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Coherent Detection of Four-Dimensional Optical Modulation Formats.

ABSTRACT - Masterthesis

The continuous increasing demands on the network data capacity requires new techniques for data transmission over the optical network systems. Coherent optical communication system considered as most promising technique for enhancing the spectral efficiency and fulfilling the ever increasing bandwidth requirements. It provides access for both phase and amplitude of the received optical signal, enabling multilevel modulation formats and improving the spectral and power efficiency.

With the recent advances in high speed digital signal processing (DSP) combined with the coherent detection technology, it is possible to digitize the electrical signal at the output of coherent receiver and then process it by mean of DSP unit. Thereby, the complex field of the received signal (in-phase and quadraure) is fully recovered. In addition, polarization multiplexing and polarization tracking algorithms permit data transmission in both orthogonal polarization components. Furthermore, it gives the possibility to compensate for different transmission impairments hence both phase and amplitude information are available.

The Binary phase-shift keying (BPSK) modulation format, which has a one-dimensional constellation space, is usually considered as the most power efficient format among all other modulation formats at a given bit rate [1, 2]. However, it has been shown recently by Karlsson and Agrell [1-3], that there are modulation formats that have better sensitivities than BPSK. Among these, they have demonstrated a Polarization-switched quadrature phase-shift keying (PS-QPSK) format that gives best possible sensitivity. This novel format can be practically implemented using the already available hardwares. Nevertheless, modification of existing DSP algorithms is required.

Laser phase noise is considered as a major impairment in coherent transmission systems that lead to performance degradation in systems based on phase-shift keying (PSK), where the information bits are encoded into the phase of the optical carrier. Therefore, estimation of the laser phase noise is one of the essential functions of the signal processing.

This Thesis is structured as follows: Chapter 2 gives an overview of 4-D optical signal, introduces a PS-QPSK as a most power efficient format, describes possible transmitter structures and finally analyses the polarization diversity coherent receiver used to detect the PS-QPSK and explains the different DSP functions.

Chapter 3 first explains the phase noise problem associated with a laser linewidth and shows the influences on the system performance. Afterwards, discuss different carrier synchronization techniques that can be utilized to cope with laser phase noise, then presents three different carrier phase estimation (CPE) algorithms for digital carrier phase recovery. First, the standard algorithm for QPSK signal the Mth-Power feed-forward algorithm. Second, a modified algorithm that works in both polarization jointly named the Joint-polarization carrier phase estimation. Finally, a proposed algorithm implemented particularly for PS-QPSK called Polarization decision Joint polarization Mth power phase estimation algorithm.

Chapter 4 is devoted for numerical simulations and results discussions, simulates the PSQPSK transmitter and receiver and explains the results, implements the Back-to-back system performance and numerically compare the performance of PS-QPSK signals with PDM-QPSK signals using offline DSP, evaluates the proposed CPE algorithm in presence of laser phase noise and discuss its tolerance against high laser linewidths.