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One-Stage Polarization Mode Dispersion Compensation for Long-Haul Fiber Optic Communication

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Abstract: The main objective of this paper is to improve the data rate capacity of optical system by compensating the Differential Group Delay (DGD) at the receiver side. The PMDC (Polarization Mode Dispersion Compensation) has become a very extreme subject of research in recent years; the PMD becomes one of the most important factors limiting high-speed optical fiber transmission. The simple PMD compensation is achieved by based on a feedback signal. Feedback indicator is used by PMD compensation for the evaluation of system performance and PMD. This method is applied for DPSK modulation scheme, leading to well-known results. We can increase the bit rate of the transmission signal for achieving maximum channel density. In single mode fiber the PMD will occur and because of PMD it difficult to transmit data reliability at high speed. Due this result the pulse widening and the capacity of transmission of the fiber will be reduced. This work will inspect the effect of PMD in optical fiber for several km link fibers. The eye diagram is used for evaluating the PMD.

Key words: Polarization mode dispersion compensation (PMDC) · Differential group delay · One stage PMD compensator · Optical communication

INTRODUCTION

The source of the optical fiber is in the form of modulated signal or light wave. The light wave is a form of electromagnetic radiation. The light wave is characterized by wavelength, frequency and polarization. Its electric field is aligned in two directions, along X and Y axis. Hence have dual polarization [1].

The speed of light in an optical fiber is mainly dependent on the refractive index of the optical fiber. The refractive index of the fiber is increased means, the speed of the light will be reduced and vice-versa [6]. Thus the refractive index is the main part there is any changes occurred means that time PMD will occur. The PMD is caused by two things like Birefringence and Differential Group Delay.

Differential Group Delay: The birefringence effect causes Differential Group Delay (DGD) between the two polarization states. The DGD is the difference in propagation times between the two polarization states. The Differential time delay between the propagation modes is called first order Polarization Mode Dispersion [5]. Since the delay depends on the frequency and varies over the bandwidth another dispersion factor arises resulting in second order PMD. It can be expressed as

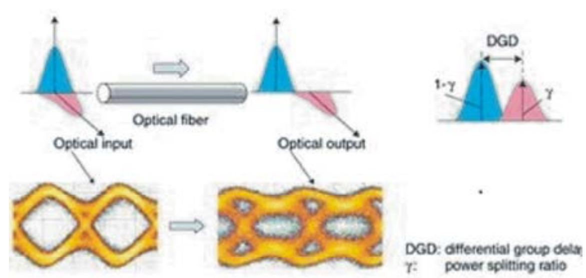

Fig. 1: Differential Group Delay Effect

$$\Delta\tau_{PMD} = D_{PMD} * \sqrt{L} \quad (1)$$

where L is the fiber length and is the amount of PMD incurred in the fiber which is expressed in ps.

Birefringence: It is the optical property of a material, due to environmental conditions like fiber stress and temperature which is having a refractive index that depends on the direction of the propagation of light. These type of optically anisotropic materials are called birefringent or birefractive.

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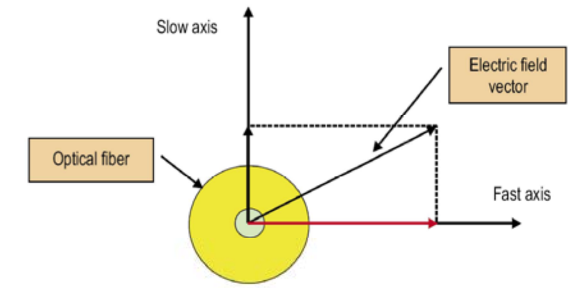

Fig. 2: Birefringence effect

The refractive index difference can be expressed as,

$$B = n_{slow} - n_{fast} \quad (2)$$

where:
n_{slow} is the refractive index of the slow axis
n_{fast} is the refractive index of the fast axis

When, $\Delta\tau$ =0, there is no pulse broadening. Hence the material is non- birefringent.

Existing Method: Today there are many modulation formats are used for the transmission of signal and their modulations, demodulations are increased [7]. To decrease the modulation and demodulation methods the PMD compensation methods are adopted. Because the PMD is time varying and also statistical in nature, this method is ineffective in real time applications [2]. Feedback and feed forward PMD compensators are in-effective, since they reduce only a small amount of PMD. Normally the electronic and electrical compensation methods are very difficult to implement and are costlier one [9]. For chromatic dispersion compensation the Fiber Bragg Gratings method is used and they are bulky and costly. Electrical signal processing has become an alternative for PMD compensation due to possible compact and cost-effective implementation of the equalizer in the receiver electronics and the need of individual compensation in Wave Division Multiplexing (WDM) systems [4]. The feedback signals are used in one stage PMD compensator for different modulation formats, since they are difficult to implement.

