Volume 6, Issue 4, April 2016 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Electronic Equalization in Optical Fibers to Compensate for ISI

Subhrajit Pradhan[1], Chintapalli Harish[2], Pratyush Mishra[3], Sambhabana Sahoo[4], Priyaranjan Meher[5], Dr. Rasmita Panigrahi[6]
[1, 5] Asst. Prof. Electronics Department, G..I.E.T Gunupur, Odisha, India
[2, 3, 4] Department of Electronics And Communication Engineering, G..I.E.T Gunupur, Odisha, India
[6] Lecturer Berampur University, Berhampur, Odisha, India

Abstract: The performance of fiber optic communication links is often limited by a phenomenon known as Dispersion, which causes optical pulses to broaden as they propagate through the fiber, thus giving rise to intersymbol interference (ISI). In this paper investigates the possibilities of using adaptive electronic equalization to compensate for ISI caused by dispersion in optical fibers.

Key Words: Adaptive Equalization, inter-symbol interference, Dispersion.

I. INTRODUCTION

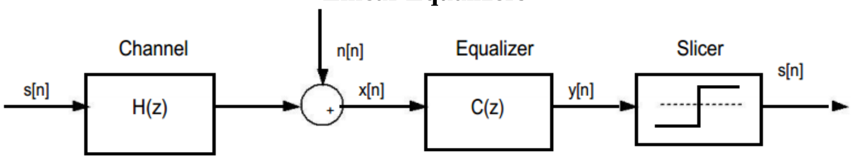
Inter-symbol interference impose the main obstacles to achieving increased digital transmission rates with the required accuracy. Channel impairments in fiber optics have traditionally been controlled in the channel itself rather than at the transmitter or receiver, predominantly by using specially designed fibers to both mitigate and compensate for dispersion. Recently however, techniques commonly used in for example radio communications to improve performance have found their way to fiber optics as well.

One such technique is equalization. Filtering the received signal with an equalizer has proven to be an effective method to combat ISI in many situations. However, it has not yet been implemented in fiber optic systems. Though recent advances in electronic hardware have opened up the possibility of designing electronic equalizers to perform equalization at the high data rates that are of interest (10 Gbps and above), the complexity of such an equalizer is still somewhat limited by hardware constraints.

II. EQUALIZATION

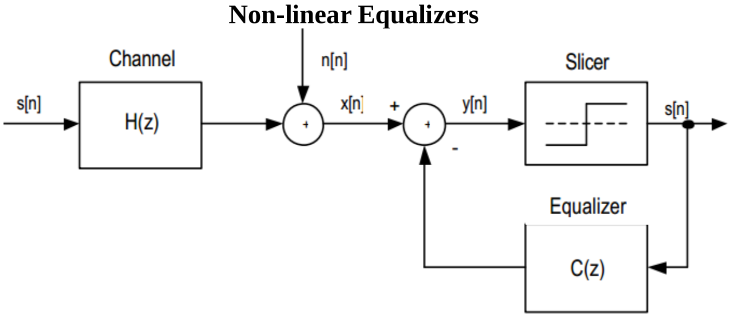
Equalization is a common way to deal with inter symbol interference in other communication systems, but it is yet to be implemented for fiber optic systems. There is no principal difference between a fiber optic channel and e.g. a radio channel in terms of ISI; the received baseband signal is distorted in a similar manner in both systems, i.e. symbols spread out over neighboring symbols as they propagate through the channel. Given below are the different types of equalizer.

Linear Equalizers



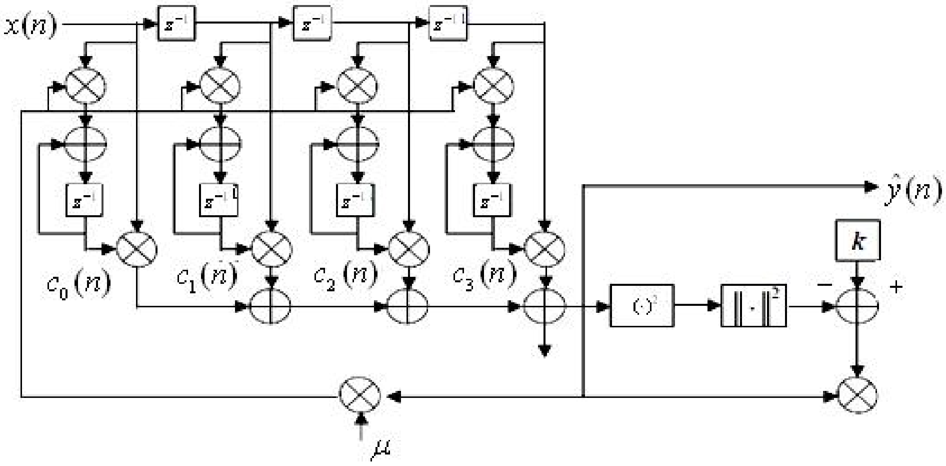
The basic idea of a linear equalizer is simply to filter the received signal through a filter that approximates the channel inverse. Here, $s[n]$ represents the transmitted symbols that are sent into the channel with frequency transfer function $H(z)$, $n[n]$ is additive white Gaussian noise (AWGN), $x[n]$ is the input to the linear equalizer with frequency transfer function $C(z)$ and $y[n]$ is the filtered equalizer output.

