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Effects of Polarization Mode Dispersion at Higher Bit Rates

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ABSTRACT: - This paper deals with the effects of Polarization Mode Dispersion (PMD), when we increase the bit rates. Unlike the chromatic dispersion phenomenon, the PMD is found to be a time varying and an unstable phenomenon. Thus compensation of PMD is required since it distorts the signal and broadens the pulse in a statistical manner. In this paper we analyze the PMD effects using the OPTSIM simulation for 0, 60, 120 and 180 ps/√km transmission systems. Here we will see the output through the eye diagrams at different bit rates and draw the graphs for eye opening, eye closing, Q value and electrical power at different bit rates. The results have been simulated and analyzed.

Keywords – Bit Rates, Dispersion, Optsim, PMD, WDM

I. INTRODUCTION

In high-speed optical communication systems working at data rates of 10 Gbps and beyond, signal distortion caused by polarization mode dispersion (PMD) is a major limitation of the transmission distance. This leads to degradation in system performance [1]. Especially in upgrading of existing transmission lines, high PMD of 'old' fibers is a serious problem. The PMD of installed fibers fluctuates with time due to environmental influences, for example changes in temperature and stress [2]. Therefore, adaptive PMD compensation during system operation is indispensable [3]. To remove the system degradation caused by the fiber PMD, several optical and electrical PMD compensation techniques have been proposed and discussed in the literature. A detailed description of PMD compensation systems, working in optical domain, structures and requirements for automatic compensation, is given in [4]. Another way to mitigate signal distortions is to use electrical signal processing techniques [5]. Based on the concept of transversal filters, an analog tapped delay line equalizer was used the first time for mitigation of signal distortions caused by PMD [5]. An adaptive compensation system realized with an electronic SiGe Equalizer IC, including a 4-tap transversal filter operating at 10 Gbps, is described in [6].

PMD can cause several undesirable effects that could be obstacles to high speed telecommunication through optical fibers. Such effects are not limited to digital communication systems but affect analog communication systems as well. With the evolution of specialized manufacturing methods, PMD in present day, telecommunication grade fibers is kept very low ($< 0.1\text{ps}/\sqrt{\text{km}}$). Still no matter how good the fiber may be, at some bit-rate-length product, PMD will be an issue. Hence, there is need to investigate strategies for PMD mitigation.

II. POLARIZATION MODE DISPERSION (PMD)

Polarization mode dispersion (PMD) is a source of pulse broadening which results from fiber birefringence and it can become a limiting factor for optical fiber communications at higher transmission rates. It is random effect due to both intrinsic (caused by non-circular fiber core residual and geometry and residual stresses in the glass material near the core region) and extrinsic (caused by stress from mechanical loading, bending or twisting of fiber) factors which in actual manufactured fibers result in group velocity variation with polarization state [7].

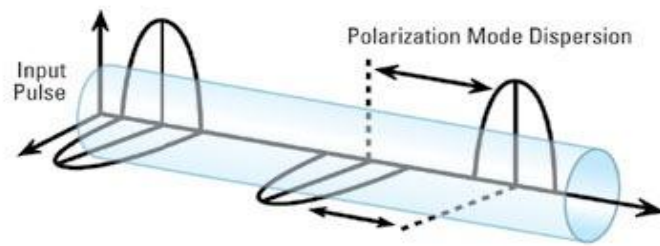


Fig. 1.1 Time domain effect of Polarization Mode Dispersion(PMD) in a short fiber length with a pulse being launched with equal power on the two birefringent axes, becoming two pulses at the output separated by the differential group delay

Polarization mode dispersion (PMD) has emerged as a key limitation at higher bit rates 10Gbps and above that use even the newest types of fibers due to non zero PMD. Moreover, the system degrading effects caused by PMD are characterized as random stochastic processes that change with many environmental effects. So, it becomes necessary to compensate the effects of the polarization mode dispersion (PMD). We can make a setup in OPTSIM (software of optical fiber communication) to compensate the PMD occurs in the fiber during transmission. This setup can be shown below and some information about the components which can be used in this setup can be explained below.

III. SIMULATION SETUP FOR PMD VARIATION

The figure (1.2) shows the structure for the analysis of PMD variation in optical link having 4 channels. The PMD is varied in four steps from 0 to $180 \text{ ps}/\sqrt{\text{km}}$.