Proposed Method: Generally for an optical network the source of the input signal is may be a laser light or LED. This will be modulated by using DPSK modulator. This modulator gives best modulated signal. The electrical signal is converted into optical signal before the signal entered into the SMF fiber. Then the optical signal

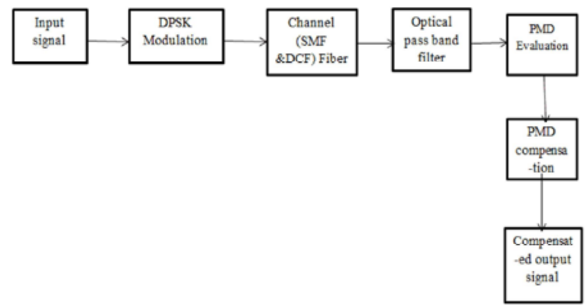

Fig. 3: PMD Compensation

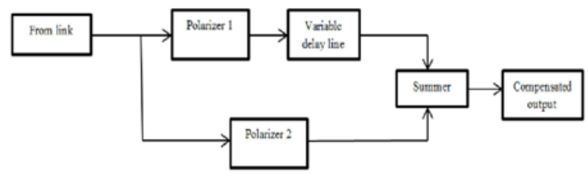

Fig. 4: Predestination DGD Method

is passed through the SMF &DCF fiber [2]. The core size of the SMF is 9um that is very small compared to MMF, it has higher bandwidth & lower attenuation, which is used in telecommunication & CATV networks and it is suitable for long distance communication, for this fiber the light source is LASER light.at the end of the optical fiber, the optical signal is mixed with the noise, this noisy signal is then filtered by optical pass band filter.

Here some amount of noise is reduced but there is some distortion due to fiber birefringence that is imperfections in the fiber like fiber bend fiber twist etc., which leads to the arrival of two modes at different times. After that the delay (DGD) is evaluated between the two modes that is called PMD evaluation by using the formula τ_{PMD} and eye diagram is also used for evaluating he delay. Then the PMD will be compensated by using the predestination DGD method [3].

The equation for Predestination Differential group Delay Method is represented as,

$$\tau' = Nearest\ Integer\ (\tau * \frac{BW_{VBS}}{0.8}) * (\frac{0.8}{BW_{VBS}}) \quad (3)$$

BW_{VBS} - Variable Bandwidth Selection (VBS) bandwidth.

The Predestination DGD method is used on the basis of splitting up of the optical signals into fast and slow axis signals [8]. Here the input signal spitted into two signals and then one signal is given into the polarizer1 & another signal is given into the polarizer2. Both the polarizers are complementary to each other. An optical delay element is used after the polarizer1 delay for optical delay element is set by the delay parameter. Where the signal coming from the polarizer2 is not delayed. At last the two signals are summed up. The fast and slow signals are compensated by using this way.

RESULTS AND DISCUSSIONS

PMD Evaluation: The polarization mode dispersion was evaluated for the demodulated signal and it is shown in eye diagram. This eye diagram shows the dispersion in the modulated signal.

Table 1: Pulse Broadening after fiber and before fiber

Bitrate (Gb/s)	Fiber length (km)	Before fiber (ns)	After fiber (ns)	Bit error rate (bits/sec)
10	10	5	8	$2x10^{-20}$

The bit error rate from the demodulated signal is 2x10-20 bits/sec and delay from the signal is 8nsecs. The tabulated result shows the pulse broadening in ns before and after compensation.

Pulse Broadening due to PMD: At the transmitter side, the given input signal is modulated using DPSK modulation and the modulated signal is transmitted through the 10km SMF & DCF fiber optic cable. At the

