Performance Evaluation of Hybrid Amplifiers

Jipsy Sudarsanan[1] Vidya Raj[2]
[1]M.Tech Scholar [2]Assistant Professor
[1] Optoelectronics and Communication Engg. Dept. [2]E.C. Engg. Dept.
[1, 2]TKM Istitute of Technology, Kollam, Kerala

Abstract--- For several years, optical fiber communication systems are being extensively used all over the world for telecommunication, video and data transmission purposes. This is because optical fiber is capable of allowing the transmission of many signals over long distances. However, attenuation is the major limitation imposed by the transmission medium for long haul networks. So, with the growing transmission rates and demand in the field of optical communication, the electronic regeneration has become more expensive. Then, power optical amplifiers came into existence, which eliminated the costly conversions from optical to electrical signal and vice versa. Due to the need of longer unrepeated transmission distances Wavelength Division Multiplexing (WDM) optical transport networks are expected to provide capacity required to satisfy growing volume of telecommunication traffic in a cost effective way. For optimum utilization of available fiber bandwidth, various combinations of optical amplifiers in different wavelength ranges are made. The combination of two or more amplifiers are termed as Hybrid amplifiers. Hybrid amplifiers are attractive in optical communication as they expand the system bandwidth in long haul transmission. In this work, different combinations of hybrid amplifiers are simulated using software OptSim 5.3 and their performance is compared with respect to transmission distance.The observation shows that SOA-RAMAN-EDFA is the best among all hybrid amplifier combinations in terms of Q factor, output power and eye opening.

Keywords: Hybrid amplifiers, Quality Factor, Optsim.

I. INTRODUCTION

Demand for larger data speed capacity has been increasing exponentially due to the massive spread of internet services. At the same time, the great development of the capability of digital technologies has made possible broadening multimedia services like high-definition television, video on demand, video conferencing and others. Due to the above mentioned facts, information revolution implies that multimedia networks need high bandwidth for real time communication services. At present, optical fiber is the only transmission medium offering such large bandwidth with low loss communication links. In fiber optic communication, there is degradation of transmission signal with increased distance. By the use of optoelectronic repeater, this loss limitation can be overcome. In an optoelectronic repeater, optical signal is first converted into electric signal and then after amplification it is regenerated by the transmitter. But such regeneration becomes quite complex and expensive for wavelength division multiplexing systems. So, in order to remove loss limitations, optical amplifiers are used which directly amplify the transmitter optical signal without converting it into electrical forms.The emergence of optical amplifiers opened the door to wavelength division multiplexing, which expanded the capacity of long haul fiber-optic systems and revolutionized backbone telecommunications.

Most optical amplifiers amplify incident light through stimulated emission. Indeed, an optical amplifier is nothing but a laser without feedback. Its main ingredient is the optical gain realized when the amplifier is pumped (optically or electrically) to achieve population inversion. The optical gain depends not only on the frequency (or wavelength) of the incident signal, but also on the local beam intensity at any point inside the amplifier. Optical amplifiers (OAMP) can be classified on the basis of device characteristics i.e., whether it is based on linear characteristic (Semiconductor optical amplifier and Rare-earth doped fiber amplifiers) or nonlinear characteristic (Raman amplifiers and Brillouin amplifiers). OAMPS can also be classified on the basis of structure i.e., whether semiconductor based (SOAs) or fiber based (Rare-earth doped fiber amplifiers), Raman and Brillouin scattering amplifiers

The combination of two or more optical amplifiers constitute a hybrid amplifier.Hybrid amplifiers provide higher power gain and also extended bandwidth for optical communication. Raman amplifier is better because it provides distributed amplification within the fiber. Distributed amplification uses the transmission fiber as the gain medium by multiplexing a pump wavelength and signal wavelength. It increases the length of spans between the amplifiers and regeneration sites and thus provides amplification over wider and different regions. HybridRaman/erbium-doped Fiber Amplifiers (HFAs) are an advance technology for future. Hybrid Raman/erbium doped fiber amplifiers are designed to maximize the long-haul transmission distance [1]. Manoj Kumar et.al[3] investigated on optical soliton transmission link with in-line SOA at 1.3 mm and showed that soliton pulses when propagated with $a\beta_2 = -0.5\ ps^2/k$ indicate the pattern effect for soliton propagation best suited for transmission upto the distance of 400 km.

