Spectral Line Pairing for Coherent Heterodyne OCDMA

Comment [jk1]: Basically this is the first time we are talking about our New Heterodybene System – so make it scream! Remove “dispersion and delay from titele- just say we ar emaking a new scheem

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Abstract: A new, coherent, heterodyne OCDMA scheme conveys the signal ensemble and reference comb to each user via one fiber. The receiver is sourceless and colorless. Distortion and relative delay impact the bit error rate.

Comment [jk2]: How about justsaying we evaluate BER and find it is OK

OCIS codes: (060.2330) Fiber Optics Communications; (060.2840) Heterodyne; (060.1660) Coherent.

1. Introduction

A new, coherent heterodyne scheme for optical code division multiple access (OCDMA) offers low multiple access interference (MAI) and sourceless/colorless receiver design. Its use on the passive optical network (PON) is an attractive candidate for next generation access networks (NGAN) because it can offer soft capacity on demand, freedom from MAC layer protocols, support for security, minimal MAI and beat noise, easy upgrade of any power-splitter-based network, and sourceless/colorless optical network units (ONUs) at user premises [1].

Comment [jk3]: This should not be the first paragraph – why do not we do it traditionally:
Paragraph (1) – Usual stuff – OCDMA is good, suffers from MAI and Speckle because codes are not truly orthogonal. The key: In all the schemes even “coherent” ones the MAI power is not really cancelled but only spread out.
Paragraph (2) Previously we have proposed SPOT – truly coherent, no MAI or Speckle – but requires 2 fibers, and phase-polarization diversity
Paragraph (3) Now we proposed a new scheme – same as SPOT (nearly because we lose spectral efficiency) but – single fiber and no PPD

Coherent, spectrally phase encoded (SPE) homodyne OCDMA has been found promising [2-4] in terms of these criteria, but a heterodyne system offers similar performance inexpensive design. In any OCDMA, each user encodes its information pulses in time, frequency, or phase with a *signature sequence* having good correlation properties. Correlation processing in the receiver recovers the signal of interest, spreading or canceling the interference, depending upon the design..

Heterodyned spectral amplitude coding (SAC) has been studied [5] with line spacing at the bit rate but achieved only a very small spectral efficiency. Using spectral designs similar to Fig. 1, [6] found an accumulation of excessive levels of MAI caused by unwanted beat noise that was mitigated by a wavelength local oscillator, offering unneeded cost and complexity and lack of a sourceless/colorless design.

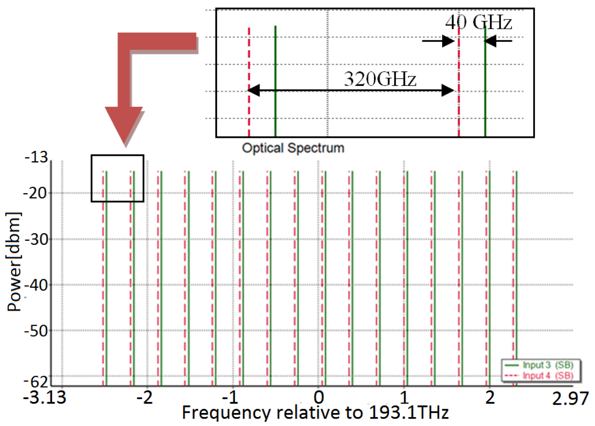

Fig. 1. Combs for encoded signal (dashed) and unencoded reference (solid)

2. System Description

Comment [jk4]: First paragraph here should be something like this:
“The key of our scheme is using two interleaved combs spectral lines separated by intermediate frequency f – forst comb carriers encoded signal and the second unencobde dcomb goes to the receiver where it is encoded by a proper code and interfered with the signal – the balanced deetcttion and spectral filtering at intermediate frequency then separates the correct signal. Because we use just one fiber the scheme is not polarization sensitive

Suitable filtering of the flattened spectrum (for orthogonality [2,7] of a 40 Gb/s, 500fs mode-locked laser (MLL) pulse stream provides two 16-line spectral combs of 320 GHz line spacing, mutually offset by 40 GHz (Fig. 1). Replication and encoding of one of the combs in the optical line terminal (OLT) affords up to 16 distinct Hadamard sequence-encoded user signals, each of which is OOK modulated by pseudorandom data (Fig. 2). The

Comment [jk5]: Now you start description….