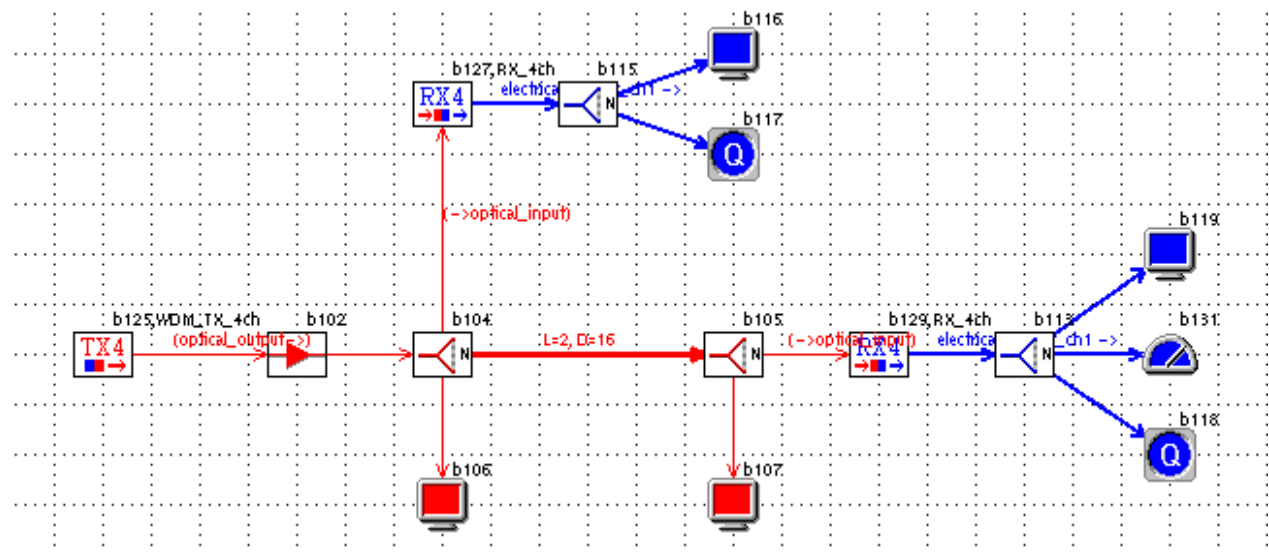


Fig. 1.2 Simulation Setup for PMD variation effects using OPTSIM

The transmitter and receiver section are connected by the dispersive fiber link. The transmitter section consists of data source, modulator driver, laser source and modulator. Data source produces a pseudo-random sequence of bits at a rate of 2.5 Gbps. The output of data source is given to modulator driver which produces a NRZ (Non return to zero) format pulse train. The transmitted signal is formed by modulating the light carrier by the NRZ data source.

The light carrier is generated by Lorentzian laser source at the 1550 nm wavelength. The transmitter output is boosted up by the fixed gain Erbium Doped Fiber Amplifier (fixed_output_power).

There are two types of optical amplifiers; Semiconductor Optical Amplifier (SOA) and the Erbium Doped Fiber Amplifiers (EDFA). Due to its high gain characteristics EDFA are used these days. The shape of the gain graph is flat having a gain of 25 dB. The noise figure value is set at 4.5 dB. The transmission medium used is a standard single mode fiber (L=2, D=6) of 2 km length. The receiver used is the system is the PIN (Receiver, PIN) receiver, which uses the PIN (p-intrinsic-n) diode as a detector. The pin photodiode simulated had 70% quantum efficiency. The dark current was simulated at 0.1 nA. The output of the receiver is given to the measurement devices which are fed through the electrical splitter, the electrical scope and the Q estimator. The optical spectrum of the signal is observed from optical spectrum analyzer (input and output) by splitting the signal from fiber link with the use of optical splitters. To analyze the effects due the variation of PMD on the specified parameters, the PMD is taken as global parameter.

IV. FIGURES AND RESULTS

The figures shown below are the results obtained for the different values of Polarization Mode dispersion for channel number 4.

