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Editorial

References

Up to now I am still waiting for the first manuscripts written by the author using the JOC-template which we have as an download on our web page www.joc-online.de. We will see; however, we only will give some time for an overlap and finally we will not accept manuscripts written without this template.
One of the critical points is the nomenclature for the references used by Journal of Optical Communications. It is not really special, but we think it is easy to read, short but has all the data needed. Most of our authors are using somewhat different – in about 50 % of the cases the nomenclature used by the authors is not consistent in itself, i. e. changes from citation to citation. So I asked most authors to rewrite the refer-ences and I take usually their reference [1] and rewrite it as an example. I assume that the authors are highly educated people. However, up to now about 90 % of them failed to rewrite their references to meet our needs fully. Obviously a real big challenge!

Sincerely yours
Ralf Th. Kersten
Editor-in-chief

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Journal of Optical Communications

Demonstration of Spectral-amplitude Encoding/Decoding for Multimedia Optical CDMA Applications

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Summary

Wavelength-time encoding/decoding for optical CDMA systems is evaluated using NRZ modulation at 10 Gbit/s. Commercial available devices are used for implementation. Experimental results are presented for the channel both in the absence and in the presence of multi-access interference.

1 Introduction

Several attractive features such as synchronous access, privacy and security in transmission, ability to support multimedia services, and scalability of the network selects the optical code-division multiple-access (OCDMA) systems as an attractive option for local area network (LAN) and possible metropolitan area network (MAN) applications [1]. Various different optical orthogonal codes (OOCs) have been proposed for various OCDMA technologies: time-spreading encoding [2–3], spectral-amplitude and fast-frequency coding [4–5], and a hybrid wavalength-time (two-dimensional-2D) encoding [2, 6]. Some proposals generalize the OOC design [7]. For multimedia applications several strict-orthogonal, multilength and multiweight codes were proposed recently [1–2, 8].

Wavelength-time OOCs can support a larger number of simultaneous users than one-dimensional OOCs, with each user operating at an acceptable bit-error rate. However, the complexity of 2D encoder/decoder is higher [2, 6].

In this paper, wavelength-time encoding/decoding using NRZ at 10 Gbit/s is demonstrated experimentally based on commercially available demultiplexing grating technology that supports electronic change of the address. To our knowledge, this is the first demonstration of OCDMA with an NRZ signal at 10 Gbit/s and the first that uses commercially available components, both aspects that would allow simpler, cheaper implementation.

The proposed scheme, the generalization of our previous spectral-amplitude-coding proposal [9], has very reasonable complexity and also solves the power budget problems inherent with tunable delay lines, if implemented using the semiconductor optical amplifiers (SOA) gates. As demonstrated later in the text, by increasing the number of wavelengths instead of the number of timeslots, a significant performance improvement can be obtained, without increasing encoder complexity. One of two main sources of performance degradation – the intensity noise, identified in [10], is completely removed. The other source – the multi-access interference (MAI) can be almost completely removed by using our [7–9] MAI cancellation schemes.

The unipolar codes supporting the architecture considered are designed using the theory of finite geometries [7]. The cross-correlation between any two codewords is 0 or 1. For the same codeword weight and length these codes support a larger number of users than in [2, 6], or equivalently, the same number of users that can be supported with much shorter and fixed delay lines. Using the algorithm we proposed in [8], the multi-weight codewords' families are designed.

2 Encoder-decoder architectures

The encoder architecture considered here is shown in Fig. 1. It can be considered as generalization of our previous proposal [9].

