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Research Article

# Design and Performance Analysis of 3D W/T/P MPR OCDMA System

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***Abstract***

*In the present work, 3D W/T/P MPR codes are designed and implemented into an OCDMA system to analyze the performance of the system. The performance has been analyzed at different data rates and attenuations at the front end of the receiver.*

***Keywords:*** *OCDMA Optical Code Division Multiple Access, 3D Three Dimensional, MPR Multiple Pulses per Row, W/T/P Wavelength/Time/Polarization, Bit Error Rate.*

## 1. Introduction

OCDMA has drawn lots of attention in last three decades. Its main advantage is it can support multiple users with high-level of security. There are various codes designed for OCDMA systems. 1D codes (A. A. Shaar et al, 1983, J. A. Salehi, 1989) are the codes in which time domain is divided into number of slots and then these slots are provided to each users. Using this method to support multiple users number of slots has to be increased but this increases the code length. To overcome this drawback 2D codes were introduced which increases the number of users without increasing the code length (E. S. Shivaleela et al, 2005; S. Shurong et al, 2006; R. Ormani et al, 2012). To further improve the performance of OCDMA system third dimension is added in 2D codes to design 3D codes (J. E. McGeehan et al, 2005; B. C. Yeh et al, 2009; S. Jindal et al, 2009; S. Jindal et al, 2013; S. Jindal et al, 2013).

The paper is organized as follows: Section II gives the formulation of W/T/P MPR codes. In section III design of 3D W/T/P MPR OCDMA system is explained. In section IV results obtained after simulating OCDMA system are discussed. Results are concluded in section V.

## 2. Formulation of W/T/P MPR Codes

A third dimension i.e. polarization is added in earlier proposed W/T MPR codes (E. S. Shivaleela et al, 2005). W/T/P MPR codes can be characterized by N(R X $L_T$ X 2, W, $\lambda_a$=1, $\lambda_c$=1) where, N is the number of codes, R is the number of wavelengths, $L_T$ is the number of timeslots, 2 represent two orthogonal polarization states, W is the weight of the code, $W_P$ = W/R is the weight per row, $\lambda_a$ is the peak out-of-phase autocorrelation and $\lambda_c$ is the peak cross-correlation. Two polarization states used are parallel and perpendicular polarization.

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By providing an encoded chip to each user which is encoded in wavelength, time and polarization domain such that interference between any two users does not increase if they have different set of polarization and hence a 3D codeset can be generated. This type of coding can increase the number of potential users.

## 3. Design of 3D W/T/P MPR OCDMA System

An experimental setup for 3D OCDMA system is shown in Fig. 1.

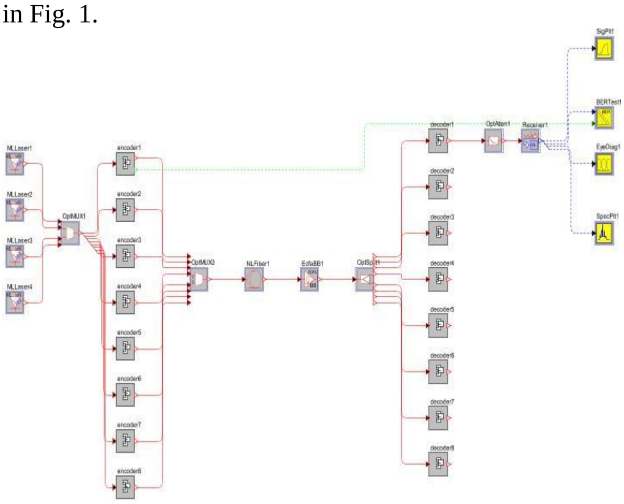

**Fig. 1** Schematic of 8 users 3D W/T/P OCDMA System

In this set-up 4-chips, four-wavelength, weight-4 (per polarization) are used that can support eight users simultaneously in 3-D system. An advantage of this codeset is that it is polarization-rotation invariant between users—while it is necessary for a given user's receiver to be able to lock on to its orthogonal polarization states (J. E. McGeehan et al, 2005). Fig. 2 shows the schematic of optical encoder.

