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The Effect of PMD (Polarization Mode Dispersion) the Fibers of New and Old In Different Distance in Numerical Systems with Optical Fiber WDM

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Abstract : *This is a study conducted in a laboratory at the university as a simulation to see the effect of new fiber PMD for different distances. This is done to compare the performance of the digital system with optical fiber WDM. In this simulation are not included remission, chromatic dispersion and nonlinear effects. In this way all of the signal distortions caused only by different combinations of PDM. Polarization effects are very important in communications systems with optical fiber. Optical fiber that is used mainly during the simulation is a standard single mode fiber (SSMF).*

Keywords: *fiber-optic communication systems, standard single-mode fibers (SSMFs), polarization-mode dispersion (PMD), polarization effects, WDM numeric system.*

I. Introduction

Polarization efects in fiber-optic communication systems are usually related to fiber birefringence [1]. It is well known that standard single-mode fibers (SSMFs) support two orthogonally-polarized modes [2]. These two modes have almost the same propagation constant, and tend to travel at the same velocity [3]. When light encountersany sort of perturbation or asymmetry within the fiber, it results very easy for optical energy to transfer from one of these modes to the other. For suficiently long fibers, such perturbations or asymmetries lead to random polarization rotation, polarization-mode coupling, and polarization-mode dispersion (PMD) [4-7]. The stochastic behavior of the polarization evolution in optical fibers is undesirable, since, most of the times, it deteriorates the performance of the communication system [8].

Optical fiber communication is regarded as the best method for transmitting audio signals, video and data. The advantage of maximum protection from electromagnetic interference, the wider band has conditioned the extension of fiber systems in a wide range of applications very many fields including industry also. Despite the greatly improved transmission system these systems maintain the basic techniques of analog signals [9]. Now a new generation of products that fully implements digital signals to transmit analog information provides the ability to raise the standard again, advancing optical fiber transmission with a completely new level.

Based on the concept of modulation, multiplexing digital systems are important in the implementation of systems with multichannel broadcasting. The most common methods for digital broadcasting in an optical system is the direct correspondence information transmitted optical power level bit signal transmitted by acquiring so-called intensity modulated (IM) [10]. The light emitted from the source entering the optical fiber consists not only of a single beam of light but some such that hit the heart of the fiber with different angles.

In the fiber multi-mode beams have different paths of different lengths depending on the angle of the fall. It is understood that the rays that fall with zero angle, parallel to the axis of the heart, depicting the same street with the length of the fiber and rays that enter the maximum permitted angle describe the longest. It is understood that fashion describing longest road pickup will have a time delay compared with axial beam. This effect is caused as a result of various fashions spread of radiation known as modal dispersion or intermodal. Measured by ns / km and increases with length [11].

1. The design of digital systems with optical fiber WDM

With the technique of wavelength division WDM allowed the aggregation of many basic channels (high speed).No difference in concept between WDM and FDM techniques used in electrical communication systems.In optical transmission environment can be defined spaces such frequency Δf. It came the task of effective use of high-capacity fiber and it is entirely possible through optical multiplicity [12].Optical multiplexing transmission comes as a need of more information in the same optical transmission medium.

Multiplexing term addresses a specific technical transmission processing stage that allows the use simultaneously the same transmission medium (coaxial cable, radio wave, via satellite, optical fiber) of several signals. In making have demultiplexing, the inverse operation of multiplicity, whereby the signal transmitted recover [13].

WDM systems can easily be implemented in each of the three technologies and architectures based telecommunications networks. We can treat in this way point on a point system with high capacity 2.5 Gbps where information flow can be viewed as independent flow SDH networks transmitted at the same carrier.WDM represents the second generation of the evolution of optical fiber telecommunications [14]. The first development occurred in the early 80's, when major phone companies bound the United States to other countries with optical fiber thus creating a "network" of channels that enable the transmission of information and that can carry greater capacity that simple conductors or microwave links [15].

