Performance of Electronic Dispersion Compensation for Multi-Level Modulation Formats using Homodyne Coherent Detection

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Abstract We investigate numerically the performance of electronic dispersion compensation with linear transversal filters of different filter lengths and tap delays for RZ-DQPSK, RZ-8-DPSK and star RZ-16-DQAM after homodyne coherent detection at 10.7 Gsymbols/s.

Introduction

Recently, coherent optical fibre communication systems attracted much interest again. With the availability of high-speed digital signal processing (DSP) carrier and phase recovery can be transferred to the digital domain [1,2] resulting in reduced complexity in the optical domain. By means of a coherent receiver in conjunction with DSP, transmission impairments like chromatic dispersion (CD) can be equalized in the digital domain. Theoretically, any amount of CD can be compensated for by the use of the inverted fibre transfer function.

In this contribution we investigate numerically the performance of electronic dispersion compensation (EDC) in combination with coherent detection for RZ-DQPSK, RZ-8-DPSK and star RZ-16-DQAM at 10.7 Gsymbols/s. EDC is achieved by linear transversal filters. We investigate the performance of different tap delays and filter lengths by Monte-Carlo simulations.

Simulation setup

At the transmitter side 21.4 Gb/s RZ-DQPSK [3], 32.1 Gb/s RZ-8-DPSK [4] and 42.8 Gb/s star RZ-16-DQAM are generated at 10.7 Gsymbols/s for identical bandwidth requirements according to fig. 1. Star RZ-16-DQAM is generated from RZ-8-DPSK by driving an additional Mach-Zehnder modulator (MZM) where the modulator bias and drive signal amplitudes are adjusted to obtain a ring-ratio (RR) (the amplitude ratio of the outer ring to the inner ring) of two [5]. The respective signal space constellations of the modulation formats are shown in fig. 2 (a-c).

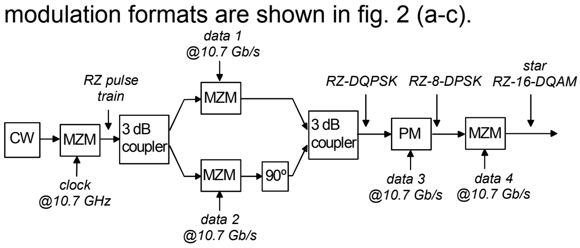

Fig.1: Transmitter setup; PM: Phase Modulator

The transmission channel is modelled as a linear single span with variable length, to achieve the desired CD.

At the receiver side the signal is amplified by an EDFA and filtered by a Gaussian optical bandpass (BP) filter with f_{3dB}=44GHz. Then the received signal and the signal of a local oscillator (LO) are combined in a 2x4 90º hybrid. The output signals of the 90º hybrid are detected with two balanced photo-detectors (BD). Afterwards the resulting electrical inphase and quadrature signals are lowpass (LP) filtered (Butterworth 3rd order, f_{3dB}=12 GHz) and then processed by digital signal processing for electronic dispersion compensation (EDC), phase estimation and data stream demultiplexing (fig. 3).

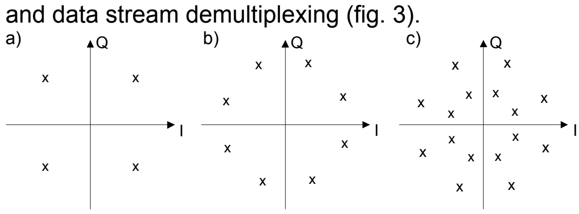

Fig.2: Signal space constellation of a) RZ-DQPSK b) RZ-8-DPSK and c) star RZ-16-DQAM

The frequencies of the signal and of the LO are assumed to be the same (homodyne detection). Thus only phase noise is considered, represented through the line width of the laser. The line width, modelled according to [6], is set to 500 kHz per laser, which results in an effective laser line width of 1 MHz.

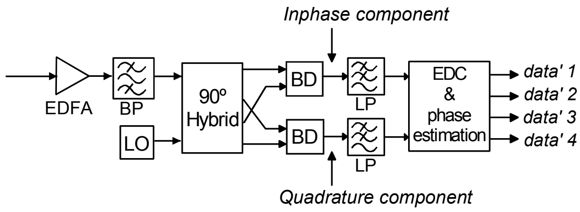

Fig.3: Coherent receiver setup

EDC and phase estimation

For EDC a linear transversal filter with different filter lengths is used. The coefficients are determined by the inverse fibre transfer function and are truncated to the desired filter length with a rectangular window.

To compensate for CD at least two samples per symbol are necessary to avoid aliasing. Therefore two types of equalizers are investigated. The first one is a T/2 and the second one a T/4 spaced equalizer, where T is the symbol duration. Thus the signal is sampled two and four times per symbol, respectively. For comparison the order of the T/4 spaced equalizer is doubled compared to the T/2 spaced equalizer.

After the equalization, carrier and phase recovery is employed. The principle of the phase estimation scheme is according to [1] and adapted to RZ-8-DPSK and star RZ-16-DQAM modulation.

