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Design and Performance Analysis of Eight Users 2-D and Spectral Phase Encoding O-CDMA time Domain Systems

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Abstract. In optical code division multiple access (OCDMA) system, many users share the same transmission medium by assigning unique pseudo-random optical code (OC) to each user. In this paper the performance of 2-D and Spectral Phase Encoding O-CDMA System in time domain is compared 2.5Gb/s for 60 km length.SPE O-CDMA systems results indicate significant improvement in term Beat Error Rate (BER) and very high quality factor in the form of Quality of Service (QoS) at -18dBm received power. In our analysis, we have used Pseudo Orthogonal (PSO) code and specific phase shift code . The simulations are carried out using OptSim (RSOFT).

Keywords: MAI, OCDMA, OOC, PSO, QoS, BER .

1. Introduction

Optical code division multiple access (OCDMA), where users share the same transmission medium by assigning unique pseudo-random optical code (OC), is attractive for next generation broadband access networks due to its features of allowing fully asynchronous transmission with low latency access, soft capacity on demand, protocol transparency, simplified network management as well as increased flexibility of QoS control [1~3]. In addition, since the data are encoded into pseudo-random OCs during transmission, it also has the potential to enhance the confidentiality in the network [4~6]. Figure1.1 illustrates a basic architecture and working principle of an OCDMA passive optical network (PON) network. In the OCDMA-PON network, the data are encoded into pseudo random OC by the OCDMA encoder at the transmitter and multiple users share the same transmission media by assigning different OCs to different users.

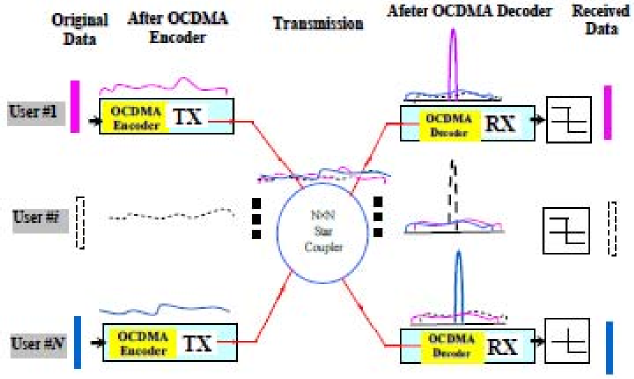

Fig. 1: Working principle of an OCDMA network .

At the receiver, the OCDMA decoder recognizes the OCs by performing matched filtering, where the auto-correlation for target OC produces high level output, while the cross-correlation for undesired OC produces low level output. Finally, the original data can be recovered after electrical thresholding. Recently, coherent OCDMA technique with ultra-short optical pulses is receiving much attention for the overall superior performance over incoherent OCDMA and the development of compact and reliable en/decoders

(E/D) [7~10]. In coherent OCDMA, encoding and decoding are performed either in time domain or in spectral domain based on the phase and amplitude of optical field. In coherent time spreading (TS) OCDMA, where the encoding/decoding are performed in time domain. In such a system, the encoding is to spread a short optical pulse in time with a phase shift pattern representing specific codes. The decoding is to perform the convolution to the incoming OC using a decoder, which has an inverse phase shift pattern as the encoder and generates high level auto-correlation and low level cross-correlations.

2. Numerical Simulation

The encoders use delay line arrays providing delays in terms of integer multiples of chip times. The placement of delay line arrays and the amount of each delay and phase shifts are dictated by the specific of the signatures. PSO matrix codes are constructed using a spanning ruler or optimum Golomb ruler is a (0,1) pulse sequence where the distances between any of the pulses is a non repeating integer, hence the distances between nearest neighbors, next nearest neighbors, etc., can be depicted as a difference triangle with unique integer entries. The ruler-to-matrix transformation increases the cardinality (code set size) from one (1) to four (4) and the ISD (=Cardinality/CD) from 1/26 to 4/32=1/8.

