10Gbps Optical Line Using Electronic Equalizer and its Cost Effectiveness

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Abstract— **Chromatic Dispersion (CD) is a very important factor in the transmission of data over a long distance. To overcome the loss caused by CD, we can use many techniques. In this paper we propose to do the same by using Electronic Equalization technique. It also helps to eliminate ISI at the receiver end by proper thresholding, the transmitted bit sequence can be obtained without any errors. The paper also analyzes the cost effectiveness of using the electronic equalizer in place of optical equalizers.**

***Keywords*— Chromatic Dispersion, Electronic Equalizer, NRZ pulse, ISI**

I. INTRODUCTION

Chromatic Dispersion: Fiber limitations like chromatic dispersion (CD) severely affect the performance of the high speed optical fiber transmission systems. Dispersion is one of the important parameters and should be carefully monitored during the design process. To avoid the extra power required due to the nonlinear effects, fibers with a small but non zero CD is required in long-haul transmission system. CD is an important issue in single mode fibers and causes Inter Symbol Interference (ISI) in the pulse. This occurs because the components of light traverse with different velocities due to the differences in frequency. It is also called Group Velocity Dispersion.

The process of balancing the positive and negative dispersion over the length of the fiber is called dispersion management. The total dispersion is near zero or within an acceptable limit, when the optical pulses reach the receiver. It is inversely proportional to the square of the data rate of the signal. Single mode fibers have CD approximately 17 ps/nm.km and have minimum attenuation when they operate around 1550 nm. Hence, the accumulation of the dispersion components limits the distance of transmission to approximately 55 km on a 10Gbits/s system if dispersion compensation techniques are not used. One of the methods to expand the fiber's capacity is to enhance the number of DWDM channels transferred over a single fiber. The greater channel density has to compensate for the dispersion as well as the dispersion slope.[2]

Electronic Dispersion Compensation (EDC) has become one of the most important parts of an optical transponder design. At present, most of the installed optical fiber in the current metropolitan environment consists of single mode fiber with a CD value of about 17ps/nm/km at a wavelength of 1550 nm. In the current cost driven metro market, Electronic Dispersion Compensation can become a very valuable tool in enhancing the existing fiber links to higher bit rates. New applications using feed forward equalizer and decision feedback equalizer are being developed by International Telecommunication Union (ITU-T) to provide seamless up gradation facilities to the existing optical network systems.[2].

Cost Effectiveness: Comparing the conventional costs of an ADFE and an electronic equalizer, we can see that the cost of operation decreases by 75-80% when an electronic equalizer is used as opposed to an ADFE.

II. EQUALIZATION HYPOTHESIS

1. By replacing the adaptive decision feedback equalizers with electronic equalizers will enhance performance:

Chromatic dispersion compensation methods: For eliminating or mitigating the chromatic dispersion, various techniques have been presented. They can be classified into two main groups :(i) Optical compensation technique (ii) Electronic compensation.

Optical Compensation: There are several methods for optical dispersion compensation.

i. Conventional dispersion compensation fiber

This method used dispersion compensated fibers (DCF). Conventional dispersion compensation fibers (cDCF) have a very high negative dispersion in the C and L bands and can be effectively used in dispersion compensation in those bands. Further reduction in the core area of the new type of dispersion compensation fibers, a little slope correction has been made possible in conventional single mode fibers.

ii. Dispersion-compensating gratings

This is a technique which uses fiber Bragg gratings (FBG). This technique uses the property of FBG i.e. it being frequency selective which is written into the core of the single mode fiber by UV light. The main disadvantage of a dispersion compensation grating is the group delay ripple caused by high frequency deviation from the main mean dispersion slope of the gratings over wavelength. Dispersion compensating modules (DCM) using FBG have a narrow operating wavelength range and are not suitable for broadband compensation in the entire optical band.

iii. High-order-mode fibers (HOM)

It is a relatively new technique. It uses the fact that the higher order mode fibers have a significant negative dispersion. HOM based dispersion management systems are characterized by a dispersion of –270 ps/nm.km at 1550 nm and a slope over the C band of approximately -5.6 ps/nm. Hence, they can be used for both dispersion and dispersion slope compensation in the complete optical band (C + L) for long distance DWDM transmission lines.[6]

