Performance Evaluation of Optical Amplifiers in Optical Communication

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***Abstract*- Dense Wavelength Division Multiplexing (DWDM) has grown to be the most popular in high speed communications. DWDM is a multi carrier system where different carriers are multiplexed onto one fiber, i.e. different signals are at different frequencies within the fiber and thus better utilization of the available bandwidth is possible. An enormous amount of bandwidth capacity is required to provide the services demanded by the consumers. In addition to this explosion in bandwidth demand, many service providers are coping with fiber exhaust in their networks. A major problem for carriers is the challenge of economically deploying and integrating various technologies in one physical infrastructure. DWDM provides the best solution to all these problems. The purpose of this paper is to find amplifier effectiveness in a DWDM transmission system. Simulation is done by using Optsim ver.5.3.**

I. INTRODUCTION

Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. The light forms an electromagnetic carrier wave that is modulated to carry information. The increasing demand in telecommunication capacity has led to wavelength -division multiplexing (WDM).This technology multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths of laser light. This technique enables bidirectional communication over one strand of fiber as well as multiplication of capacity. WDM systems are divided into different wavelength patterns, coarse (CWDM) and dense (DWDM).Conventional WDM systems provide up to 8 channels in the 3rd transmission window (C-Band) of silica fibers around 1550 nm. Dense wavelength division multiplexing (DWDM) uses the same transmission window but with denser channel spacing. Channel plans vary, but a typical system would use 40 channels at 100 GHz spacing or 80 channels with 50 GHz spacing. Some technologies are capable of 12.5 GHz spacing (sometimes called ultra dense WDM).

DWDM is a fiber optic transmission technique which allows the transmission of voice, email, multimedia, video and data over the optical layer. It increases the capacity of embedded fiber by first assigning incoming optical signals to specific frequencies within a designated frequency band and then multiplexing the resulting signals onto one fiber. Future DWDM terminals will have the capacity to transmit 90,000 volumes of encyclopedia in one second. It allows longer transmission distance before transmission (80 km with SDH, 600 km with DWDM).It saves time and cost of laying new fibers (fiber exhaust). It has higher granularity protection switching. DWDM systems are bit rate and format independent (IP, ATM, SONET, SDH) and can accept any combination of interface rates on the same fiber at the same time.

DWDM technology is known as a kind of technology coupling and transmitting optical signals of different frequency (wavelength) to an optical fiber by using the tremendous bandwidth of SMF’s low-loss area in DWDM system, which is not only conducive to the realization of switching and recovery in optical networks but also convenient to the expansion and upgrade, and thus the further realization of transparent and high survivability optical networks. DWDM technology is now in a mature development period. With the development of the society, the requirement of people to communication quality and speed is higher and higher. The way to use the optical bandwidth huge resources and to upgrade the capacity of fiber-optic communications systems is an important theoretical and technical subject.

DWDM is a key component in the world’s communications infrastructure. The tremendous growth in telecommunications services is possible today in part through optical networks, where DWDM systems allow much greater bandwidth over existing optical systems. Telecommunication companies have sought out such technologies to help respond to a growing array of customer demands, including streaming video, which require large amounts of bandwidth to create transmissions in real time. Some leading service providers have reported the doubling of bandwidths about every six to nine months. DWDM allows such transmissions by virtually splitting the fiber's capabilities into more than two carriers. From both technical and economic perspectives, the ability to provide potentially unlimited transmission capacity is the most obvious advantage of DWDM technology. As demands change, more capacity can be added, either by simple equipment upgrades or by increasing the number of lambdas on the fiber, without expensive upgrades.In this work the most efficient amplifier in a point to point link and 16channel DWDM was found.

