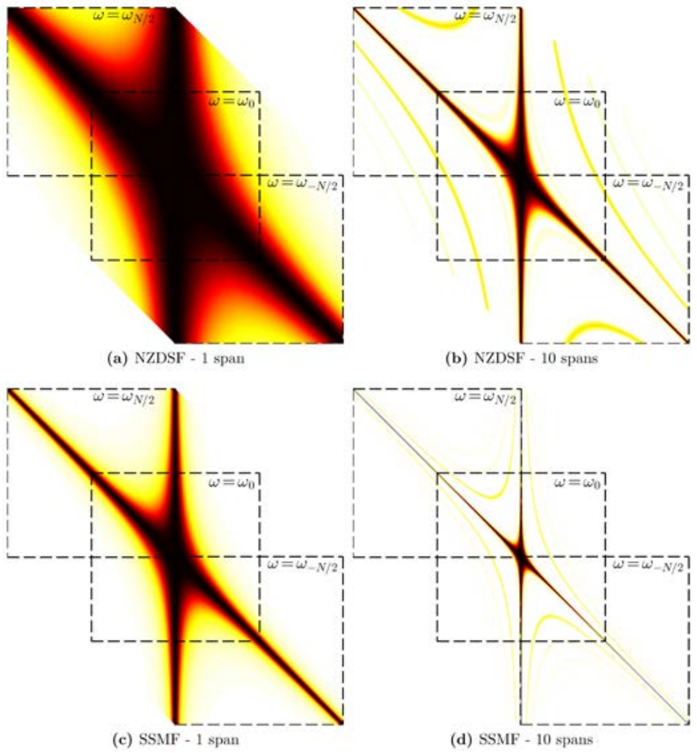
Digital Nonlinear Equalization in Very-High Speed Coherent Optical Transmission Systems

The exponentially growing traffic demand in optical core networks has exhausted the linear fiber capacity. We develop novel digital equalization strategies in order to counteract the signal distortion imposed by fiber nonlinearities. An efficient compensation of nonlinear distortions will translate into increased signal reach and spectral efficiency, enabling the deployment of next-generation 400G and 1T coherent optical channels.



PROJECT WEBPAGE URL
http://www.av.it.pt/dineq/

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Funding Agencies	
FCT	**104,006€**
Start Date	01/07/2013
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Indicators	
Journal Papers	15
Conference Papers	27
Patents	1
Concluded PhD Theses	3
Concluded MSc Theses	3

Two Main Publications

F. P. Guiomar, S. B. Amado, R.M.F. Ferreira, J.D. Reis, S. M. R. Rossi, A. C. Chiuchiarelli, J. R. F. O. Oliveira, A. Teixeira, A. N. Pinto, **Multi-Carrier Digital Backpropagation for 400G Optical Superchannels**, IEEE/OSA Journal of Lightwave Technology, Vol. 34, No. 8, pp. 1896 - 1907, April, 2016

S. B. Amado, F. P. Guiomar, N. J. Muga, J. D. Reis, A. Teixeira, A. N. Pinto, **Low Complexity Advanced DBP Techniques for Ultra-Long-Haul 400G Transmission Systems**, IEEE/OSA Journal of Lightwave Technology, Vol. 34, No. 8, pp. 1793 - 1799, April, 2016

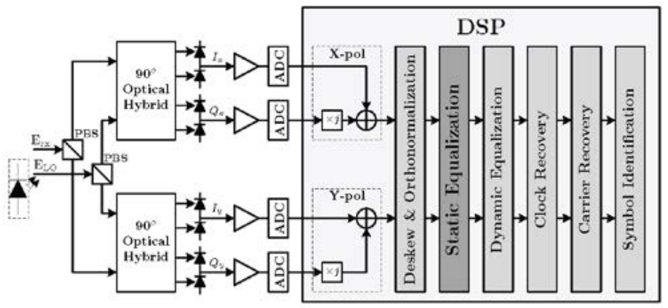

Fig. 1 Physical structure and general DSP subsystems of a polarization-diversity digital coherent optical receiver.

