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Monitoring And Suppression Of Chromatic Dispersion Using Electronic Equalizer In Fiber Optic Communication Link

Mehtab Singh

Assistant Professor, Electronics and Communication Engineering Department, Satyam Institute of Engineering and Technology, Amritsar, India
Email:mehtab91singh@gmail.com

ABSTRACT: Dispersion phenomenon limits the performance of an optical fiber communication link very often, which causes the optical pulse to broaden as they travel through the fiber. These expanded pulses may overlap with each other at the output giving rise to Intersymbolic Interference (ISI). Dispersion posses a great hindrance to achieve high data rates and longer links in fiber optic communication system and hence dispersion compensation has become an issue of great importance. One of the methods to reduce ISI in signal is equalization of received signal. In this paper investigation has been done an adaptive equalization to reduce ISI caused by dispersion in optical links. Simulations are performed using Electronic Equalizer in order to monitor and suppress dispersion in optical links. Considerable improvement in the overall quality of signal can be seen in results of these simulations. Q factor before equalization was measured and found to be 64.037. Q factor was shown to improve after equalization and attained highest value of 102.843 when leakage factor was taken to be 1, step size 0.003, forward tap space 2, and no of forward taps 4.

Keywords: dispersion compensation, equalization, Electronic Equalizer, ISI

1 INTRODUCTION

One of the most important factors in optical communication is dispersion compensation. Fiber optical networks are optical links which have high data transfer rates and capacity. In fiber optical networks we transmit information from source to destination in form of light signals. This light signal can either be generated by Light Emitting Diode (LED) or LASERs. But like every other communication system available, fiber optical communication system also faces certain problems like bending losses, scattering, scintillations, absorption, non linear effects and chromatic dispersion [1],[5]. Out of all the problems faced by fiber communication system chromatic dispersion is considered to be the most important factor that affects the performance of an optical fiber link. In chromatic dispersion due to the dependence of speed of light signal on refractive index of fiber material which in turn depends upon the wavelength of the light used to carry information signal, the information carrying light signal gets expanded at the output of the fiber when it passes through a time dispersive optical link. If the data rate at the transmitter section is very high, these spread pulses at the output of the fiber may overlap with each other giving rise to Intersymbolic Interference (ISI) [3]. Due to ISI the quality of the signal received at the output is very poor and the receiver might not be able to differentiate between 0 and 1. As a result chromatic dispersion posses a severe limitation on the data transfer rate of an optical fiber link [2]. There are many techniques proposed to compensate dispersion in fiber optic communication link such as Dispersion Compensation Fiber (DCF), Fiber Bragg Grating (FBG), Electronic Dispersion Compensation (EDC), digital filters and use of digital signal processing at the receiver end. In this paper Electronic Dispersion Compensation technique has been discussed to compensate dispersion in a 2.5 Gbps fiber optical link. An electronic equalizer is capable of reducing Intersymbolic Interference (ISI) which is produced as a result of chromatic dispersion and polarization mode dispersion in a single mode fiber [1] and differential mode delay in a multimode fiber [2]. An electronic equalizer might use feed forward equalization, decision feedback equalization or combination of both to compensate dispersion. The EDC technique is capable of improving the average BER and overall OSNR of an optical fiber link [4]. The rest of the paper is organized as follows; in section 2, the electronic equalizers are discussed in detail. Simulation setup is described in section 3. In section 4, the results and discussion is discussed and section 5 conclusion of the paper is presented.

2 ELECTRONIC EQUALIZATION

Electronics alongside with optics is used in Electronic Dispersion Compensation (EDC) technique to compensate dispersion. Multiple ways by which dispersion can be compensated by use of EDC are available. One of them is using complementary Polarization Mode Dispersion (PMD) vector at the receiver end to cancel out first order PMD produced in the optical fiber due to time dispersive properties of optical fiber [6],[7]. The use of electronic circuits is one of the most commonly used techniques to equalize a time dispersed signal in a fiber optical link. According to Hui Wu, transversal filters making appropriate use of delay lines and gains at each stage can be an effective way to reduce ISI which is produced as a result of dispersion in an optical fiber link [2]. Another EDC technique used to compensate dispersion is use of Asymmetric Mac-Zender Interferometer (AZMI) having a large differential time delay capable of suppressing thermal noise and fiber non-linearity [7]. The improvement of the optical signal quality in the system making use of MZI as a tool to equalize dispersion slope in Specrta Amplitude Coding-Optical Code Division Multiple Access (SAC-OCDMA) integrated with Arrayed-Waveguide Grating (AWG) router is another technique of EDC. One of the most common and most easy to implement technique in electronic dispersion compensation to reduce distortion in signal is by making use of either feed forward equalizer or decision feedback equalizer or combination of both to minimize ISI. Figure no. 1 shows a five tap FFE. A FFE is considered as a delay line whose output is given by:

