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DEVELOPMENT OF PULSE POSITION MODULATION/OPTICAL CDMA (PPM/O-CDMA) FOR GB/S FIBER OPTIC NETWORKING

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1. Introduction

Pulse position modulation (PPM) in lasercom systems is known to provide potential advantages over other modulation schemes. [1]. In PPM, a periodic time frame is established and data is transmitted by placing a pulse in any one of several subintervals (or "slots") within each frame. In PPM/O-CDMA all users use the same frame structure and each transmits its unique address code in place of the PPM pulse. The advantage of PPM as a pulsed signal format is that 1) a single pulse can transmit multiple bits during each frame; 2) decoding (determining which subinterval contains the pulse) is by comparison rather than threshold tests (as in on-off-keying); 3) each user transmits in only a small fraction of the frame, hence the multi-access interference (MAI) of any user statistically spreads over the entire frame time, reducing the chance of overlap with any other user; and 4) under an average power constraint, increasing frame time increases the peak pulse power (i.e., PPM trades average power for peak power). The most straightforward approach to implementing PPM/O-CDMA data modulator inserts the PPM pulse modulation first, then imposes the O-CDMA coding. A pulsed PPM modulator converts bits (words) into pulse positions. In the case of wavelength/time (W/T) matrix codes, multi-wavelength pulses are generated at the beginning of each frame, at the frame rate. For M-ary PPM, a block of k bits represents M = 2^k unique interval positions in the frame corresponding to M-l specific time delays (the zero delay is also a position). PPM modulation is achieved by shifting the initial pulse into an interval position with delay D(i) (i=0,1,2,..,M-1). The location of a pulse position (se1ection of a delay) therefore identifies a unique k-bit word in the frame. At the receiver, determining which delay occurs relative to the frame start time decodes the data word. The probability of pulse overlap between two users decreases with M, which therefore decreases the probability of MAI buildup. Spreadsheet simulations suggest that a slot-synchronous M-ary PPM/O-CDMA system will support more concurrent users than a chip-synchronous or frame-synchronous system.

2. Description of the Binary PPM/O-CDMA Technology Demonstrator

The W/T matrix code O-CDMA Technology Demonstrator (TD) [2,3] incorporates a guard-time (GT) in the matrix codes to avoid inter-symbol interference (ISI) caused by the crosscorrelation of unmatched codes spilling over into adjacent bits (an effect that aggravates the accumulation of MAI). With a GT the code occupies only the first half of the bit, leaving the second half unoccupied. This GT makes this class of 2D codes and the TD ideal for developing and demonstrating binary (M = 2) PPM/O-CDMA.

Figure 1 depicts the labeling of "1s" and "0s" in binary PPM/O-CDMA, as well as the comparison operation following the CDMA correlator. The TD was converted to accommodate this binary PPM signaling; see Figure 2. A single multi-wavelength pulse source produces an encodable carrier (EC) that is sent to the PPM data modulator and then distributed to a bank of O-CDMA encoders. The (1.25 Gb/s) PPM data modulator consists of a dual output polarization maintaining (PM) modulator that generates complementary data paths. One is then time shifted relative to the other and recombined in a PM combiner to produce data-modulated PPM pulses. The use of a PM combiner reduces system losses and has the added benefit of producing polarization-diversified output, thereby reducing optical beat interference (OBI). Each encoder (and the decoder) wavelength demultiplexes the EC, applies a time delay to each wavelength, and then recombines the wavelengths to produce coded signals. On the receiver end, differential detection is applied to perform the comparison test between the two PPM slots, converting the unipolar O-CDMA signal into an electrical bipolar signal.

3. Experimental Results

Figures 3(a) and 3(b) respectively show single-ended and differential detection measurements of the eye-diagram for four concurrent and randomly timed users. Errors occur when the eye closes and/or the “1s” (“0s”) cross into the wrong polarity after the comparison test, owing to MAI contributed by additional users. Figure 3c shows the differentially-detected bit-error-rate (BER) of the correctly decoded user as three MAI peaks are scanned across it. (For more than one interferer, previous interferers align to the desired user at time = 0 ps.) As expected, the BER increases as it approaches the peak of the desired user.

