Electronic Compensation for Intramodal Dispersion

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***Abstract*- Optical fiber communication is a way of transmitting the information from one place to another by modulating the light signal with the information signal. Optical fiber communication systems primarily operate at wavelengths near 1.55 µm in order to coincide with the minimum loss point of optical fiber and thereby maximizing the transmission distance. But, at this wavelength, there is a significant amount of group velocity dispersion (GVD) that limits the achievable propagation distance. Dispersion in a single mode fiber (SMF) is known as intramodal dispersion or chromatic dispersion (CD) which results in pulse spreading and causes intersymbol interference (ISI). Coherent detection employing multilevel modulation formats has become one of the most promising technologies for next generation high speed transmission systems due to the high power and spectral efficiencies. Using the powerful digital signal processing (DSP), coherent optical receivers allow the significant equalization of intramodal dispersion, Intramodal dispersion only causes ISI, but it also introduces a power penalty, which can cause degradation of the system's SNR. In this paper, electronic dispersion compensation (EDC) achieved with the help of DSP. The simulation has to be carried out using optisystem v 12**

Keywords: Dispersion, intersymbol interference, group velocity dispersion, intra modal dispersion, single mode fiber, signal to noise ratio, electronic dispersion compensation

I. INTRODUCTION

Nowadays communication systems use optical waves as carriers; hence, the bit rate-distance product BL can be improved several orders of magnitude compared to other system. The most appropriate media that are used as channels in these systems are optical fibers. The first-encountered problem was that available optical fibers during that time had extremely high loss, exceeding 1000 dB/km. This problem challenged the researchers and engineers to find processes by low-loss optical fibers could be fabricated. Finally, solved in 1970 when optical fibers having acceptable attenuation were first made. The combination of low-loss optical fibers and the advance in semiconductor technology made optical fiber communication systems practically possible.

In 1978, the first systems were commercially deployed. Their operating wavelength was at 0.8 µm, and they were capable of carrying data at the bit rate of 50–100 Mb/s with a repeater spacing of approximately 10 km. As the technologies in optical-fiber fabrication as well as system components progressed, the BL product was increased continually. Telecommunications service providers have to face continuously growing bandwidth demands in all networks areas, from long haul to access. Because installing the new communication links would require huge investments, telecommunications carriers prefer to increase the capacity of their existing fiber links by using dense wavelength-division multiplexing (DWDM) systems and/or higher bit rates systems. Most of the installed optical fibers are old and exhibit physical characteristics that may limit their ability to transmit high-speed signals. An information signal becomes distorted due to attenuation and dispersion as it travels in an optical fiber. Dispersion is the spreading in the time domain of a signal pulse as it travels through the fiber. Both attenuation and dispersion affect repeater spacing in a long distance fiber-optic communication system. Dispersion affects the bandwidth of the system, hence maintaining low dispersion is of equal importance for ensuring increased system information capacity, versatility and cost effectiveness

Different types of optical fibers have different dispersions. For a single-mode optical fiber, the only source of dispersion is due to group velocity dispersion (GVD). CD is the destructive forces for pulse propagation in ultra high-bit-rate optical transmission system and cause power penalty. In order to improve overall system performance influenced by the dispersion, several dispersion compensation technologies were proposed. Intramodal dispersion compensation in optical fiber Communication systems is an open issue. In the case of dispersion-uncompensated metropolitan and regional networks, transmission over standard single mode Fiber (SMF) at 10 Gb/s is strongly limited to about 80–100 km .For conventional non return-to-zero (NRZ) intensity-modulated, Direct-detected (IM-DD) signals. Dispersion compensation can be generally achieved by either optical or electrical techniques. Optical techniques, such as the use of dispersion-compensating fibers (DCF) or chirped fiber Bragg gratings, are generally expensive and not easily reconfigurable for varying dispersion conditions. In this project, Intra modal dispersion compensated with the help of dsp. More compact electronic components should be used in order to increase system performance and achieve better integration