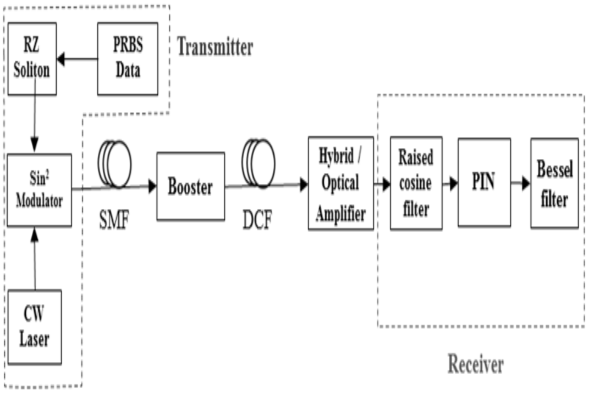

Fig. 1: Simulation setup

Ramandeep Kaur et al.[2] investigated a 10 Gbps WDM systems at 16,32, and 64 channels with EDFA, RAMAN and SOA amplifiers individually by varying the transmission distance (40-200 km)and dispersion (2-10 ps/nm/km) in the terms of output power, BER,Q factor and eye closure. Then the performance has been compared on the basis of transmission distance and dispersion with and without nonlinearities.Lee et al. [5] have experimentally compared the performance of hybrid Raman+EDFA amplifiers, in which the Raman gain is provided in a dispersion compensating fiber (DCF) section of fiber. In their works, the residual Raman pump power is recycled to pump the EDFA stage. Several different configurations based on a single pump laser over DCFs were studied. They found that by recycling the residualRaman pump in a cascaded erbium-doped fiber (EDF) section, as a secondary signal amplification stage, pump conversion efficiency can be increased. The amplifier characterization has been calculated in terms of global gain, and noise figure (NF). However, it has been restricted to the single channel characterization only, disregardingthe ripple parameter within the amplifier effective gain bandwidth, which is a veryimportant issue in WDM optical communication systems. John D. Downie et al. [6]demonstrated the transmission of 112 Gb/s PM-QPSK signalsover a system with 200 km span lengths. Amplification provided byhybrid backward-pumped Raman/EDFA amplifiers reached lengths up to 6000 km for an 8 channel system and 5400 km for a 32 channel system. As a means of maximizing OSNR, M.M.J.Martini et al. [4] have experimentally compared EDFA/Raman hybrid amplifier configuration in which the recycling of the residual Raman pump is utilized. This optimization was made by adjusting the Raman gain profile in order to equalize the EDFA gain spectrum. Simulations with two and three pumps were performed and for both cases a flat global gain has been successfully obtained for a bandwidth of around 30nm. The Raman+EDFA hybrid amplifier under recycling residual Raman pump, allied with the properly chosen of the pump wavelengths and powers, enables the construction of broadband amplifiers with enhanced power conversion efficiency and high and flat gains.

II. SIMULATION SETUP

The performance of hybrid amplifiers are analysed in single channel. The transmitter section consists of the data source, electrical driver, lasersource and external Mach-Zehnder modulator as shown in the Figure 1. The data source is generating signal of 10 Gb/s with pseudo random sequence. The electrical driver, RZ- Soliton converts the logical input signal into an electrical signal. The CW laser sources generates laser beam at 193.414 THz. The signals from data sourceand laser are fed to the external Mach–Zehnder modulator (sin^{2}MZ for all configurations)where the input signal from data source is modulated through a carrier(optical signal from the laser source).Then the optical signal is transmitted through optical fibers of varying transmission distances i.e. 40, 80, 120, 160 and 240 km. Further hybrid amplifiers are chosen such as SOA-RAMAN, SOA-RAMAN-EDFA and SOA-EDFA-RAMAN. Optical power meter is used for calculating signal power. Apart from output power parameters like quality factor and eye opening were analysed. Receiver is used to receive output signals and these signals are then converted into electrical signal.The receiver section consists of raised cosine filter , photodetector and bessel filter. The modulated signal is converted into original signal with the help of PIN photodiode and filters.