kapil2: Eye Diagram at b119, Run 1

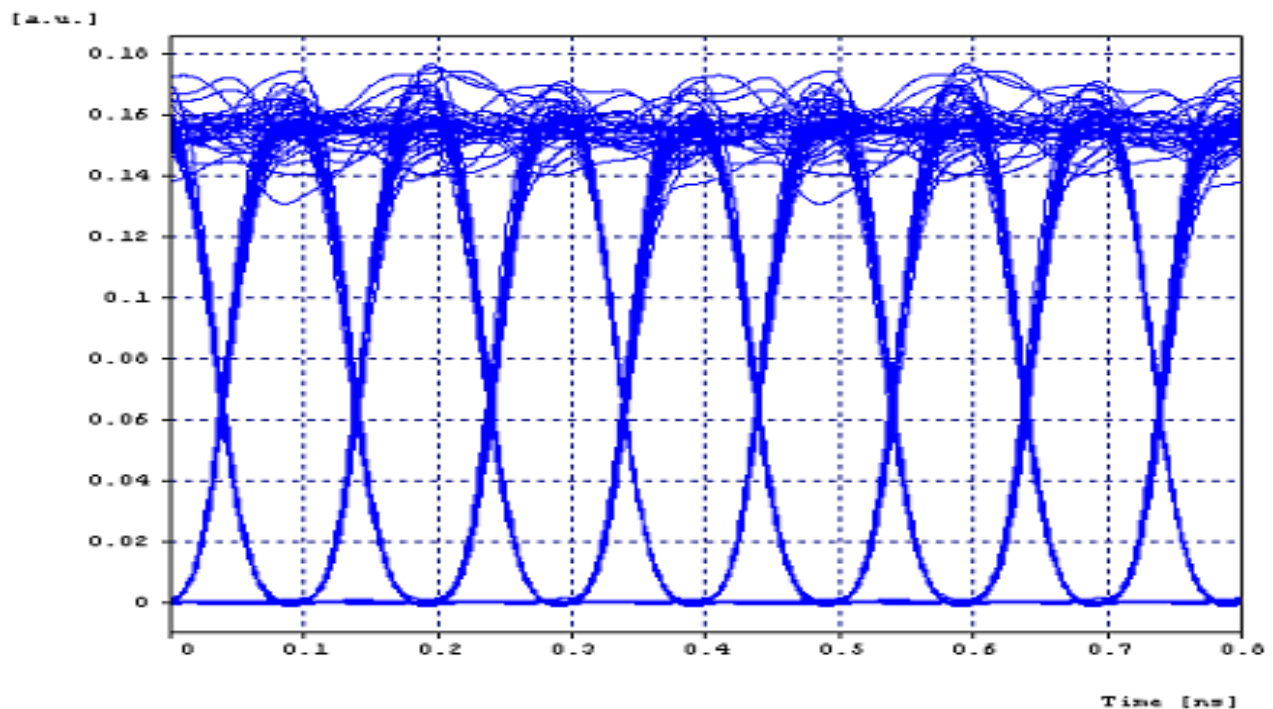


Fig. 1.3 Eye Diagram at PMD = 0 ps/√km

kapil2: Eye Diagram at b119, Run 2

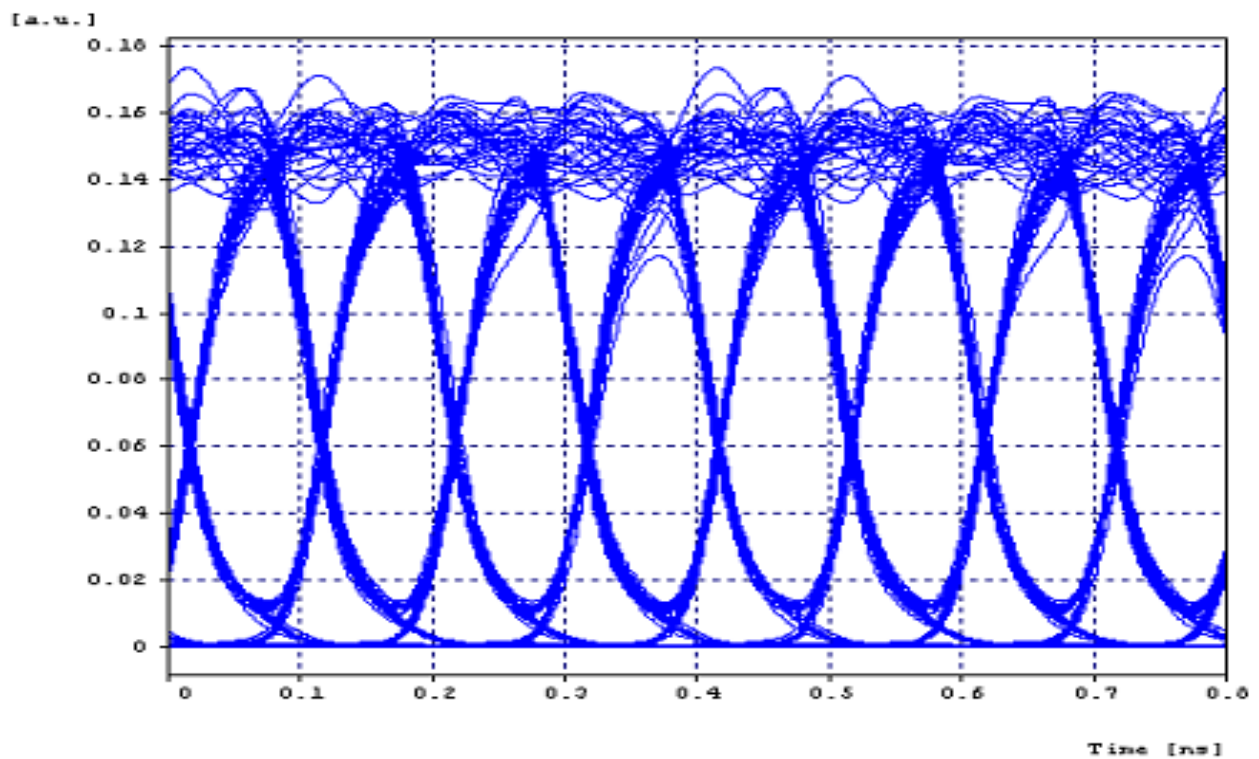


Fig. 1.4 Eye Diagram at PMD = 60 ps/√km

kapil2: Eye Diagram at b119, Run 3

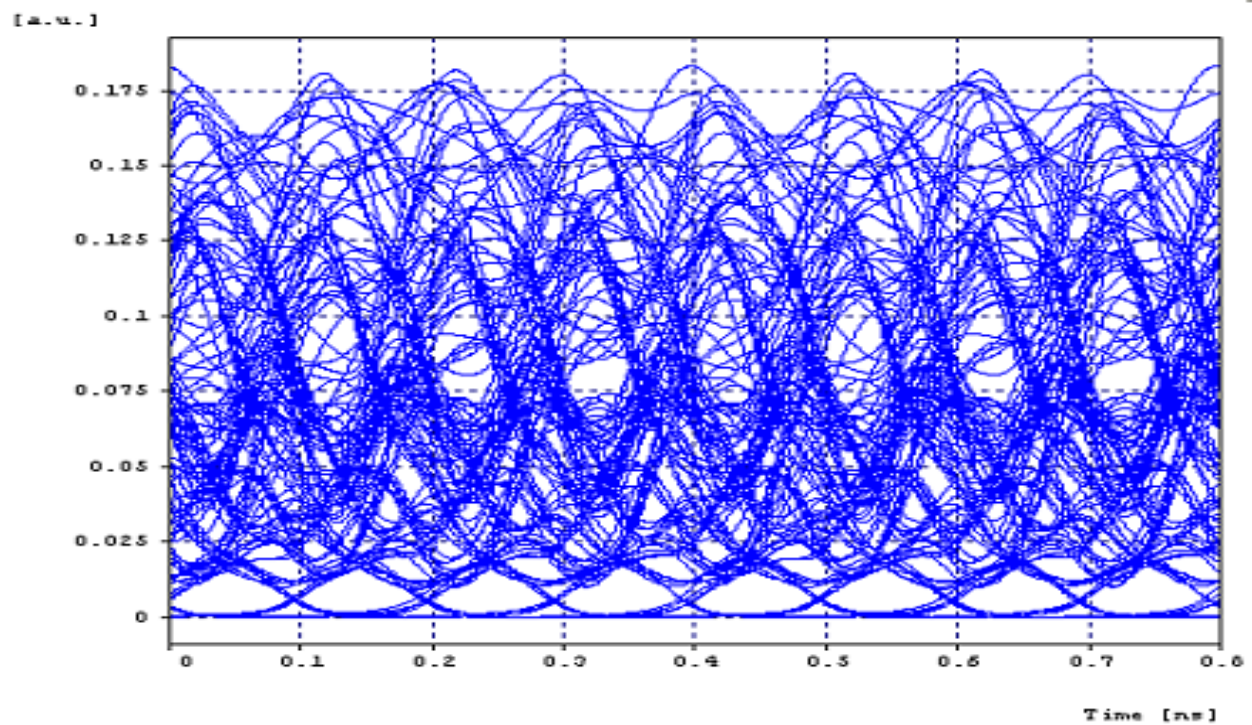


Fig. 1.5 Eye Diagram at PMD = 120 ps/√km

kapil2: Eye Diagram at b119, Run 4

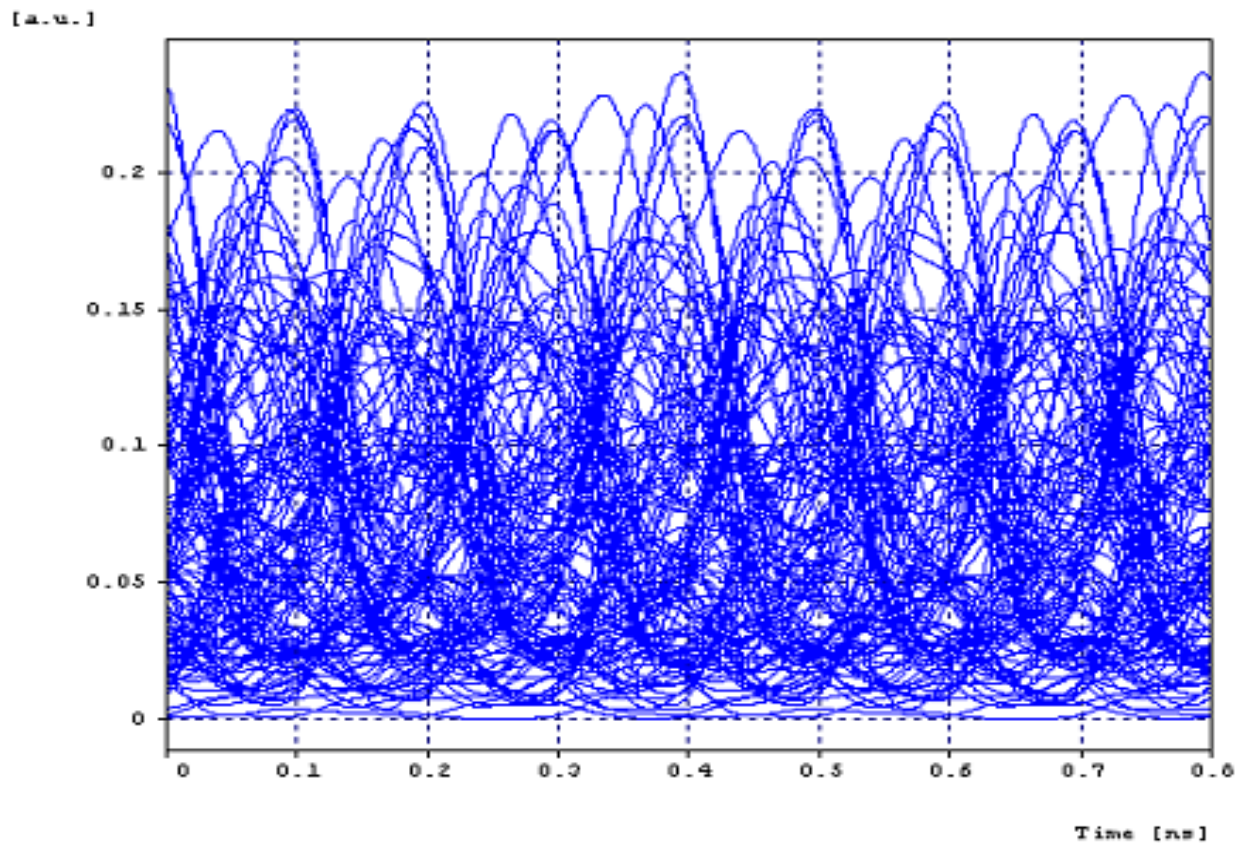


Fig. 1.6 Eye Diagram at PMD= 180 ps/√km

The figures (1.3 to 1.6) show that the performance of the system is getting weakened as the PMD increases. We can see that the eye diagram is least distorted at 0 ps/√km, as we go on increasing the bit rates to higher values the eye diagram is getting more and more distorted. At very high bit rate such as at 180 ps/√km we are not able to distinguish the original signal which was sent by the transmitter as the signal is very much distorted. Hence we have shown that the Polarization Mode Dispersion (PMD) has very adverse effects at higher bit rates.

Furthermore we will show the graphs for Q values, eye opening, eye closing and output power characteristics at the corresponding values of PMD. These graphs will show that the behavior of PMD becomes unpredictable at higher values of PMD. It is studied that any further increase in value of PMD causes the great fluctuation in the characteristics of the measured parameters.