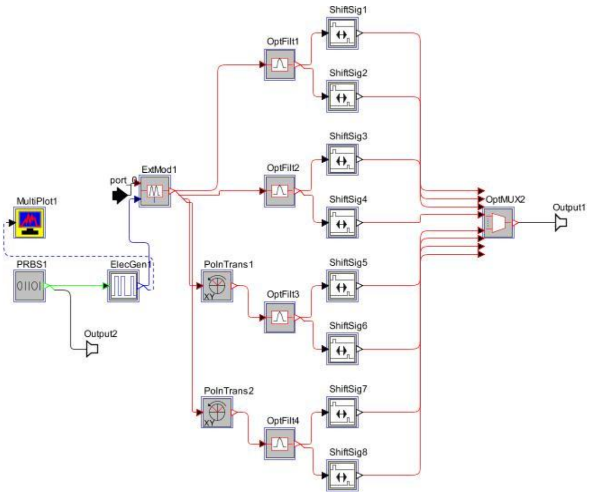


**Fig. 2** Schematic of Optical encoder

As shown in Fig. 2, in this encoder signal is encoded at two polarizations i.e. perpendicular and parallel. To obtain perpendicular polarization, signal is provided with a rotation polarization of 90̊. Then these signals are passed through optical filter whose center frequencies are set at different wavelength provided earlier. After that these signals are provided with time delay according to the MPR codes. Time delays can be calculated using equation 1

Time Delay = Code * Chip Period (1)

where Chip Period = Bit period/ Total no of time slots

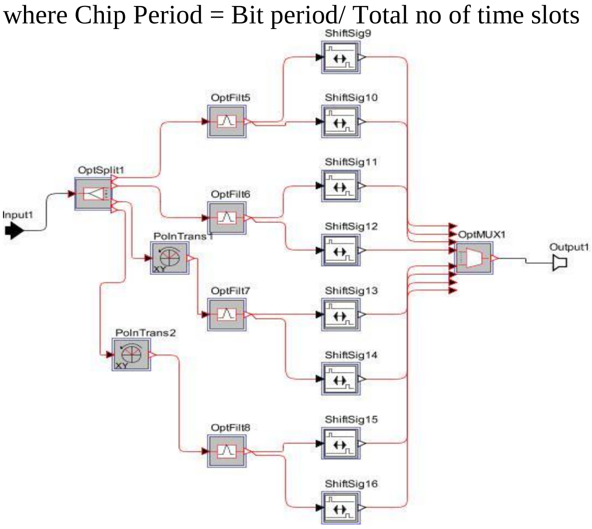


**Fig. 3** Schematic of Optical Decoder

As shown in fig. 3, power splitter is used to divide the signal carrying equal power. Then signal is divided into two stages. First stage decodes the signals which are having parallel polarization. Second stage provides polarization rotation of -90̊, as these signals were perpendicularly polarized. These signals are passed through optical filter which are having the same center frequency as defined earlier. Then time delay is provided to these signals. Time delays for decoder can be calculated using equation given below:

Time delay= (Total Number of time slots- Code)* Chip period.

**Table 1** System parameters used in OCDMA system

| S. No. | Parameter | Value |
|---|---|---|
| 1) | Bit rate | Variable |
| 2) | Bit Period | 1/ Bit rate |
| 3) | Time slots | 97 |
| 4) | Chip Period | Bit period/ Time slots |
| 5) | Laser Wavelengths | 1.55e-6 to 1.5524e-6 |
| 6) | Delta | 8e-10 |
| 7) | Peak Power of Laser | 0.003 W |
| 8) | Rep Rate | 5Gbps |
| 9) | No. of Lasers | 4 |
| 10) | Combiner loss | 3dB |
| 11) | Pattern Type | PRBS |
| 12) | Pattern length | 7 bits |
| 13) | Pre bits | 2 |
| 14) | Post Bits | 3 |
| 15) | Fiber Length | 10 to 100 Km |
| 16) | Polarization at encoder level | 90̊ |
| 17) | Polarization at decoder level | -90̊ |

## 4. Results and Discussions

Simulation of this system has been carried out at OPTSIM. System is analyzed at various data rates and attenuations at the front end of receiver. The data rates used in this system are 5 Gbps, 10 Gbps, 12 Gbps, 15 Gbps and 18 Gbps. Fig. 4 to Fig. 8 shows eye diagrams obtained at different data rates and attenuations.

