

# Design and Performance Analysis of Eight User Spectral Phase Encoding O-CDMA time domain System at Different bit rate for MANET

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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. OCDMA 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. Hence, In this paper the performance of Spectral Phase Encoding O-CDMA System in time domain system is compared at Different bit rate from 1Gb/s to 6Gb/s for Metropolitan area Network

Results indicate significant improvement in term Bit Error Rate (BER) and very high quality factor in the form of Quality of Service (QoS). SPE O-CDMA supports eight user at 4Gb/s bit rate and 6Gb/s bit rate for four users. In our analysis, we have used Pseudo Orthogonal (PSO) codes and specific phase shift codes. The simulations are carried out using OptSim (RSOFT).

**Keywords** – MAI, OCDMA, OOC, PSO, QoS, BER

## I INTRODUCTION

Optical code division multiple access (OCDMA), where users share the same transmission medium by assigning unique pseudo-random optical code (OC), which 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 illustrates a basic architecture and working principle of an OCDMA passive optical network (PON) network. In the OCDMA-PON network, the data is 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. Different users are separated by orthogonal codes.

At the receiver, the OCDMA decoder recognizes the OCs by performing matched filtering, where the auto-correlation

for intended user OC produces high level output, while the cross-correlation for undesired OC produces low level output.

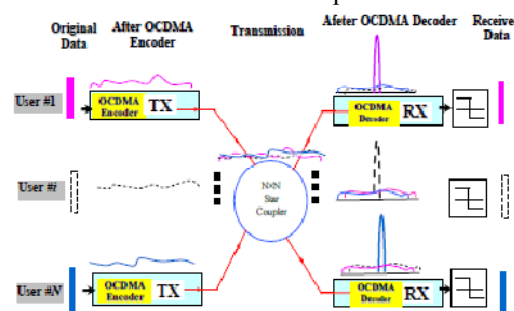


Figure 1. Working principle of an OCDMA network

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) [7~15]. 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 is 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.

## II 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

$$g(1,7)=$$

|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

Mi from g(1,7)

|    | Column 1 (C1) | Column 2 (C2) | Column 3 (C3) | Column 4 (C4) | Column 5 (C5) | Column 6 (C6) | Column 7 (C7) | Column 8 (C8) |
|----|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| r1 | 1             | 1             | 0             | 0             | 0             | 0             | 0             | 0             |
| r2 | 1             | 0             | 0             | 0             | 0             | 0             | 0             | 0             |
| r3 | 0             | 0             | 1             | 0             | 0             | 0             | 0             | 0             |
| r4 | 0             | 0             | 0             | 1             | 0             | 0             | 0             | 0             |

M1

|    | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|----|----|----|----|----|----|----|----|----|
| r1 | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  |
| r2 | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  |
| r3 | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 0  |
| r4 | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  |

M2

|    | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|----|----|----|----|----|----|----|----|----|
| r1 | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  |
| r2 | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  |
| r3 | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 0  |
| r4 | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 0  |

M3

|    | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|----|----|----|----|----|----|----|----|----|
| r1 | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 0  |
| r2 | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  |
| r3 | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  |
| r4 | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 0  |

M4

|    | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|----|----|----|----|----|----|----|----|----|
| r1 | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  |
| r2 | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 0  |
| r3 | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  |
| r4 | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  |

Constructing the four pseudo orthogonal (PSO) matrices M1. . .M4 from the single optimum Golomb ruler g(1,7).

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:

$$\begin{aligned}
 \text{ISD} &= \frac{(\text{throughput})}{(\text{bandwidth required})} \\
 &= \frac{(\text{cardinality} \times \text{data rate})}{\left(\frac{1}{T_b}\right)(\text{bandwidth expansion})} \\
 &= \frac{(n \times r \times R)}{(R)(CD)} \\
 &= \frac{n \times r}{(CD)}
 \end{aligned}$$

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 matrices M1....M32 are numbered 1...32 in the table, with the corresponding assignment of wavelengths and time-slots. For example, code M1 is ( $\lambda_1$  ;  $\lambda_1$  ;  $\lambda_3$ ;  $\lambda_1$  ) and M9 is (  $\lambda_1, \lambda_4$ ; 0;  $\lambda_7, \lambda_8$ ; 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 like M9 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.