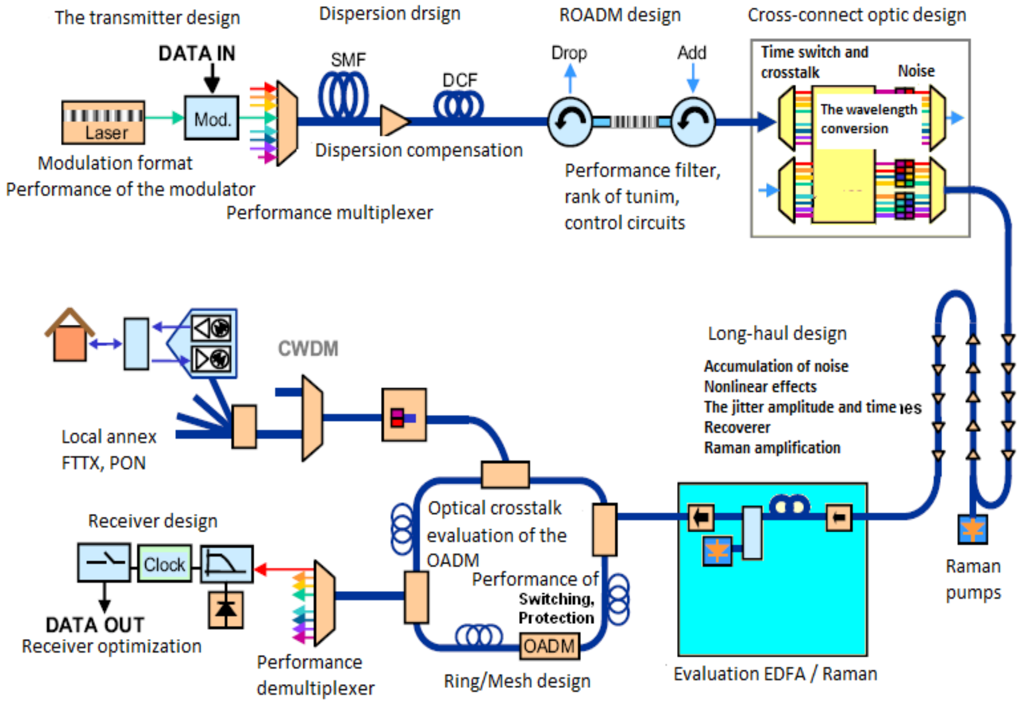


Fig.1 Architecture of of digital systems with optical fiber WDM

WDM is another great progressive step that multiplies the capacity of fiber allowing transport not only one but several different wavelengths, each able to carry different optical signals. So the whole spectrum uses optical WDM attaching any color that constitutes a different channel data transmission. Components are used in WDM passive components technique [16].

Typical features of the technology are:

1. Use low gang suppression of 1200-1600 nm.
2. Capacity to carry some Gbps WDM in the same channel.
3. The high number of channels multiplexed that can go to 100 channels.
4. Compliance WDM-TDM techniques in particular to reduce the number of holders wavelength.

Multiplexes and demultiplexes used in interfaces with transmitting and receiving stations.To ensure the propagation distances of hundreds km optical amplifiers OA needed to use every 50-100 km. Compensation systems are used as chromatic dispersion and dispersion compensation CDC to insert the fiber. WDM principle appears simple and known by time. The reason why is not applied in prior periods have been appropriate optical amplifiers. When the transmission systems used in optical fibers, the only way to ensure the long-distance transmission was through signal regeneration opto-electronics [17].Recovery in these weaker broadcast impulses transformed after the discovery of a photoelectric reconnaissance and amplified by a modulated laser transmitter. The problem is that an inventor is not different wavelength from another.A network designers need to optimize optical and electrical parameters to provide minor operations multiplicity DWDM network [18].However topology using ring, mesh or point-to-point, system design must be considered divided into two parts. The projection optical system and the electrical system or the projection of the upper classes of the system [19].

Global optical network layer (WDM layer) appears as the physical layer which has the function of a series of bits transmission with a high speed and a negligible loss. However, some transmission errors can be disastrous. As long as the transmission distance and transmission speed are within the limits set (for example small nets) is not required consideration of optical parameters [20].