II SIMULATION SET UP

To investigate the performance of different amplifiers in a point to point link and in multi point link, the Optical amplifier (OA) is replaced by the different amplifiers namely Erbium Doped Fiber Amplifiers (EDFA), Semiconductor Optical Amplifier (SOA), Raman Amplifier and hybrid amplifiers such as SOA-EDFA, Raman-SOA and Raman-EDFA. The power meter is used to measure the input and output power of signal. The optical probe provides power spectrum data. Each transmitter section includes a Data Source, NRZ coder, Electrical filter, Mach-Zender Modulator (MZM) and a Continuous Wave Laser. The receiver section consists of optical filter, PIN photodiode, and electrical filter. The optical filter is to reduce Amplified Spontaneous Emission (ASE). The PIN photo detector is used to detect an optical information signal and convert into the electrical signal. Electrical Scopes simulates an oscilloscope for electrical signals. It collects data that will be available for the following diagrams such as amplitude of the electrical signal, eye diagram, histogram of optimum sampling instant and power spectrum of the electrical signal.

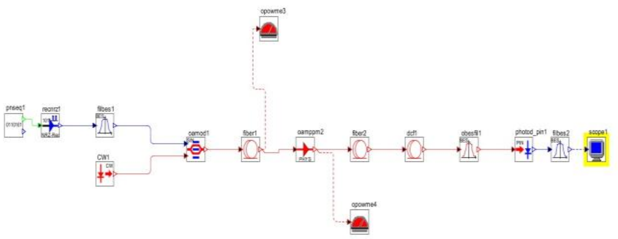


Fig. 1. Simulation model for a point to point link

The continuous optical signal is externally modulated by NRZ coded electrical pulses via an electro optical MZM. Then the generated optical signal is transmitted through 73 kilometres of Single Mode Fiber (SMF) with 0.2 dB/km attenuation and16 ps/nm/km chromatic dispersion. This SMF fiber length is determined by the required optical signal power at the input of the optical amplifier, which is important due to amplifier saturation effect, especially when using a SOA. For a discrete Raman amplifier this is not so relevant. This is why small signal power at the amplifier input has been optimized for the SOA. The simulation block using Erbium Doped Fiber Amplifier (EDFA) is shown in fig 1. In order to find the amplifier efficiency EDFA is replaced by Semiconductor Optical Amplifier (SOA), Raman Amplifier, Raman-EDFA, Raman-SOA, and SOA-EDFA. After processing through an amplifier, the amplified signal is transmitted through an SMF fiber of various lengths, which will be varied in order to obtain the maximum transmission distance, and then it enters a Dispersion Compensation Fiber (DCF). After propagating through the DCF fiber, the optical signal is detected and converted into electrical current using a PIN photodiode. DCF fiber attenuation at 1550 nm for the fiber is 0.55 dB/km, and dispersion at the same wavelength is -80 ps/nm/km.

The investigation on the performance on different amplifiers have been carried out on 16channel DWDM Transmission system operating at a data rate 10Gbit/s with non-return-to zero encoding technique, intensity on-off keying modulation format, and 50 GHz channel spacing has been introduced. The simulation scheme is shown in fig 2.

The transmitter block consists of 16 channel transmitters, each of them operating at its own frequency in range from 193.05 THz to 193.8 THz. Each transmitter includes a Data Source, NRZ coder, Electrical filter, Mach-Zender Modulator (MZM) and a Continuous Wave Laser. The continuous optical signal is externally modulated by NRZ coded electrical pulses via an electro optical MZM. Then all of the 16 generated optical signals are combined and transmitted through 73 kilometres of Single Mode Fiber (SMF) with 0.2 dB/km attenuation and16 ps/nm/km chromatic dispersion.

Fig. 2. Simulation model for a 16 channel DWDM Transmission system

After processing through an amplifier, the amplified signal is transmitted through an SMF fiber of various lengths, which will be varied in order to obtain the maximum transmission distance, and then it enters a Dispersion Compensation Fiber (DCF). After propagating through the DCF fiber, the optical signal is divided among16 receivers, where the optical signal is detected and converted into electrical current. Dispersion post compensation has been chosen in order to reduce the impact of FWM on the transmitted signal.

The most convenient way of assessing transmission quality is analyzing the Eye-diagrams and obtaining the bit-error-rate (BER) values of the received signal at each of the 16 channels. In order to assess optical amplifier performance and to estimate transmitted signal distortions, which occur during the amplification process, Eye-diagrams of a specific transmitted signal channel at the input and output of the optical amplifier are analysed.

