Comparative Investigation of various Data Formats for 96 × 10 Gb/s RAMAN/EDFA Amplifier

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Abstract
In this paper, we have analyzed the performance and feasibility for RAMAN/EDFA Hybrid Optical Amplifier operating at the bit rate of 10 Gb/s for 96 channels. In the network, the data is successfully transmitted to a distance of 290 km with a very low BER of 1×10−40 thus improving the performance over DS_Anomalous fiber. This paper also presents the comparative investigation and suitability of various data formats like NRZ Rectangular, NRZ Raised cosine, RZ Rectangular and RZ Raised cosine for optical transmission link. It has been shown that RZ Raised cosine yields the highest value of Q, good eye opening and lowest BER.

Keywords
HOA, RAMAN, EDFA, BER, Q-Factor, EYE- Opening, Dispersion, Transmission Distance, WDM and Data Format.

I. Introduction
Wavelength-division-multiplexing (WDM) plays a key role in optical communications. Therefore, broadband erbium-doped fiber amplifiers (EDFAs) have greatly contributed to recent advances in WDM networks due to their high transmission capacities and wide-band gain. Recently, the L-band (1560–1610 nm) fiber amplifiers have been realized, such as EDFAs using a longer erbium-doped fiber (EDF) than that of C-band EDFAs, [Sun et al. (1997)] thulium-doped fiber amplifiers, [Kitabayashi et al. (2001)] fiber Raman amplifiers, [Namiki and Emori (2001)] and hybrid amplifiers [Masuda and Kawai (1999)]. Moreover, a wide-band EDFA from C- to L-bands employing a coupled structure has also been reported [Yamada et al. (1997)]. As the demand is increasing for capacity in long-haul light wave transmission systems, so to select which optical modulation format will be best is a main issue to ensure optimum system performance. Today as we know that long-haul transmission systems represent the fourth generation utilizing multiple carrier wavelengths, which has led to an explosion of channel capacity. At the same time, deregulation of telecommunication markets and global success of the Internet has driven up the demand for higher and higher system capacity. Conventionally, non-return to zero (NRZ) modulation format has been used in long-haul transmission systems [Trischitta et al. (1996)]. These systems are based on the fact that fiber dispersion and nonlinearities are detrimental effects. NRZ is used advantageously as it provides minimum optical bandwidth and minimum optical peak power per bit interval forgiven average power [Barnett et al. (1996)]. However, with increased bit rates, it has been shown that NZ modulation format offer certain advantages over NRZ, as they tend to be more robust against distortions [Richter (2002)]. For instance, NZ modulation is more tolerant to non-optimized dispersion maps than NRZ schemes [Mohs et al. (2000)]. These can be explained by the fact that optimum balancing between fiber nonlinearities and dispersion is dependent on the pulse shape. ARZ-modulated signal stream consists of a sequence of similar pulse shapes, whereas an NRZ-modulated stream does not. From system designer’s point of view, impairments in optical transmission need to be addressed. Moreover, how these affect the performance of the transmission link has to be investigated and ways to improve it have to be suggested. Therefore, it is important to investigate the robustness of various existing data format on the performance of optical transmission link. For high-speed optical communication, the data transmission reliability is degraded by the system impairments like GVD and fiber nonlinearities [Amersfoort (2002)]. [Kaler and Kaler (2010)] experimentally demonstrated the results for different data formats, viz. NRZ Rectangular, NRZ Raised cosine, RZ Rectangular and RZ Raised cosine. In the case of RZ Raised cosine its highest value of Q (26.33 dB), good eye opening, lowest BER and its non-susceptibility at different chirps makes it the best choice among the data formats mentioned. Jitter value remains low for all the data formats in general and also no considerable impact of chirp on jitter has been recorded. In a comparative study, power level in case of RZ Rectangular has been reported to be the best, however, it is also reasonably good (second best) for RZ Raised cosine.

[Ishida et al. (2001)] In this paper, we expand the repeater spacing from 40 km to 100 km using Raman/EDF hybrid configuration and demonstrate 1.28 Tbit/s (64 × 20 Gbit/s) transmission over 4,200 km with CS-RZ format and 22.4Gbit/s “OSW Super FEC” line bit-rate 161.

[Foursa et al. (2002)] have demonstrated for the first time the transmission of two hundred and fifty six 10 Gb/s WDM channels over 11,000 km in 80 nm of continuous optical bandwidth using a simple combination of distributed Raman gain and single-stage EDFA. With the use of concatenated Reed-Solomon FEC coding error free performance was achieved for all channels.

[Pizzinat et al. (2003)] describe the impact of hybrid erbium-doped fiber amplifier-(EDFA) distributed Raman amplification on a high bit rate wavelength-division-multiplexed optical communication system is studied by means of a reliable simulation model that takes into account noise properties of Raman amplification. Pure Raman amplification allows the decrease of the mean input power of about 6 dB, keeping the bit error rate at the same level.

[Rivera et al. (2009)] determined the best performance, however, is obtained for loss compensation provided by hybrid EDFA/Raman amplifiers, due to the reduction of nonlinear distortion. In this work a rigorous numerical model has been implemented for the EDFA-Raman hybrid amplifier that provides a good design that flattens the characteristic of the EDFA gain, enlarging the useful amplification bandwidth and link length. The numerical model has been validated through experimental measurements, for a simple hybrid configuration.