The ISD translates to bit/s/Hz when the codes are associated with a data rate and the code dimension is translated into the bandwidth expansion associated with the codes as follows:

$$\text{ISD} = \frac{(\text{throughput})}{(\text{bandwidth required})}$$

$$= \frac{(\text{cardinality} \times \text{data rate})}{\left(\frac{1}{\text{Tb}}\right)(\text{bandwidth expansion})}$$

$$= \frac{(n \times r \times R)}{(R)(CD)}$$

$$= \frac{n \times r}{(CD)}$$

The enhanced cardinality and ISD, while preserving the OOC property, are general results of the ruler-to-matrix transformation

We can convert the PSO matrices to wavelength/time (W/T) codes by associating the rows of the PSO matrices with wavelength (or frequency) and the columns with time-slots, as shown in TABLE I. The matricesM1….M32 are numbered 1…32 in the table, with the corresponding assignment of wavelengths and time-slots. For example, code **M1** is (λ1 ; λ1 ; λ3; λ1) and **M9** is (λ1,λ4;0;λ7,λ8;0); here the semicolons separate the timeslots in the code. (The codes M1 and M9 are shown in bold numerals.). We focus on codes like M1 because it shows extensive wavelength reuse, and on codes likeM9 because it shows extensive time-slot reuse. It is the extensive wavelength and time-slot reuse that gives these matrix codes their high cardinality and high potential ISD. Four mode-locked lasers are used to create a dense WDM multi-frequency light source. Four time slots are used for time shifting.

Table 1: The 32 PSO Matrix Codes Interpreted as W/T Matrix Codes

Wavelengths (W)	**Time slots (S)**			
	1	**2**	**3**	**4**
λ1	**1**,**9**,17,25	**1**,14,29	19,24,26	**1**,7,10,11,20,32
λ2	2,10,18,26	2,15,17,30	20,25,27	2,8,11,12,21
λ3	3,11,19,27	3,16,18,31	1,21,26,28	3,12,13,22
λ4	4,**9**,12,20,28	4,19,32	2,22,27,29	4,13,14,23
λ5	5,10,13,21,25,29	5,20	3,23,28,30	5,14,15,24
λ6	6,11,14,22,26,30	6,21	4,17,24,29,31	6,15,16
λ7	7,12,15,23,27,31	7,17,22	5,**9**,18,30,32	7,16
λ8	8,13,16,24,28,32	8,18,23,25	6,**9**,10,19,31	8

Pseudo-orthogonal (PSO) matrix codes [3] are popular for OCDMA applications primarily because they retain the correlation advantages of PSO linear sequences while reducing the need for bandwidth expansion. PSO matrix codes also generate a larger code set. An interesting variation is described in [1] where some of the wavelength/time (W/T) matrix codes can permit extensive wavelength reuse and some can allow extensive time-slot reuse. In this example, an extensive time-slot reuse sequence is used for User 1 (λ1λ3;0;λ2λ4;0). There are four time slots used without any guard-band giving the chip period of 100 ps. Code set for time spreading is mapped as C1:{0;λ2;0;λ4}, C2:{λ1;0;λ3;0}…C8:{λ1; λ2;0;0}. Code set to apply binary phase shift mapped as M1:{0;1;0;1;}, M2:{1;0;1;0;}…..M8:{0;0;1;1;}.(1represents as a π phase shift, 0 represent as no phase shift).