1.1 The polarization mode dispersion PMD

The polarization mode dispersion (PMD) is a feature of single-mode fiber where the spread pulsed modes performed by the polarized that spread at different speeds. Optical fiber can be modeled through two polarized orthogonal axes that can be called the initial conditions of polarization (PSP). The signal optical fiber spreads divided into two components axes PSP. Any polarization axis (fast and slow) has spread at different speeds. This is due to the different indices of refraction caused by inhomogeneous material.

Components of optical pulse propagating at different speeds lead to expansion in the making impulse for optical receiver is insensitive to polarization of light downward. The amount of spread of impulses in time by polarization axis is known as the differential group delay (DGD) and measured picosecond [ps]. The time it takes an impulse to spread fiber is a group delay. DGD is an instant value that varies randomly along the length of a fiber. PMD is defined as the amount of the linear average value of the group delay with respect to a wavelength λ. PMD is measured in units of picoseconds [ps]. Fibre length greater than 2 km and average RMS values are similar. The following equation shows the relationship between these two averages [21]:

$$PMDrms = \sqrt{\frac{3\pi}{8}}PMDmes \qquad (1)$$

$$PMD_{rms} = 1.085\ PMD_{mes} \qquad (2)$$

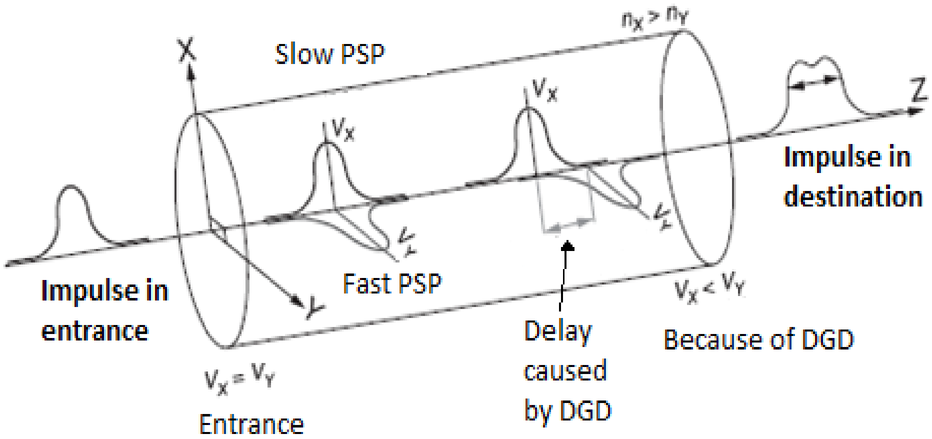


Fig.2 Shows the two polarized orthogonal axes that causes PMD and the signal optical fiber spreads divided into two components axes PSP which the amount of spread of impulses in time by polarization axis is known as the differential group delay (DGD).

PMD becomes dominant at higher speeds over 5Gbps. PMD is caused by nonlinearity fiber. This asymmetry is called birefrigrence where two polarization modes Ex and Ey are part of the phenomenon of overlapping. As a result of this effect two ways does not mate with each other but the impulse is distributed in time. The main type of PMD originates from dispersion wavelength of the signal depending on the signal spectrum. PMD is expressed as a differential group delay DGD that difference becomes apparent as multiple spectral components in a given fiber length. The polarization axes not grow together and sharing impulse transmission along the fiber. The difference is proportional to the DGD.

So DGD used as a measure of PMD in a given system and is calculated by the equation. During the pulse spread in the fiber optical random changes due to local fiber ***birefringence*** enable an impulsive part of the optical power of a fashionable pair to another which is known as pairing mode (mode coupling). Experiments have shown that fiber length greater than 2 km appear the greatest pairing mode and PMD is proportional to the square root of the fiber length. PMD coefficient is measured with picosecond to the square root of a kilometer [ps / √ km]. PMD coefficient is determined by the manufacturer of optical fiber and PMD represents characteristic of a certain length. Often referred PMD coefficient PMD, which may cause confusion with these two terms [22].

$$PMD = PMD_c\sqrt{L} \qquad (3)$$

where PMD_c expressing PMD coefficient.