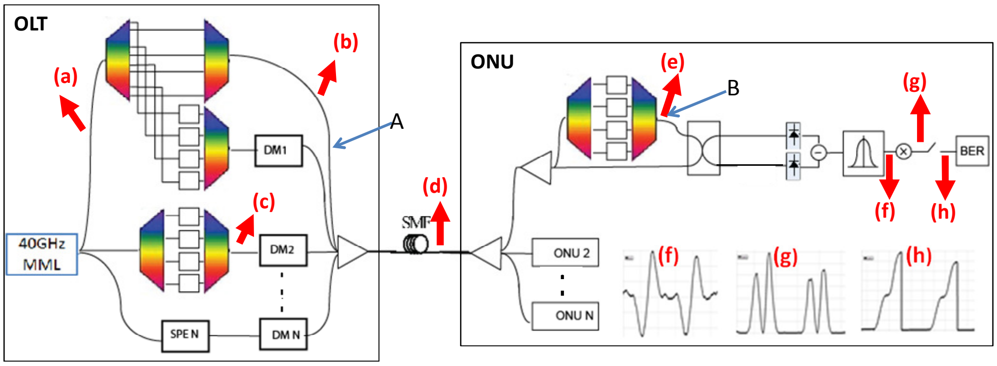

Fig. 2. System configuration and simulation model

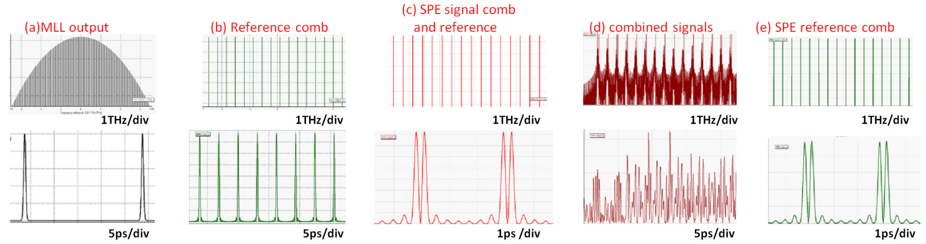

Fig 3. Waveforms

offset comb (Fig. 3(b)) remains unencoded. The 17 signals are combined in a star coupler (Fig 2) and conveyed (Fig. 3(d)) via one single mode fiber to each user's optical network unit (ONU), where the unencoded reference comb is extracted, encoded with the sequence of the desired signal, and mixed with the received signal in a balanced mixer and filter that restore the desired user's data modulated on a 40 GHz *intermediate frequency* carrier, while canceling the MAI. A 79 GHz filter centered at 40 GHz removes higher frequency beat signals (Fig. 2(f)).

For uplink transmission, the received reference comb would be encoded, modulated, and sent over a second fiber. Thus, all optical signals in the system are derived from a single MLL (as in [2]) and use the same two optical combs, resulting in sourceless/colorless operation. The rest of this work focuses on the synchronous downlink and its transmitted set of pairwise orthogonal signals.

3. Simulations and Results

Comment [jk6]: Should just say we evaluate performance considering two factor sthat may cause SNR deterioration the worse

Because signal and reference travel over the same fiber, they experience the same dispersion that stretches the encoded pulses so that they are no longer orthogonal over the information bit interval and are susceptible to pulse broadening by compromise of the phase coherence of the encoded pulse spectrum. The effect is shown in Fig 4, which also shows that decreasing the user number in the system can mitigate the MAI caused by dispersion.