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,

extensive time-slot reuse sequence is used for User 1 ( $\lambda_1 \lambda_3$ ; 0;  $\lambda_2 \lambda_4$ ; 0). There are four times slots used without any guard-band giving the chip, period of 100 ps. Code set for time spreading is mapped as C1: {0;  $\lambda_2$ ; 0;  $\lambda_4$ }, C2: { $\lambda_1$ ; 0;  $\lambda_3$ ; 0}.... C8: { $\lambda_1$ ;  $\lambda_2$ ; 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; }. (1 represents as a  $\pi$  phase shift, 0 represents as no phase shift)

TABLE I

THE 32 PSO MATRIX CODES INTERPRETED AS W/T MATRIX CODES

| Wavelengths (W) | Times slots (S)          |                     |                          |                             |
|-----------------|--------------------------|---------------------|--------------------------|-----------------------------|
|                 | 1                        | 2                   | 3                        | 4                           |
| $\lambda_1$     | <b>1,9</b> ,<br>17,25    | <b>1</b> ,14,<br>29 | 19,24,<br>26             | <b>1</b> ,7,10,<br>11,20,32 |
| $\lambda_2$     | 2,10,<br>18,26           | 2,15,<br>17,30      | 20,25,<br>27             | 2,8,11,<br>12,21            |
| $\lambda_3$     | 3,11,<br>19,27           | 3,16,<br>18,31      | <b>1</b> ,21,<br>26,28   | 3,12,<br>13,22              |
| $\lambda_4$     | <b>4,9</b> ,12,<br>20,28 | 4,19,<br>32         | 2,22,<br>27,29           | 4,13,<br>14,23              |
| $\lambda_5$     | 5,10,13,<br>21,25,29     | 5,20                | 3,23,<br>28,30           | 5,14,<br>15,24              |
| $\lambda_6$     | 6,11,14,<br>22,26,30     | 6,21                | 4,17,24,<br>29,31        | 6,15,<br>16                 |
| $\lambda_7$     | 7,12,15,<br>23,27,31     | 7,17,<br>22         | <b>5,9</b> ,18,<br>30,32 | 7,16                        |
| $\lambda_8$     | 8,13,16,<br>24,28,32     | 8,18,<br>23,25      | <b>6,9</b> ,10,<br>19,31 | 8                           |

TABLE II

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 to 6 Gbs                               |
| Fiber length    | 60 to 130 km                                   |
| Measurements    | Eye diagram, Bit error rate and Quality factor |

### III PROPOSED SCHEME SPE O-CDMA

1) Lasers (mode locked laser)2) Encoders 3) Multiplexers 4) Optical fiber of 60to 130 km length 5) De multiplexers 6) Decoders 7) Receiver 8)BER analyzer 9) Eye Diagram analyzer 10) Signal analyzer The simulation setup for Spectral Phase Encoding Optical CDMA is shown in figure 3 The MLL is used to generate four wavelengths, range from 1550 nm to 1551.2 nm, with 0.4nm wavelength spacing, this carrier signal is used to modulate the pseudo random bit sequence (PRBS) data of the user. An intensity modulator

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graph LR; OS[Optical Source] --> E[Encoder]; EG[PRSB Generator] --> E; E --> OF[Optical fiber for transmission]; OF --> R[Receiver]; R --> D[Decoder]; R --> BT[BER Tester]; subgraph BT [BER Tester]; EDA[Eye diagram analyzer]; SA[Signal analyzer]; end
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#### IV SIMULATION OF SPE O-CDMA SYSTEM ONE USER

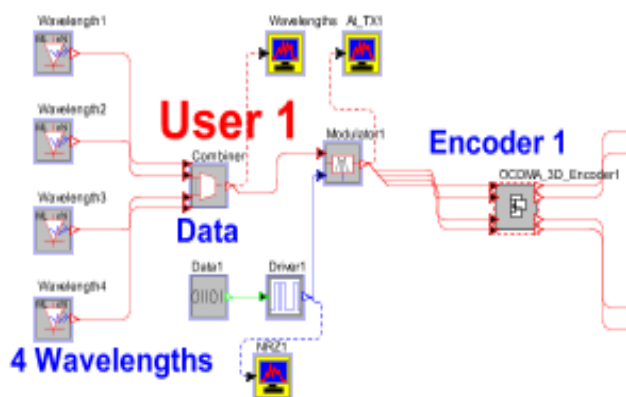


Fig. 5 shows dense wavelength spectrum for four wavelengths respective encoders, which have been assigned a unique W/T code respective to each encoder. The encoded data from all users are multiplexed by Optical MUX and then passed through a 60 km span of standard single mode optical fiber followed by a loss compensating optical amplifier which is Opt Amp. The output signal from a fiber span is then passed through OptSplit1 to 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 (Receiver), BER Test and Eye Diagram. 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.