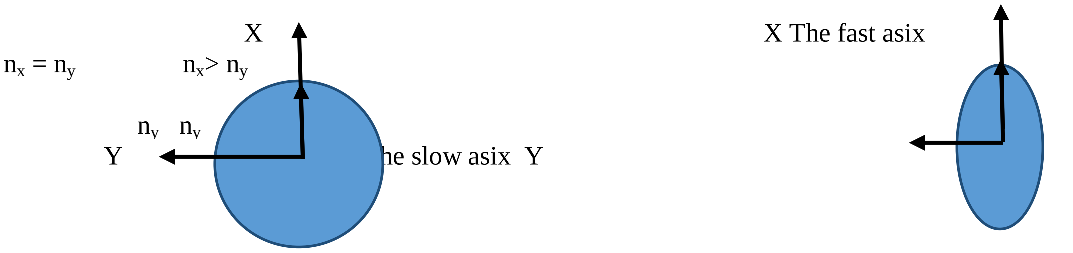
Due to expansion impulse that travels along the optical fiber, PMD can cause interferanca intersimbol resulting in errors in the signal transmitted. This effect is negligible and should be considered only in systems where the transmission speed is equal to or greater than 10 Gbps. It should also be taken into consideration for analog systems with fiber because of its contribution to the growth of signal distortion and reduce the OSNR [23].

1.2 Causes of generation DGD

DGD due to ***birefringence*** of the fiber that comes as a result of pressure from the interior and exterior in fiber and imperfect processes of production. In an ideal fiber of her heart geometry it is circular and therefore symmetrical refraction indices along the x and y axes (axes PSP) and the speeds are equal (DGD = 0) as shown in the figure in case (a). Indeed, the fiber geometry and asymmetry is due to ***birefringence*** have different indices of refraction for both PSP's. This leads to different speeds for both polarozations axes as shown in the figure in the case (b). The speed of light in a material depends on the refraction index of the material, as defined by the following equation [24].

$$v_x = \frac{c}{n_x} = v_y = \frac{c}{n_y} \quad (4)$$

$$v_x = \frac{c}{n_x} < v_y = \frac{c}{n_y} \quad (5)$$



a) Ideal fiber optic **b) Real fiber optic**

Fig.3 Shows the DGD due to birefringence for both ideal fibre optic and real fibre optic

PSP axes are not uniform along the entire length of the fiber, PSP axes can rotate accordingly there will be changes in the polarization orientation of the PSP, fashions pairing occurs between the fast axis and the slow PSP, which affects the DGD. Leading causes of DGD includes the fiber produced with low quality, fiber geometry not circular heart, the air present in the fiber, the impurities in the fiber, the pressures of the external and internal exercised in fiber links between fibers, splices, temperature changes and pairing mode. PMD is not static and can change and because fiber installed and may change over time. Change of DGD that depends on the length of the wave is known as the second order PMD [25].

1.3Probability distribution

DGD is a function of the fiber ***birefringence*** and varies randomly along the fiber. As a result, DGD for a given wavelength in a given time is a random variable.

Since DGD appears as a random event, probability that DGD event exceed the value x can be found via the integral distribution of Maxwell-given by the following equation. Often it may happen that the value of DGD exceed the maximum value tolerated by the recipient (DGDmax) which causes communication error bits [26]. DGDmax is defined as:

$$p_r(\Delta\tau_{DG}) = \frac{32}{\pi^2} \cdot \frac{\Delta\tau_{DG}{}^2}{\langle\Delta\tau_{DG}\rangle^2} exp\left(-\frac{4\Delta\tau_{DG}{}^2}{\pi\langle\Delta\tau_{DG}\rangle^2}\right) \quad (6)$$

where$p_r(\Delta\tau_{DG})$ =Maxwell probability distribution for a given wavelength

$\Delta\tau_{DG}$ = DGD

$\langle\Delta\tau_{DG}\rangle = DGD\ average$

DGDmax represents the value of DGD that the transceiver must tolerate that the maximum degradation of sensitivity to be no more than 1 dB. DGD probability that event occur in a fiber is expressed by the following equation where x is represented by the DGDmax:

$$p_r(\boldsymbol{\Delta}\tau_{DG} \geq x) = 1 - \int_0^x p_r(\boldsymbol{\Delta}\tau_{DG})\, d\boldsymbol{\Delta}\tau_{DG} \quad (7)$$

where$p_r(\boldsymbol{\Delta}\tau_{DG} \geq x)$DGD is the probability that the event be greater than the value of x.