II. SYSTEM ARCHITECTURE

The system can be divided into five main parts: DP-QPSK Transmitter, Transmission Link, Coherent Receiver, Digital Signal Processing, and Detection& Decoding. The block diagram of dsp based intramodal dispersion compensation is given below

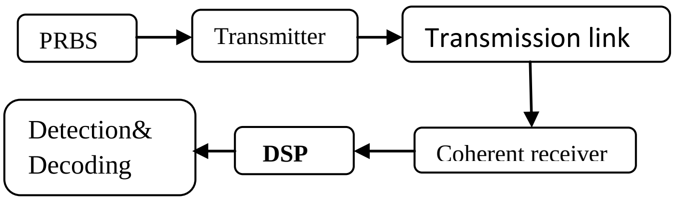

Figure 1 Block diagram of dsp based EDC

The most advanced detection method is coherent detection where the receiver computes decision variables based on the recovery of the full electric field, which contains both amplitude and phase information. Coherent detection thus allows the greatest flexibility in modulation formats, as information can be encoded in amplitude and phase, or both in-phase (I) and quadrature (Q) components of a carrier. Coherent detection requires the receiver to have knowledge of the carrier phase, as the received signal is demodulated by a LO that serves as an absolute phase reference In direct detection as shown in Figure (2), in an opt electrical photo detector (a photodiode) the light intensity $|E|^2$ is converted in an electrical signal and the phase information is totally lost.

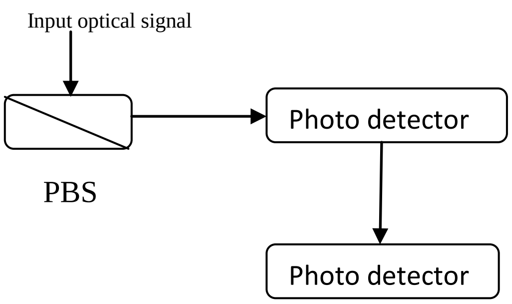

Figure 2 Direct detection

An alternative way to detect the optical signal is coherent detection, in which the received signal is mixed with local laser being detected in the photodiode, and two detectors and proper phase delays are used, both amplitude and phase can be preserved as shown in Figure (3)

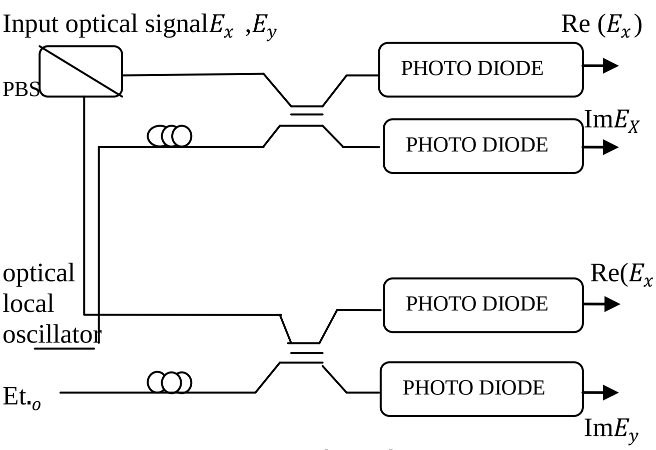

Figure 3 Coherent detection

While coherent detection was experimentally demonstrated as early as 1979, its use in commercial systems has been hindered by the additional complexity, due to the need to track the phase and the polarization of the incoming signal. In a digital coherent receiver, these functions are implemented in the electrical domain leading to a dramatic reduction in complexity. Furthermore, since coherent detection maps the entire optical field within the receiver bandwidth into the electrical domain it maximizes the efficacy of the signal processing. This allows impairments, which have traditionally limited 40Gbit/s systems to be overcome, since both chromatic dispersion and polarization mode dispersion

III. DSP FOR DP-QPSK

This is used for linear impairment of the fiber for 16 QAM modulation format through the following modulation format

