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Comparison study of digital modulated signals in a DRA based DWDM communication system

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Abstract

The objective of this work is to compare the performance of digital modulated signals in Distributed Raman Amplifier in Dense Wavelength Division Multiplexed (DWDM)communication link on the basis of bit error rate (BER) and Q-factor through simulations. Simulation results indicate that error rates are much lesser for Raman Amplifier systems with Quadrature Phase Shift Keying-Non return to Zero (QPSK-NRZ) modulation format..

Keywords: Distributed Raman Amplifier; modulation formats; BER; Q-factor

1. Introduction

Optical communication systems based on Wavelength Division Multiplexing (WDM) [1] demand momentous upgrades to deal with the present traffic growth. Dense WDM (DWDM) technology efficiently makes use of the fiber bandwidth at the physical transmission level as well as in the network level. Fiber has a low loss window in the range 850nm-1625nm with a potential bandwidth of 168-THz. However, the usable bandwidth as well as the achievable data rate is decided by the technology available. The current optical communication window is fixed at 1550 nm-1557 nm(C-band). Erbium Doped fiber Amplifier(EDFA) which uses Erbium doped fiber of specific length as gain media has been reported to the best choice for that range [1]-[2]. The increased demand for bandwidth and higher data rate has motivated the researchers to implement Raman amplifier in long and ultra-long haul optical communication systems [3]. Raman amplifiers relatively have a broad gain and the gain spectrum can be tuned by varying the parameters like pump wavelength and pump power[4]. Unlike EDFA systems which operate around a narrow band around 1550 nm, the Raman amplifiers do not contain any doped media.

The transmission fiber itself acts as the gain medium and is independent of any dopant material[5].A simple communication link consists of a source which generates the information encoded in digital domain as 1s and 0s –On –Off modulation, a transmitter which is an LED or a Laser depending on the application, a channel to carry

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the information (a multimode fiber for small distance transmission or a single mode fiber for long distance transmission), optical amplifiers to provide gain in the optical domain and a receiver including a photo diode followed by a trans-impedance amplifier.

The largest transmission line rate is decided by how fast the laser be turned on/off and how fast can the receiver and the corresponding trans-impedance amplifier electronics work. According to the current state of art, the maximum rate is limited to 60 GHz, beyond which it is difficult to modulate with the current systems[6]. Here we choose lower order modulation formats such as Binary Phase Shift Keying(BPSK), QPSK and On-Off Keying(OOK) with Non return to zero (NRZ) modulation format for our study as higher order modulation format like 16 –Quadrature Amplitude Modulation(QAM) requires very high Optical Signal to Noise Ratio (OSNR) at the receiving section to recover the data successfully in long distance communication links[7].

2. Simulation Setup

The simulations were performed in RSoft OptSim software. The simulation setup consists of 80 Gbps, 8 channel DWDM communication link with a bit rate of 10 Gbps. Three setups with different modulation formats mentioned above were analysed for a communication link of 80 km length. It has been previously demonstrated that the NRZ format shows better performance when compared to RZ formats for distributed amplification[8].