Table 2: SPE O-CDMA system parameters used for simulation

Parameter	Value
Code weight	6
Channel spacing	0.4 nm
Wavelength	4 at 1550,1550.4,1550.8,1551.2 nm
Chip time	4
Chip rate	1.25E-10
Bit rate	2.5 Gbs
Fiber length	60 km
Measurements	Eye diagram, Bit error rate and Quality factor

3. Proposed SPE O-CDMA Scheme

1) Lasers (mode locked laser requited to produce 4 wavelength signal) 2) Encoders consisting of required components like PRBS Gen. External Modulator, Multiplexers, Fiber delay lines 3) Multiplexers 4) Optical fiber of 60 km length 5) De- multiplexers 6) Decoders corresponding to each encoder 7) Receiver etc. 8) BER analyzer 9) Eye Diagram analyzer 10) Signal analyzer

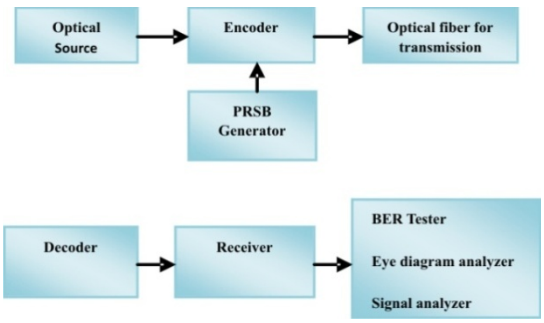

Fig. 2: Schematic Block Diagram for Spectral Phase Encoding Optical CDMA

4. Simulation Setup of One User SPE O-CDMA System

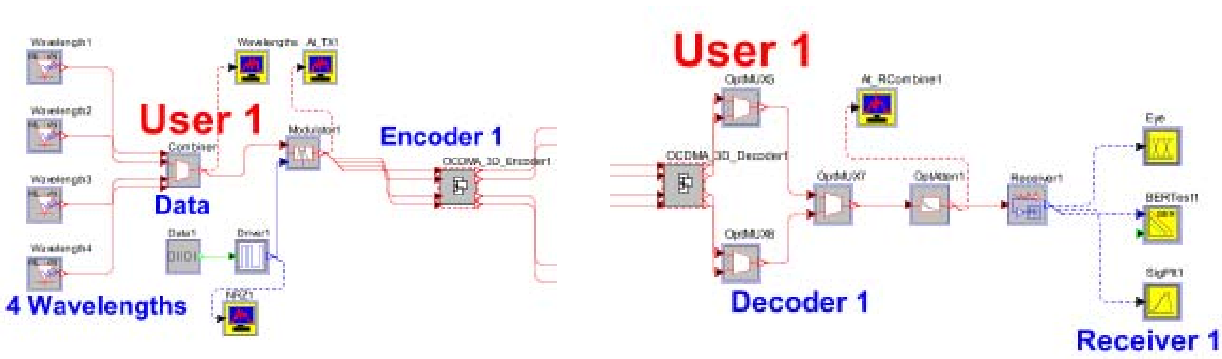

Fig.3: Simulation setup for Spectral Phase Encoding Optical CDMA system using for 1 User

The simulation setup for Spectral Phase Encoding Optical CDMA is shown in figure 3 The MLL is used for generating coherent pulses .The wavelengths range from 1550 nm to 1551.2 nm, with 0.4nm wavelength spacing. This four MLL (wavelengths 1 to4) are used to create a dense WDM multi- frequency light source i.e. carrier signal and this carrier signal is used to modulate the pseudo random bit sequence (PRBS) data of the user. An intensity modulator which is Ext Mod is uses on-off keying modulation to modulate the multiplexed 4 wavelengths according to the NRZ electrical data. For analysis, Eye Diagram analyzer, Beat Error tester and Signal analyzer are used.

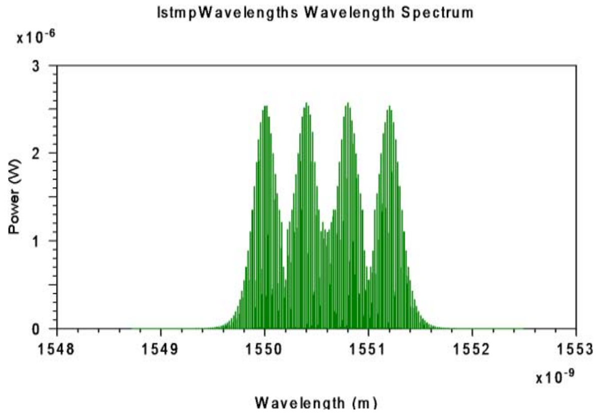

Fig. 4: Wavelength Spectrum for Spectral Phase Encoding Optical CDMA for Eight Users

