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Citation for published version (APA):

Al Fiad, M. S. A. S., Borne, van den, D., Wuth, T., Kuschnerov, M., Lankl, B., Weiske, C-J., Man, de, E., Napoli, A., & Waardt, de, H. (2008). Effect of carrier phase estimation for 111 Gbit/s POLMUX-RZ-DQPSK equalization in presence of 10.7 Gbit/s OOK neighbours. In *Digest of the IEEE/LEOS Summer Topical Meetings, 21-23 July 2008, Acapulco, Mexico* (pp. 175-176). Institute of Electrical and Electronics Engineers. <https://doi.org/10.1109/LEOSST.2008.4590546>

DOI:

[10.1109/LEOSST.2008.4590546](https://doi.org/10.1109/LEOSST.2008.4590546)

Document status and date:

Published: 01/01/2008

Document Version:

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
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- The final published version features the final layout of the paper including the volume, issue and page numbers.

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Effect of Carrier Phase Estimation for 111Gbit/s POLMUX-RZ-DQPSK Equalization in Presence of 10.7Gbit/s OOK Neighbours

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Abstract We optimize carrier phase estimation (CPE) to increase the XPM tolerance of 111-Gb/s POLMUX-RZ-DQPSK in the presence of 10.7-Gb/s OOK neighbours transmitted over an 1140 km EDFA-only link.

Introduction

Recently, significant interest has been shown into realizing long-haul transmission solutions for the 100Gb/s Ethernet protocol that is currently under consideration [1,2]. An important consideration for such next-generation long-haul optical transmission solutions is the possibility to upgrade deployed networks. First of all, this requires the signal to fit within a 50-GHz channel grid. Secondly, it must be robust to cross phase modulation (XPM) related impairments generated by its 10.7-Gb/s on-off keying (OOK) neighbours. 111-Gbit/s polarization-multiplexed return-to-zero differential quadrature phase shift keying (POLMUX-RZ-DQPSK) modulation, combined with coherent detection has been thoroughly studied in [1], including its compatibility with a 50-GHz channel grid. Moreover, the joint use of coherent detection and electronic equalization reduces the optical signal to noise ratio (OSNR) requirement and provides a considerable tolerance against linear transmission impairments, including, polarization mode dispersion (PMD) [3, 4] and chromatic dispersion (CD) [1, 4]. On the other hand, the phase noise generated by the XPM from neighbouring channels can be a limiting factor for such a phase and polarization modulated optical modulation format.

In this paper we investigate the optimization of the carrier phase estimation (CPE) within the digital intradyne coherent receiver and consider the impact of this for both OSNR and XPM-limited transmission.

Experimental setup

Fig.1 depicts the experimental setup for the transmitter, the re-circulating loop and the digital coherent receiver. At the transmitter, the output of an external cavity laser (ECL), emitting at a wavelength of 1550.116 nm, is pulse-carved using a Mach-Zehnder modulator (MZM) driven with a clock of 27.75 GHz. After pulse-carving, the signal is split into two parts using a polarization maintaining coupler and each tributary is DQPSK modulated using a nested-MZM. The two drive signals of the nested-MZM consist of a PRBS with length 2^{16} at a data rate of

27.75-Gb/s. The drive signals are shifted over 8 symbols with respect to each other in order to generate a pseudo-random quaternary sequence (PRQS) with length 4^8 . Both DQPSK modulated signals are then combined by means of a polarization beam splitter (PBS) to generate 111-Gb/s POLMUX-RZ-DQPSK modulation. To investigate the effect of XPM on the 111-Gb/s POLMUX-RZ-DQPSK signal, ten NRZ-OOK modulated signals, each with a data rate of 10.7-Gb/s, are combined with the 111-Gb/s signal using a 3-dB coupler. The OOK neighbouring channels are modulated using a MZM driven with a 10.7-Gb/s PRBS with length 2^{15} .

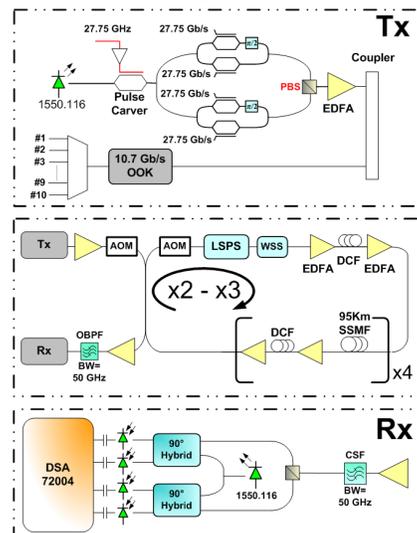


Fig. 1: System setup, WSS: wavelength selective switch, LSPS: loop synchronized polarization scrambler