$$y(t) = \sum_{k=0}^{N-1} c_k . x(t - [k.\Delta t])$$

Where N is the no of taps in the Feed Forward Equalizer (FFE) structure and x(t) is the value of signal at time t. A single stage Decision Feedback Equalizer (DFE) is shown in Figure no. 2.

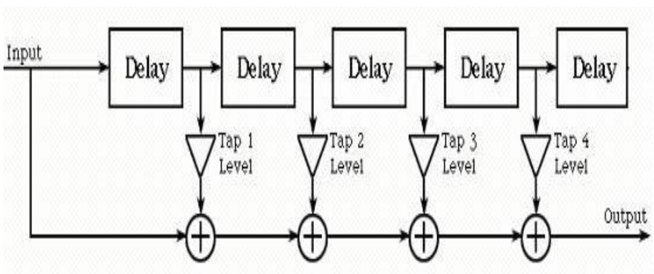

Figure no. 1 *A five stage Feed Forward Equalizer (N=5) [4]*

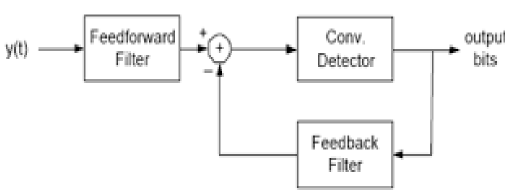

Figure no. 2 *A single stage Decision Feedback Equalizer [4]*

3 SIMULATION SETUP

The goal of the simulations is to determine how the number of taps, the resolution of the coefficients, step size and the leakage factor the affect equalizer performance. The motive is to use the outcome of the simulations to establish a feasible hardware implementation. The model used in the simulations is a Optisystem simulation of a fiber optic system with a continuous wave 1550 nm laser, a standard optical fiber of length 50km and a detector in the form of a avalanche diode followed by a low pass filter (to remove high frequency noise) at the receiver. The simulated model is shown in Figure no. 3and the Optisystem simulation is shown in Figure no. 4

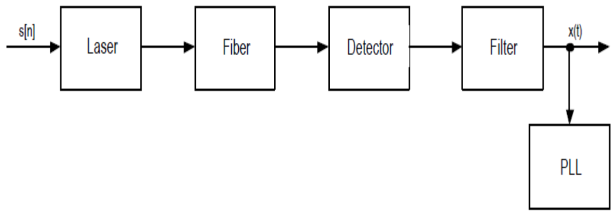

Figure no.3 *Fiber optic model used in simulations [5]*

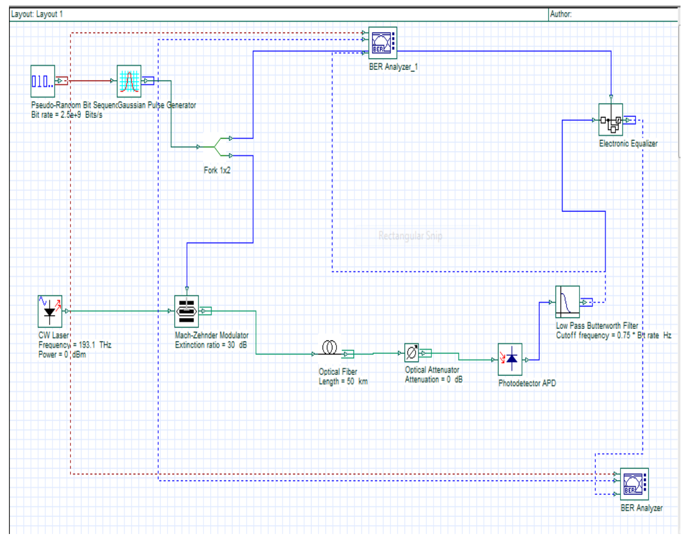

Figure no. 4 *Optisystem simulation of equalization using Electronic Equalizer*

The various simulation parameters are shown in table no.1.