The signal from a broad-band source is spectrally sliced by a grating. The peak-wavelength λ_i ($i = 1, 2,\ldots, N$) experiences the delay of iT/N, where T is a bit duration, and N is the number of wavelengths and the number of time slots. According to the position of ones in a codeword, the corresponding wavelengths are enabled and

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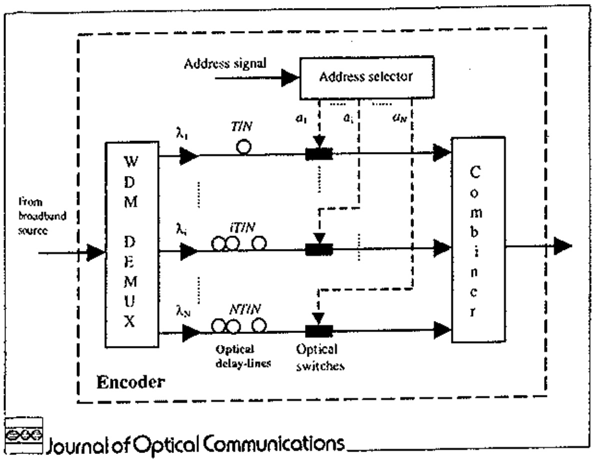

Fig. 1: Encoder architecture for 2D OCDMA systems

amplified or disabled by SOA gates, and multiplexed together by using a power combiner. For the cost-effective solution the SOA gates may be replaced by the optical switches or even by optical attenuators. At the receiver/decoder side, the peak wavelengths λ_i experience the delay $T - iT/N$, and therefore, the total delay of each particular peak-wavelength is the same and different spectral slices can be merged back into a pulse. With balanced reception the MAI can be supressed, as we proposed in [9].

3 Unipolar codes

It has been shown (e.g., [7–8]) that an OOC can be represented as a combinatorial t-design [12]. In the constructions proposed here, projective planes and affine planes (AP), oval and unital designs [13], are special classes of $2-(v, k, \{0,1\})$-design, where v is the design set cardinality, k the size of the block in a design, and the overlaping between the blocks is 0 or 1. An one-to-one correspondence may be established between $2-(v, k, \{0,1\})$-design and a 2D OOC $(v, k, \{0,1\})$; v now representing the codeword length, k the codeword weight and maximum cross-correlation being 1; by assigning a point-block matrix $A = (a_{ij})$ of dimensions v x b, with elements determined by

$$a_{ij} = \begin{cases} \lambda_j & \text{if i-th point is contained in j-th block} \\ 0 & \text{otherwise} \end{cases}$$

and the columns in the matrix representing different OOC codewords (λ_j-the j-th peak-wavelength). The OOC cardinality is determined by

$$b \approx v(v-1)/[k(k-1)]. \quad (1)$$

For example, the codewords of an OOC based on AP(2,3) are: {1,2,3}, {4,5,6}, {7,8,9}, {1,4,7}, {2,5,8}, {3,6,9}, {1,5,9}, {2,6,7}, {3,4,8}, {1,6,8}, {2,4,9}, {3,5,7}, where the labels denote the positions of ones within the codewords. The codewords can be written in the form of a matrix

$$A = \begin{bmatrix} \lambda_1 & 0 & 0 & \lambda_1 & 0 & 0 & \lambda_1 & 0 & 0 & \lambda_1 & 0 & 0 \\ \lambda_2 & 0 & 0 & 0 & \lambda_2 & 0 & 0 & \lambda_2 & 0 & 0 & \lambda_2 & 0 \\ \lambda_3 & 0 & 0 & 0 & 0 & \lambda_3 & 0 & 0 & \lambda_3 & 0 & 0 & \lambda_3 \\ 0 & \lambda_4 & 0 & \lambda_4 & 0 & 0 & 0 & 0 & \lambda_4 & 0 & \lambda_4 & 0 \\ 0 & \lambda_5 & 0 & 0 & \lambda_5 & 0 & \lambda_5 & 0 & 0 & 0 & 0 & \lambda_5 \\ 0 & \lambda_6 & 0 & 0 & 0 & \lambda_6 & 0 & \lambda_6 & 0 & \lambda_6 & 0 & 0 \\ 0 & 0 & \lambda_7 & \lambda_7 & 0 & 0 & 0 & \lambda_7 & 0 & 0 & 0 & \lambda_7 \\ 0 & 0 & \lambda_8 & 0 & \lambda_8 & 0 & 0 & 0 & \lambda_8 & \lambda_8 & 0 & 0 \\ 0 & 0 & \lambda_9 & 0 & 0 & \lambda_9 & \lambda_9 & 0 & 0 & 0 & \lambda_9 & 0 \end{bmatrix}$$