III RESULTS AND DISCUSSIONS

The aim of this section is to compare the results received simulating a transmission system with no signal amplification, with an inline EDFA, inline SOA,inline distributed Raman amplifier and different hybrid amplifiers namely Raman-SOA, SOA-EDFA and SOA-EDFA. The most efficient amplifier in a point to point link in terms of transmission distance with least BER is obtained and results are shown in table.

TABLE 1 MAXIMUM TRANSMISSION DISTANCE OBTAINED FOR DIFFERENT AMPLIFIERS

Amplifier	Distance	DCF	BER
None	69Km	9.5Km	1.473e-008
EDFA	100Km	14Km	1e-040
SOA	113Km	16Km	5.29e-027
Raman	119Km	17Km	1.416e-036
Raman-SOA	121Km	17Km	1.577e-013
SOA-EDFA	130Km	18Km	4.825e-023
Raman-EDFA	135Km	17Km	1e-040

The length of the DCF Fiber was also varied to find the balance between compensated dispersion and DCF inserted loss. The result shows Raman-EDFA gives maximum transmission distance with minimum BER in a point to point link.

BER = 1e-040 BER = 4.44876e-023

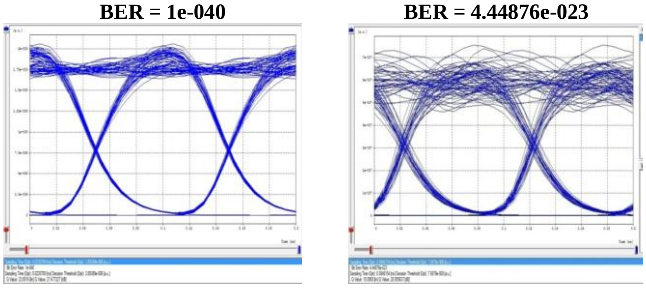


Fig. 3. Eye diagrams of EDFA at 100Km and 150Km

Amplifier efficiency with respect to transmission distance is analyzed in a point to point link. Figure 3 shows signal quality degradation with distance.

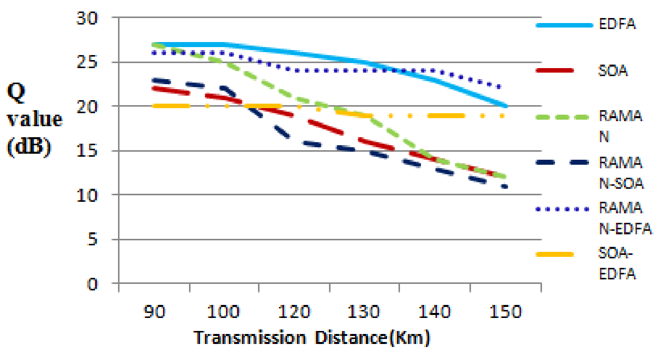
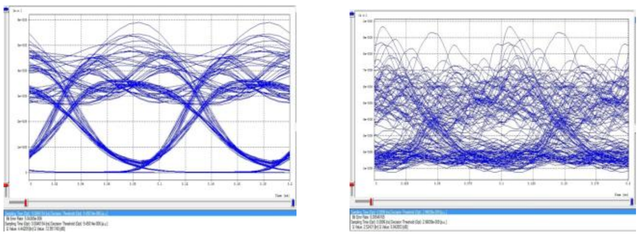


Fig. 4. Q value versus transmission distance

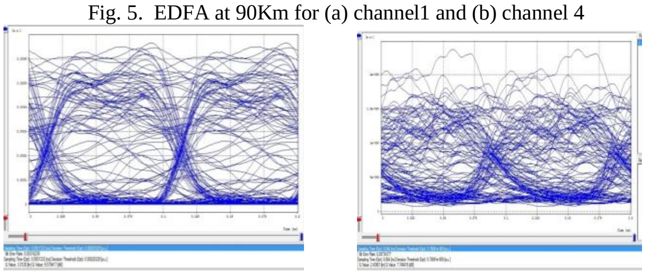
Fig 4 shows Q value obtained for different amplifiers in a point to point link. The result shows that EDFA and Raman-EDFA shows good performance for different wavelengths. It can be seen that EDFA's performance slightly degrade for longer distance but Raman-EDFA shows consistent good and stable performance for long distance.

