Simultaneous Nonlinearity and Dispersion Compensation into an Embedded Link: Experimental Demonstration

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Abstract: We experimentally demonstrate for the first time, simultaneous compensation of nonlinearity and dispersion into an embedded link with strongly asymmetrical power profiles. Two configurations satisfying the mid-nonlinearity-temporal-inversion principle are tested.

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1. Introduction

In high bit-rate transmission systems, fiber nonlinear effects are among the main sources of signal degradation [1, 2]. Several techniques have been proposed in the literature to compensate these effects, such as the use of particular dispersion maps or signal regenerators. Much attention has also been paid to the techniques based on optical phase conjugation, potentially allowing for the simultaneous compensation of both dispersive and nonlinear effects.

The typically considered structure is based on the use of the so called mid-span spectral-inversion (MSSI) technique [3], where an optical phase conjugator (OPC) is positioned in the center of the link. Unfortunately, this configuration yields complete nonlinearity compensation only in the ideal case in which the power profile is perfectly symmetrical with respect to the midpoint of the link. Simulations show that nonlinearity compensation into an embedded link with standard (lumped amplification) power profiles can be obtained considering a more general approach called mid-nonlinearity-temporal-inversion (MNTI) [4, 5]. In this paper, we present and discuss the first experimental demonstration of simultaneous dispersion and nonlinearity compensation using two different configurations designed following the MNTI predictions. The performances are compared with those obtained utilizing a standard MSSI setup.

2. Tested configurations

In order to check the validity of the MNTI approach, we compared the performance of four different link configurations where the system impact of fiber nonlinearities has been enhanced by the use of high optical signal power. Bit-error-rate (BER) measurements have been performed in different system conditions to obtain a detailed analysis of the setup under test. Fig.1b and Fig.1d show the MNTI configurations under test, whose effectiveness has been theoretically demonstrated in [5], that have been obtained modifying two standard MSSI setups (Fig.1a and Fig.1c, respectively). In configuration b), nonlinearity compensation is obtained by adding a linear dispersive element at an amplifier site, while in d) an additional amount of nonlinear propagation has been inserted.

![Fig. 1. Considered structures: MSSI applied to a 6 and 5 spans-system, a) and c), and MNTI-based configurations, b) and d)
The solutions have been tested in a link composed by 6 and 5 spans of 100km each and the optical power input to fiber spans has been first set to 12 dBm, and then to 13 dBm, so to accumulate a significant nonlinear distortion.

3. Experimental setup and results

The transmitter used for the experiment is composed by two cascaded lithium-niobate MZ-modulators used to generate 10 Gb/s RZ pulses with a full-width-half-maximum of 45 ps. At the receiver’s photodiode, optical power is varied by means of an optical variable attenuator, and the BER value is registered. The line is composed of non-zero dispersion-shifted-fiber in the normal dispersion regime ($D=-2.9$ ps nm$^{-1}$ km$^{-1}$; $D_2=0.067$ ps nm$^{-2}$ km$^{-1}$; $A_{	ext{eff}}=55$ µm$^2$; $\alpha=0.22$ dB km$^{-1}$). The phase conjugation device used for the experiment is based on a fiber-pigtailed reverse-proton-exchange waveguide realized on a periodically poled lithium niobate (PPLN) substrate.

Regarding the configurations reported in Fig. 1a and Fig. 1b, the BER curves obtained using 12 dBm of optical input power for two different values of the pseudo-random bit-sequence (PRBS) length ($2^{11}$ and $2^{31}$) are reported in the left side of Fig. 2, together with the Back-to-Back data. The penalty introduced by the OPC is negligible. Regardless of the pattern length, the MNTI configuration results in a performance improvement of more then 1 dB with respect to standard MSSI. Comparing the BER curves obtained raising the optical power from 12 to 13 dBm, the advantage given by the MNTI configuration is even more evident due to the increased impact of fiber nonlinearities, as can be seen in the right side of Fig. 2. At the BER-floor level observed using the MSSI configuration, an advantage of more than 7 dB is given by the MNTI approach, while the floor level is simultaneously reduced by more than two decades.

4. Conclusions

We experimentally demonstrated that, even into an embedded link, the use of a properly modified phase-conjugation setup allows for a significant reduction of the nonlinear impairments, while also yielding substantial dispersion compensation. This has been demonstrated by comparing the system impact of the nonlinear effects depending on the link configuration, optical power, and PRBS length. Two different MNTI-based configurations resulting in a reduction of the nonlinear effects have been tested, demonstrating the validity of this approach.

Further experiments using different configurations and modulation formats are currently being conducted.

5. References