Report DGDmax to PMDtot (DGD on a link) can be referred to as the safety factor (SF). The safety factor is a simple method to represent the probability of events that cause DGD communication concerns.

$$SF = \frac{DGD_{max}}{PMD_{tot}} \quad (8)$$

where SF = safety factor

DGD_{max} = maximum DGD on a link to a specific wavelength

PMD_{tot} = the total PMD in a link to a specific wavelength

1.4The total PMD link

The components of a fiber link can contribute to the total PMD-in link. PMD of components such as WDM, DWDM, CWDM, DCM (except for DCM which uses DCF) and optical amplifiers is deterministic (DGD no time varies but can vary depending on the wavelength). Specifications for these components should be reviewed and PMD values should be included in calculating the budget of the link PMD's. However, if it is using the same fiber and any other element PMD, to calculate the PMD used the first two formulas. In the links comprised of different fiber types of calculations performed by the last formula [27].

$$PMD_f = PMD_Q \times \sqrt{L} \quad (9)$$
$$PMD_f = PMD_{max} \times \sqrt{L} \quad (10)$$

$$PMD_f = \left(\sum_i L_i PMD_{Qi}^2\right)^{1/2} \quad (11) \qquad PMD_{tot} = \left(\sum_i L_i PMD_{mi}^2\right)^{1/2} \quad (12)$$

II. Some Simulation Of PMD

2. Polarization dependent loss

Loss of polarization dependent loss of the optical signal in a fiber components or due to the change of the polarity of the signal. Because the laser light is polarized to some degree and differ substantially randomly along the fiber, this effect can cause signal strength fluctuations in the making. Maximum power fluctuations optical signals are represented by PDL and defined as the ratio of maximum output transmitance to minimum retirement transmitance for all the possible states of polarization at the entrance when a constant force at the entrance [28].

$$PDL = 10log\left(\frac{T_{rmax}}{T_{rmin}}\right) \quad (13)$$

Transmitance defined as the ratio of output optical power to the optical input power and calculated by the formula:

$$T_t = \frac{P_{out}}{P_{in}} \quad (14)$$

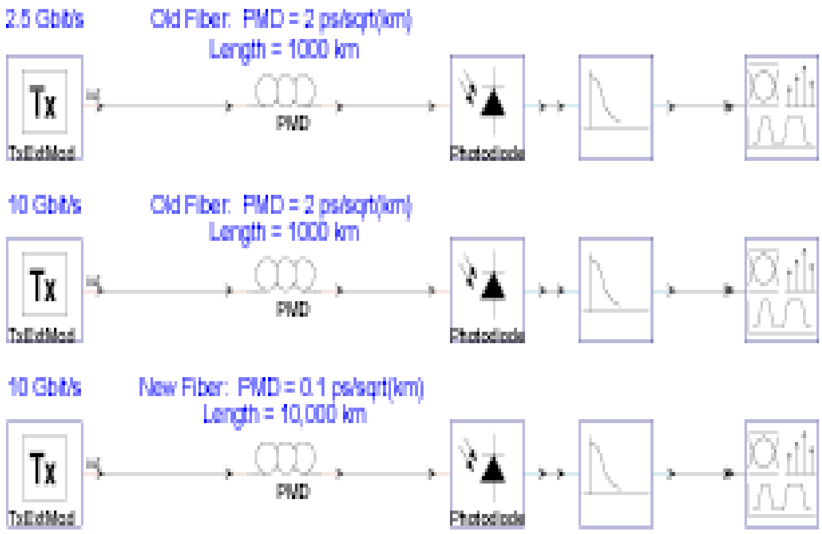
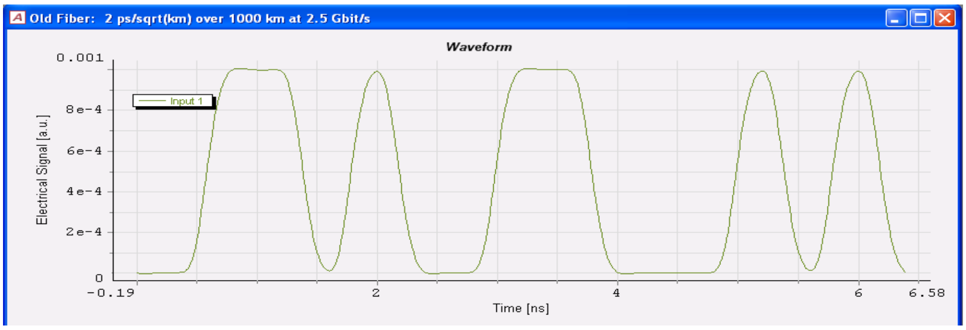