Non-linear Equalizers



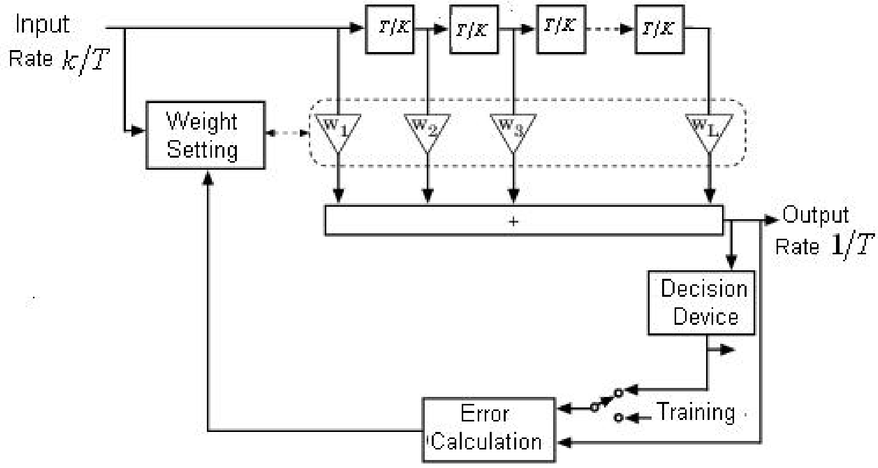
The basic idea of a DFE is very straightforward; the ISI caused by each received symbol on the succeeding symbols can simply be subtracted from these if the amount of ISI is known. In principal, a sufficiently long DFE removes all postcursor ISI (i.e. ISI from prior symbols) caused by each symbol. Precursor ISI (due to subsequent symbols) is usually handled by a preceding feed forward filter. Though the feedback filter is a linear filter, the DFE is nonlinear since the symbol decision is a nonlinear operation.

Blind Equalization



In the Blind Error is selected as the basis for the filter coefficient update. In general, blind equalization directs the coefficient adaptation process towards the optimal filter parameters even when the initial error rate is large. For best results the error calculation is switched to decision directed method after an initial period of equalization, call this the shift blind method. Referring to, the Reference Selector selects the Decision Device Output as the input to the error calculation and the Error Selector selects the Standard Error as the basis for the filter coefficient update. A Fractionally Spaced Adaptive Equalizer ([6]is a linear equalizer that is similar to a symbol-spaced linear equalizer.

Fractionally Spaced Adaptive Equalizer



Sometimes the input to the equalizer is oversampled such that the sample interval is shorter than the symbol interval and the resulting equalizer is said to be Fractionally Spaced Adaptive Equalizer. Equalizer Taps are spaced closer than the reciprocal of symbol rate. Advantages of FSE are it has ability to be not affected by aliasing problem, shows fast convergence and sample rate is less the symbol rate.

More recently, Fractionally Spaced Adaptive Equalizers (FSE's) have assumed an increasing presence, especially in the area of voice band data transmission. This technological shift is based upon at least two factors: first, the performance superiority of FSE's relative to that of Conventional equalizer and second, the availability of variants on the conventional stochastic gradient algorithm that mitigate coefficient drift during decision-directed operation.

