Frequency Line Pairing for Heterodyne OCDMA

Yi Yang, A. Brinton Cooper III, Jacob B. Khurgin

***Abstract*—A novel OCDMA scheme uses spectral line paring to generate signals suitable for heterodyne decoding. Both signal and local reference are transmitted in one optical fiber and a simple balanced receiver performs sourceless heterodyne detection.**

***Index Terms*—Optical fiber communication, OCDMA, Heterodyne detection**

I. INTRODUCTION

Optical code division multiple access (OCDMA) over the passive optical network (PON) is emerging as a key access network technology [1]. It has been established that coherent spectrally phase encoded (SPE) OCDMA with a phase and polarization diversity (PPD) combiner eliminates speckle and most multiple access interference (MAI) in a homodyne configuration without the need for fast detectors or phase locking [2]. This work proposes a heterodyne scheme that pairs an encoded optical comb with the unencoded comb that is spectrally offset by the bit rate and a much simpler receiver with comparable dispersion tolerance.

II. SYSTEM DESCRIPTION

As in [2], all optical signals are sourced from a single mode-locked laser (MLL). Sets of spectral lines for SPE and for the unencoded reference comb (Fig. 1) are obtained by filtering the MLL pulse with an arrayed waveguide grating (AWG). The spacing of each comb is 320 MHz, and the reference comb is offset from the data-carrying comb by the bit rate of 40 GHz. Sixteen spectral lines are encoded with up to 16 distinct, orthogonal Hadamard codes. User signals are modulated and passively combined with the reference comb for transmission (Fig. 2). At the receiver, user and reference signals are split using AWG filtering. The reference comb is encoded with the target signal's sequence, and both signals are applied to the balanced detector, which effectively multiplies the two signals, producing baseband data at 40 GHz.

III. SIMULATION AND RESULTS

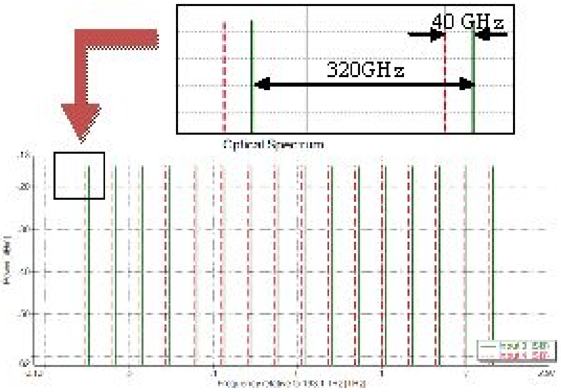

Fig. 1: Frequency combs for signal and reference.

Fig. 2 shows the system model and simulated waveforms for 16 users at 40 GHz. The 1550 nm mode-locked laser (MLL) pulse width is 500 fs, and the main lobe of the optical comb is flattened (perhaps by adapting quantum dot gain materials into the MLL [3]) to ensure full signal orthogonality. SPE for 16 users is performed as in [2]; the reference comb (Fig. 2b) is not encoded. The signals travel via one fiber to all users (Fig. 2d). In the receiver, the reference comb is captured and encoded with the desired user's sequence. The encoded reference is shown at Fig. 2e with the balanced mixer following. A 79 GHz band pass filter centered at the 40 GHz intermediate frequency filters out higher frequency beat signals (Fig. 2f).

Fig. 3 compares the BER of the heterodyne detection OCDMA with that of the SPOT homodyne scheme [2]. The nearly 2 dB improvement is the result of using two photodiodes instead of eight.

As previously reported (Fig. 5, from [4]) for homodyne reception with on-off keying (OOK), encoded signals with energy concentrated at the edges of the pulse interval (*e.g.,* H9 in the figures) are susceptible to $1 \rightarrow 0$ bit errors due to dispersive channel effects smearing energy to the 0 interval. However, the same sequence, when used in the proposed heterodyne system, can withstand twice the dispersion for the same BER (Fig. 4). Conversely, a waveform with energy concentrated away from the boundaries of the interval (*e.g.,* H10) is highly dispersion resistent in the homodyne system (Fig. 5) but relatively far less so in the proposed heterodyne system (Fig. 4). Therefore, it appears that the proposed scheme is resistant to the "spilling" of energy into the adjacent pulse interval, but is susceptible to pulse broadening by dispersion-induced compromise of the phase coherence among the lines of the encoded pulse.

IV. CONCLUSION

A new heterodyne architecture for SPE-based OCDMA has been proposed. Its power efficiency compares favorably with the SPOT homodyne design and its resistance to total dispersion is competetive with that of SPOT. The receiver design is markedly simpler.

