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Simultaneous compensation of PMD and CD in a 10.7Gb/s Field Trial based on the MLSE

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***Abstract*—**The performance of an electronic dispersion compensator based on the maximum likelihood sequence estimation (MLSE) is investigated in a 10.7Gb/s field trial under the simultaneous influence of polarization mode dispersion and chromatic dispersion.

I. Introduction

Polarization Mode Dispersion (PMD) is one of the major impairments in optical communication systems deployed with data rates of 40Gb/s and higher. This effect causes severe signal distortions even though newly installed fibers may have low average PMD values. Different methods have been proposed to combat this effect in the optical as well as in the electrical domain [1][2]. A further challenge exists for optical network systems in which old fibers have been deployed. Such relatively old fibers may exhibit fairly large average PMD values, which could even become the dominant impact if data rates of 10Gb/s will be transmitted through dispersion compensated metro and long-haul systems.

To mitigate the PMD problem, electronic dispersion compensators (EDC) seem to be quite promising as they are easy to implement and cost effective. Three types of EDC have been evolved in the near past. These are the feed forward equalizer (FFE), the decision feedback equalizer (DFE), and the maximum-likelihood sequence estimator (MLSE) [2][3][4]. Within these three EDC, the MLSE has the highest complexity but can be expected to deliver the best performance against impairments such as PMD and chromatic dispersion (CD).

In this paper, we present the results of a field trial using a commercial EDC based on the MLSE technology (CoreOptics). We demonstrate the EDC performance on two different field fiber configurations by measuring the bit error ratio (BER) in dependence on the optical signal to noise ratio (OSNR) under the simultaneous impact of PMD and CD. Detailed description of the EDC's operation has already been reported in [5]. An investigation of the same EDC was performed in a laboratory environment to compensate for the joint impact of chromatic dispersion and first-order PMD [6].

II. Experimental Setup

Fig. 1 and Fig. 2 show the laboratory and the field setups. An optical signal having the standard G.709 optical transport network (OTN) frame was generated by an optical bit error rate tester (BERT). The payload was a pseudo-random bit sequence (PRBS) of length 2^{31}-1. Its operation wavelength was at 1556.82 nm with an output power of 0.5 dBm. Prior to launching into the field link configuration, an erbium-doped fiber amplifier (EDFA) and a variable optical attenuator (VOA 1) were used to adjust the input power into the field to 5.0 dBm.

At the receiver side, a noise source with a second attenuator (VOA 2) was applied and coupled via a 3 dB coupler to adjust the OSNR whose values were measured with an optical spectrum analyzer at a resolution bandwidth of 0.1 nm. The tunable band pass filter (TBF) was used to filter out spectral noise and had a full width at half maximum (FWHM) of 1.0 nm. The third attenuator (VOA 3) kept the input optical signal into the device under test (DUT) – the CoreOptics receiver – at a constant -10.0 dBm power level. Finally, the equalized bits from the DUT were then optically forwarded into the optical BERT to perform the BER measurements.

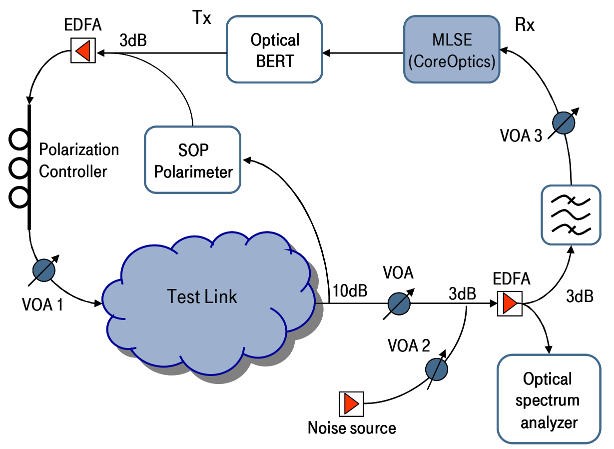

Fig. 1: Laboratory configuration

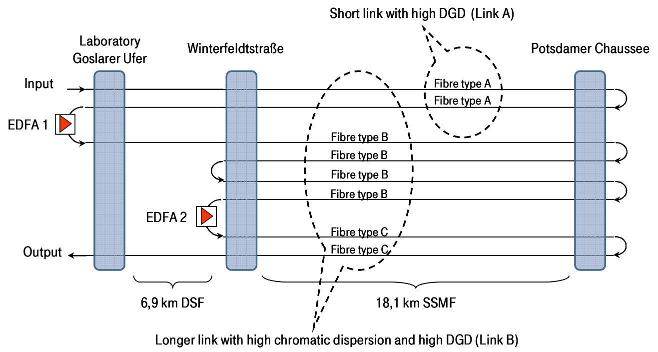

Fig. 2: Field fiber test configuration

In our field trials, two different fiber configurations were used which we call Link A and Link B. The field fiber configuration was buried between the labs of T-Systems in Berlin, Germany in the mid 1980s. Link A was without inline optical amplifiers and in Link B two amplifiers were used. To reach both link configurations from the laboratory, 6.9 km of buried dispersion shifted fibers (DSF) with relatively low measured PMD and CD values were used; these fibers were buried in 1996.

