INVITED

NONLINEARITY COMPENSATION IN COHERENT OPTICAL COMMUNICATION SYSTEMS

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In this talk compensation of nonlinear fiber optic impairments will be addressed. Different methods will be reviewed and explained.

Currently, the communication technology and thereby the ability to generate, process and store digital information constitutes a backbone of our modern society. Modern digital communication technology finds applications ranging from chip-to-chip communication found in/and between our computers, long haul transport networks carrying internet traffic, and space communication for collection of scientific data. Each of the applications can be addressed using wireline, wireless or optical fibre communication. So far, optical fibre has the advantage in terms of bandwidth and transmission distance over the other technologies, and optical fibre communication is therefore the preferred choice when transferring large amount of data like it is done in today's networks.

Even though the optical fibre has large bandwidth, the never ending introduction of new bandwidth hungry broadband services and content such as YouTube, Facebook, My Space, High Definition TV, etc., has resulted in a significant growth of the total data traffic, and this demand on bandwidth is strongly expected to continue [1-3]. This explosive growth of services pushes the demand for bandwidth by more than factor of 2 every 18 months [2]. Additionally, the upcoming applications where communication technology is involved such as tele-medicin, autonomous sensor networks, grid computing are expected to have a huge impact on the future demand on bandwidth [1].

Given the constraints of the optical fibre channel and taking into consideration the future Petabit capacity demands, an essential parameter to characterize an optical communication channel is its spectral efficiency, S [1-3]. The spectral efficiency expresses how many bits per second [bits/s] can be transmitted in a specific bandwidth [Hz]. The achievable spectral efficiency over a certain transmission distance D, the so-called SxD product, should exceed 100 b/s/Hz x 1000 km in order to reach the capacity demands projected in 10-15 years [1-3]. It has been shown that for long distance (>1000 km) communication systems, employing traditional technology, the spectral efficiency is currently limited to 5.6 b/s/Hz due to phase noise and optical fibre nonlinear impairments [4], see spectral efficiency vs. power chart in

In order to accommodate for the future bandwidth requirements, during the last four years, optical communication systems have experienced a paradigm shift by moving from a primitive and very inefficient way of encoding data (intensity modulation) to more sophisticated and spectrally efficient modulation techniques. However, in order to realize spectrally efficient optical communication systems there are still many scientific challenges to tackle. This is due to the fact that optical fibre channel is nonlinear and thereby limiting the achievable transmission distance. Therefore, the race on how to increase spectral efficiency □ transmission reach product is on. Additionally, phase noise associated with the lasers used for data modulation and demodulation is another limiting factor.

The application of digital signal processing (DSP) based coherent detection has allowed optical communication systems to operate closer to the nonlinear Shannon capacity limit by employing spectrally efficient modulation formats. Therefore, there is currently a lot of ongoing research on DSP based algorithms for signal detection and optical fibre channel impairment compensation. Linear signal processing algorithms can be effectively used to compensate for linear fibre channel impairments and have been demonstrated very successfully for higher order quadrature amplitude modulation (QAM) signaling. However, for long-haul systems employing higher order QAM, nonlinear optical fibre impairments can severely limit the transmission distance as well as the achievable total capacity [4]. Mitigation of optical fibre nonlinearities is therefore very crucial as it will allow launching more power into the fibre and thereby enhancing the transmission distance. Additionally, mitigation of fibre nonlinearities will help us reduce the nonlinear crosstalk from the neighboring channel in a multi-channel transmission system.

In this paper, we show numerically and experimentally that expectation maximization (EM) algorithm is a powerful tool in combating system impairments such as fibre nonlinearities, inphase and quadrature (I/Q) modulator imperfections and laser linewidth. The EM algorithm is an iterative algorithm that can be used to compensate for the impairments which have an imprint on a signal constellation, i.e. rotation and distortion of the constellation points. The EM is especially effective for combating non-linear phase noise (NLPN). It is because NLPN severely distorts the signal constellation and this can be tracked by the EM. The gain in the nonlinear system tolerance for the system under consideration is shown to be dependent on the transmission scenario. We show experimentally that for a dispersion managed polarization multiplexed 16-QAM system at 14 Gbaud a gain in the nonlinear system tolerance of up to 3 dB can be obtained. For, a dispersion unmanaged system this gain reduces to 0.5 dB.

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Darko Zibar was born in Belgrade, ex-Yugoslavia, on Sepetmber 9, 1978. He received the M.Sc. degree in telecommunication and Ph.D. degree in optical communications from the Technical University of Denmark, Lyngby, Denmark, in 2004 and 2007, respectively. He was a Visiting Researcher with Optoelectronic Research Group, University of California, Santa Barbara, January 2006 to August 2006, and in January 2008 where he was involved in coherent receivers for phase-modulated analog optical links. From February 2009 to July 2009, he was a Visiting Researcher with Nokia-Siemens Networks where he worked on 112 Gb/s polarization multiplexed systems. He is currently Associated Professor at DTU Fotonik, Technical University of Denmark. His research interests include coherent optical communication, with the emphasis on digital signal processing.

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