Different components have different operational parameters. The EDFA used is 20 dB fixed gain and 980 nm pump wavelength. Various parameters for SOA are biased current is 100 mA, amplifier length is 300 ×10^{-6}m, confinement factor is 0.35, insertion loss is 3 dB and output insertion is 3 dB. The various parameters for RAMAN are Raman fiber length is 10 km, operating temperature is 300 K, pump wavelength is 1480 nm and pump power is 300 mW, with counter propagation pumping. In order to increase the signal strength a booster is used between the single mode fiber and dispersion compensated fiber (DCF). The physical optical amplifier is used as booster.DCF is used to compensate the dispersion effects in single mode fiber.

III. RESULTS AND DISCUSSIONS

Using the above setup, measurements of Output Power, Q-factor and eye opening at 10Gbps with respect to the length are taken. The results discussed gives optimized parameters for different hybrid optical amplifiers (SOA-RAMAN, SOA-RAMAN-EDFA and SOA-EDFA-RAMAN). The optimization is done on the basis of BER, Q-factor, eye closure and output power for hybrid optical amplifier by changing the transmission distance varying from 40 km to 240 km in a single channel.

Inorder to observe the performance of different amplifiers the quality factor versus transmission distance graph is plotted in Figure 2. As we increase the transmission distance from 40 km to 240 km, the quality factor decreases because of the crosstalk and carrier density fluctuation in SOA. The variation in Quality Factor for different optical amplifiers at length 160 km is 23.903123 dB for SOA-RAMAN, 24.909727 dB for SOA-EDFA-RAMAN and 26.434458 dB for SOA-RAMAN-EDFA.

As shown in the Figure 3, the output power decreases with distance from 11.167-3.027 dBm for SOA-RAMAN, 24.577-20.816dBm for SOA-EDFA-RAMAN, 31.102-22.97 dBm for SOA-RAMAN-EDFA. The acceptable power for optical transmission is 10 dBm. Hence it is observed that by increasing the distance from 40 to 240 km power is decreasing.

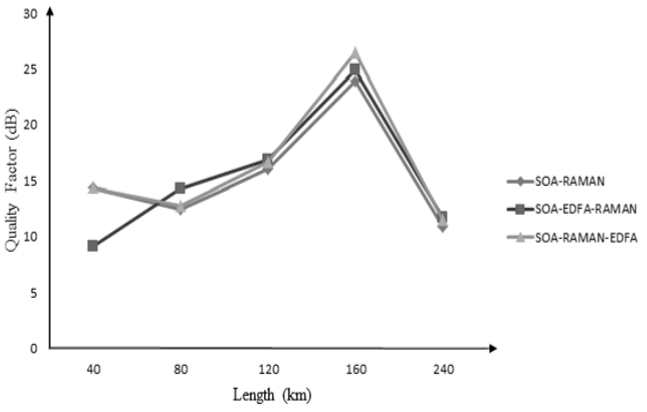

Fig. 2: Quality factor versus Length (km)

Figure 4 depicts the performance of different hybrid amplifiers in terms of eye opening. Larger the eye opening means less BER and good communication. The graph shows that as the transmission distance is increased from 40 to 240 km, the eye opening decreases simultaneously from 10^-2 to 10^-8.

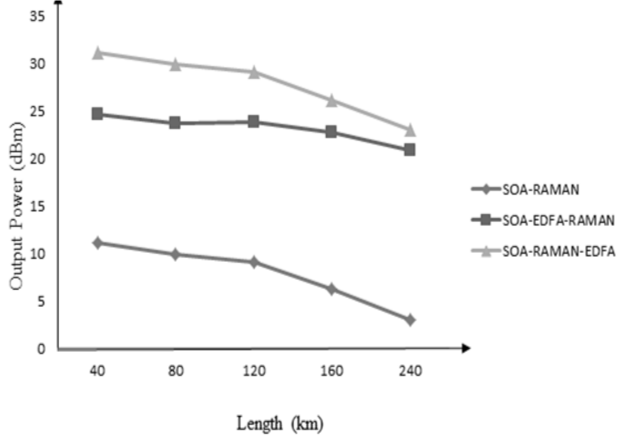

Fig. 3: Output power versus Length (km)

