

Sequences for Impairment Mitigation in Coherent SPE-OCDMA

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Abstract: Robust performance of spectrally phase encoded OCDMA with key impairments depends on the encoding sequences, according to correlation properties and pulse shapes.

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1. Introduction

The need for increased fiber optic network flexibility, security, and throughput has boosted interest in optical code division multiple access (OCDMA). Spectral phase encoded (SPE) [1] signals demodulated with phase and polarization diversity (PPD) combining [2] receivers constitute a SPOT [(S)PE (PPD), (O)CDMA (T)echnique] [3] architecture that cancels beat noise and multiple access interference (MAI) without using phase locking or nonlinear optics. When orthogonal SPOT waveforms are subject to impairments such as dispersion and signal-to-reference delay, orthogonality is lost, and MAI results. This work shows how the properties of the SPE pulses interact with certain impairments to impact the system bit error rate (BER). OOK-modulated SPOT signals from a single source plus the unmodulated downstream optical comb are transmitted downstream to several receivers (details in [3]). In each a PPD correlates the K input signals with the SPE-encoded downstream (reference) comb to de-spread the desired signal coherently. Binary sequences from each of three widely used families [orthogonal Hadamard (H) sequences of length N [4], the $N = 2^k - 1$ cyclic shifts of a maximal length (m) sequence [5], and the length $N = 2^k - 1$ Gold (G-) sequences [6]] encode a 40 GHz stream of 500 fs pulses (Fig 1); $N = 15$ or 16.

2. Noise and Impairments

The 18 dB SNR for a BER of 10^{-9} (Fig. 2a) falls between the 15.6 dB shot noise and the 21.6 dB thermal noise limits [7]. Delay and dispersion are applied at an impairment-free SNR of 22 dB. G- and m-sequences achieve a BER of 10^{-9} . With no impairments, BER for H-sequences drops exponentially with SNR, but for G- and m-sequences with large SNR, the BER exhibits an *error floor* due to non-orthogonality. For low SNR, BERs for all sequences converge (Fig. 2a) because performance is dominated by noise and not non-orthogonality. For a *relative delay* of one pulse

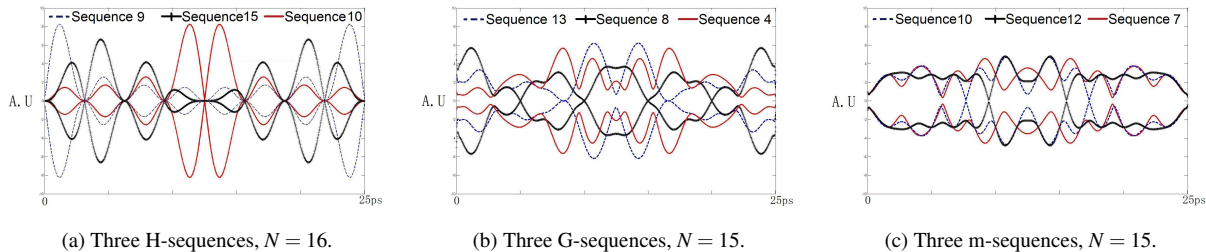


Fig. 1: Typical spread waveform envelopes

width, 4-user systems with m- and some H-sequences achieve $BER < 10^{-9}$ (Figs. 2b and 2c). BER vs *total dispersion* (TD) (Fig. 3) varies significantly among sequences in each family and among families. For m-sequences (Fig. 3a), $BER < 10^{-9}$ for $TD < 5$ ps. For H- and G-sequences (Figs. 3a,b) BER is sensitive to the specific sequence.

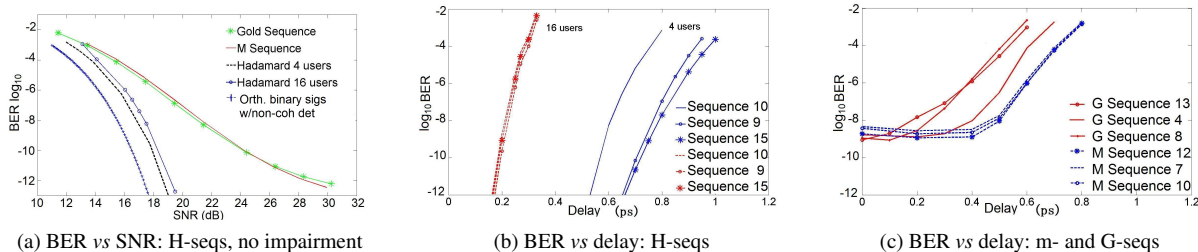


Fig. 2: SPOT Performance

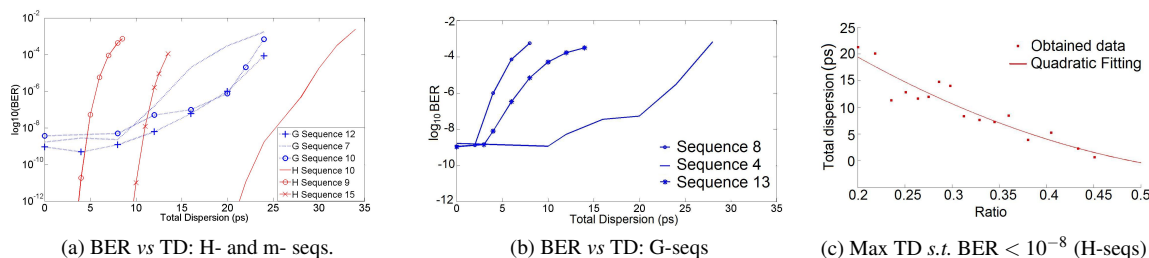


Fig. 3: SPOT Performance with Dispersion

3. Discussion and Conclusions

Impairment-free BER of Fig. 2a is proportional to $0.5 \cdot \exp(-0.5 \cdot SNR)$, the BER for noncoherent binary orthogonal signaling. The error floor (Fig. 2a) is due to MAI caused by non-orthogonality; the receiver is *MAI limited*: increased SNR does not appreciably reduce BER. Only small relative delays are tolerated, but a synchronous downlink can be achieved by delay adjustment during installation. Because delay and dispersion (Figs 2, 3) for most m- and G-sequences are flat at minimum BER, these sequences offer more robust performance with these impairments than H-sequences. SPOT waveforms with high energy concentration at the pulse edges (Fig 1) are less tolerant of dispersion. To quantify this, the maximum TD for which $BER \leq 10^{-8}$ vs the ratio of the average power in the first and last deciles to the total average pulse power (Fig 3c) supports the conjecture. Thus, with carefully chosen sequences, impairments in coherent SPE-OCDMA can be successfully mitigated.

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