- ➢ Analog to digital conversion(down sampling)
- ➢ Dispersion compensation

Analog to digital conversion is a down sampling process. Here we have select two bit per sampling. However, the sampling rate can be changed. For intramodal dispersion in the absence of nonlinearity the optical fiber can be modulated as a phase only filter with the following transfer function

$$G\,(z,\omega) = \exp\left(-j\frac{D\lambda^2 Z}{4\pi C}\omega^2 + \frac{jS\lambda^4\omega^3 z}{24\pi^2 C^2}\right)$$

In which the first part is the effect of fiber dispersion and the second term is the dispersion slope for multi-channel applications. To compensate for the dispersion, multiply the output field with the inverse of the channel transfer function (FIR filter). The order of the filter increases as the amount of dispersion (length of the propagation) increases.

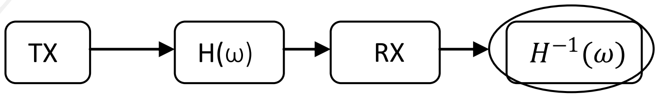

Figure 4 DSP for DP-QPSK

IV. SIMULATION OF ELECTRONIC COMPENSATION

The system set up is established using optisystem V 12 software. Simulation diagram is shown below. System divided in to five section .transmitter, optical link, receiver, amplification and filtering unit, decoding and detecting unit

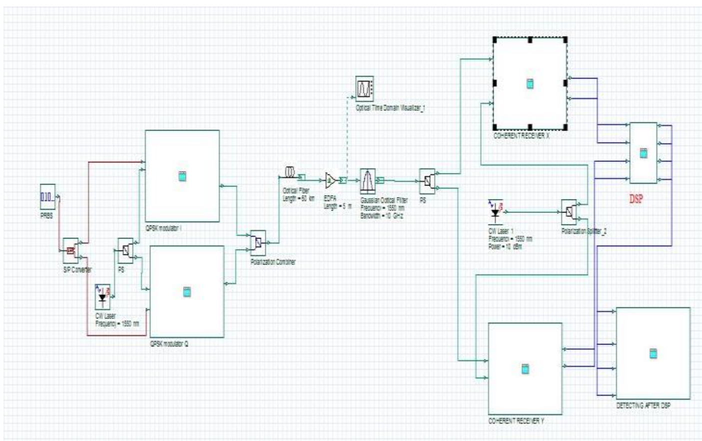

Figure 5 **S**imulation of DSP based EDC

40 Gbps PRBS signal is passed in to a serial to parallel converter. There the input sequence at bit rate R into two output sequence R/2 bit rate and Modulated into two orthogonally polarized QPSK optical signals by two QPSK modulators, Bit rate is 40 Gb/s, Sample rate is 1.28×10^{12}Hz, and Wavelength is 1550 nm .Figure 6 shows the QPSK modulator.

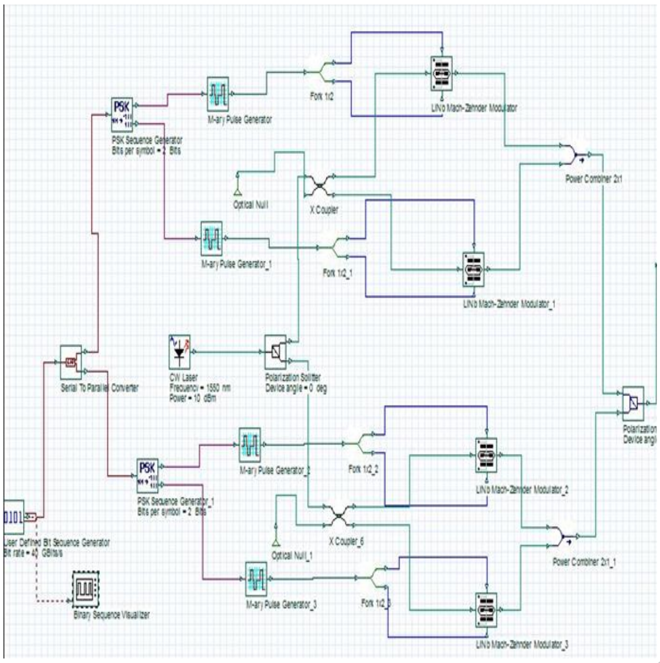

Figure 6 QPSK modulator.