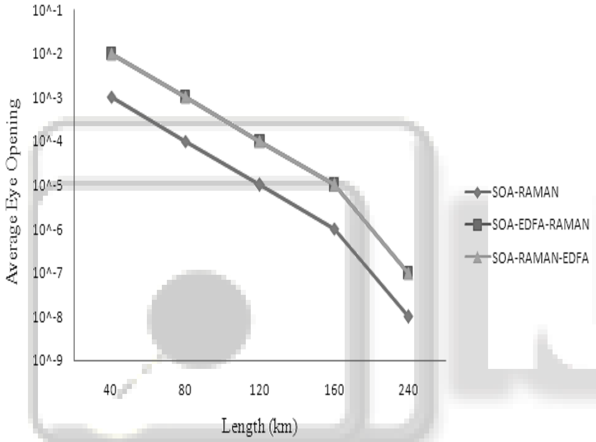

Fig. 4: Eye opening versus Length (km)

The eye diagram for SOA-RAMAN, SOA-EDFA-RAMAN and SOA-RAMAN-EDFA are shown in the Figures 5, 6 and 7 respectively. From the eye diagrams and obtained results the hybrid combination SOA-RAMAN-EDFA has obtained the better results.

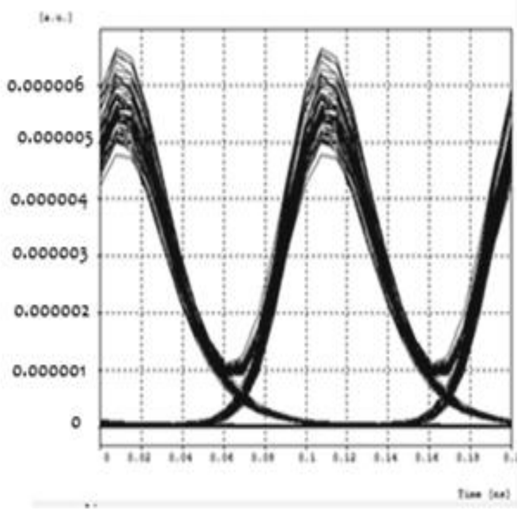

Fig. 5: Eye diagram at 160 km of SOA-RAMAN

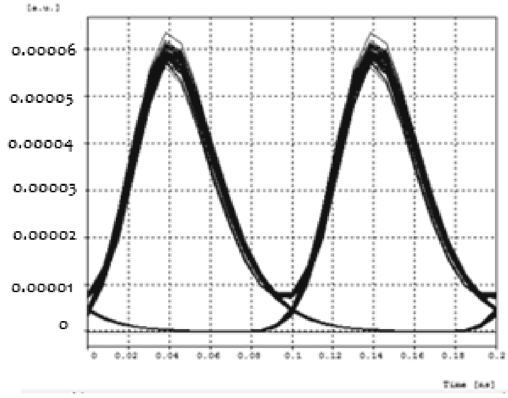

Fig. 6: Eye diagram at 160 km for SOA-EDFA-RAMAN

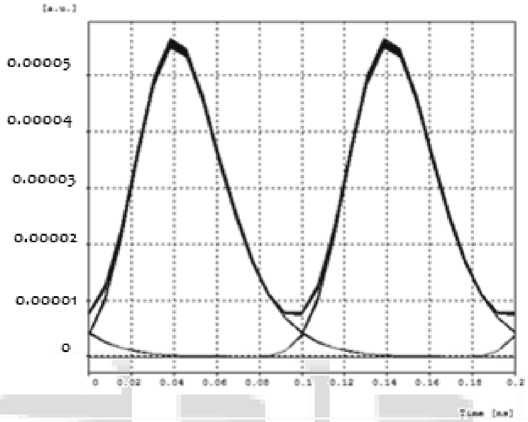

Fig. 7: Eye diagram at 160 km for SOA-RAMAN-EDFA

IV. CONCLUSION

The main motivation of this work is to increase the long haul and ultra-broadband transmission distance, cascadability and flexibility of the optical networks. In order to achieve these goals, it is of utmost importance to optimize the optical hybrid amplifiers in optical communication networks. In this work the performance of optical amplifiers and hybrid amplifiers in terms of the eye patterns, the output power and the Q factor are evaluated. From the comparison of the results, it is conceded that SOA-RAMAN, SOA-EDFA-RAMAN and SOA-RAMAN-EDFA combinations provides better performance. Also it was observed that optical hybrid amplifier SOA-RAMAN-EDFA provides the highest output power (31.102 dB and 22.97 dB) and better eye diagram from 40 km to 240 km compared to other optical amplifier. These results are only valid upto 160 km and above 160 km distance, there is more distortion in the detected signal, which reduces the output power Q factor and eye opening. So the proposed model is best suited upto 160 km distance.

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