When signal and reference must travel on separate fibers [2], reception becomes asynchronous with relative delay $\Delta t_{s-r} = (\phi_s - \phi_r)\omega_o^{-1}$ (where ϕ_s and ϕ_r represent phase shifts of signal and reference, respectively, and ω_0 is the optical carrier frequency). This reduces the peak value of the signal's autocorrelation and causes sidelobe amplitudes to increase [8], producing MAI. To study this asynchronism, delay is introduced at (point B, Fig. 2) before the encoded reference comb is sent to the coupler. Fig. 6 shows the resulting bit error rates. The system can tolerate more asynchronism when the load is small, and this tolerance decreases as system loading increases. The difference between Fig. 4 and Fig. 5 is that in Fig. 4, MIA comes from the targeted encoded signal, while in Fig. 5, the cause of MIA comes from all loaded users.

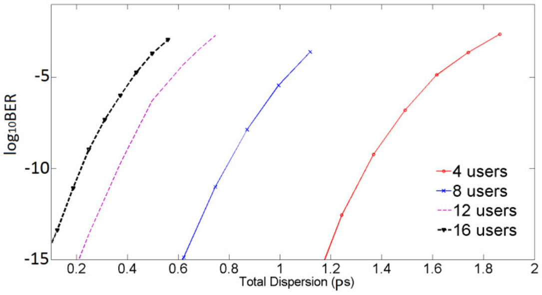

Fig 4. Performance vs total dispersion

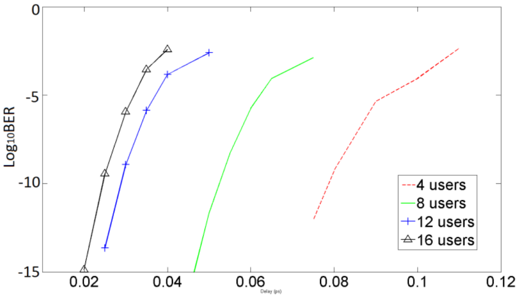

Fig. 5. BER vs Delay

4. Conclusion

A new heterodyne architecture with a simple balanced receiver for SPE-based OCDMA has been proposed. Delays would typically arise in an integrated ONU design and can be compensated by one-time final adjustments. Dispersion is but a small fraction of the 25ps pulse width and is well tolerated.

Comment [jk7]: Simple conclusion – propose dnew system and shown it works

5. References

[1] J. Mitchell, M. Parker, G. Cincotti, F. Lucarz, M. Kantor, F. Matera, “Building the Future Optical Network in Europe,” BONE Consortium, Dec. 12, 2009.

[2] A. B. Cooper III, J. B. Khurgin, S. Xu, and J. U. Kang, “Phase and polarization diversity for minimum MAI in OCDMA networks,” IEEE J. Select. Topics in Quantum El., vol. 13, pp. 1386–1395, Sept. 2007.

[3] J. Salehi, A. Weiner, J. Heritage, “Coherent ultrashort light pulse code division multiple access system,” *J. Lightwav. Technol.,* vol. 8, no. 9, pp 478-491, Mar 1990.

[4] K. Kitayama, “Code division multiplexing lightwave networks based upon optical code conversion,” *J. Sel. Areas Commun.,* vol. 6, no. 7, pp 1309-1319, Sep 1998.

[5] D. Zacccarin, and M. Kaverad, “An optical CDMA system based on spectral encoding of LED,” *IEEE Photon Technol. Lett.,* vol. 4, no. 4, Apr 1993.

[6] Yoshino, M.; Kaneko, S.; Taniguchi, T.; Miki, N.; Kumozaki, K.; Imai, T.; Yoshimoto, N.; Tsubokawa, M.; , "Beat Noise Mitigation of Spectral Amplitude Coding OCDMA Using Heterodyne Detection," *Lightwave Technology, Journal of* , vol.26, no.8, pp.962-970, April15, 2008.

[7] J.S.Parker, P. Binetti, A. Bhardwaj, R. Guzzon, E. J. Norberg, Y. Hung, L.A. Coldren. “Comparison of Comb-line Generation from InGaAsP/InP Integrated Ring Mode-locked Lasers,” (CLEO) ’11, Optical Soc. of Amer., 2011.

[8] S.W. Golomb, *Shift Register Sequences,* Holden-Day, 1967.

Fig. 3. Performance vs. total dispersion