Output from the serial to parallel converter fed into phase shift keying generator. There m ary is generated. The bandwidth required for transmission of binary digital waveforms may be very large. In particular, for a channel of bandwidth B Hz the Nyquist rate is 1/T = 2B symbols per second. In the case of binary signaling each symbol carries one bit of information, so the information rate is limited to 2B bits per second. Clearly one can increase the information rate through a channel by increasing the bandwidth and the associated symbol rate. However, if the channel bandwidth is to remain fixed, then the only option is to increase the amount of information encoded in a symbol. M-ary signaling provides a means of achieving this:

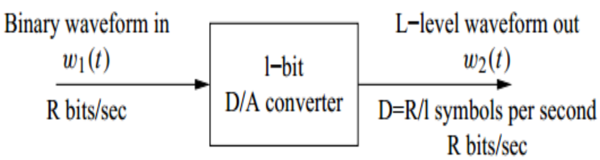

Figure 6 M-ary signaling

After that, it passes through M-ary Pulse signal is modulated by Lithium Niobate Mach-Zehnder Modulator and combined Together to form the QPSK signal..This QPSK feed into optical transmission link. This link consists of 60 km fiber, amplifier and optical filter. After passing 60 km the signal, get distorted due to intramodal dispersion .after that the signal is received with the help of a QPSK receiver. Figure 8 shows the structure of QPSK receiver

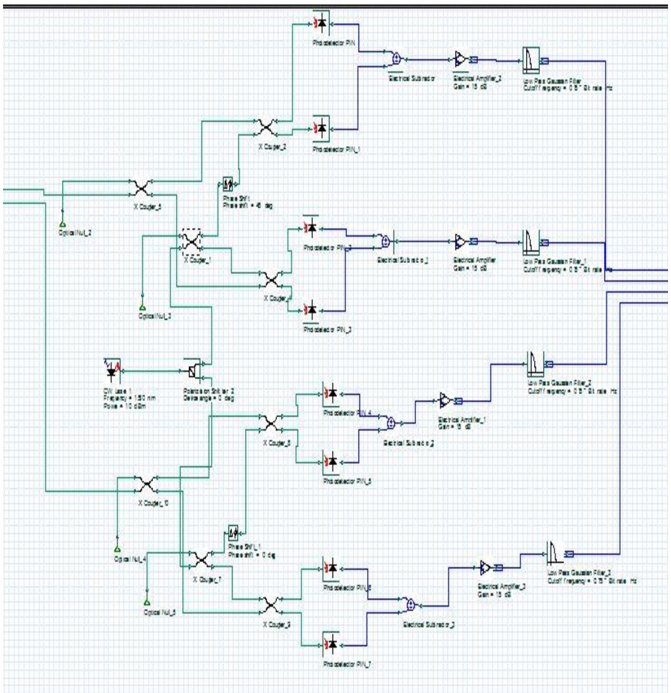

Figure 8 Structure of QPSK receiver

The four output signals form Optical Coherent DP-QPSK Receiver are I and Q of the two polarizations(X,Y), which have the full information of transmitted signal can be represented as Output X-I, Output X-Q, Output Y-I and Output Y-Q. These received electrical signals are then amplified with a set of four electrical amplifier having gain =15dB .After amplification the signals are passed through Low Pass Gaussian filters for eliminating the frequencies above required band. After the four signals are amplified and filtered, they passed in to the DSP unit for intramodal dispersion compensation. The four signals enter the DSP first they are converted to digital domain for processing then the fiber dispersion is compensated using a simple transversal digital filter. In the absence of fiber nonlinearity, the fiber optic could modeled as a filter with the transfer function as given in Equation

$$G(z,\omega)=\exp(-j\frac{D\lambda^2 Z}{4\pi C}\omega^2+\frac{jS\lambda^4\omega^3 z}{24\pi^2 C^2})$$

After the digital signal processing is completed, the signal is sent to the detector and decoder unit and output is analyze with the help of a eye diagram analyzer and spectrum analyzer.