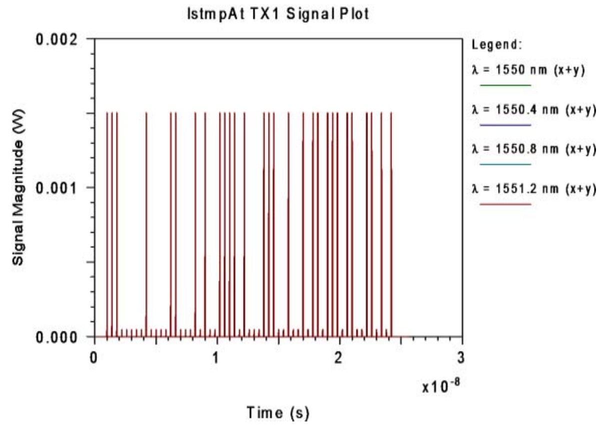

Fig. 5: Modulated data before encoder of User 1

After modulation an encoder is used to encode the signal. The modulated signals are distributed to the respective encoders, which have been assigned a unique W/T code respective to each encoder. The encoded data from all users are multiplexed by Optical MUX and then passed through a 60 km span of standard single mode optical fiber followed by a loss compensating optical amplifier which is OptAmp. The output signal from a fiber span is then passed through OptSplit1to split the signal and routed to the user's decoder. The decoder uses optical filters and inverse delay line arrays providing delays in terms of integer multiples of chip times. The decoded signal finally arrives at optical receiver, BER Tester and Eye Diagram analyzer. Eye diagram analyzer has been used to take the plot of Eye pattern at the receiver end. Bit error rate values for different number of transmitting users have been taken from BER Tester. The system has been redesigned for different number of users. In spite of the use of orthogonal codes, the main effect limiting the effective signal-to-noise ratio of the overall system is the interference resulting from the other users transmitting at the same time, which is called Multiple Access Interference (MAI). MAI is the major source of noise in OCDMA systems.

5. Performance Analysis

Table 3 : 2-D O-CDMA system at -18 dBm Rx. Power

No of Users	BER	Quality factor
User one	1.7323e-018	1.8786e+001
User two	2.2990e-017	1.8482e+001
User three	2.8294e-017	1.8457e+001
User Four	4.7021e-016	1.8099e+001
User Five	3.5847e-015	1.7821e+001
User Six	1.7915e-014	1.7588e+001
User Seven	6.6366e-014	1.7389e+001
User Eight	9.6995e-010	1.5567e+001

Table 4: SPE O-CDMA at -18 dBm RX Power

No of Users	BER	Quality factor
User one	1.089E-60	2.4293E+01
User two	2.7019E-59	2.4188E+01
User three	3.7821E-51	2.3521E+01
User Four	9.8190E-43	2.2704E+01
User Five	2.7585E-41	2.2547E+01
User Six	1.4772E-38	2.2234E+01
User Seven	1.2992E-36	2.1996E+01
User Eight	1.6624E-35	2.1855 E+01

6. Conclusion

The multiple access interference effect was also seen at the optical receiver end in optical CDMA which degraded the efficiency of system by increasing bit error rate. Spectral phase encoding O-CDMA system reduced the MAI as seen in the bit error rate performance. It has been seen that SPE O-CDMA offers extremely high Quality of service at -18 dBm received power and offers low Beat Error Rate. This newly designed system supports 8 Users at 2.5Gb/s over 60 km fiber length. Moreover these results are more realistic as practical impairments have been considered with -18 dB received power, high quality factor and BER<10^{-9}.

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