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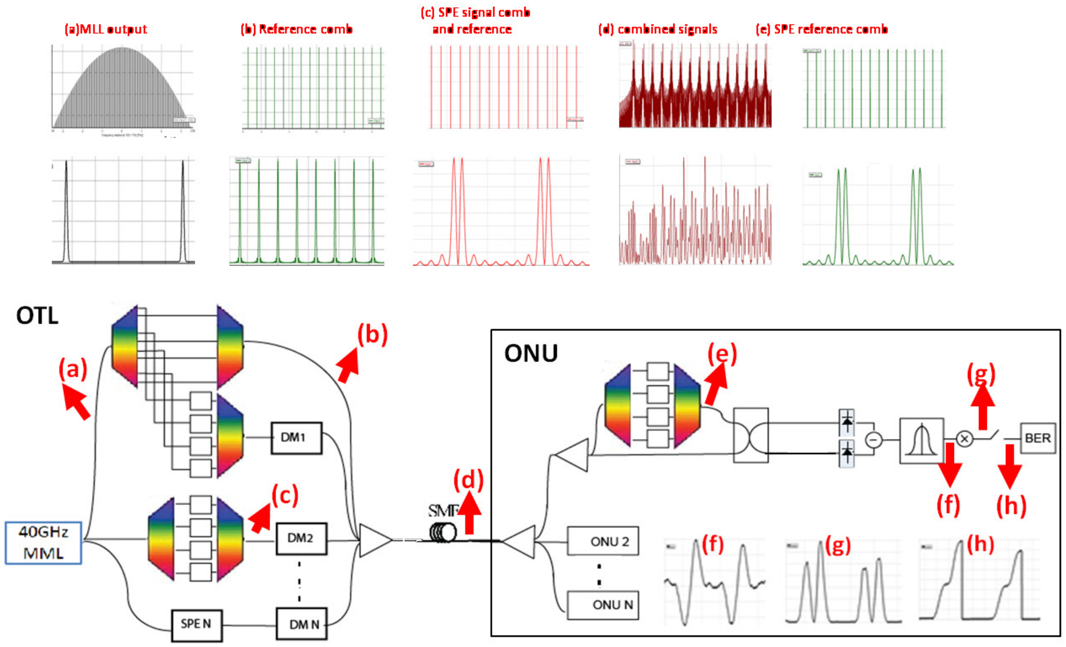

Fig. 2: System setup and output

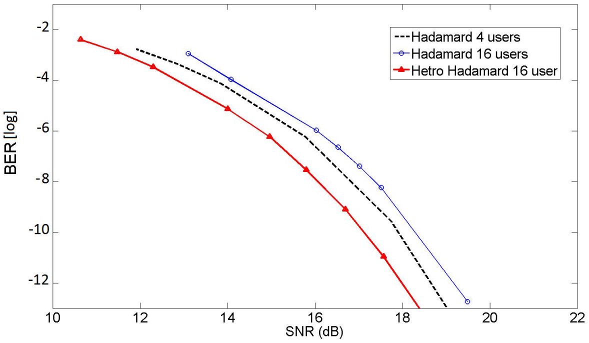

Fig. 3: BER vs SNR for homodyne and heterodyne detection

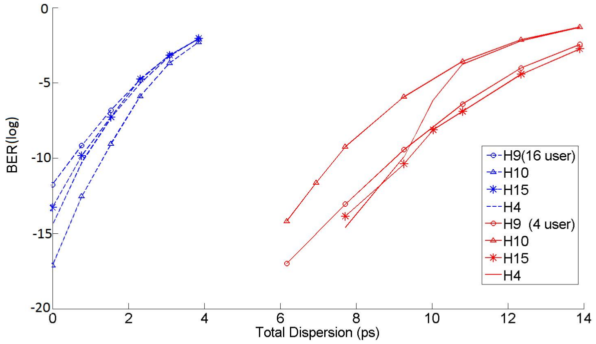

Fig. 4: Performance vs total dispersion

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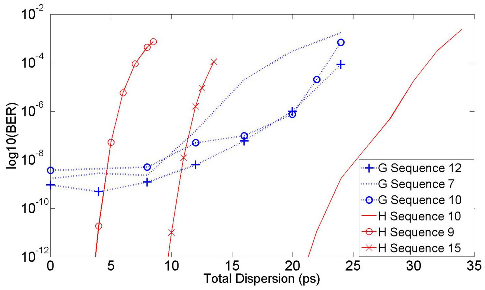

Fig. 5: Homodyne performance vs total dispersion (from [5])