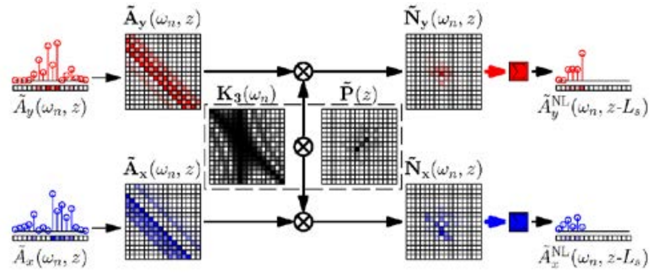

Fig. 2 Parallel implementation of the dual-polarization VSNE algorithm.

GENERAL MOTIVATION AND OBJECTIVES

The exponentially growing traffic demand in optical core networks has exhausted the single-mode fiber capacity within the linear regime. We propose to develop novel digital equalization strategies in order to counteract the signal distortion imposed by fiber nonlinearities, in very-high speed (>= 100 Gbit/s/ch) and ultra-dense (>= 4 bit/Hz) multi-wavelength coherent optical transmission systems. An efficient compensation of nonlinear distortions in long-haul optical fiber systems will translate into increased signal reach and spectral efficiency, enabling the deployment of next-generation 400G and 1T optical channels. Following these ideas, and building on the previous team's work and experience on this topic, the main scientific objectives of the DINEQ project are:

- Development of digital equalization algorithms for the mitigation of intra- and inter-channel nonlinearities in single-mode WDM transmission systems;
- Optimization of computational effort of digital nonlinear equalizers;
- Experimental validation of the developed algorithms and analytical tools by means of offline processing of experimental data;
- Implementation of reduced-complexity nonlinear equalization algorithms in real-time, resorting to high-speed and flexible hardware platforms.

CHALLENGE

The modern coherent optical receiver is able to extract information from the amplitude and phase of the two orthogonal polarizations of an optical field making possible to mitigate most of the signals distortions that occurs during propagation. However, in order to allow real time processing of signals that carry hundreds of gigabits per second very computationally efficient algorithms are required. Up to the present, computational requirements have preclude the introduction in deployed systems of equalization of nonlinear distortions. The major challenge of this project is to prove and to show how it is possible to have equalization of nonlinear distortions in real time in hundreds of gigabits per second transmission systems. Our efforts include the extension of nonlinear equalization to polarization-multiplexing and WDM transmission. We will focus a great deal of our attention into the problem of inter- and intra-channel nonlinear equalization, developing efficient and moderate complexity techniques to partially mitigate cross-phase modulation (XPM) and four-wave mixing (FWM) distortions.

WORK DESCRIPTION AND ACHIEVEMENTS

The development of novel nonlinear equalizers for WDM transmission systems was the core project task. This task comprised the development of digital equalization algorithms for the mitigation of inter- and intra-channel nonlinearities in WDM transmission systems relying on single-mode fibers. We proposed a novel closed-form time-domain (TD) VSNE for the mitigation of Kerr-related distortions in polarization-multiplexed (PM) coherent optical transmission systems. Employing novel TD approximations, we demonstrated the equivalency between the VSNE algorithms formulated in time and frequency domains. In order to enhance the computational efficiency, we inserted a power weighting time window in the TD-VSNE, yielding the weighted VSNE (W-VSNE) algorithm. The proposed W-VSNE was experimentally demonstrated in a WDM (75 GHz flexigrid) ultra-long-haul (ULH) transmission system composed of 5 dual-carrier PM-16QAM 400G super channels. We have shown a reach improvement of 600 km over linear equalization, using only 6 digital back-propagation (DBP) stages for an optical link composed of 5000 km of ultra-low loss (ULL) fiber. The performance of the W-SSFM technique was experimentally evaluated and compared against the standard and widely used split-step Fourier method (SSFM) algorithm, showing a very good comprise in terms of performance versus computational requirements.