V. RESULTS AND DISCUSSION

For analyzing intramodal dispersion compensation using EDC with the help of DSP, first 8-bit data transmit with the help of PRBS. After passing through the optical fiber (60 km –dispersion length) the data are distorted and delay occurs. After that, the signal is passed into DSP unit and compensated output is obtained with the help of spectrum analyzer. Transmitted and received signal shown in figure 9

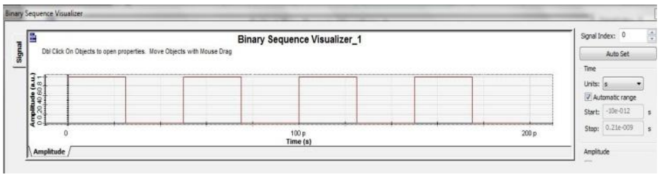

Figure 9 (a) Transmitted signal

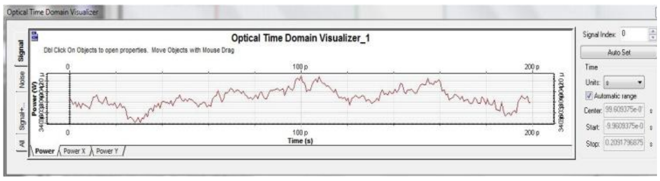

Figure 9 (b) signal after passing 60 km fiber

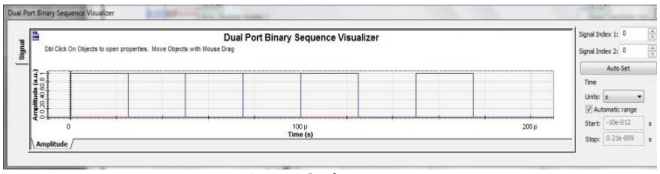

Figure 9 (c) signal after compensation

Figure 10 shows the optical power spectrum of the transmitted QPSK signals .

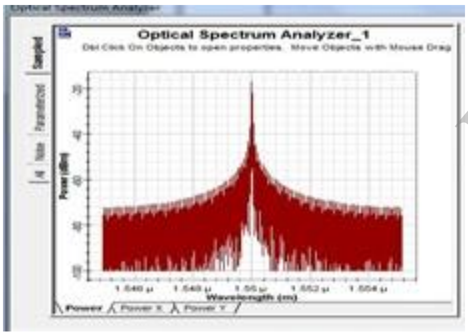

Figure 10(a) optical power spectrum of the transmitted QPSK signals I polarization

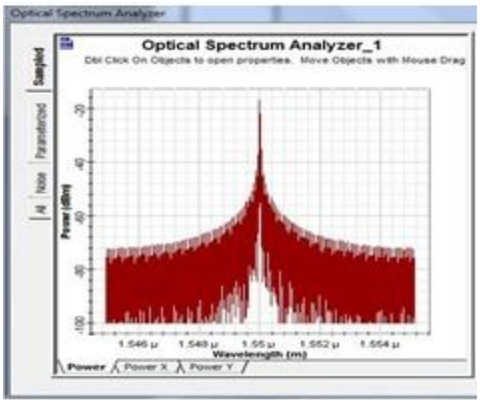

Figure 10 (b) optical power spectrum of the transmitted QPSK signals Q polarization

In optical communication systems, optical signal to noise ratio (OSNR) could not accurately measure the system performance. Typically, as a quality factor, Q is one of the important indicators to measure the optical performance by which to characterize the BER. The OSNR is the most important parameter that is associated with a given optical signal. It is a measurable (practical) quantity for a given network, and it can be calculated from the given system parameters. The logarithmic value of Q (in dB) related to the OSNR

$$Q_{dB} = 20\log\sqrt{OSNR}\sqrt{\frac{B_O}{B_C}}$$

Figure 11 shows the eye diagram of compensated output after passing 60 km maximum Q factor is 7.47986, minimum bit error rate is 3.70247×10^{-14} and eye height 0.00503885 is obtained .