Electronic Compensation: It is a very attractive technique to compensate for dispersion at the electrical part of the recceiver ot the transmitter. It is a simple technique that doesn't need any changes in optical transmitting or receiving and also doesn't have considerable loss. Any network changes or adding new devices in the network can be done easily because of adaptive capability of electronic compensator. But there are some disadvantages of this system, for example circuits have limitation in speed compare to optical ones. There are various techniques for using an electronic equalizer, such as: Feed Forward Equalizer (FFE), Feed Forward-Decision Feed Back Equalizer (FFE-DFE), Non Linear Feed Forward- Decision Feedback Equalizer (NL-FFE-DFE) and Maximum Likelihood Sequence Estimator (MLSE).[7]

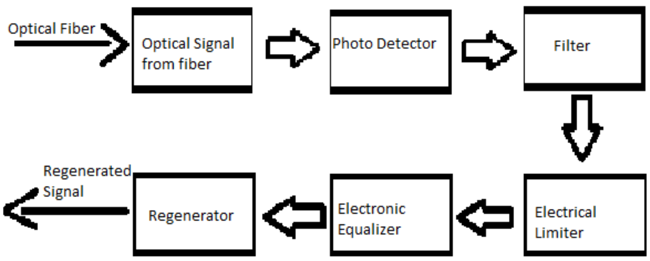
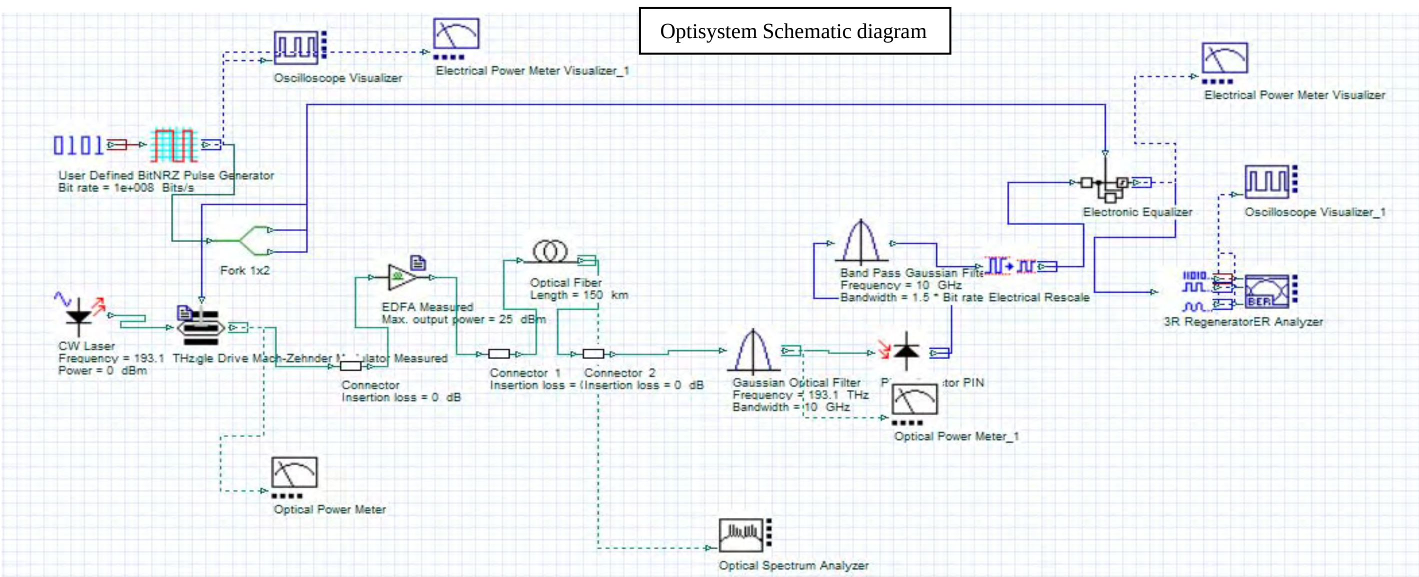


Fig 1: Block diagram for the electronic equalizer

Optical fiber communication systems are affected by the effect of chromatic dispersion of the fibers used. Dispersion in the optical link makes it difficult to decode the received signal as the bit symbols get broadened and distorted. Dispersion compensation is generally done before the photo detection, in the optical domain. But, there are other techniques of electronic dispersion compensation that use electronics for that purpose.