Table No. 1

Serial No.	Parameter	Value
1	Pulse form	Gaussian Pulse
2	Bit rate	2.5 e+9 bits/sec
3	Sample Bit rate	64
4	No of Samples	8192
5	Laser central frequency	193.1 THz
6	Transmitting Power	6 dBm
7	Modulator	Mach Zender
8	Extinction ratio	30 dB
9	Fiber Length	50 km
10	Attenuation coefficient	0.2 dB/km
11	Dispersion coefficient	16.75 ps/nm.km
12	PMD coefficient	0.5 ps/sqrt(km)
13	Effective Area	80 um^2
14	Ionization ratio APD	0.9

4 RESULTS AND DISCUSSIONS

Because there are larger no of variable and hence large no of possible variable settings in simulations, it is almost impossible to carry out simulation of each and every possible combination within a specific amount of time. The technique utilized here is to change one parameter at a time, analyze the effects and use these analyses to narrow down the scope of the variables to reasonable amount, keeping hardware considerations in mind. The simulations are performed not for a particular equalizer configuration, rather for different possible solutions with different hardware limitations, results are discussed for a variety of possible implementations. To get an idea of the equalizer capabilities, it may be useful to visualize the performance in the form of eye-diagrams. In Figure no. 5, the eye of the received signal is shown before equalization and in figure no. 6 after equalization for a 50 km link with an externally modulated laser is shown. The equalizer has 4 FFE taps, leakage factor of 1, forward tap space 2, step size of 0.003 and utilizes the standard LMS algorithm. Although this configuration may be slightly too complex to implement at a reasonable cost at 2.5 Gbps, it is still useful for showing the equalization potential. As can be seen in figure no. 6, the equalizer opens the eye to a great extent, but not totally. None of the simulated equalizer configurations have been able to open the eye very much more than this for 50 km. The main reason for this is non-linearity present in channel.

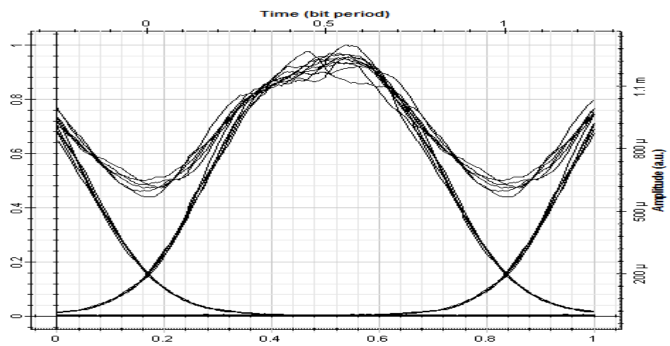

Figure No.5 Eye diagram of received signal before equalization (Q=64.037)

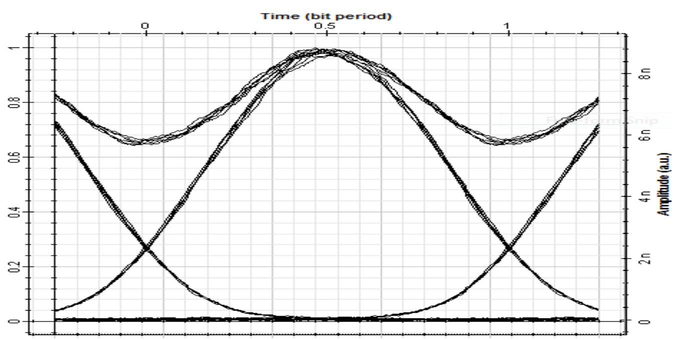

Figure No.6 *Eye diagram of received signal after equalization (Q=102.843)*

5 CONCLUSION

This paper analyses the performance of an Electronic Equalizer to compensate dispersion in a 2.5 Gbps optical fiber link. From the above discussions it is concluded that Electronic Equalizer is indeed an effective way to compensate dispersion in a time dispersive optical link. . Q factor before equalization was measured and found to be 64.037. Q factor was shown to improve after equalization and attained highest value of 102.843 when leakage factor was taken to be 1, step size 0.003, forward tap space 2, and no of forward taps 4. By carefully manipulating various parameters, the distorted signal can be equalized for even higher data rates fiber links.

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