Feb. 19~22, 2012 ICACT2012

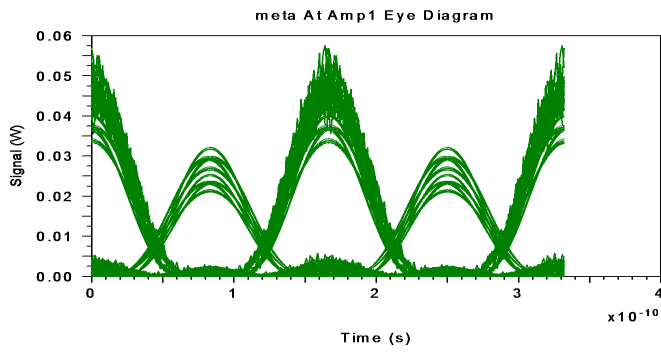


Figure 7. User 4 Tx Eye Diagram at 6 Gb/s  
meta Eyeinner 6 Eye Diagram

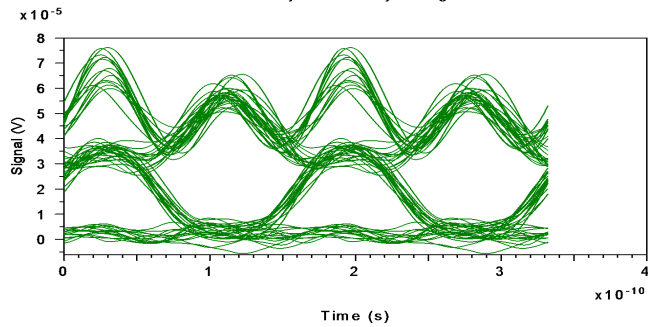


Figure 8. User 4 Rx Eye Diagram at 6 Gb/s

TABLE III  
BER AT USER -1 FOR SPEO-CDMA

| Bit rate    | BER         | $Q^2(\text{dB})$ |
|-------------|-------------|------------------|
| 1.0000e+009 | 1.4555e-083 | 2.5725e+001      |
| 2.0000e+009 | 3.7256e-034 | 2.1676e+001      |
| 3.0000e+009 | 1.5550e-026 | 2.0503e+001      |
| 4.0000e+009 | 8.4236e-011 | 1.6107e+001      |
| 5.0000e+009 | 7.5103e-007 | 1.3645e+001      |
| 6.0000e+009 | 6.5801e-005 | 1.1649e+001      |

TABLE IV  
BER AT USER -4 FOR SPEO-CDMA

| Bit rate    | BER         | $Q^2(\text{dB})$ |
|-------------|-------------|------------------|
| 1.0000e+009 | 2.4890e-058 | 2.4114e+001      |
| 2.0000e+009 | 1.1441e-034 | 2.1745e+001      |
| 3.0000e+009 | 7.2619e-028 | 2.0732e+001      |
| 4.0000e+009 | 1.2746e-014 | 1.7638e+001      |
| 5.0000e+009 | 4.1709e-009 | 1.5211e+001      |
| 6.0000e+009 | 5.2998e-007 | 1.3769e+001      |

TABLE V  
BER AT USER -8 FOR SPEO-CDMA

| Bit rate    | BER         | $Q^2(\text{dB})$ |
|-------------|-------------|------------------|
| 1.0000e+009 | 0.0000e+000 | 6.3010e+001      |
| 2.0000e+009 | 4.7052e-047 | 2.3142e+001      |
| 3.0000e+009 | 1.9875e-032 | 2.1437e+001      |
| 4.0000e+009 | 4.5984e-008 | 1.4554e+001      |
| 5.0000e+009 | 1.0574e-004 | 1.1376e+001      |
| 6.0000e+009 | 4.7735e-002 | 4.4399e+000      |

BER rate indicates that for four users at 5Gb/s the performance of SPE O-CDMA is at permissible BER of  $10^{-9}$ . BER performance degrades fast as bit rate increases and number of active user's increases.