Fig.4 The system where made simulations to see the system's performance compared to fibre with different PMD coefficient.

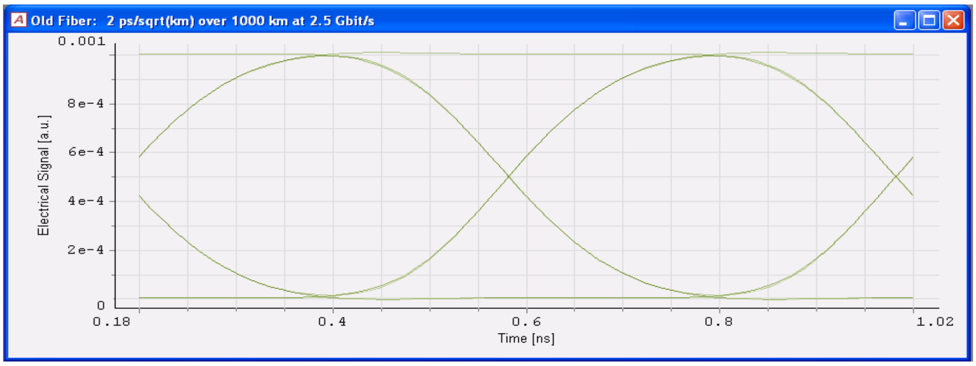
In the above system is the system's performance compared to fiber with different PMD coefficient. In the fiber with PMD coefficient equal to 2ps / √km which supports transmission speeds at 2.5 Gbitps a length greater than 100 km. This simulation examines the effect of fiber PMD for new and old in different distance. Each iteration uses PMD different and random. Extinction, chromatic dispersion and nonlinear effects are not included so that all signal distortions caused only by PMD. For different combinations of PMD, bit rate and different lengths of fiber look eye diagram form.

The first simulation : L=1000km BR=2.5 Gbps $PMD_c = 2ps/\sqrt{km}$



(a)

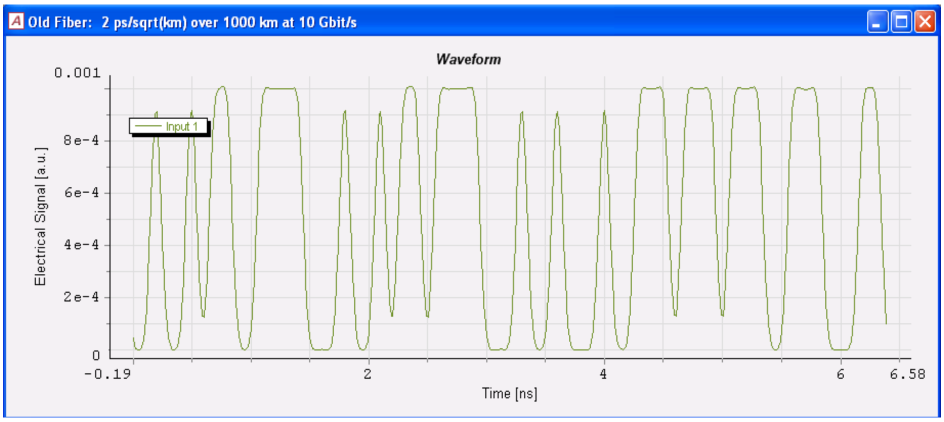
(b)



