First Order PMD-Compensation in a 10 Gbit/s NRZ Field Experiment Using a Polarimetric Feedback-Signal

H. Rosenfeldt, R. Ulrich (1), U. Feiste, R. Ludwig, H.G.Weber (2), A. Ehrhardt (3)

(1) Technische Universitaet Hamburg-Harburg FSP 2-03 Optik und Messtechnik, D-21073 Hamburg, Germany
(rosenfeldt@tu-harburg.de)
(2) Heinrich-Hertz-Institut Berlin GmbH, Einsteinufer 37, D-10587 Berlin, Germany (ludwig@hhi.de)
(3) Deutsche Telekom AG, Goslarer Ufer 35, D-10589 Berlin, Germany

Abstract:We demonstrate PMD-compensation of an installed high-PMD fiber ($\Delta\tau$=80.5ps, L=45 km) by means of a variable delayline and a set of polarization controllers. The compensation-algorithm minimizes a feedback-signal derived by a frequency-resolving stokes-polarimeter.

Introduction

Automatic first-order compensation of polarization mode dispersion (PMD) has been a topic of many recent publications [1,2,3]. The typical approach in these investigations is to split the distorted signal into the two principal states of polarization (PSP), the slow and fast eigenstate. The fast eigenstate is then delayed before the two signals are recombined [1]. Since the polarization of the delayline input signal and the delay have to be adjusted to an optimum, a feedback-signal is needed. It is desirable to derive this feedback-signal directly from the optical signal without modifying the receiver. In the present paper, we describe a 10 Gbit/s NRZ transmission experiment over 45 km standard singlemode fiber (SMF) which is embedded in the city of Berlin. This fiber has a very high PMD value of 80.5 ps with maximum differential group delay (DGD) values up to 150 ps. We demonstrate the PMD compensation using a variable delayline and a set of polarization controllers [1]. A compensation algorithm is used to minimize the frequency dependence of the state of polarization (SOP).

Feedback Signal

In presence of PMD the SOP changes with respect to the optical frequency ω as follows [4]:

$$\frac{d\vec{C}}{d\omega}=\vec{\Omega}\times\vec{C},$$

where $\vec{C}$ is the output SOP, $\vec{\Omega}$ is the dispersion vector and $|\vec{\Omega}|=\Delta\tau$ is the differential group delay. The signal distortion is correlated to $d\vec{C}/d\omega$, since this quantity is small for either low DGD or an SOP near a PSP. Both conditions lead to small signal-distortions. In our experiment we use a scanning Fabry-Perot filter and a fast Stokes-polarimeter for monitoring the change of the SOP with the optical frequency. The adaptive compensation algorithm minimizes the standard deviation of the SOP with respect to the average SOP over the central bandwidth of the data signal.

Experimental Setup

The experimental setup is shown in Fig. 1. The 10 Gbit/s NRZ transmitter consists of a CW tunable laser source and a modulator driven by a 2^{31}-1 PRBS from a bit pattern generator. The data signal is amplified, filtered and launched into a 45 km installed fiber span. The launched average power is 6 dBm. The fiber span has a high attenuation of 29 dB due to fiber splices and fiber connectors as well as high PMD values leading to more than 150 ps of DGD at certain wavelengths (average PMD = 80.5 ps). After the fiber span, we first compensate for the chromatic dispersion using dispersion compensating fiber (DCF). The PMD compensator (Fig.2) consists of a motor-driven polarization controller based on 4 Lefèvre-loops and a motor-driven variable delayline which is able to generate a maximum DGD of 140 ps. The fiber span did not show any fast PMD fluctuations, thus the limited speed of the compensator is sufficient.

Figure 1: Experimental Setup

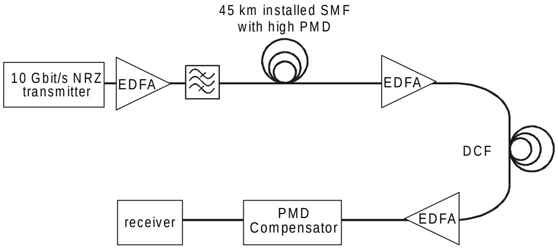
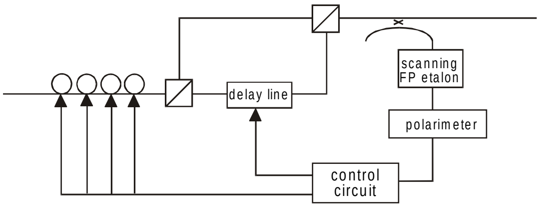


Figure 2: PMD Compensator Setup



However, for practical applications a compensator should be able to track fast PMD-changes induced for example by moving patchchords [5]. The Fabry-Perot etalon has a free spectral range of 50 GHz and a finesse of 40 which leads to a spectral resolution of 1.25 GHz. The scanning period of the filter is 20 ms.