Figure 1.7 shows the Q value at the corresponding values of PMD. We can see that we get maximum Q value at 0 ps/√km but as we go on increasing the bit rates the Q value decreases simultaneously. At 180 ps/√km the Q value is minimum.

- o Correlation Diagram: Q Value at b118

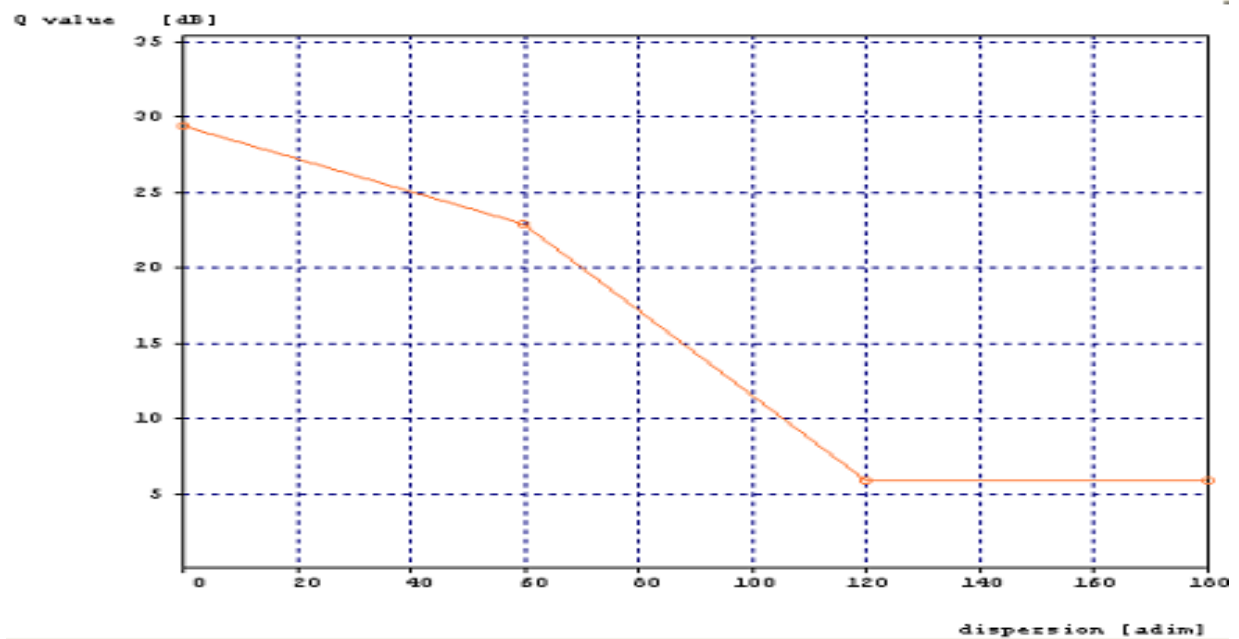


Fig. 1.7 Q Value at Different values of PMD

- o Correlation Diagram: Eye Opening at b118

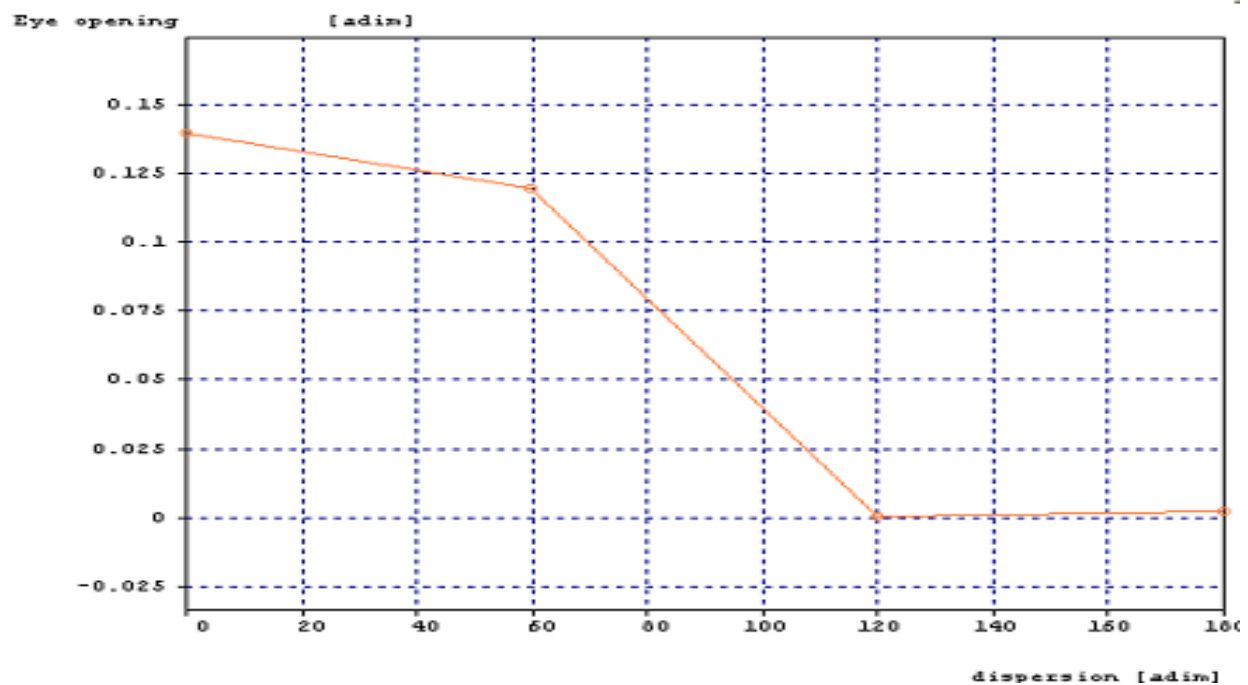


Fig. 1.8 Eye Opening at Different values of PMD

Figure 1.8 shows the value of eye opening at the different values of PMD. We get the maximum eye opening at 0 $\text{ps}/\sqrt{\text{km}}$ and minimum eye opening