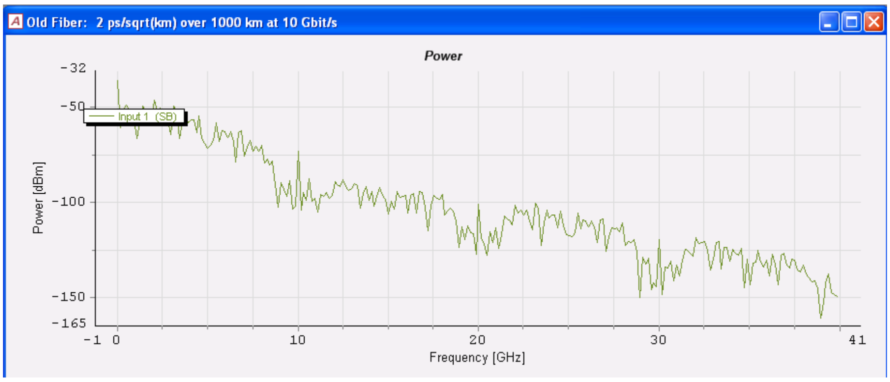
(c)

Fig. 5 Shows the first simulationto the old fibre optic for bite rate 2.5Gbps where waveform is in contest (a), the power is in content (b) and electrical signal is in content (c).

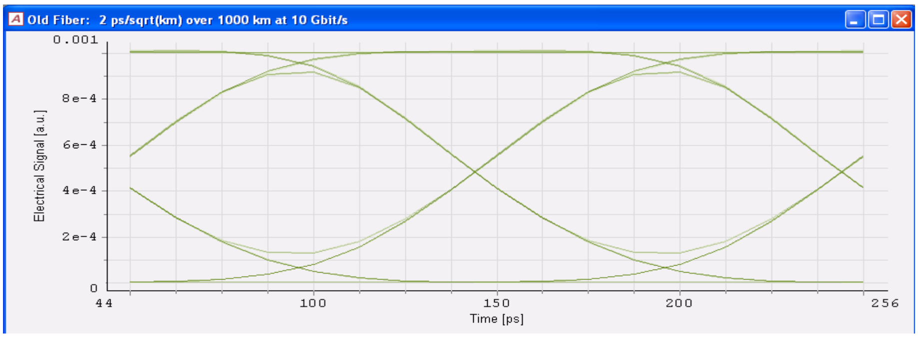
The second simulation : L=1000km BR=10 Gbps $PMD_c = 2ps/\sqrt{km}$



(a)



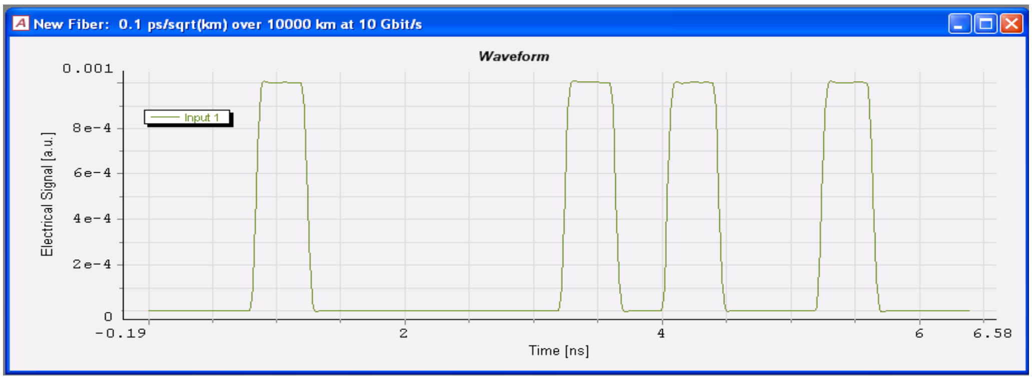
(b)