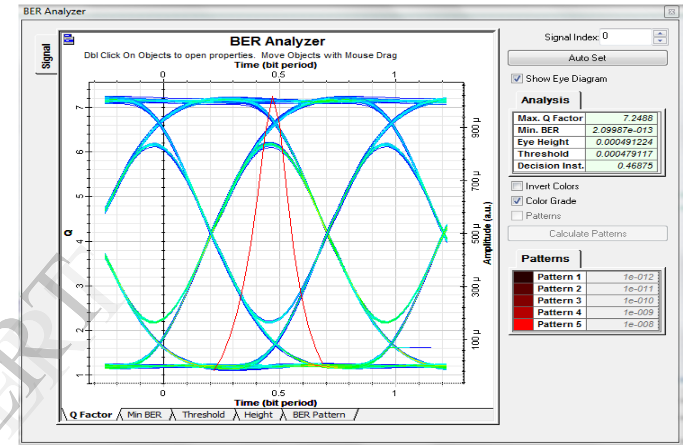

Figure 11 Eye diagram of dispersion compensation using DSP at 60km

Figure 12 shows the eye diagram of compensated output after passing 80 km maximum Q factor is 7.21986, minimum bit error rate is 2.09997×10^{-13} and eye height 0.000491224 is obtained

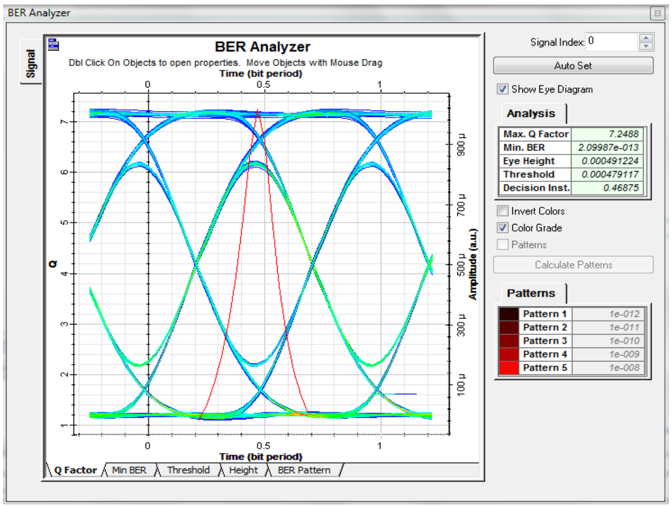

Figure 11 Eye diagram of dispersion compensation using DSP at 80km

Table: 1 Result obtained from the simulation of microwave tunable dispersion compensator with various distance

	60 km	80 km
Maximum Q factor	7.47986	7.21986
Minimum Bit error rate	3.70247×10^{-14}	2.09997×10^{-13}
Eye height	0.00503885	0.000491224
Threshold	0.000511646	0.00479117
Decision instant	0.59375	0.46875

VI. CONCLUSION

In fiber optical high bit rate long-haul transmission systems, dispersion compensation is one of the most important items to be considered for design. Variety of linear and nonlinear transmission impairments are suffered by optical networks this project concentrated in intramodal dispersion .This directly affect the Bit Error Rate (BER) performance of the system and that support higher data rates and large number of channels. By suitable system simulations, demonstrated 40 Gbps propagation with acceptable penalties, achieved by the experimented electronic compensator. This compensator can be applied to compensate fiber intramodal dispersion in Metro/Regional networks characterized by distances between nodes from 10 to 400 km

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