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(article starts on next page)

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Feature issue introduction: Nonlinearity mitigation for coherent transmission systems

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Abstract: The authors introduce the feature issue on nonlinearity mitigation for coherent transmission systems.

OCIS codes: (060.2330) Fiber optics communications; (190.4370) Nonlinear optics, fibers.

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1. Introduction

Fiber nonlinearity remains one of the most serious limiting factors in long-haul fiber optic transmission reach and capacity. All long-haul systems are limited by additive amplifier noise in the low-power regime and nonlinear distortions in the high-power regime, and they must therefore have an optimum signal power at which the bit-error ratio is minimum. The amplified spontaneous emission noise from the inline amplifiers is close to the fundamental

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limit and hard to reduce further. The nonlinearity, however, is partly deterministic and signal dependent, and thus has a potential for mitigation. Nonlinear mitigation has the potential to increase transmission distances, enable higher spectral efficiencies and is thus widely regarded as one of the most important research areas in optical communications.

The situation is however complicated by the large amounts of dispersion in long-haul links, that gives the otherwise instantaneous Kerr-nonlinearity a memory that can span sequences as long as thousands of symbols. The situation can be orders of magnitude worse if crosstalk from 100 wavelength channels and 10 spatial modes are accounted for as well.

The emergence of coherent transmission and digital signal processing (DSP) has, however, opened up new possibilities to mitigate the nonlinear impairments in the electronic domain. Approaches such a digital backpropagation (DBP), Volterra equalizers, and nonlinear-tolerant modulation formats are examples of schemes that are being explored. Also optical mitigation schemes are of interest, and approaches based on optical phase conjugation and phase sensitive amplifiers are showing promise. In addition, improved transmission fiber design, which is a complicated optimization game between attenuation, dispersion and nonlinearity can still lead to improved systems.

Even estimation and bounds of the channel capacity of long-haul links is a difficult problem due to the instantaneous nature of the Kerr nonlinearity, paired with the long memory of the fiber dispersion.

This feature issue is intended to give a snapshot of the current research in this active area. It consists of 2 invited and 12 contributed papers.

The first invited paper, by Hasegawa et al. [1], covers fiber design and figure of merits to optimize transmission performance. Optical mitigation is discussed in two papers; Bottrill et al. [2] uses phase-sensitive amplifiers to regenerate signals periodically, whereas Hu et al. [3] implements a sequence of optical phase conjugators.

Two approaches based on nonlinear-tolerant modulation schemes are investigated next. Guiomar et al. [4] optimizes the number of subcarriers while maintaining bandwidth to minimize nonlinearities, while Skidin et al. [5] exploits the different distortions of the 3 rings that forms the rectangular 16-QAM constellation.

The second invited paper, by Cartledge et al. [6], is a broad review of different mitigation schemes based on digital signal processing, that should give the reader a nice overview of this area. The paper by Sorokina et al. [7], tackles the problem of compensating nonlinearities in spatially multiplexed systems, using a scheme based on machine learning algorithms.

Digital predistortion and backpropagation are in focus for the next five papers. In [8] Galdino et al., quantifies DBP in presence of transmitter noise. Goncalves et al. [9] combines DBP and Volterra equalization to demonstrate improved performance, and Lavery et al. [10] studies the performance differences for backpropagation, predistortion and their combinations. In [11], Czegledi et al. introduces a scheme that can account for polarization mode dispersion in multi-channel DBP. Xu et al. quantifies the efficiency of DBP for different modulation formats in [12].

Channel models are crucial in order to well estimate distortions and not least channel capacity, and in the two final papers nonlinear fiber channel models are in focus. Gagni et al. [13] presents a simplified Volterra model that may lead to simplified compensation schemes. Finally, Sorokina et al [14] use a derived channel model and a novel modulation scheme to give a lower (but increasing with power) bound on the channel capacity for the nonlinear fiber channel.

To conclude, we believe this feature does indeed give a broad overview of the contemporary research of fiber optic nonlinearity mitigation with a plethora of novel and important results.

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