at 180 $\text{ps}/\sqrt{\text{km}}$. It is observed that eye opening decreases slowly as PMD increases from 0 to 60 $\text{ps}/\sqrt{\text{km}}$. After the PMD value of 60 $\text{ps}/\sqrt{\text{km}}$, the eye opening decreases up to minimum

value at 120 ps/√km. After the PMD value of 120 ps/√km, the eye opening remains almost constant upto 180 ps/√km.

- o Correlation Diagram: Eye Closure at b118

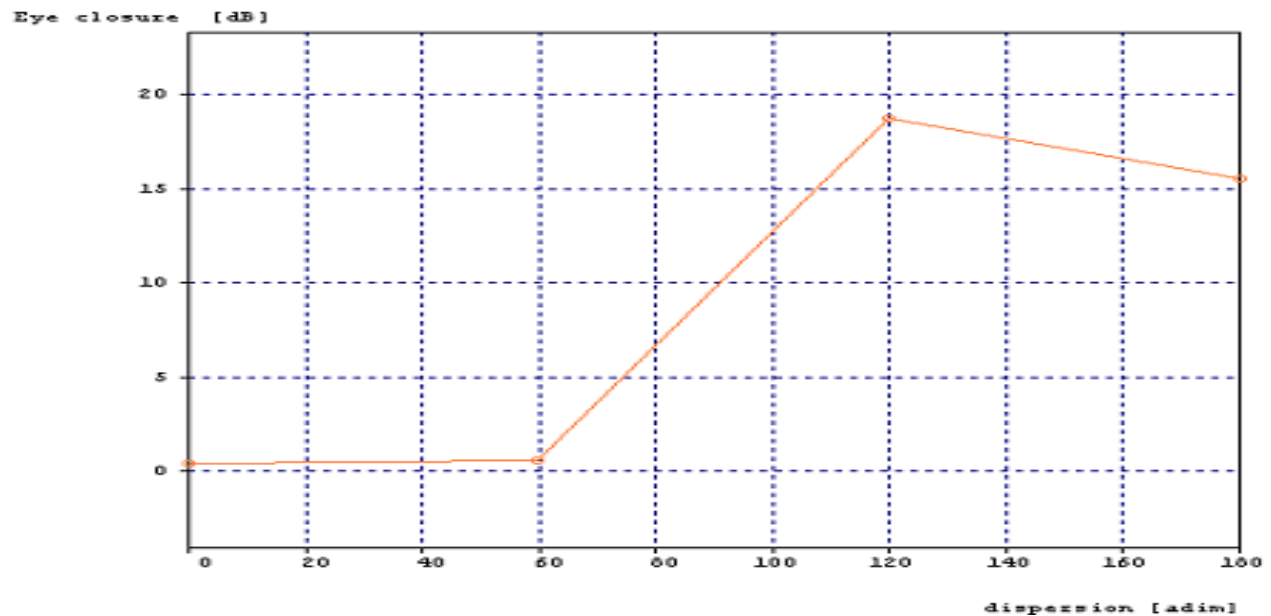


Fig. 1.9 Eye Closure at Different values of PMD

Figure 1.9 shows the value of eye closure at the corresponding values of PMD. We get the values of eye closure at different bit rates from 0 ps/√km to 180 ps/√km.