in which each column represents a particular codeword, where l's are filled with corresponding active wavelengths. Using the concepts of a pairwised balanced designs we outlined in [8] we are able to design multiweight unipolar codes capable to support multimedia OCDMA applications. For example, the population vector [1 0.6 0.6] (see [8] for definition) yields to an OOC in AP(2,3) that is able to support three different services with 12 users, and this code is used in the experiment. There are 5 codewords of weight 3: {1,2,3}, {4,5,6}, {1,4,7}, {2,6,7} and {3,5,7}, 6 of weight 2: {2,5}, {3,6}, {1,5}, {3,4}, {1,6}, and {2,4}, and one codeword of weight one: {7}.

The performance of multi-weight AP(2,8) wavelength-time code for the population vector [1 0.5 0.5 1 1 0.5 0.5 1], in the presence of multi-access interference only, is shown in Fig. 2. The code supports 5 services with at most 9 codewords of weight 4, 12 of weight 5, 30 of weight 6, 12 of weight 7, and 9 of weight 8 (72 users in total). The last service is error free. In performance calculation, the method described in [14] is employed and an equal fraction of codewords from different services is assumed. Again, to design the multi-weight codes from the single-weight ones, the algorithm we proposed earlier in [8] is employed. Therefore, by employing larger number of wavelengths than the codeword weight the BER performance can be significantly improved.

4 Experimental setup and results

Experimental setup is shown in Fig. 3. The purpose of the experiment is to demonstrate the feasibility of the proposed coding scheme. Experimental results for {3,6} OCDMA channel both in the absence and in the presence of multi-access interference are shown in Figs. 4–5 as the proof of principle. It is evident from Fig. 4(b) and Fig. 5 that error-free encoding and decoding is possible at 10 Gbit/s using simple NRZ modulation format and comercially available devices. There is no power penalty associated with coding and decoding the signal, as shown in Fig. 5 where the back-to-back and decoded BER vs. received power plots overlap. Figure 4(c) shows the eye diagram of the decoded signal in the presence of MAI down 6 dB from the signal. The interference has degraded the eye, however we are still able to do error-free (10^{-9}) BER detection with a ~5 dB power penalty.

The origin of intensity noise, discussed in [10], is in non-completely compensated delays of different peak-wavelengths. By employing the method we proposed in [15] the peak-wavalength delays after decoding are identical resulting in completely removing of intensity noise.

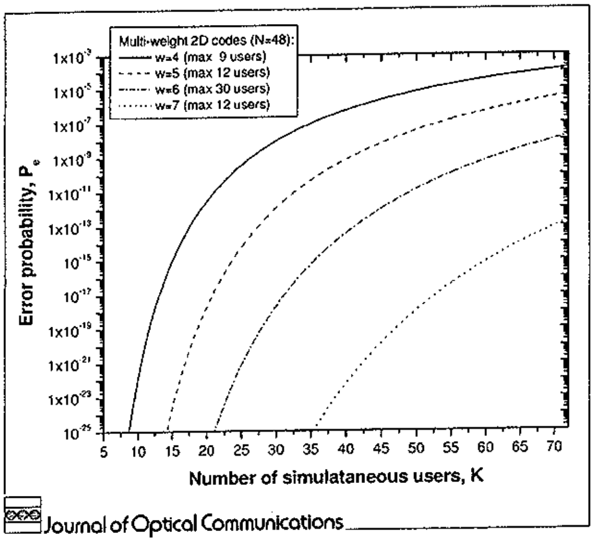

Fig. 2: BER vs. number of users for 5 services. (Population vector: [1 0.5 0.5 1 1 0.5 0.5 1], N = 48)

