Asia-Pacific Optical Communications (APOC 2007), Wuhan/China, November 2007, (invited), paper 6783-37

Overview of important results concerning the application of optical phase conjugation to increase system robustness

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Keywords: Optical phase conjugation, differential quadrature phase shift keying, long-haul transmission, digital transmission systems, optical regeneration, dispersion compensation.

Optical phase conjugation (OPC) is a well know technique to compensate for deterministic impairments in fiber-optic transmission systems. In this paper, transmission experiments of 40-Gb/s DQPSK will be discussed showing simultaneous compensation of nonlinear effects and chromatic dispersion. In order to enable long-haul transmission experiments, a re-entrant re-circulating loop is employed as described in [1-2].

The performance of OPC is compared to the performance of DCF for chromatic dispersion compensation, transmitting 26 channels modulated with 42.8 Gbit/s RZ-DQPSK. The feasible transmission distance for a Q-factor ~10 dB is limited to approximately 5,000 km and 3,000 km for the OPC and the DCF based configuration, respectively. When the Q-factor as a function of the transmission distance is observed, at shorter distances, the Q-factor of the OPC based configuration is about 1 dB higher than that of the DCF based transmission system. Up to 2,500-km transmission a linear decrease in Q is observed for both configurations. After 2,500-km transmission, the Q-factor of the DCF based configuration deviates from the linear decrease whereas the OPC based performance is virtually unaffected. We conjecture that the performance degradation of the DCF aided transmission results from SPM induced nonlinear impairments, including nonlinear phase noise. Additional nonlinear phase noise impairments are caused by modulator imperfections. In the OPC aided transmission experiment the SPM induced nonlinear impairments resulting from both modulator imperfections and transmission line are reduced through mid-link OPC [3], resulting in an increased transmission reach.

As OPC compensates for deterministic nonlinear impairments only, the most significant impairment that fundamentally can not be compensated for is polarization-mode dispersion (PMD). Recently many different methods have been proposed to compensate for linear impairments (PMD and chromatic dispersion) in the electrical domain, such as for instance coherent detection in combination with FIR filters [5] and maximum-likelihood sequence estimation (MLSE) [6]. The dispersion of the complete transmission line can be compensated for with these techniques, but this would require powerful electrical dispersion compensators (EDCs) that are expensive and high power consuming [7]. By placing one OPC in the middle of such a transmission link, the gross dispersion is compensated for and the nonlinear tolerance can be increased. A "weak" EDC can subsequently be used to compensate for residual chromatic dispersion and PMD [7]. Another method to effectively compensate for PMD and chromatic dispersion is by using an advanced modulation format such as orthogonal frequency division multiplexing (OFDM) [8]. However, low input powers are required to minimize nonlinear impairments. Thus by adding OPC to such a transmission link the nonlinear tolerance could be significantly enhanced.

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