Till now, the work is done on operating at the bit rate of 10 Gb/s. In the network, the data is successfully transmitted to a distance of 50 km with a very low BER of 1 × 10−40 thus improving the performance over various data formats like NRZ Rectangular, NRZ Raised cosine, RZ Rectangular, RZ Raised cosine for optical transmission link. It has been shown that RZ Raised cosine yields the highest value of Q, good eye opening and lowest BER [12]. Moreover, no work over comparative...
analysis for suitability of better data modulation format was done at bit rate of $10 \times 96$ Gb/s, using RAMAN/EDFA Hybrid optical Amplifier based transmission links with relative low losses and with a very low BER of $1 \times 10^{-40}$ for a transmission distance of 50 km. Thus, comparative analysis of various data formats has also been done to find out the most suitable data format for transmission of data using RAMAN/EDFA Hybrid Optical Amplifiers.

The different data formats used by us present some notable differences in the context of data-rate/distance trade-offs and other device related parameters that affect transmission performance. Data formats have been investigated for certain performance measures viz. Q-factor, bit error rate (BER), eye opening, etc. The investigations have been carried out with different transmission distances of 50, 80, 110, 140, 170, 200, 230, 260, and 290 km over the Optical fiber. The paper is organized as follows. Section I presents the introduction. Section II presents the descriptive model for the transmission distance using RAMAN/EDFA. Section III describes the simulation model and the description of its components. Section IV includes the discussion of the results. Section V presents the conclusion about the feasibility of the network.

II. Descriptive Model

The basic architecture of the network based on $96 \times 10$ Gb/s is shown in Fig. 2. Each node is connected to the network via two fibers, i.e. one for transmission and the other for reception. After the amplification by EDFA the data is transmitted through single-mode optical fiber. EDFA’s gain is 5 dB. Similarly, after the transmission fiber data is amplified by the EDFA and the signals are distributed by a wavelength-insensitive splitter. Each node is equipped with a laser diode (LD) and a photodiode (PD) for data transmission and reception, respectively.

III. Simulation Model

The transmitter as shown in Fig 1. is composed of data source, laser source indicated by component CW Lorentzian, optical amplitude modulator indicated by component Sin2 MZ and optical link section. Data source generates a binary sequence of data stream. After the amplification by EDFA the data is transmitted through single-mode optical fiber, EDFA’s gain is 5 dB. Similarly, after the transmission fiber data is amplified by the EDFA and the signals are distributed by a wavelength-insensitive splitter. Each node is equipped with a laser diode (LD) and a photodiode (PD) for data transmission and reception, respectively. The set up illustrates how to simulate optical transmission consisting of 96 channels at 10 Gb/s speed. The analysis is done by taking eight nodes of transmitter and the architecture is composed of $12 \times 8$ channels as shown in simulation setup in fig 2. The transmission medium consists of 17 km long DS_Anomalous fiber based RAMAN and an optical amplifier (EDFA). Each node is further composed of, one transmitter source and one receiver source. The used distances in the optical transmission are, 50, 80, 110, 140, 170, 200, 230, 260, 290 km i.e. with the difference of 30 km. Modulation driver generates different types of data formats such as NRZ Rectangular, NRZ Raised cosine and RZ Rectangular. The pulses are then modulated using MZ modulator at 10 Gb/s bit rate. Amplitude Dual-Arm Mach Zehnder Modulator is used to modulate optical signal of desired form. Single receiver is composed of optical raised cosine filter indicated by the component Raised cosine1, PIN photodiode indicated by the component name Pin Photodiode and low-pass Bessel filter indicated by the component name Bessel electrical filter. Electrical scopes with Gaussian filter are used to observe change in performance. Optical filter implements a raised cosine transfer function filter having band pass filter synthesis.

IV. Results and Discussion

At the receiver measurements are made with the help of an optical spectrum analyzer, optical probe and electrical scope. The results of optical communication model based on transmission of Optical fiber using RAMAN/EDFA Hybrid Optical Amplifier. It presents a summary of comparative investigation on the performance metric indices viz. Q (dB); eye opening and BER operating at 10Gb/s with different data formats viz. NRZ Rectangular, NRZ Raised cosine, RZ Rectangular at different distances.
We observed that Q-factor is highest; 28.391db in case of RZ Rectangular followed by NRZ Rectangular, NRZ Raised cosine with Q values 25.564, 19.299 respectively as shown in fig 3.

Fig 4. shows the BER rate plot for various data formats at different transmission distances. This plot shows that the BER of RZ and NRZ Rectangular cosine is lowest when plotted against different values of transmission distance. Fig 5. show the eye diagrams for various data formats and it is observed from our results that best eye diagram is for RZ and NRZ Rectangular cosine with the lowest value of BER i.e. $1 \times 10^{-40}$ and 2.655 × 10^{-05} ns and 1.657 × 10^{-05} respectively. These values can be compared with the values of the other data formats. In a comparative investigation, eye opening in the case of RZ Rectangular has been reported to be the best; however, it is also reasonably good for RZ Rectangular.

Refrences

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