Gaussian optical filter is used to to filter the respective input signals. Then a PIN photodetector is used to convert optical signal into electrical form. A BER analyser and WDM analyser are used to analyse the incoming signals.

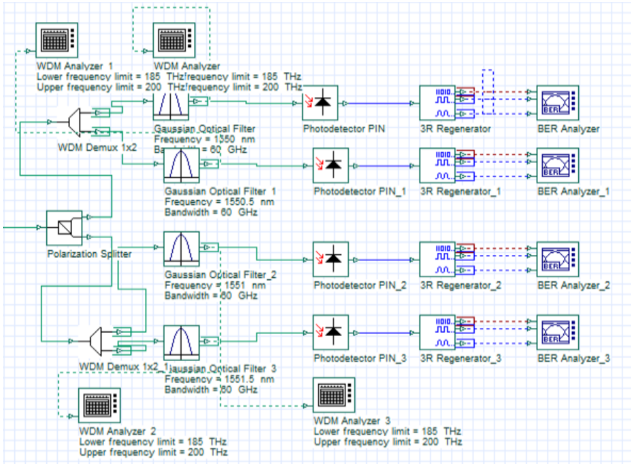

Figure 3: The receiver section.

3. Results and discussions

In analysis part the fiber length is varied from 15 Km to 60 Km and parameters such as received input power, optical SNR, Q factor and BER are are observed using a BER analyser and WDM analyser for all the four received input signals. Table 1 shows variation of above said parameters.

Fiber length	Channel	Received Power(dBm)	Optical Signal to	BER	Q-factor

			noise ratio(dbm)		
15 Km	1550 nm	15.59	40.41	5.84 x 10-54	15.40
	1550.5 nm	16.72	41.54	5.04 x 10-53	15.25
	1551 nm	15.65	40.53	2.22 x 10-48	14.24
	1551.5 nm	16.70	41.58	1.54 x 10-51	15.03
30 Km	1550 nm	13.50	40.38	1.09 x 10-51	15.06
	1550.5 nm	14.62	41.50	2.34 x 10-63	16.74
	1551 nm	13.55	40.51	3.79 x 10-44	13.87
	1551.5 nm	14.59	41.54	5.05 x 10-47	14.33
45 Km	1550 nm	11.14	40.33	5.33 x 10-41	13.34
	1550.5 nm	12.25	41.43	3.81 x 10-49	14.67
	1551 nm	11.19	40.45	4.45 x 10-33	11.90
	1551.5 nm	12.21	41.48	1.58 x 10-42	13.60
60 Km	1550 nm	8.55	40.23	2.03 x 10-29	11.18
	1550.5 nm	9.65	41.33	1.34 x 10-24	10.15
	1551 nm	8.59	40.35	4.63 x 10-20	9.08
	1551.5 nm	9.61	41.38	8.88 x 10-30	11.26

Table1: Variation for Received power, SNR, BER and Q- factor with distance.

Figure 4 and Figure 5 show the eye diagram of all the four channels at 15 Km and 60 Km respectively.

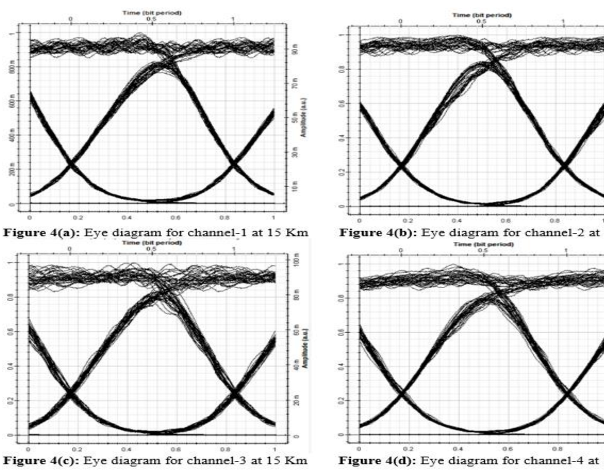

Figure 4(a): Eye diagram for channel-1 at 15 Km
Figure 4(b): Eye diagram for channel-2 at
Figure 4(c): Eye diagram for channel-3 at 15 Km
Figure 4(d): Eye diagram for channel-4 at

Figure 4: Eye diagram at optical fiber length of 15 Km

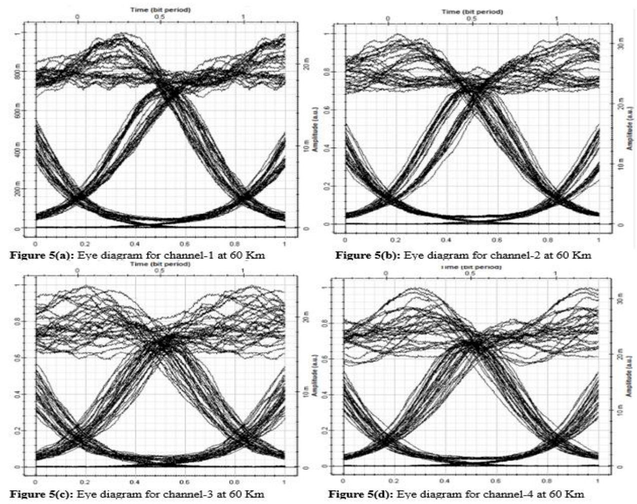

Figure 5(a): Eye diagram for channel-1 at 60 Km
Figure 5(b): Eye diagram for channel-2 at 60 Km
Figure 5(c): Eye diagram for channel-3 at 60 Km
Figure 5(d): Eye diagram for channel-4 at 60 Km

Figure 5: Eye diagram at optical fiber length of 60 Km

4. Conclusion

In this research, a radio over fiber system is realized which utilizes WDM and PDM multiplexing techniques. Furthermore, amplifiers used along transmission channel are Raman and EDFA amplifiers. As the distance between transmitter and receiver is increased from 15 Km to 60 Km, the eye diagram is found to deteriorate. The BER and Q factor at 15 Km for channel 1 is found as 5.84 x 10^{-54} and 15.40, for channel 2 is found as 5.04 x 10^{-53} and 15.25, for channel 3 is found as 2.22 x 10^{-48} and 14.24, and for channel 4 is found as 1.54 x 10^{-51} and 15.03. As fiber length is incremented the BER and Q factor worsens but it is well within the acceptable limit and thus signifying a robust system.

5. References

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