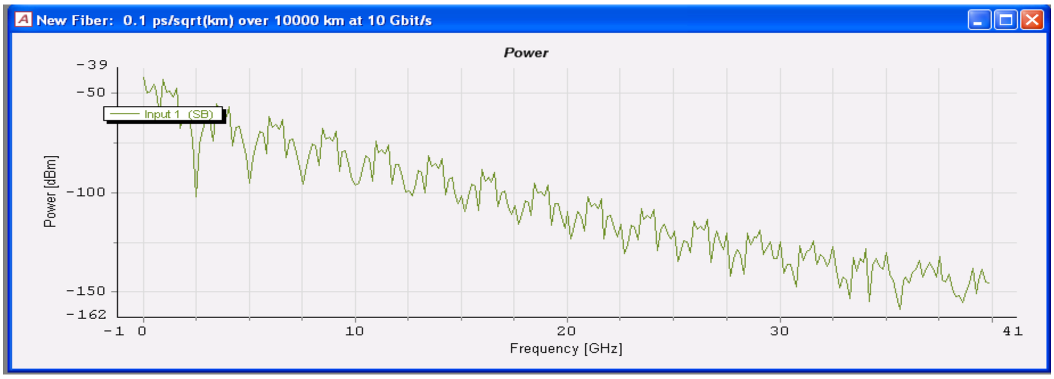
(c)

Fig. 6 Shows the second simulation to the old fibre optic for bite rate 10Gbps where waveform is in contest (a), the power is in content (b) and electrical signal is in content (c).

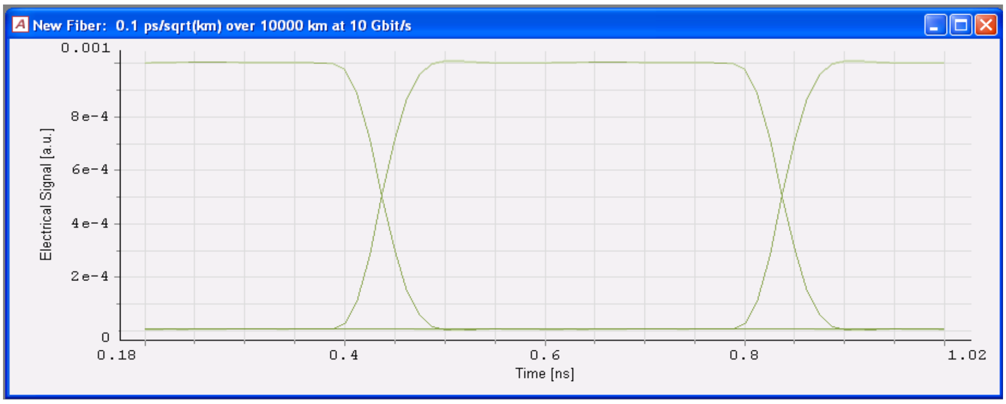
The third simulation : L=10000km BR=10 Gbps $PMD_c = 0.1 ps/\sqrt{km}$



(a)



(b)



(c)

Fig. 7 Shows the third simulation to the new fibre optic for $\mathrm{PMD_c} = 0.1\mathrm{ps}/\sqrt{\mathrm{km}}$ where waveform is in contest (a), the power is in content (b) and electrical signal is in content (c).

PDL also can be defined as output optical power when the input power is constant for all states of polarization.

$$\mathrm{PDL} = 10\log\left(\frac{\mathrm{P_{max}}}{\mathrm{P_{min}}}\right) \qquad (15)$$

Polarization dependent losses also depend on the wavelength PMD although not depend on the speed of transmission.

III. Conclusion

The rapid stride toward high-speed transmission at 40 Gb/s and beyond has stimulated extensive research efforts on PMD. Is important covered the fundamental understanding of the PMD effect and its impact on optical transmission systems. The statistical nature of PMD, the development of PMD emulators, and the mixture of PMD with other impairments, e.g., polarization-dependent losses (PDL) and nonlinearity, were discussed. The analysis of the tolerance of different modulation formats to PMD effects also received a great attention. The reason is that modulation formats with smaller duty cycle tend to have larger bandwidth and therefore they are more sensitive to high-order PMD. Notice that the impairments in PMD compensated systems are mainly caused by high-order PMD. In general, the smaller the bandwidth of the modulation formats, the more improvement of PMD tolerance can be obtained after PMD compensation.

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