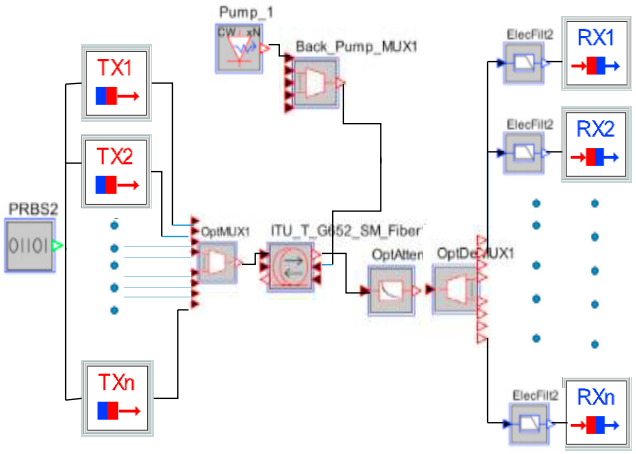

Fig. 1. Block diagram of the simulation setup

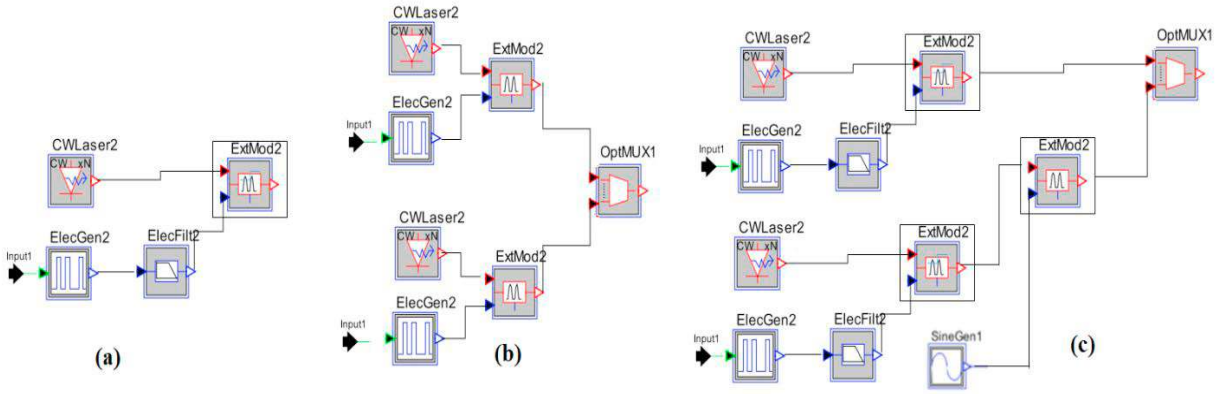

Fig. 2. Different Modulation formats (a) OOK-NRZ (b) BPSK-NRZ and (c) QPSK-NRZ

A single counter-propagating pump at 1450 nm wavelength with 0.5 W power is considered, as the direction of the pump will not affect the signal propagation. Fig1 shows the block diagram of the setup. An attenuation factor of 24 dB is used for all the setups. Fig. 2 shows the expanded block of the different modulation formats used for the simulation.

3.Equations

In this paper, the comparison of the digital modulated signals in DRA based WDM communication system is done by calculating the BER (bit error rate) and Q factor (quality factor). The gain of the amplifier which is the measure of how much the signal is amplified is given in equation (1) [9]. Noise figure(NF) is the measure of degradation occurred to the signal after amplification and it can be defined as the ratio of input SNR at the input with the SNR calculated at the output. SNR is shown in equation (2). For better performance, the gain of the amplifier should be high and the noise figure should be low. When a signal is transmitted over a long distance through a communication channel BER should be the least value possible and Q factor should be high. Bit error rate can be related to SNR as in equation (3)

The gain of the amplifier is calculated as [10]

$$G = 10\log(\exp(gPpL)) \quad (1)$$

where,
Pp: pump power in Watts
L: fiber length (m)
g: Raman gain coefficient.

Signal to Noise Ratio(SNR) is given by equation

$$SNR=10log_{10}(\frac{\text{Signal Power}}{Noise\ Power}) \quad (2)$$

$$BER \sim \frac{1}{SNR} K\text{^}, \text{ where } K\text{^} \text{ is specific subcarrier index} \quad (3)$$

4. Results and Discussion

The performance of Distributed Raman amplifier in a DWDM communication link for different modulation formats via. OOK, BPSK and QPSK were compared. The BER performance and Q-factor is evaluated for each of the source wavelengths and is plotted in Fig. 3. From the graph, it may be observed that QPSK modulation format is showing better performance than the other formats. The measured gain and noise figure is shown in the Table1.

Table.1: Gain and noise figure as a function of different modulation formats

Modulation Format	Gain (dB)	Noise Figure (dB)
OOK	21.10	2.35
BPSK	21.65	2.35
QPSK	17.09	1.45

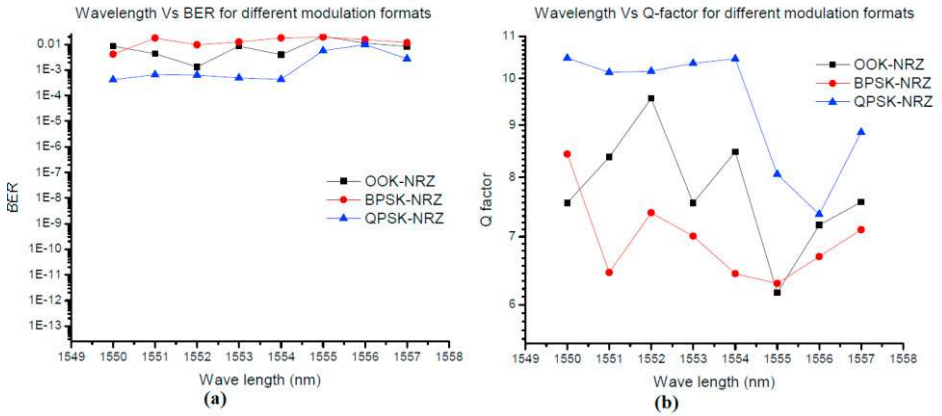

Fig.3. Performance plots for various modulation formats (a) BER as a function of wavelength and (b) Q-factors as a function of wavelength.

It may be noted that although the gain in QPSK system around 4 dB lesser than others, the improvement in BER performance comes from the lower noise figure value for the same. Thus QPSK is found to be a better modulation format when compared to other formats.

5. Conclusion

In this study, the performance of distributed Raman Amplifier in a WDM communication link is analysed in terms of BER and Q–factor. Different modulation formats namely OOK, BPSK and QPSK used. Counter pumping helps to have better noise figure which aids to get better SNR, which in turn results in better BER for the system. The BER and Q-factor is at its best for the link where QPSK is used as the modulation format. QPSK may be considered to be the preferred modulation format for long haul communication systems.

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