Two completely different techniques of electronic dispersion compensation have to be differentiated, which are applied in different types of data receivers:

The effect of dispersion cannot be directly removed in a direct detection receiver ass it is a frequency-dependant phase change, and the phase information is most of the times lost in the detection process. As long as it is not too strong, the dispersion effect can be mitigated. Such methods typically rely on tapped delay equalizers where different portions of the electronic input signal are subject to different time delays and are recombined after amplification with suitable levels. The signal processing in the presence of nonlinear distortions such like those occurring due to self-phase modulation due to fiber nonlinearities can be improved by using purely linear equalization techniques. There exist nonlinear equalization techniques also. For instance, lost spectral information can be compensated using a nonlinear decision feedback equalizer that makes decision thresholds on past decisions of the receiver. The full potential of optical dispersion compensation cannot be reached, though the signal quality can be significantly improved if the settings of such a system are carefully optimized. Based on the analog or digital signal processing techniques, the parameters may be adjusted automatically using the feedback techniques, thus, minimizing the bit error rate. The effect of intermodal dispersion can also be mitigated in multimode fibers that are used for short distance fiber optic links. Receivers that use optical heterodyne detection or homodyne detection offer a greater potential for electronic dispersion compensation, the phase information is not lost. The effect of chromatic dispersion can be directly removed if an electronic filter having an appropriate frequency response is applied to an intermediate frequency.

CD compensation with electronic equalizer: In this method we use band pass filter after photo detector. Also an electrical limiter is added exactly before our electronic equalizer as can be seen in Fig. 1. In our experiment we utilized FFE method, because it is a simple and consume power reasonably.

2. Replacing adaptive decision feedback equalizer with electronic equalizer is more cost effective:

Adaptive decision feedback equalizers will lead to the system being more costly as the equalization unit costs about 100$. But, with the help of an electronic equalizer, the cost of operation can be brought down to about 20-25$. This is a giant leap in the cost of operation and hence, we can achieve better performance without spending much.

III. SIMULATION

We have taken a binary source and encoded it using a NRZ pulse as shown in Fig 1.The optical source used is a CW Laser. Light is used as the carrier and modulated using the Mach Zehnder modulator. The signal is pre amplified using EDFA optical amplifier as the signal has a wavelength of 1550 nm. No inline amplification is used. At the receiver end, the output optical signal is filtered using the band pass Gaussian filter. The photo detector converts the received optical signal to electrical and then an electrical filter is used to further smooth the received output. Electrical limiter is used to limit the signal to a certain level. Then the signal is sent to the electronic equalizer where the equalization takes place. BER of the received signal is obtained using the BER analyser

IV. RESULTS

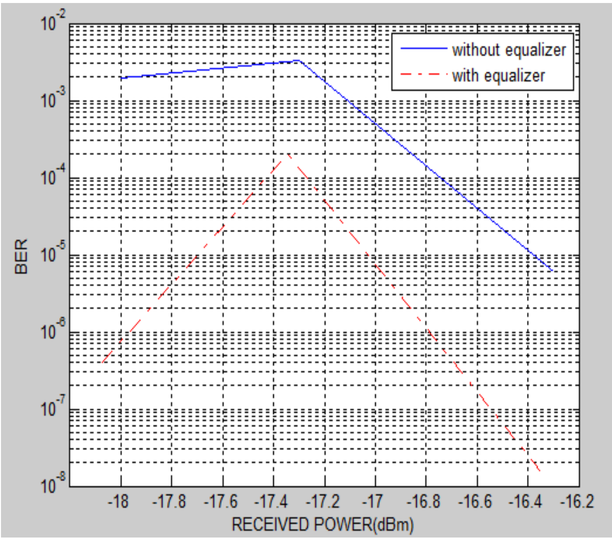


Fig. 2.BER comparison for with and without equalizer.