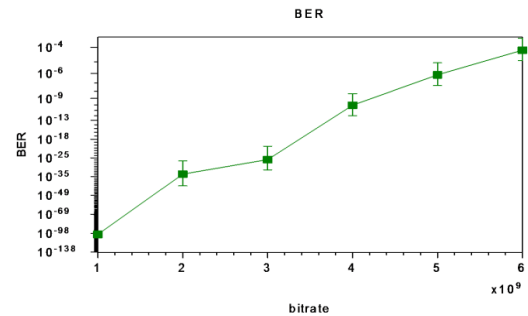


Figure 9. BER at User1 Spectral Phase Encoding Optical CDMA for Different bit rate

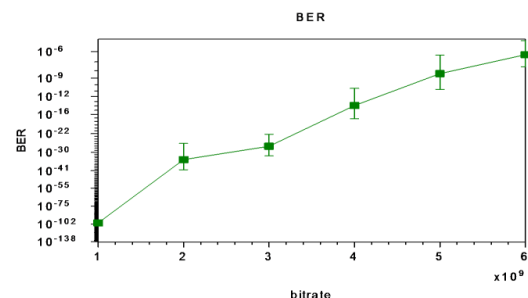


Figure 10. BER at User4 Spectral Phase Encoding Optical CDMA for Different bit rate

Figure 11, 12 and 13 shows that SPE O-OCDMA system performance is extremely good at 4 Gb/s for eight user. Spectral phase encoding O-CDMA system supports eight user at 4Gb/s. system performance degrades as bit rate increases The SPE O-CDMA system offers high Quality factor and extremely less BER at 3Gb/s at -15 dBm received power.

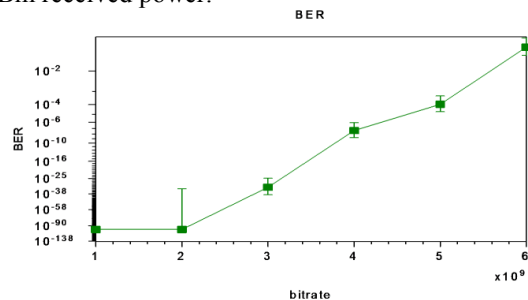


Figure 11. BER at User 8 SPEO- CDMA at different bit rate

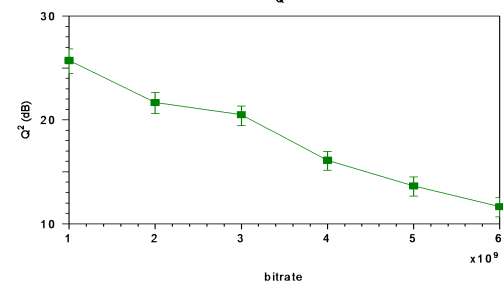


Figure 12. Quality factor at User 1 SPEO-CDMA at different bit rate

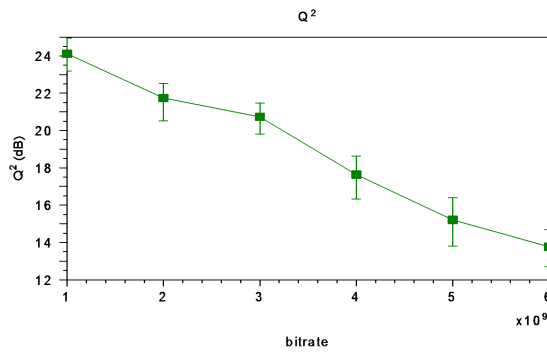


Figure 13. Quality factor at User4 SPE O-CDMA at different bit rate

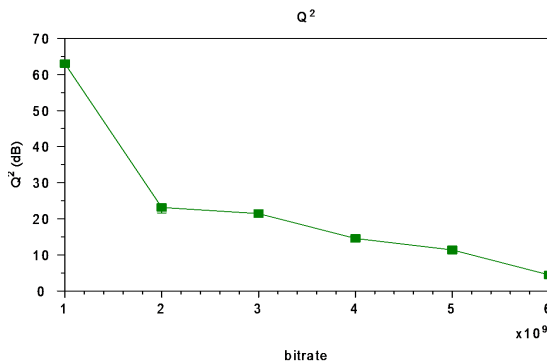


Figure14 Quality factor at User 8 SPEO-CDMA at different bit rate

Results indicate that Q factor performance is good up to 6 Gb/s for four users' quality factor performance is satisfactory up to 5 Gb/s for eight users.

## V 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. Use of spectral phase encoding O-CDMA system reduced the MAI as seen in the bit error rate performance. The spectral phase encoding O-CDMA system performance is good for four users at 6Gb/s bit rate. The performance of SPE O-CDMA system is analyzed at 1Gb/s to 6Gb/s bit rate. The SPE O-CDMA system has been successfully demonstrated at 4Gb/s for eight user. SPE O-CDMA offers high Quality factor and less Beat Error Rate  $<10^{-9}$ .

Moreover these results are more realistic as practical impairments have been considered with -15 dB received power and for permissible BER of  $10^{-9}$ .

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