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ScienceDirect

Procedia Engineering 140 (2016) 209 – 216

Procedia Engineering

www.elsevier.com/locate/procedia

MRS Singapore – ICMAT Symposia Proceedings

8th International Conference on Materials for Advanced Technologies

Simultaneous Monitoring of CD and PMD Using RF Tone Power

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Abstract

We propose and demonstrate a novel method for simultaneous chromatic dispersion (CD) and polarization-mode-dispersion (PMD) monitoring using RF spectrum analysis. In this method, the clock frequency of single sideband of the optical signal is removed by using a narrow bandwidth fiber Bragg grating (FBG) notch filter. After photon detection of the filtered optical signal, the clock tone power of the radio frequency (RF) signal is changed with differential group delay (DGD), which is insensitive to the CD variation. Once DGD value is known, CD value can be estimated from the low-frequency RF tone power after the DGD induced RF power variation is removed. This method enables simultaneous CD and PMD monitoring using detected RF spectrum in the tap line without affecting the received data stream and can be implemented without major modification of the transmitter.

Selection and/or peer-review under responsibility of the scientific committee of Symposium 2015 ICMAT

*Keywords:*Chromatic dispersion; Polarization-mode-dispersion; Differential group delay; Fiber Bragg grating

1. Introduction

PMD arises in an optical fiber due to random anisotropy in a long single mode fiber (SMF) caused by the noncircular cores and variations in the stresses, bending and cabling [1]. The small amount of induced birefringence also randomly varies along the length of the fiber due to change in temperature and other physical conditions. This birefringence causes the power of optical pulses to split between the two orthogonal polarization modes of the fiber.

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Selection and/or peer-review under responsibility of the scientific committee of Symposium 2015 ICMAT
doi:10.1016/j.proeng.2016.07.347

These modes travel at different speeds as they see slightly different refractive indices, creating a DGD between the two modes causing pulse spreading and inter symbol interference (ISI). PMD is typically represented as a vector on the Poincaré sphere whose magnitude is the DGD and whose direction represents the polarization state of one of the two orthogonal polarization modes of the fiber which are called the principal states of polarization (PSP) [2,3].

The impairments of PMD may be seen in relation with other factors like CD and amplified spontaneous emission (ASE) noise from amplifiers. The latest trend of optical communication towards polarization division multiplexed (PDM) quadrature phase shift keying (QPSK) system with coherent receiver shows the prospect of higher data rates at longer distances. With the growth of bandwidth demand and development of communication related technologies, PDM-QPSK system supported by the digital signal processing has emerged with successful demonstrations. As the equalization is carried out at the receiver in this system, the need of monitoring the CD and PMD has emerged with greater importance [4]. A key difficulty with managing PMD related effects in long fiber transmission systems is that they are stochastic processes [5]. Thus a system can randomly wander in and out of high-penalty states and needs step to reduce the probability that the penalty will exceed a certain level to a negligible value (typically minute per year) [6-8]. This non-catastrophic effect of PMD and CD lead to the need for dynamic and constant monitoring of the system.

A number of monitoring techniques for the CD and PMD have been reported. The optical domain techniques include the degree of polarization (DOP) of polarized lights, measuring the phase difference between two frequency components located on orthogonal PSPs and calculating the arrival time of polarization-scrambled light [9-13]. The electrical domain techniques include analysing the spectral frequency components, calculating the eye-opening penalty and adding a subcarrier tone to the data [14-16]. However, each of these techniques suffers from one or more of the following disadvantages [9]: 1) monitoring window not covering the whole window, 2) the necessity for transmitter modification, 3) low monitoring sensitivity, 4) pulse width dependence and inability to monitor the CD and PMD simultaneously. It has been shown that NRZ signals suffer greater degradation due to PMD than RZ signals and phase modulation proved more tolerant to PMD[16,17].Since phase modulation has proved to be more resilient in long range high speed optical data transmission, differential quadrature phase shift keying (QPSK) data format is considered in this paper.

Therefore, this report focuses on the monitoring method of PMD and CD simultaneously for NRZ-QPSK signals. The aim of this paper is to propose as well as demonstrate a novel method for simultaneous CD and PMD monitoring using RF spectrum analysis. Advantage of our proposed technique is that it does not require any major modification at the transmitter. The paper is organized as follows. Operational principles are discussed in the following section. In Section 3, we briefly discussed about the simulation setup and the results obtained from simulation. Experiment results are discussed in Section 4. Finally, we conclude our findings and discussion in the final section.

2. Operation Principle

When one sideband of the optical spectrum is removed and passed through the square law detector, the RF tone power at frequency equal to half of the data rate is insensitive to CD and affected by the PMD alone. The RF tone power at frequency equal to quarter of the data rate is affected by both CD and PMD. For 50 Gb/s QPSK system, the data rate of each channel is 25 Gb/s. If lower sideband (LSB) of the optical spectrum is removed by appropriate notch filter and then detected using square law, the RF tone power at 12.5 GHz will be affected by PMD only and RF tone power at 6.25 GHz will be affected by both CD and PMD. These localized effects can be compared to separate and measure their individual effects. Again, the RF tone power at 12.5 GHz with and without optical filtering can be used to compare and separate the effect of CD and PMD. In this paper the process of comparing the RF tone power at 12.5 GHz and 6.25 GHz will be discussed.

At first, the PMD is measured using the knowledge of the RF power at frequency equal to half of the data rate (12.5 GHz). After that, CD is measured from the knowledge of the RF power at frequency equal to quarter of the data rate (6.25 GHz) which shows the effects of both CD and PMD. Therefore, CD and PMD can be monitored simultaneously using the knowledge of the RF tone power. Here, the monitoring signal is processed from a tap line and thereby the main data flow is not interrupted.