References

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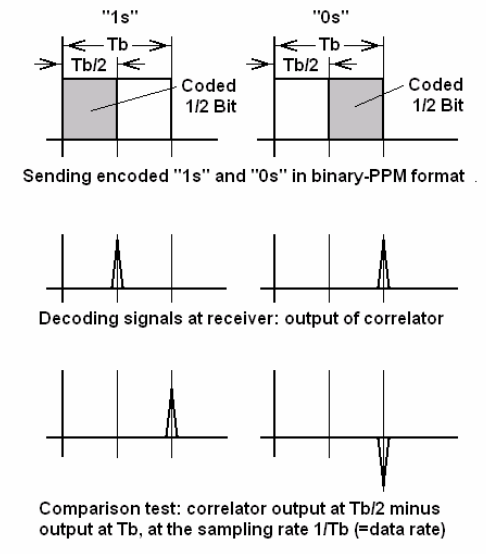

Figure 1. Operation of the PPM/ O-CDMA Comparison Test.

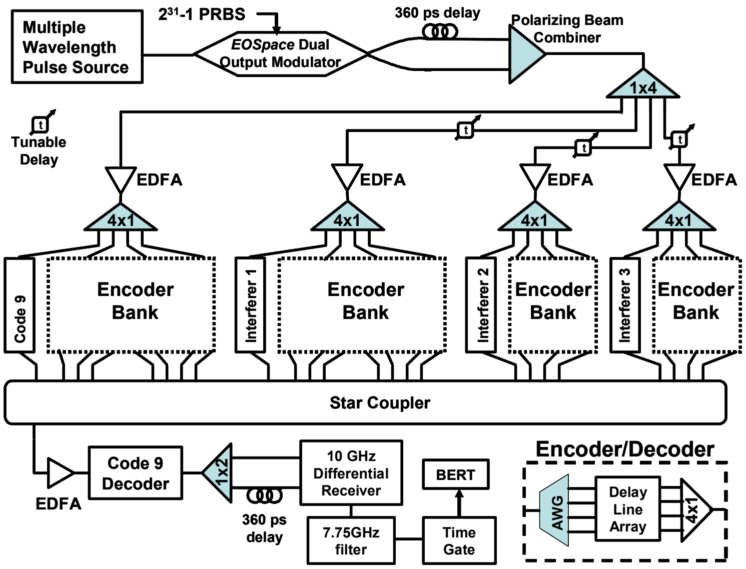

Figure 2. The TD Modified for Binary PPM/O-CDMA.

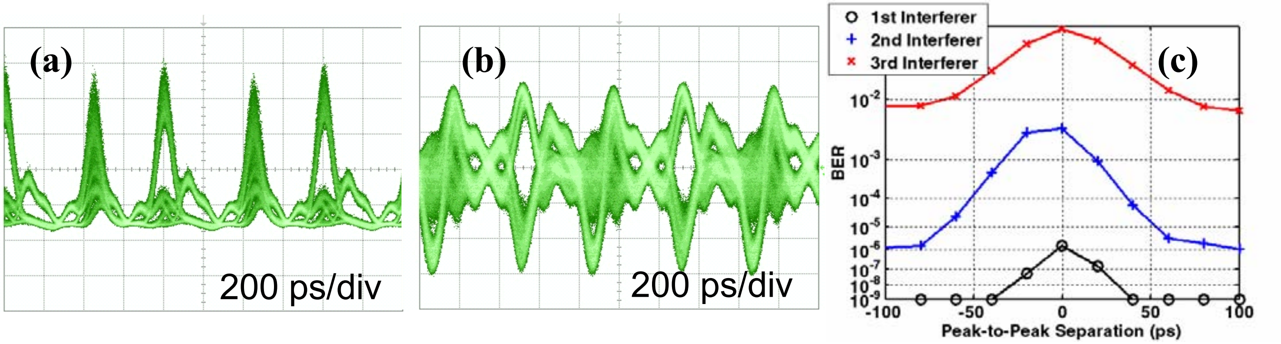

Figure 3. (a) Single-ended and (b) differentially detected correlation outputs for four users with (c) differentially detected BER at 1 dBm out of the decoder.