In order to monitor the instantaneous DGD for each fiber length, a polarimeter was used with a tunable probe laser set to the operating wavelength of the actual optical signal. Prior to each measurement, the optical signal was turned off and the probe laser was turned on in order to analyze the DGD performance of the field fiber configuration. After the BER versus OSNR performance was tested the same procedure was repeated so that the DGD values before and after each test were recorded. Furthermore, a manual polarization controller was inserted at the transmitter side to assure the same state of polarization (SOP) launch of both laser sources. The CD and the DGD values before and after the OSNR measurement for Link A (including 2×DSF) were 666.1 ps/nm, 93.3 ps and 92.9 ps and for Link B (including 4×DSF) 2639.9 ps/nm, 97.9 ps and 96.1 ps. The DGD values for both links are close to each other whereas the longer link has a higher overall CD.

III. Results and Discussion

The MLSE performance was evaluated by measuring the pre and post-FEC error rates. In order to count possible burst errors especially at low BER during our post-FEC measurements, the duration of each measured BER was at least 10 minutes. The results for back-to-back (btb), Link A (including 2×DSF) and Link B (including 4×DSF) are given in Fig. 3. The OSNR value for btb at a post-FEC error rate of 1E-11 is 12.4 dB. This is rather a large value compared with previous results [5][6]. One reason could be the relatively low extinction ratio (ER), which was 10.6 dB. In typical applications the ER is at least 13 dB. Another reason could be the high noise figure of the booster used at the receiver. Fig. 3 further shows the eye diagrams after the optical signal having propagated through both links respectively. All eye diagrams were measured prior to the receiver input of the MLSE.

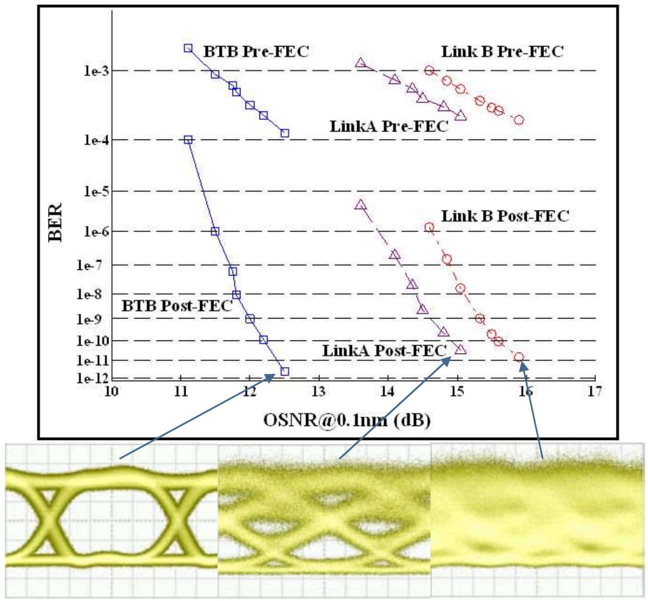

Fig. 3: BER vs. OSNR pre/post-FEC MLSE performance and corresponding eye-diagrams at the receiver input of the MLSE.

Link A shows an OSNR penalty of 2.75 dB and Link B a penalty of 3.75 dB at a post-FEC error rate of 1E-11 with respect to btb. These fairly low penalties indicate the superior performance of the MLSE with a required assumption of an excellent clock and data recovery of it. Furthermore, one would expect a linear increase in the OSNR penalty with the joint impact of PMD and CD. However, as PMD being the major contribution of errors to the transmitted signal, the addition of significant CD would rather add a minor contribution of further penalty to the performance of the MLSE.

IV. Conclusion

We have demonstrated the performance of a commercial EDC in a field trial where it applies the MLSE based technology. The unit allows the simultaneous equalization of the detrimental effects of PMD and CD that can be seen in fiber configurations typically deployed in core networks, especially for fiber plants with relatively old fiber spans having high PMD values. This effective compensation would enable service providers to introduce a cost effective and robust solution in their transmission systems in the backbone and metro network. It would also give the opportunity to upgrade such networks to 10Gb/s data rate with minimal disruption and without expensive new system designs.

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