Sign LMS

The idea of sign LMS is to reduce the computational complexity by replacing multiplication with addition (which is simpler to implement in hardware) by using only the sign of the error function e[n] and/or the tap input signals ***x***[*n*] to update the coefficients. There are a few of possible variations of this such as sign-data, sign-error and sign-sign LMS. The sign-data and sign-error variants perform the sign operation on the data signal and error signal respectively, and the coefficient update functions are thus given by

$$\circ\ [n+1] = \ [n] + \mu e[n]\,\mathrm{sgn}(\ [n])$$

and

$$\circ\ [n+1] = \ [n] + \mu\,\mathrm{sgn}(e[n])\ [n]$$

Sign-sign LMS is an even coarser variant that uses the sign of both the error function and the input signal, i.e.

$$w[n+1] = w[n] + \mu\,\mathrm{sgn}(e[n])\,\mathrm{sgn}(x[n])$$

If the multiplication of μ is implemented as a fixed bit shift (which requires that μ is a power of two) these algorithms eliminate the need for hardware multiplications.

III. 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.

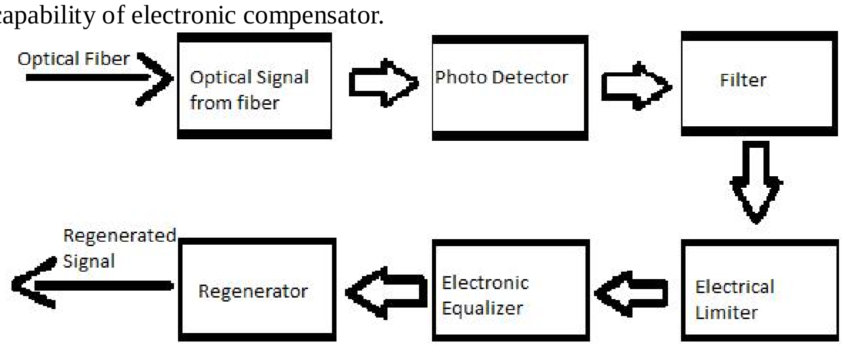
ii. Dispersion-compensating gratings:

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.

Electronic Compensation: It is a very attractive technique to compensate for dispersion at the electrical part of the receiver at 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.



IV. SIMULATION

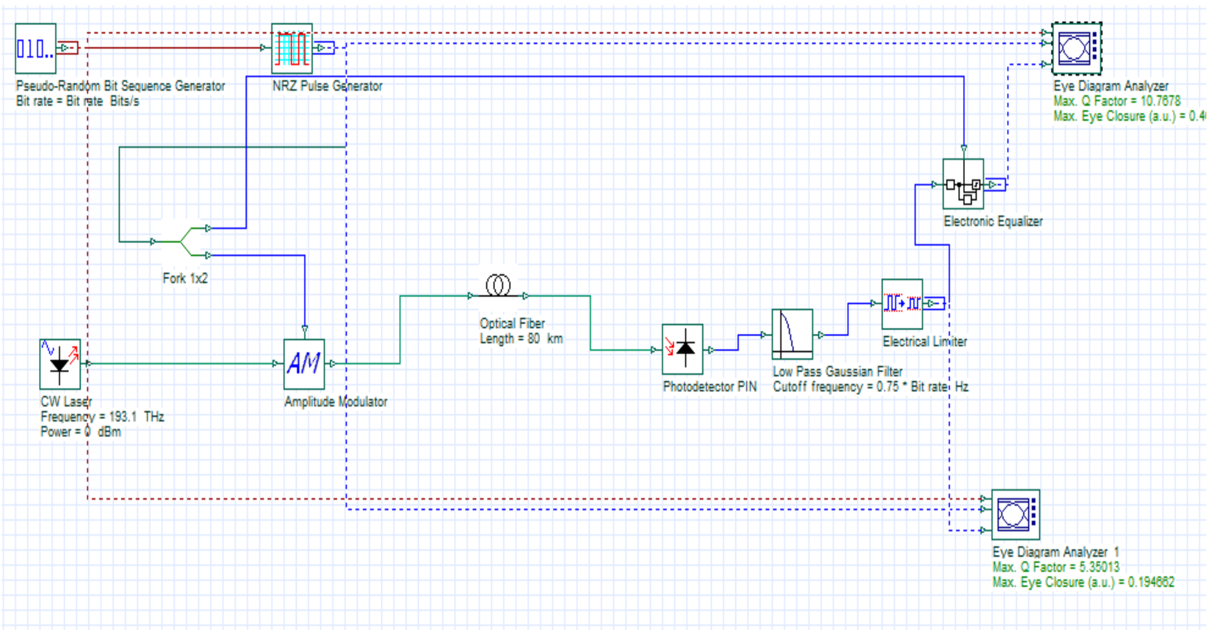


Figure: simulation diagram for electronic equalizer.

