Robustness of Coherent SPE-OCDMA to Combined Dispersion Impairments

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Abstract: The sensitivity of spectrally phase encoded OCDMA performance in an environment of chromatic dispersion plus polarization mode dispersion with several signature sequence families is investigated.

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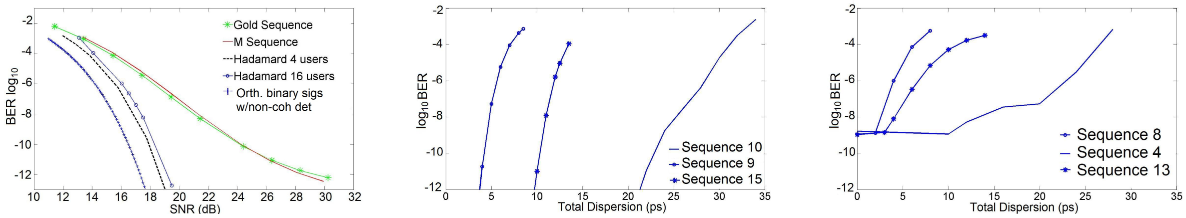
1. Introduction

The purpose of this work is to report the combined effects of chromatic dispersion and polarization mode dispersion (PMD) on the performance of a coherent optical code division multiple access (OCDMA) system over fiber optic cable for two families of signature sequences. The SPOT ([**S**]PE [**P**]hase and polarization diversity (PPD) combining, [**O**]CDMA [**T**]echnique) architecture [1] uses the simple, but effective PPD combiner [2] for coherent demodulation of the SPE [3] signal in a robust and economical way, avoiding nonlinear optics and phase locking while cancelling beat noise and most performance-limiting multiple access interference (MAI). Photonic component impairments tend to destroy the orthogonality between users' signals, thus elevating MAI levels. Dispersion is an important impairment to understand and control.

A recent study of SPOT performance for several families of signature sequences [4] shows that BER performance in chromatic dispersion is sensitive to the SPE waveform shape, with those having the highest energy concentrations at the pulse edges experiencing greater BER than pulses with more uniform energy distributions across the interpulse interval. To isolate the effects of specific impairments, [4] assumed no polarization rotation, and the receiver used only a phase diversity combiner.

This work reports on the combined effects of polarization mode dispersion (PMD) and polarization loss in the optical components of the SPOT signal path and uses a full PPD combiner. In the configuration of interest, the spectral comb of a single, mode-locked laser drives many SPE's, each using a distinct signature sequence. The SPE signals are then modulated with data, recombined, and transmitted along a single fiber to each user, where the desired signal is demodulated with the appropriate sequence. The unmodulated spectral comb is provided on a second fiber. For more detail, see [1]. In the current work, Hadamard sequences were chosen because they were shown to be the most power efficient (Fig 1a). For Hadamard (H) sequence 10 (H-10), the pulse energy is concentrated at the center of the interval, away from the pulse edges, so the probability of a (10 → 11) error is small, even with pulse stretching caused by dispersion, while energy for H-15 is relatively uniform across the pulse (See [4] for waveforms.).



(a) Power Efficiency (b) Chromatic Dispersion, Hadamard Sequences (c) Chromatic Dispersion, Gold Sequences

Fig. 1: SPOT BER without PMD [4]

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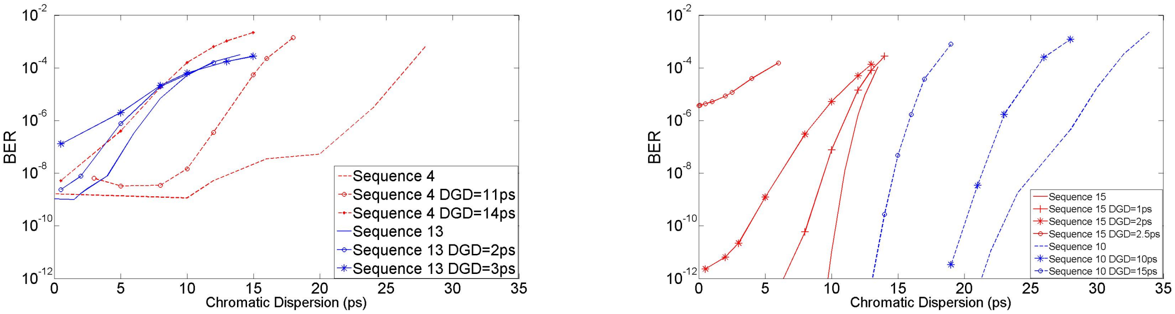
Gold sequences were chosen because they tended to perform well for relatively large values of chromatic dispersion. With Gold (G) sequences, G-4 was chosen for this study because of its excellent performance with total chromatic dispersion, and G-13 was chosen for contrast . At BER = 10^{-09}, H-10 tolerated about 23 ps of dispersion and H-15, about 11 ps (Fig. 1b), while G-4 tolerated 10 ps and G-5, 5 ps (Fig 1c).

This study shows the effects on BER when both chromatic dispersion and polarization mode dispersion (PMD) are introduced. The two fibers carrying the local reference and user data signals are assumed to have the same length and to experience the same dispersion phenomena. Total chromatic dispersion is introduced by varying the first order group velocity dispersion (GVD) value of each fiber component. PMD is introduced using the VPI PMD_Emulator module which supports pure first order PMD as well as several higher-order PMD emulators. The deterministic mean differential group delay (DGD) is set in each transmitting fiber to evaluate the effects on BER introduced by PMD. The transmitter is set to an azimuth of $\pi/4$ in order to maximize the power splitting between the fast and slow polarization axes for the first order PMD analysis. For each plot, a fixed level of mean DGD is set and BER is determined as a function of total chromatic dispersion.



(a) Gold Sequences

(b) Hadamard Sequences

Fig. 2: Effects of PMD and Chromatic Dispersion for Two Sequence Families

Clearly, both PMD and chromatic dispersion degrade SPOT system performance. For H-15, PMD is the more limiting factor. As DGD increases, the slope of the plot of BER vs total chromatic dispersion decreases and for H-10, increasing DGD resulted in a left shift of the whole BER curve. A similar affect can also be found for the Gold sequence case, although it is not so pronounced because the difference in pulse energy descriptions is less striking.

References

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