Optical Performance Monitoring of Data Degradation by Evaluating the Deformation of an Asynchronously Generated I/Q Data Constellation

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Abstract *We present a technique of using asynchronously generated constellation pattern to simultaneously monitor CD and first order PMD in DQPSK systems. By characterizing deformations in the patterns, the amount of accumulated CD and PMD can be estimated.*

Introduction

Optical performance monitoring of a data signal is of great interest for systems that have impairments that can change with time. A desirable attribute of a monitor is to determine the specific impairment that is degrading the data signal. Moreover, it might be beneficial for the monitor to: (i) accommodate different advanced modulation formats, such as quadrature-phase-shift-keying (QPSK), and (ii) be asynchronous and not require exact clocked timing. In general, the eye diagram that can be generated by an oscilloscope after detection is a powerful diagnostic tool for evaluating system performance.

It has been shown a clever adaptation of the eye diagram to asynchronously generate a new type of diagram [1, 2]. This asynchronous diagram is fairly straightforward to generate and will deform in generally predictable ways by different types of impairments, i.e., chromatic dispersion, polarization-mode-dispersion (PMD), optical signal-to-noise-ratio (OSNR).

At present, there is significant interest in phase- and quadrature-phase-modulated systems due to the increased receiver sensitivity, increased tolerance to fiber nonlinearities, and higher spectral efficiency. In QPSK, a generically valuable way of portraying the signal is to plot the data constellation on the I (in-phase) and Q (quadrature-phase) planes. A key challenge might be tailoring the constellation in order to monitor data impairments for phase modulated signals. In [3], a constellation diagram was used to measure the phase noise of light sources. In [4] we presented a method to monitor CD or first order PMD in DQPSK systems based on the constellation diagram using synchronous samples of the received signal, which was so sensitive to sampling time.

In this paper we propose asynchronously generated constellation evolution of a DQPSK data stream. The constellation is generated by continuously plotting the phase and amplitude changes in the data. We show that this I/Q plot will deform in a fairly predictable way due to CD and first-order PMD, such that the pattern can recognizably be used to determine the amount of accumulated impairment.

Concept of Constellation Pattern Monitoring

The block diagram of a DQPSK system is shown in Fig 1. The transmitter is a parallel DQSPK modulator that converts the input electrical I and Q signals at 20-Gb/s to 40-Gb/s optical DQPSK. The fiber link then introduces dispersion to the signal which can be modelled by a CD and a PMD emulator. The receiver is incoherent and it consists of two out of phase delay-line-interferometers (DLI) followed by two balanced photo-receivers and the received I and Q signals are finally sampled with analog to digital converters (A/D). The outputs of A/Ds are the coordinates of the data in complex plane which forms the constellation diagram. The optical part of the system was simulated in OptSim and the constellation plotting was done in MATLAB. For each pattern, 64000 symbols were used. The maximum CD and differential group delay (DGD) is 50-ps equal to the symbol time.

In the ideal case, in which the transmitted symbols are perfectly modulated and there is no distortion/noise in the link and the samples are taken at the exact right moment, the constellation can be one of the 4 points in the four quadrants of the I/Q plane, but any nonideal effect at any part of the system changes the coordinates of the received signal.

If the receiver is not locked to the reference clock and all the received samples are plotted in one I/Q plane, patterns like in Fig 2 will be obtained. From Fig 2 it can be observed that increasing CD (left to right) makes the branches of the constellation pattern wider where the branch in the third quadrant has the