As the number of channels increases, it can be seen that efficiency of amplifiers namely Erbium Doped Fiber Amplifiers (EDFA), Semiconductor Optical Amplifier (SOA), Raman amplifier, Raman-SOA, Raman- EDFA, SOA-EDFA decreases. Multi channel systems has linear effects (optical attenuation, chromatic dispersion) and non linear effects like Self phase modulation (SPM), Cross phase modulation (XPM) and Four wave mixing effects which causes in serious signal distortion and results in dramatic degradation of system performance and thereby limits transmission distance. Moreover closeness of a channel to the center of transmitted signal spectrum increases Inter channel cross talk which can be seen from the performance of channel four. In addition to it as the distance increases Q value of each of the channel decreases.



(a) (b)

Fig. 5. EDFA at 90Km for (a) channel1 and (b) channel 4



(a) (b)

Fig. 6. EDFA at 130Km for (a) channel 1 and (b) channel 4

The performance comparison of different amplifiers in a 16 channel DWDM transmission system is performed at 90 Km and 130Km confirms the stable performance of EDFA and Raman-EDFA. For long distance Raman-EDFA showed consistent performance.

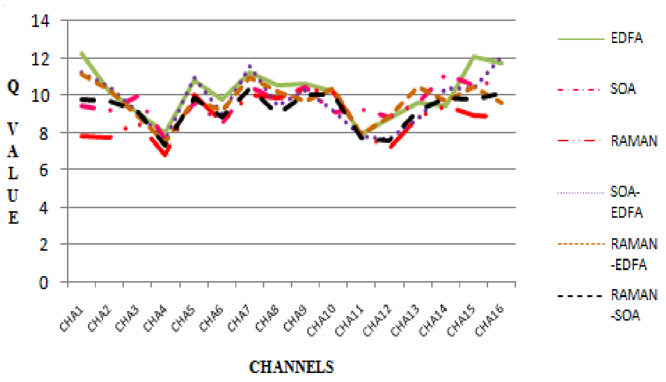


Fig. 7. Performance comparison of different amplifiers at 90Km

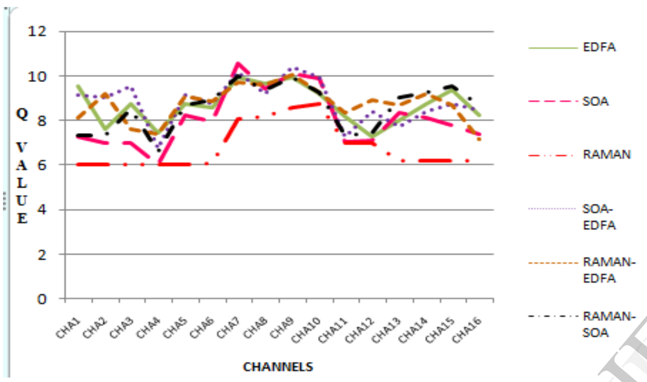


Fig. 8. Performance comparison of different amplifiers at 130Km

CONCLUSION

The main aim of this article is to find most efficient amplifier with respect to transmission and to identify the degradation factors that influenced transmission distance the most. Raman-EDFA showed better performance than any other amplifiers mentioned. The main factor that has limited transmission was amplifier produced noise, the amount of which was more in the case of the SOA. The main factor that held down transmission in the system with a discrete Raman amplifier was inter channel crosstalk, which was a product of the Four Wave Mixing non-linear effect.. It is also necessary to note that this difference in accumulated inter channel crosstalk in our case is mostly explained by the signal intensity difference at the amplifier output. On the other hand the non-linear response of the semiconductor optical amplifier and the small effective area together with the high nonlinear coefficient of the discrete Raman amplifier also made serious impact on the quality of transmission and limited the total achievable length of the link. The parameters of SOA were adjusted so that it would produce higher amplification with less signal distortions.

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