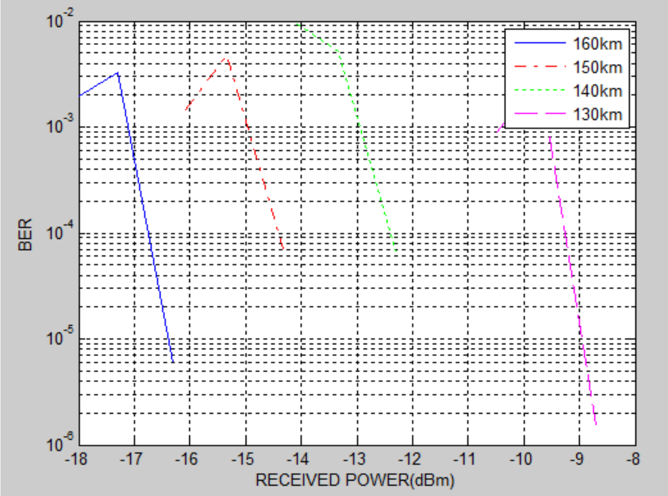


Fig. 3. Received power vs. BER for different lengths of optical fiber.

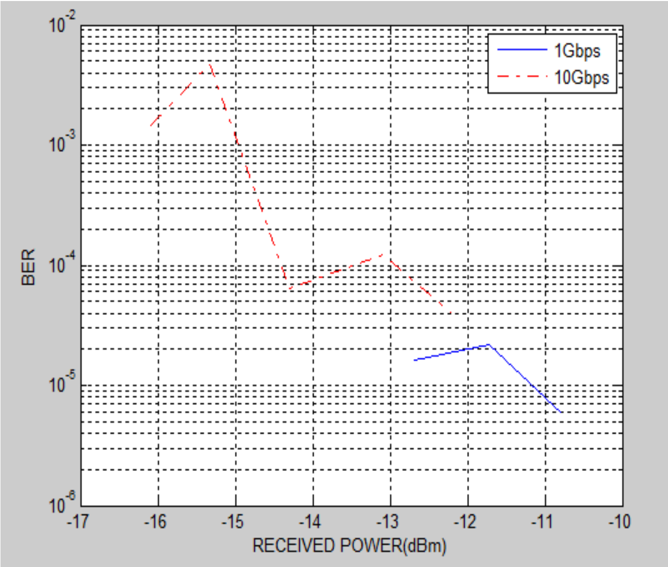


Fig.4 . Received power vs. BER for different bitrates.

For a transmission distance of 150-km on a single mode fiber, the simulation results without an equalizer and with an electronic equalizer are shown in Figure.2 clearly shows the advantage of using an electronic equalizer. Electronic equalizer achieves a performance gain above 2.4dBm for the bit error rate (BER) between10e-3 and 10e-5 when compared to an optical transmission system without equalization after 100km.

Figure 3 shows the variation of BER and received power for different transmission lengths and it has been observed that the fiber length with least distance gives maximum power in the receiver.

Figure 4 gives the variation of the BER and received power for different rates of transmission. It has been observed that the model has been optimized for 10Gbps transmission rate.

V.USES OF OPTICAL LINE AND EQUALIZERS

Optical lines are the backbones of any communication network nowadays. They play a major role in carrying data from one place to another without much loss in data and are highly reliable as tapping them is quite difficult.

Equalizers are those which are used to remove the anomalies in the received data. They have become an important part in the communication system and play a significant role in the process of obtaining reliable information. They find applications in many areas like music systems, television sets and also mobiles.

VI.CONCLUSION

A variety of linear and nonlinear transmission impairments are suffered by optical networks as they are analogue in nature. These impairments directly affect the Bit Error Rate (BER) performance of the system and the impact importantly increases in systems that support higher data rates and a larger number of channels.

From the results obtained it is clear that when the Electronic Equalization technique is used, data can be transmitted over an optical fiber up to a distance of 160 km with 10 Gbps data rate without any inline amplifier or repeater. Also performance of the line is improved as compared to that of unequalised line.

Noise enhancement effects were not considered and the performance of EDC will be highly affected by noise enhancement due to the electronic compensation. But, minimization of nonlinear terms is followed by minimization of noise.

Thus, we can conclude that we should shift from using adaptive decision feedback equalizers to electronic equalizers as the performance of the line is not compromised and also the cost of operation reduces by about 75-80%. Hence, we should shift from ADFEs to Electronic equalizers.

VII.FINDINGS

It is highly recommended that we shift from adaptive decision feedback equalizer systems to electronic equalizer systems as we are not compromising on the performance and we are able to operate the links at a cost less than the cost of operation in ADFE systems.

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