Experimental Results

First we measured the wavelength dependence of the DGD of the investigated fiber span. The results are given in figure 3. The DGD varies from less than 25 ps to more than 150 ps. The operating wavelength was 1550.14 nm where the DGD is about 60 ps.

Figure 3: Measured wavelength dependence of total DGD of 45km installed SMF-fiber

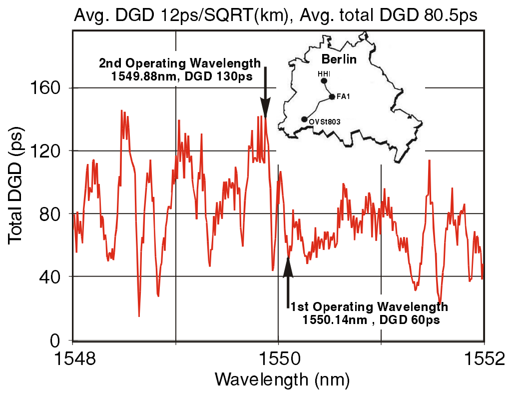


Figure 4 depicts BER measurements versus the receiver input power for back-to-back measurements, for a transmission over 50 km high-quality standard fiber with negligible PMD ($PMD < 0.05\ ps/\sqrt{km}$), and finally for the PMD-compensated transmission line. Due to the signal degradation without PMD compensation no BER measurements could be performed. With PMD compensation error-free transmission was possible with a penalty of 2dB. The good correlation between the BER values at constant receiver input power and the standard deviation of the SOP with respect to the average SOP is shown in Figure 5.

Figure 4: BER performance λ=1550.14 nm, Δτ=60 ps.

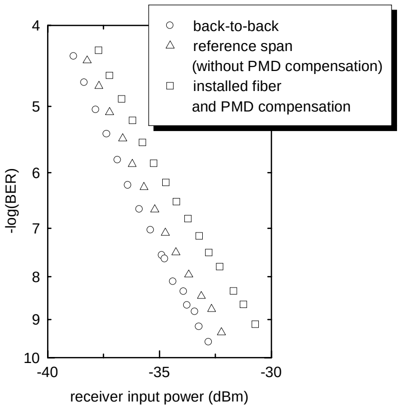


Figure 5: Correlation between feedback signal and BER at constant receiver input power λ=1550.14 nm, Δτ=60ps

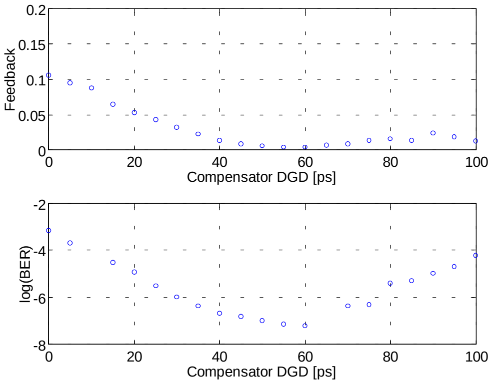
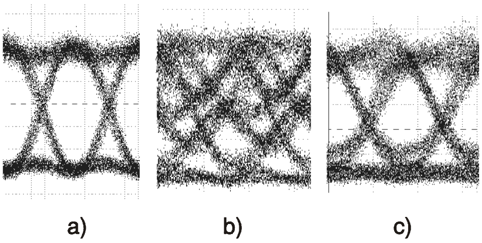


Figure 6 shows the eye diagrams for a different wavelength at the transmission fiber input (a), at the input of the PMD-compensator for the worst input SOP (b) and finally behind the PMD-compensator (c). It is evident that no signal detection is possible without PMD-compensator. A good eye-opening is achieved after PMD compensation.

Figure 6: Eye diagrams at fiber input (a), compensator input (b) and after compensation (c). λ=1549.88 nm, Δτ=130 ps.



Conclusion

We demonstrated the operation of a PMD-compensator in a 10 Gbit/s NRZ transmission experiment over 45 km of installed standard fiber with high PMD value. The PMD compensator minimizes the standard deviation of the SOP with respect to the average SOP. A good correlation between these standard deviations of the SOP and the BER values was obtained.

/1/ F. Heismann et al., Proc. ECOC'98, Madrid (Spain), Vol 1, p. 529-530, (1998)

/2/ R. Noé et al., Proc. ECOC'98, Madrid (Spain), Vol 3, p. 157-158, (1998)

/3/ H. Bülow, Proc. OFC’99, San Diego (USA), WE1-1 p. 74-76, (1999)

/4/ D. Andresciani et al., Opt. Lett. 12(10) p. 844-846, (1987)

/5/ H. Bülow et al., Proc. OFC’99, San Diego (USA), WE4-1 p. 83-85, (1999)