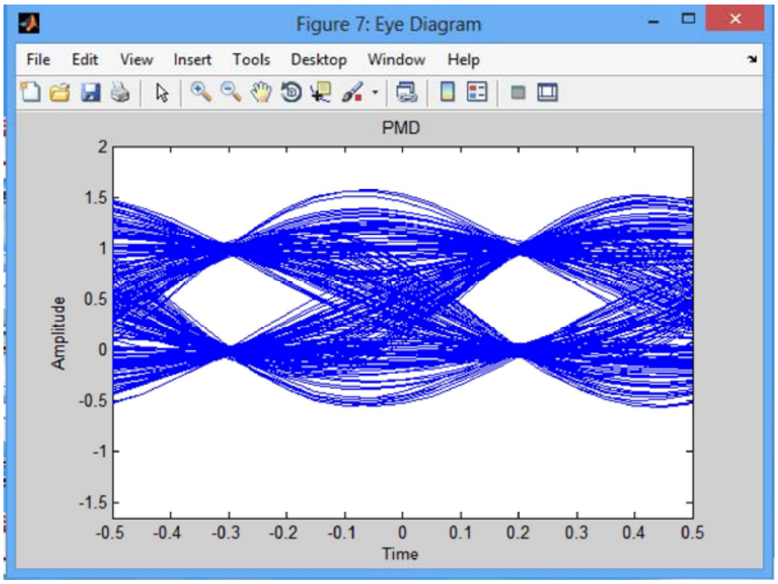

Fig. 5: PMD Evaluation

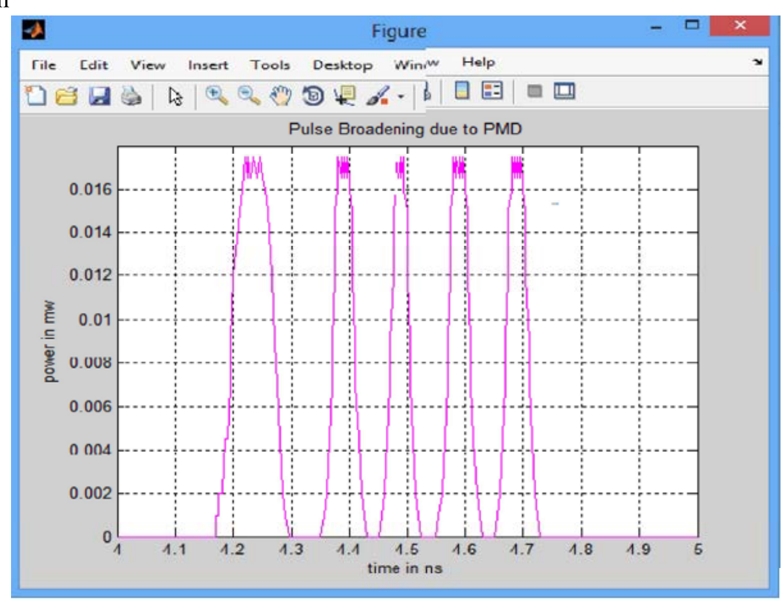

Fig. 6: Pulse Broadening due to PMD

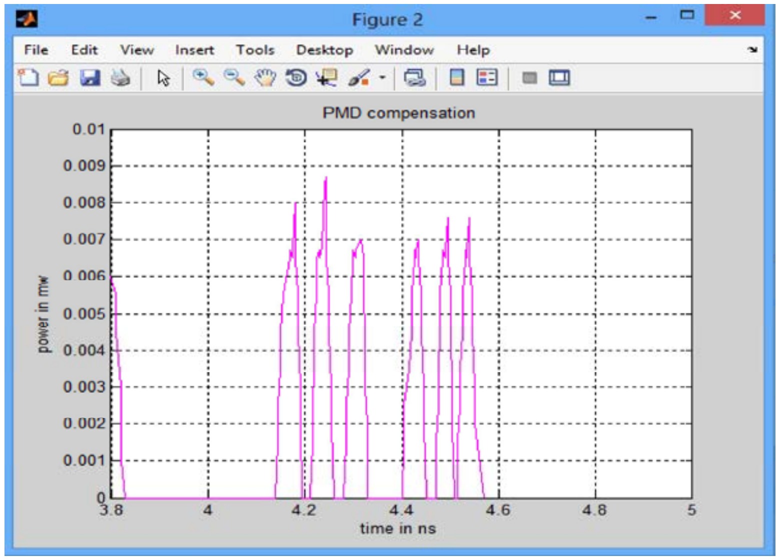

Fig. 7: Compensated output

receiver side, due to the noise in the received signal, it is given into the optical pass band filter. Due to birefringence in the optical fiber the optical signal is broadened.

PMD Compensation: The broadened optical signal is reduced to its normal pulse size by using the predestination differential group delay method. The result shows the original optical pulse.

CONCLUTION

Thus from the above explanations the PMD effects are analyzed and evaluated effectively to the original signal. With the PDGD method, Bit Error Rate is found to be very low of the order of 2x10-20 from the fiber. At the end of the fiber we got 8ns delayed signal.

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