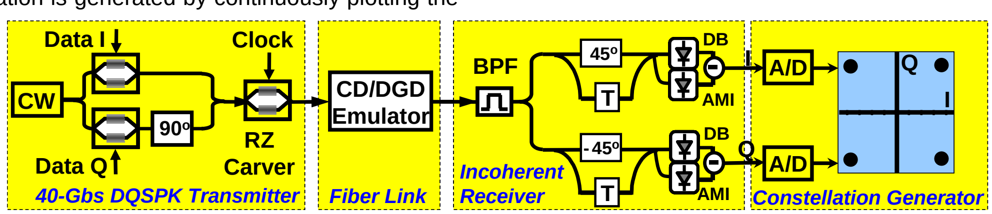

Fig. 1: Block diagram of DQPSK system

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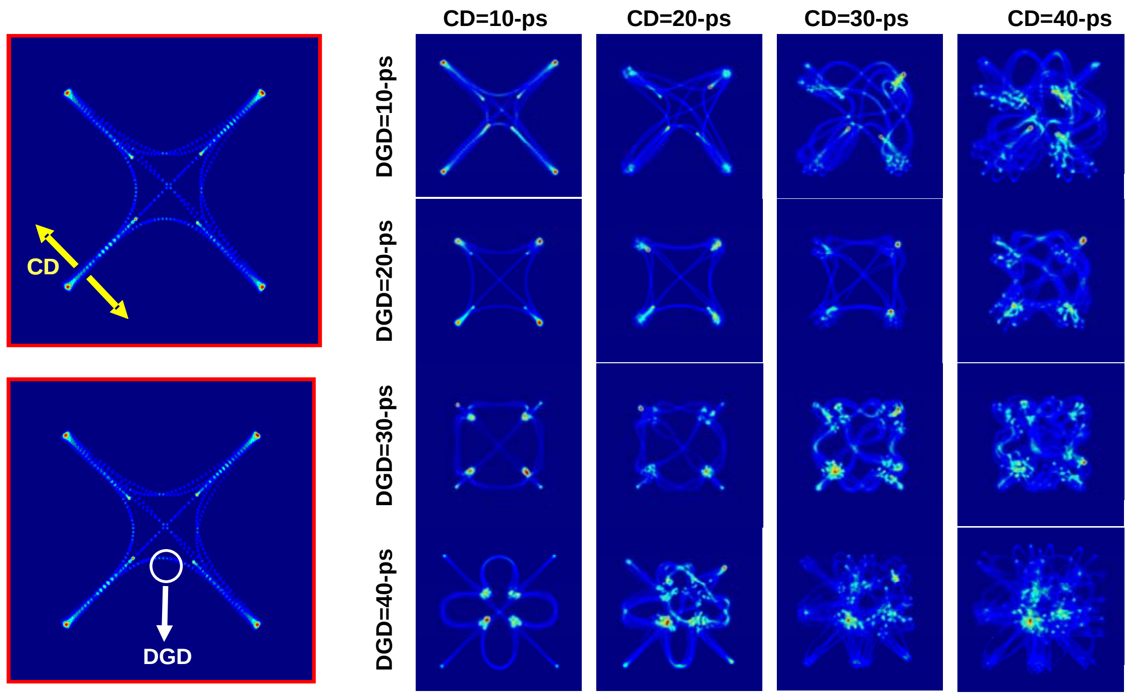

Fig. 2: Simultaneous effects of CD and DGD on the constellation pattern of DQPSK signals

maximum sensitivity to CD. The reason is that the third quadrant is composed of the signals with negative I and Q. From the receiver structure in Fig 1, it can be seen that I and Q are negative when the Alternate-Mark-Inversion (AMI) ports of the DLIs are active and since AMI format occupies more bandwidth, the effect of CD is more and the pattern dependency is larger.

Increasing DGD in the link (top to bottom) makes some portions of the constellation pattern to be concentrated around *I* and *Q* axes. This effect can be viewed as the emerging of 4 new signal phases in the middle of 4 existing initial phases and the reason is constructive and destructive interfering of the phase modulated signals along the fiber due to DGD [5].

Results and Discussion

In order to measure the effects of CD and DGD on the constellation pattern, some image processing techniques have been used to extract required features. The amount of DGD can be estimated by finding the deviation of the middle part of the constellation pattern from the center of the plane. In Fig 3a, normalized deviation for different values of CD is plotted versus DGD and it can be seen this deviation is independent of CD.

In Fig 3b, the normalized width of the third branch is plotted versus CD but unlike Fig 3a, the curves are different for different values of DGD. It can be observed that more DGD in the link reduces the slope of the curves. This can also be viewed in Fig 2 where in each column the width of the third branch is decreased from top to bottom. The reason is that signals interfere along the fiber due to DGD; this interference resembles a low pass effect, i.e., in addition to 90^o phase steps, DGD creates 45^o phase steps which smoothes the spectrum and relaxes the bandwidth, thus the effect of CD is less. So in order to measure CD from the pattern, DGD must be determined first and then the amount of CD can be estimated by using the curve corresponding to the obtained DGD.

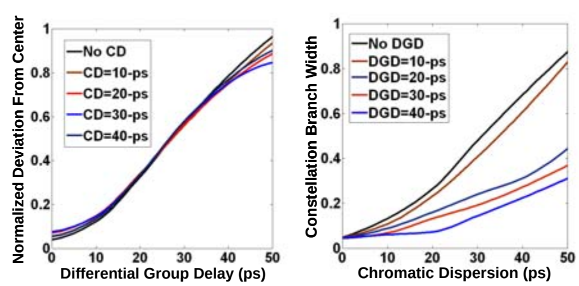

Fig. 3: (a) Deviation of the middle part of the constellation pattern due to DGD for different values of CD, (b) Normalized width of the constellation pattern branch versus CD for different values of DGD

Acknowledgement

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