An Enhanced Combining Technique of Homodyne ASK Optical System with Laser Phase Noise

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***Abstract*—A new method to detect binary optical homodyne amplitude shift keying (ASK) signals in the presence of laser phase noise and receiver shot noise is presented. This method is rely on an efficient least square (LS) algorithm to mitigate the negative effects of phase noise error. The error rate performance of non-ideal ASK system is investigated under LS detection and the signal-to-noise ratio (SNR) gain penalty is observed. To show the effectiveness of the proposed LS combining technique we compared our results for non-ideal systems with some previous results in the literature. The numerical results obtained through this work showed that LS technique has the ability to reduce the SNR gain penalty caused by the lasers phase error, and hence, can be used in any wire-line or wireless coherent systems suffer from imperfect (non-ideal) phase recovery.**

Index Terms— Homodyne ASK, Laser phase noise, Partially coherent detection.

I. Introduction

Coherent (heterodyne or homodyne) optical detection offers better error rate performance compared to direct detection (DD). The performance advantage of coherent detection over DD is mainly due to two factors: the gain resulting from the use of a high-power local laser signal at the receiving side, and the employment of sophisticated modulation techniques. The trend in modern communication systems is towards the use of digital modulation techniques such as ASK, phase shift keying (PSK) and frequency shift keying (FSK) which are possible in coherent detection systems. Variations of these basic techniques can also be used, often resulting in substantial performance advantages. In spite of these advantages, coherent reception is rather complicated because a strong local laser optical signal is required. The polarization state of the local laser must be perfectly matched to that of the received signal. This condition usually requires a sophisticated polarization control scheme.

It has been known for decades that optical homodyne detection provides better performance and is inherently 3-dB more sensitive than optical heterodyne detection. However, homodyne systems require that the local oscillator (LO) has the same frequency and phase as the incoming data signal, i.e., the data signal and the LO are equal and locked to each other [1]. One previous approach for carrier recovery includes transmitting the carrier along with the data signal [2], [3], [4]. With this approach, the carrier occupies some part of the spectrum and polarization state suffers from fiber loss and can accumulate phase noise. Another approach is to have a local laser oscillator in the receiver, for which a phase-locked loop (PLL) and signal processing algorithms ensure the locking of the local laser to the same frequency and phase [5]. However, this tends to be fairly complex and requires time to lock. Additionally, there have been optical methods to recover the carrier of an incoming data signal using nonlinear processing, but these techniques typically required an optical feedback loop for stabilization [5], [6]. Recently, with the advent of high-capacity wave-division multiplexing (WDM) transmission technologies, spectral efficiency has become one of the main concerns of researchers [7], [8] . An ultimate goal therefore would be to enable optical homodyne detection for which the local laser oscillator is automatically locked in frequency and phase to the incoming data signal without the need for feedback or phase/frequency tracking [9], [10], [11], [12], [13], [14].

The performance of coherent optical systems in the presence of both additive shot noise and laser phase noise has been the subject of extensive studies. The current state of this research is that accurate performance evaluations can be made for different modulation schemes using approaches that do not take into account the phase noise process. Some original solid works in this regard can be found in the old literatures [15-18]. Foschini and Greenstein [15] considered both shortening the bit period and using a postdetection lowpass filtering for FSK systems. Their results showed that performance gains could be achieved by both approaches. Postdetection filtering has also been considered in [16]. On a different track, the authors in [17] used another approach to improving differential phase shift keying (DPSK) performance by repeated transmissions of a signal over several chips in one bit period. A majority logic decoding technique for homodyne PSK receiver was proposed by Irshid and Kavehrad [18]. In this approach the receiver divides the original bit interval into N subintervals and decides whether the signal in each subinterval is $+1$ or 1 using an integrate and dump filter followed by a sign detector. By selecting N to be odd, a majority logic decoder is used to make the final decision based on the outcomes of the decisions on the subintervals.

More recently the authors in [5] provided some implementation and experimental results for a robust phase locking technique considering to a 10 Gb/s binary homodyne ASK signals which showed an improved performance