The above simulation is done by using optisystem 14 software. Here we have taken a binary source and encoded it using a NRZ pulse as shown in the above figure. The optical source used is a CW Laser. Light is used as the carrier and modulated using the amplitude modulator. The signal is pre amplified using EDFA optical amplifier as the signal has a wavelength of 1550 nm. At the receiver end, the photo detector converts the received optical signal to electrical signal and is filtered using the low pass filter. 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. The output of the given system is measured by using eye-diagram analyzer.

V. RESULTS

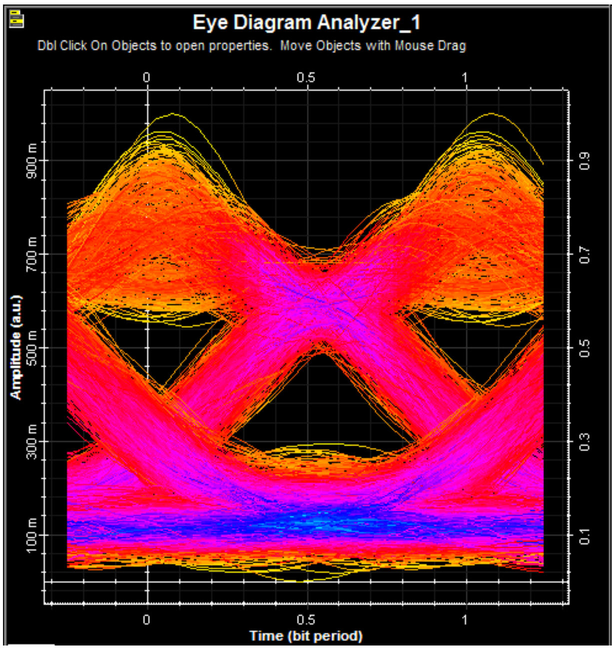


Fig: Eye Diagram before Equalization.

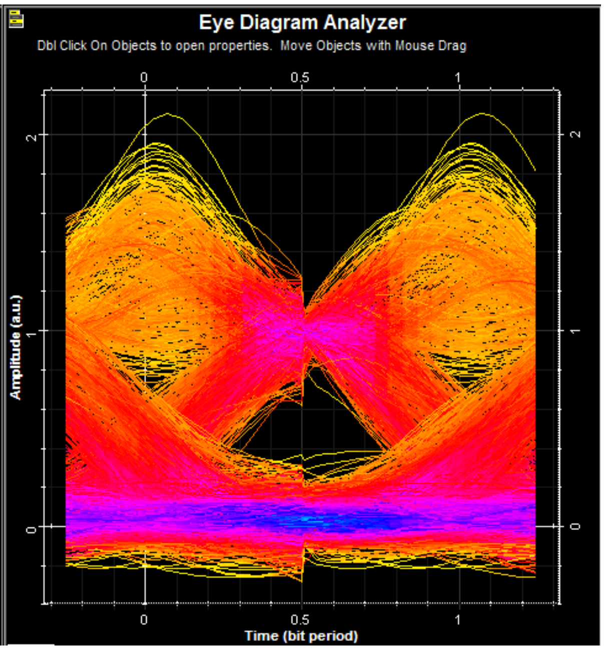


Fig: Eye Diagram after Equalization.

For a transmission distance of 80-km on a single mode fiber, the simulation results without an equalizer and with an electronic equalizer are shown in the above figure clearly shows the advantage of using an electronic equalizer.

In this paper the analysis is done by taking different lengths of optical fiber and their respective Q factor, bit error rate and eye height of the received signal is measured before and after the Equalization.

	Before Equalization			After Equalization		
FIBER LENGTH	MAX Q FACTOR	MIN BER	EYE HEIGHT	MAX Q FACTOR	MIN BER	EYE HEIGHT
60 KM	9.13406	3.20443e-020	0.448204	18.0752	2.4962e-073	0.82005
70 KM	7.1184	5.4293e-013	0.313874	15.2718	5.7302e-053	0.784502
80 KM	5.3501	4.3864e-008	0.196358	10.7678	2.3370e-027	0.694817
83 KM	4.759	9.6810e-007	0.1579	9.64616	2.44e-022	0.659658

VI. CONCLUSION

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 83 km with 10 Gbps data rate without any inline amplifier or repeater. 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.