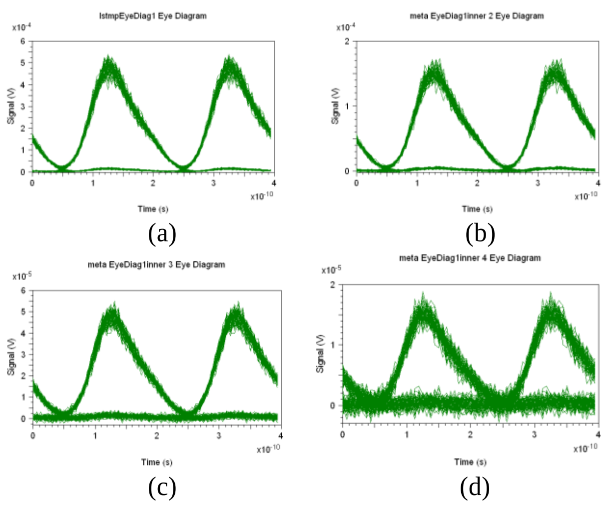


**Fig. 4** Eye Diagrams at a bit rate of 5 Gbps and attenuation of (a) 0dB, (b) -5dB, (c) -10dB, (d) -15dB

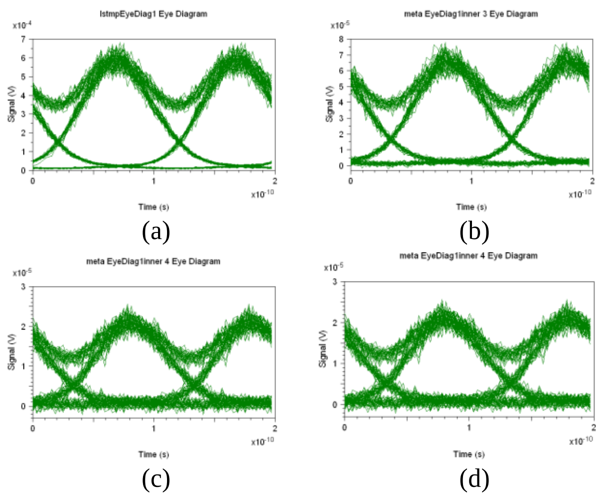


**Fig. 5** Eye Diagrams at a bit rate of 10 Gbps and attenuation of (a) 0dB, (b) -5dB, (c) -10dB, (d) -15dB

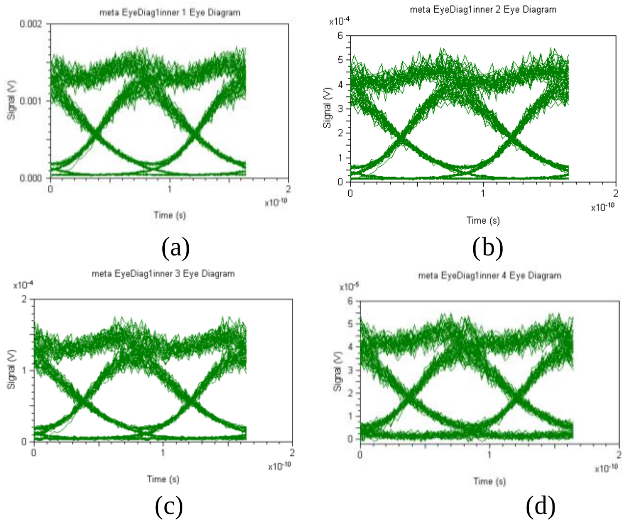


**Fig. 6** Eye Diagrams at a bit rate of 12 Gbps and attenuation of (a) 0dB, (b) -5dB, (c) -10dB, (d) -15dB

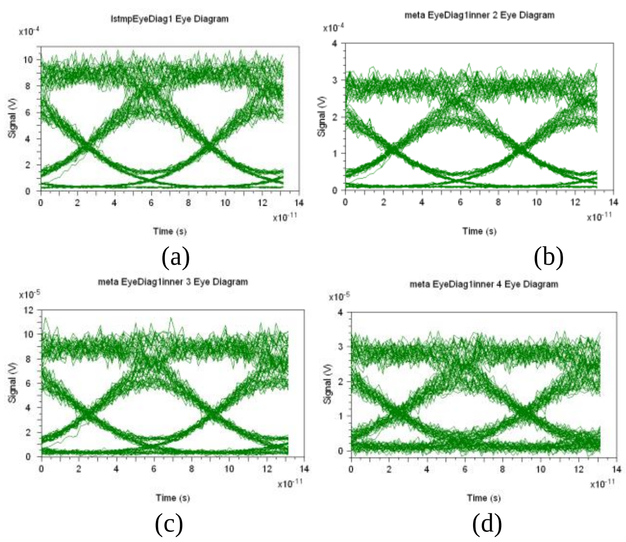


**Fig. 7** Eye Diagrams at a bit rate of 15 Gbps and attenuation of (a) 0dB, (b) -5dB, (c) -10dB, (d) -15dB

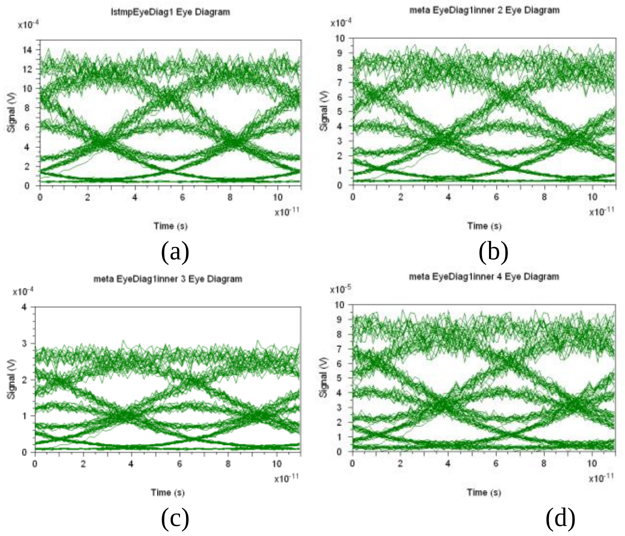


**Fig. 8** Eye Diagrams at a bit rate of 18 Gbps and attenuation of (a) 0dB, (b) -5dB, (c) -10dB, (d) -15dB

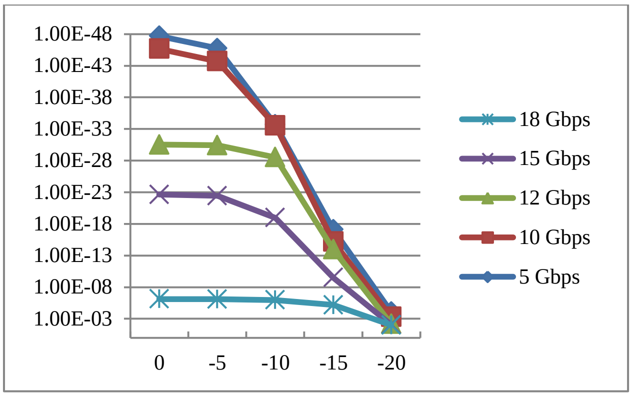


**Fig. 9** BER versus attenuation (in dB) at various data rates

**Table 2** BER at various data rates and attenuations

| Attenuations | 0dB | -5 dB | -10dB | -15dB |
|---|---|---|---|---|
| BER at 5Gbps | 2.05e-048 | 1.80e-046 | 2.12e-034 | 7.99e-018 |
| BER at 10Gbps | 2.07e-046 | 1.97e-044 | 7.29e-035 | 6.25e-016 |
| BER at 12Gbps | 2.98e-031 | 3.75e-031 | 2.99e-029 | 1.07e-014 |
| BER at 15Gbps | 2.31e-023 | 3.83e-023 | 1.11e-019 | 3.12e-010 |
| BER at 18Gbps | 7.72e-007 | 8.06e-007 | 1.06e-006 | 6.62e-006 |

## Conclusions

The design and analysis of incoherent 3D W/T/P OCDMA system is presented in this paper. The performance analysis shows significant scalability improvement without any significant performance degradation at 5, 10, 12, 15 and 18 Gbps using 4 wavelength X 8 Time slots X 2 Polarization states W/T/P OCDMA system. This system supports 8 simultaneous users and gives acceptable BER at 18 Gbps with an attenuation of -15 dB when 100Km long optical fiber is connected to the system. This system can support transmission length of 100 Km for data rate of 18 Gbps. Proposed system is compared with already existing 3D OCDMA system given by Mcgeehen , Jindal et.al. (J. E. McGeehan et al, 2005; S. Jindal et al, 2009) and found that these systems work at higher data rate and gives satisfactory performance even at high attenuation.

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