Results and discussion

Fig. 4 depicts CD versus OSNR penalty at a BER of 10^{-4} for the investigated modulation formats without EDC. The approximated residual dispersion tolerance for 2 dB OSNR penalty is displayed in table 1. We notice that the dispersion tolerance is almost similar for all modulation formats. However, RZ-DQPSK shows superior tolerance due to the larger symbol distance in the signal space constellation.

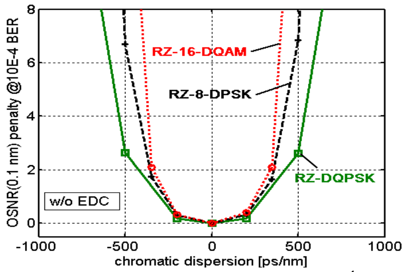

Fig.4: OSNR penalty at BER of 10^{-4} versus CD without EDC for RZ-DQPSK (□, solid), RZ-8-DPSK (+, dashed) and star RZ-16-DQAM (o, dotted).

Now, EDC with the T/2 spaced equalizer is considered (fig. 5). There is a slight improvement in CD tolerance for all investigated formats. However, with increasing filter length only RZ-DQPSK shows superior performance even for higher amounts of CD.

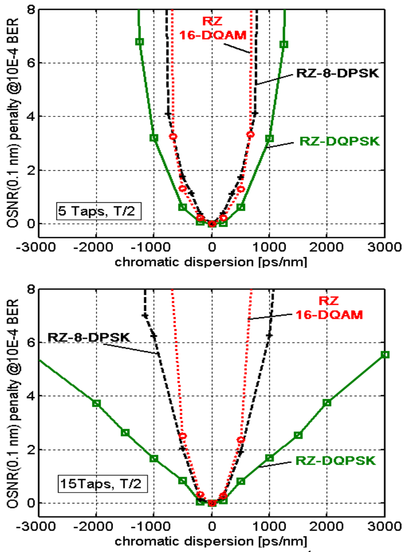

Fig.5: OSNR penalty at BER of 10^{-4} versus CD after equalization with T/2 spacing for a) 5 taps and b) 15 taps. Markers according to fig. 4.

Spectral overlapping due to the sampling with only T/2 as well as phase noise produce distortions, which results in “clouds” instead of sharp points in the signal space constellations. Here RZ-DQPSK is more robust due to the larger distance between adjacent symbols. Thus, a higher sampling rate for RZ-8-DPSK and star RZ-16-DQAM is necessary. Therefore the T/4 spaced equalizer is now considered. Fig. 6 shows that the combination of the T/4 spaced equalizer with RZ-DQPSK results in a very large improvement compared to the other two modulation formats for both considered filter lengths. Significant gain of performance for RZ-8-DPSK and star RZ-16-DQAM can only achieved by longer filter lengths.

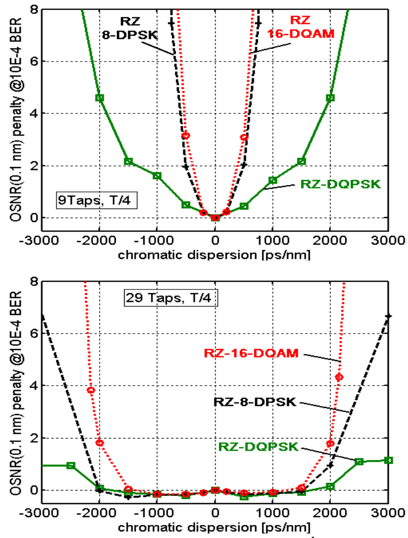

Fig.6: OSNR penalty at BER of 10^{-4} versus CD after equalization with T/4 spacing for a) 9 taps and b) 29 taps. Markers according to fig. 4.

Table 1: Residual dispersion tolerance in ps/nm for 2dB OSNR penalty for the investigated equalizers.

Tap delay:	*w/o*	*T/2*	*T/2*	*T/4*	*T/4*
Taps:	*EDC*	*5*	*15*	*9*	*29*
RZ-DQPSK:	*850*	*1500*	*2300*	*2900*	*>6000*
RZ-8-DPSK:	*700*	*1000*	*1000*	*1000*	*4500*
RZ-16-DQAM:	*700*	*1000*	*1000*	*800*	*4000*

Conclusions

We investigated the performance of EDC in conjunction with homodyne coherent detection for RZ-DQPSK, RZ-8-DPSK and star RZ-16-DQAM in presence of CD. To achieve a significant OSNR improvement the T/2 spaced equalizer with a sufficient length can be used for RZ-DQPSK. For RZ-8-DPSK and star RZ-16-DQAM the T/2 spaced equalizer has only slight performance improvement. Hence, these formats require T/4 spaced equalizers. Compared to the other two modulation formats the T/4 spaced equalizer results in a very large CD tolerance in combination with RZ-DQPSK.

References

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