- o Correlation Diagram: Electrical Power at b131

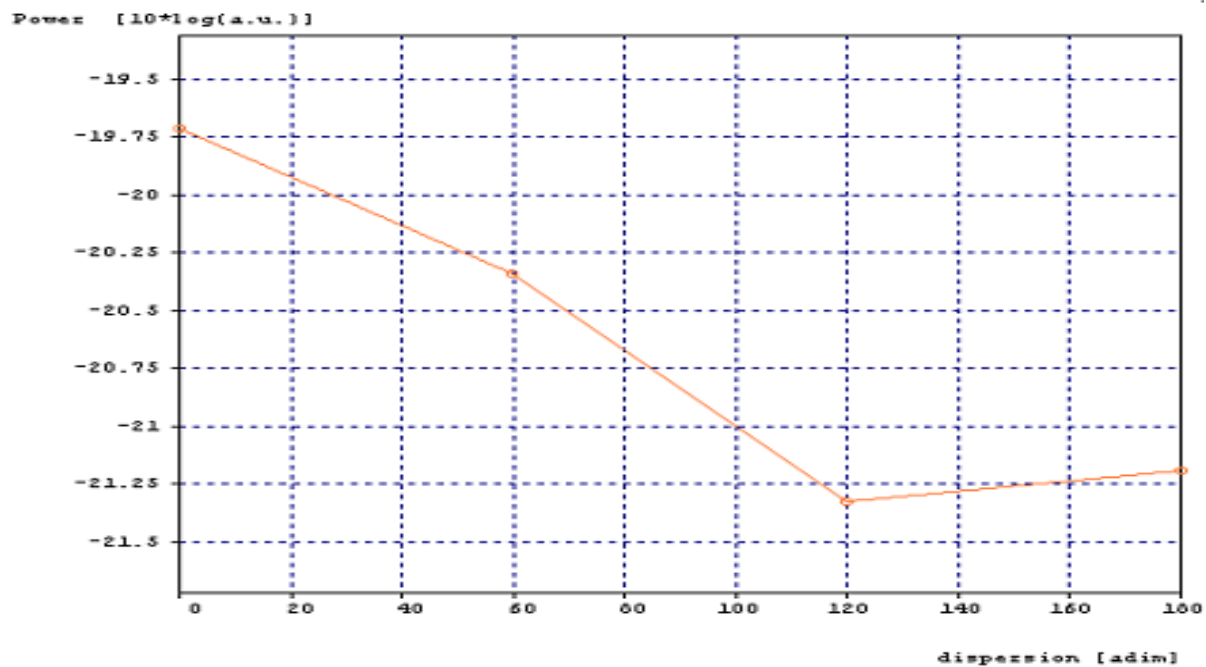


Fig. 1.10 Electrical Power at Different values of PMD

In figure (1.10) the adverse impact of PMD variation over power is also observed. At 0 PMD power is -19.6 dBm and it is reduced to -21.35 dBm at 120 ps/ $\sqrt{\text{km}}$. But a rise is seen as PMD goes to 180 ps/ $\sqrt{\text{km}}$ to the power - 21.20 dBm.

V. CONCLUSION

The effect of changing the value of PMD for four channels is reported in this paper. These effects are seen from the eye diagram drawn for the different values of Polarization Mode Dispersion (PMD). Furthermore we have also shown the graphs for eye opening, eye closing and output power characteristics at the corresponding values of PMD. The above discussed results show that the behaviour of PMD becomes unpredictable at higher values of PMD. It is reported that up to the PMD value of 120 ps/ $\sqrt{\text{km}}$, the value of eye opening and output power decreased. It is studied that any further increase in value of PMD causes the great fluctuations in the characteristics of the measured parameters. Therefore some sort of PMD Compensator is required to filter the adverse effects of Polarization Mode Dispersion (PMD). We can use the Polarization maintaining fibers for the purpose which can reduce the Polarization Mode Dispersion up to some extent. But we are still not able to completely remove the Polarization Mode Dispersion from the optical fiber specially at higher bit rates, which is a topic of research and a challenge for the various scientists in the optical fiber field.

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