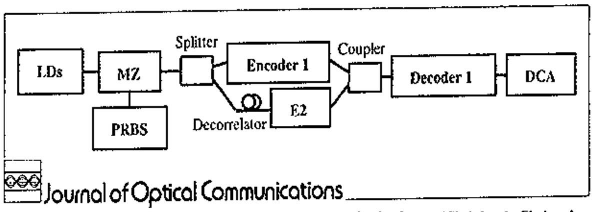

Fig.3: Experimental setup. LDs-laser diodes(λ_1,λ_3,λ_6), MZ-Mach-Zehnder modulator, PRBS-$2^{31}-1$ pseudorandom bit sequence at 10 Gbit/s, DCA-digital communications analyser, E2-encoder 2

Therefore, the system considered in this letter is MAI limited. By employing larger number of wavelengths, the BER performance can be further improved as illustrated in Fig. 2. The MAI can be supressed by employing the balanced detection schemes we proposed in [7–9].

5 Conclusion

The possibility of wavelength-time encoding/decoding for optical CDMA systems using NRZ at 10 Gb/s is demonstrated and a class of unipolar codes for multimedia optical CDMA applications is proposed. With number of employed wavelengths larger then the number of time slots significant performance improvement is expected.

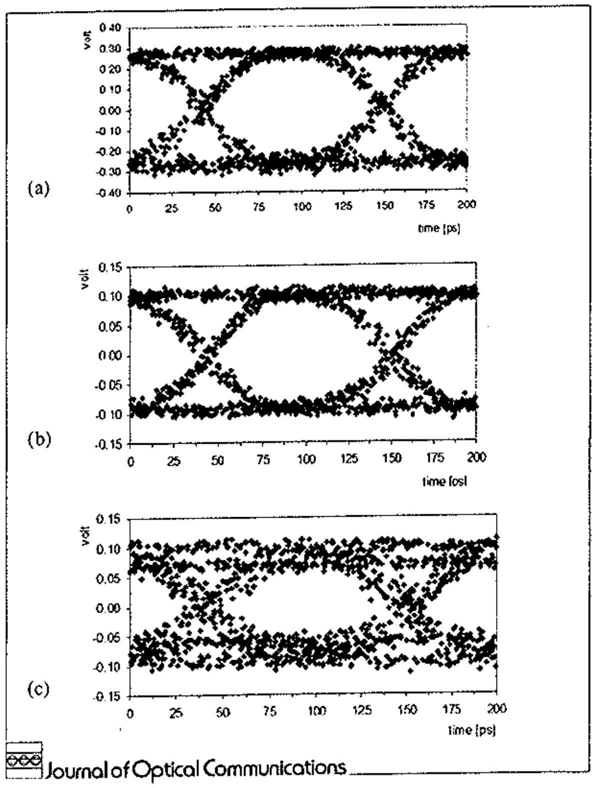

Fig. 4: Experimental results (observed channel: {3, 6}, interfering channel: {1,6}): (a) back-to-back eye diagram (Q = 15.72), (b) decoded signal (3, 6) in the absence of interference (Q = 15.28), c) decoded signal (3, 6) in the presence of interference (1, 6) (interfering channel 5.7 dB less, Q = 5.60)

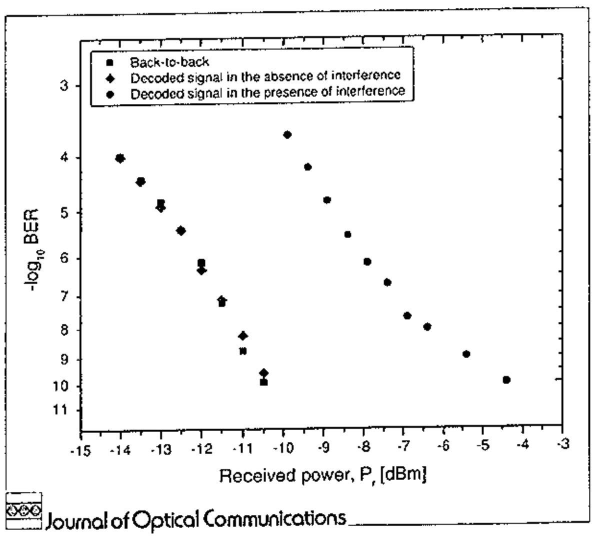

Fig. 5: Bit-error rate versus received power

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