REFERENCES

[1] Adinoyi, S. Al-Semari and A. Zerquine (Jan. 1999) Decision feedback equalization of coded I-Q QPSK in mobile radio environments. Electron. Lett. , 35:13-14, No.1.

[2] Antoinette Beasley and Arlene Cole-Rhodes (2005) Performance of Adaptive Equalizer for QAM signals. IEEE, Military

[3] B. Petersen, D. Falconer (1994) Suppression of adjacent-channel, co-channel and intersymbol interference by equalizers and linear combiners. IEEE Trans on Communication, 42: 3109-3118.

[4] B.P.Lathi (1998) Modern Digital and Analog Communications system. Third edition. USA: Oxford University Press.

[5] D. N. Godard (Nov. 1980) Self-recovering equalization and Carrier Tracking in Two-dimensional Data communications Systems. IEEE Trans. Communication, COM-28(11):1867-1875.

[6] J.R. Treichler, I. Fijalkow, and C.R. Johnson, JR. (1996) Fractionally Spaced Equalizers. IEEE Signal Processing Magazine, 13(3):65-81.

[7] Kevin Banovic, Mohammed A.S., Khalid Esam and Abdel-Raheem (2007) FPGA Implementation of a Configurable Complex Blind Adaptive Equalizer. IEEE International Symposium on Signal Processing and Information Technology, 150-153.

[8] R.D. Gitlin and S. B.Weinstein (February 1981) Fractionally-Spaced Equalization an improved digital transversal Equalizer. Bell Syst. Tech. J., 60 (2):275-296.

[9] S. U. H. Qureshi (1985) Adaptive equalization. Proceedings of the IEEE, 73(9):1349-1387.

[10] Vladimir D. Orlic and Miroslav Lutovac (2009) A solution for efficient reduction of intersymbol interference in digital microwave radio. TELSIKS, 15(2):463-464.

[11] I.P. Kaminov, T.L. Koch, *Optical Fiber Telecommunications IIIA*, Academic Press, 1997.

[12] J. Proakis, D. Manolakis, *Digital Signal Processing*, Prentice Hall, 1996

[13] J. Proakis, M. Salehi, *Communication Systems Engineering*, Prentice Hall, 1994

[14] Z. Ding, Y. Li, *Blind Equalization and Identification*, Marcel Dekker, 2001

[15] S. Haykin, *Adaptive Filter Theory*, 2nd edition, Prentice Hall, 1991

[16] J. Ryan, "Next-generation NZ-DSF Fibers will Balance Performance Characteristics", *Lightwave*, March 2000.

[17] L. Clyde, "System Tradeoffs in Optical Fiber Design for Long-haul Applications", *Lightwave*, August 1999

[18] H. Bülow et al., "Measurement of the Maximum Speed of PMD Fluctuation in Installed Field Fiber", *Proc. OFC'99*, 1999.

[19] H. Bülow, "Equalization of Bit Distortion Induced by Polarization Mode Dispersion", *Core and ATMNetworks NOC '97*, June 1997

[20] S. Särkimukka, "Compensation of Polarization Mode Dispersion", Master Thesis, Department of Physics, Royal Institute of Technology, December 1999

[21] S. Särkimukka et al., "Mitigation of Polarization-Mode Dispersion in Optical Multi-Channel Systems", *IEEE Journal of Lightwave Technology, Volume 18, Number 10*, October 2000.

[22] C.R. Johnson et al., "Blind Equalization Using the Constant Modulus Criterion: A Review", *Proc. ofthe IEEE, Special Issue on Blind System Identification and Equalization, vol. 86, no. 10*, October1998.

[23] D.R. Brown, P.B. Schniter, C.R. Johnson, "Computationally Efficient Blind Equalization", *Proc.Allerton Conf. on Comm., Control, and Computing*, September 1997.

[24] C. Tidestav, "A Short Introduction To Adaptive Equalization", Signals and Systems, Uppsala University, April 1998.

[25] J. M. Cioffi, *Digital Communication - Signal Processing; EE379A - Course Reader,* 1999 Stanford University.

[26] S. McLaughlin, A. Stogioglou, J. Fackrell, "Introducing Higher Order Statistics for Detection of Nonlinearities" *UK Nonlinear News*, September 1995.

[27] M. Tennare, "Modeling of Semiconductor Lasers for Transmission Analyses", Master Thesis, Department of Electronics, Royal Institute of Technology, 1998.