The re-circulation loop consisted of a pre-compensation DCF with a CD of -1360 ps/nm followed by 4 spans of SSMF with a length of 95 km and an average span loss of 18.5 dB. Double stage EDFA-only amplification is employed, and the input power into the DCF is kept 5 dB lower than the SSMF input power. The inline DCF has a CD of -1530 ps/nm/span, which results in inline under-compensation of 85 ps/nm. At the receiver side, an optical band pass filter (OBPF) with a bandwidth of

50 GHz is used to de-multiplex the 111-Gb/s signal. The signal is then amplified and further filtered to guarantee a constant power into the receiver. A free running ECL laser with a linewidth of 100 KHz is used as a local-oscillator (LO) and the LO-to-signal ratio at the QPSK-mixer is kept to about 22 dB. The four outputs of the QPSK-mixer are detected using four single ended PIN/TIA photodiodes (PD). After the PDs, a DSA72004 digital storage scope samples the four tributaries at a sampling rate of 50 Gsamples/s and stores 2×10^6 samples from each tributary. For each measured point, 5 sets of data at different time instants were stored, to generate obtain a total of 2×10^7 bits. A PC is used for off-line processing the stored data, which was first re-sampled into exactly 2 samples/bit and then equalized by using a FIR filter with a butterfly structure [1]. Following the equalization, a carrier recovery is implemented to remove the frequency offset between the LO and the transmitter laser. The carrier phase estimator (CPE) technique employs the Viterbi & Viterbi algorithm [5], and was implemented as described in [6].

Experimental Results

Fig. 2(a) shows the BER versus launch power for the 111-Gb/s POLMUX-RZ-DQPSK after a transmission distance of 760 km, along with 10x10-Gb/s OOK neighbours, as function of the number of bits averaged in the CPE. For launch powers below -1dBm, transmission is mainly limited by the low OSNR at the receiver. In this case a performance improvement is obtained when the CPE averages the phase over more symbols. Therefore, the best performance is obtained in the case of 9 and 17 symbol CPE. For launch powers in excess of -1dBm, transmission is mainly limited by XPM-related impairments. Averaging over a shorter interval for CPE is now beneficial as the XPM induced phase changes cannot be averaged out.

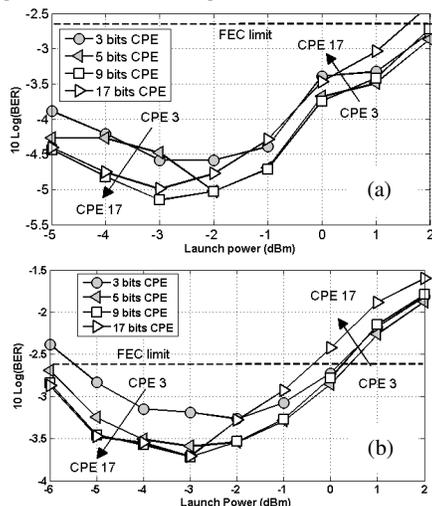


Fig. 2: BER results versus launch power after a transmission of: (a) 760 km (b) 1160 km

A similar behaviour is shown in Fig. 2(b), which represents the results after a transmission distance of 1140 km. In both cases an averaging length of 9 symbols for CPE provides the optimum performance.

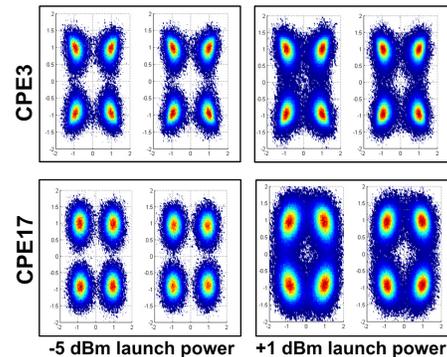


Fig. 3: Constellation diagrams for 2-polarizations

Fig. 3 shows the constellation diagrams after 1140 km when either linear (-5 dBm/ch) or non-linear effects (+1 dBm/ch) are dominant for both a 5 and 17 symbol CPE interval. A clear difference in the spread of the constellation points is evident in the case of +1dBm launch power. Finally, in order to emphasize the advantage of averaging over more symbols in CPE in case of a OSNR limited transmission, Fig. 4 depicts the BER results while spacing the 10x10.7-G/s OOK neighbours 200 GHz away from the 111-Gb/s signal. This shows a clear advantage of using a 17 symbol CPE interval compared to using only 3 symbols.

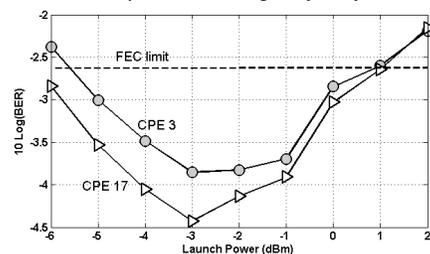


Fig. 4: Transmission results for 1140 km, with 200-GHz spacing from OOK neighbours

Conclusions

We experimentally demonstrated the effect of optimizing the CPE averaging interval for 111-Gb/s POLMUX-RZ-DQPSK modulation. We show that the length of the CPE averaging interval is dependent on transmission link parameters.

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