10Gbps 2D MGC OCDMA Code over FSO Communication System

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Abstract: Currently, wide bandwidth signal dissemination along with low latency is a leading requisite in various applications. Free space optical wireless communication has introduced as a realistic technology for bridging the gap in present high data transmission fiber connectivity and as a provisional backbone for rapidly deployable wireless communication infrastructure. The manuscript highlights on the implementation of 10Gbps SAC-OCDMA FSO communications using modified two dimensional Golomb code (2D MGC) that possesses better auto correlation, minimum cross correlation and high cardinality. A comparison based on pseudo orthogonal (PSO) matrix code and modified two dimensional Golomb code (2D MGC) is developed in the proposed SAC OCDMA-FSO communication module taking different parameters into account. The simulative outcome signifies that the communication radius is bounded by the multiple access interference (MAI). In this work, a comparison is made in terms of bit error rate (BER), and quality factor (Q) based on modified two dimensional Golomb code (2D MGC) and PSO matrix code. It is observed that the 2D MGC yields better results compared to the PSO matrix code. The simulation results are validated using optisystem version 14.

Keywords: FSO, PSO matrix code, SAC-OCDMA, 2D MGC code.

I. INTRODUCTION
With the global challenge for substantial radio frequency and greater portability there is a brisk improvement, in the field of broadband wireless communications. The modern drive for communication with carrier waves at optical frequencies owes its creation to the exploration of the laser and optical communication experiment involved laser beam transmission through the atmosphere. Free space optics (FSO) is an optical communication technology that employs laser source to convey information between two points accounting free space as its propagating medium. In contrast, to microwave link and radio frequency based technology FSO system delivers diverse interests, including inherent security, license free spectrum, higher data transmission and less power dissipation for point to point communication [1]. Despite, FSO performance is prone to several weather conditions. FSO can also overcome the last mile access congestion by sending data at gigabits per second rates over metropolitan distances of a few kilometers [2].
In a burst traffic environment of multiple accesses, local area network (LAN) asynchronous multiplexing schemes are more coherent than synchronous schemes, as fixed bandwidth is not assigned among the users without any access delay [3]. An Optical code division multiple access (OCDMA) system uses pseudo-orthogonal sequences in the time domain to encode data, but multiple access interference (MAI) limited the number of parallel users. OCDMA has been referred as an eminent architecture in raising versatile, resilient, high capacity passive optical networks (PONs) that holds a combination of diversified information and enhanced transmission capacity [4]. FSO is a line of sight (LOS) connectivity based technology that is used for enterprise connectivity, and fiber backup last mile access.

More interestingly, OCDMA combined with FSO become more appealing to protect the major characteristic of both technologies that is asynchronous transmission operation. The combined system has several amazing attributes like soft capacity on-demand, high ductility and provides multirate as well as equal bandwidth support for uplinks and downlinks [5, 6]. Spectral amplitude coding, optical code division multiple access (SAC OCDMA) is the most acceptable technique for optical multi-access network over other OCDMA techniques by mitigating the effect of MAI and upgrading the network performance. One of the productive ways for withdrawing interference is the design of improved codes with required auto and cross correlation properties. Hence, there is a necessity for 2D coding technique which has the potential to enhance cardinality and proper correlation property [7]. Golomb rules are used to generate 16 X 4 matrix codes for each user, making it less susceptible to coherent interference effects and more viable for asynchronous transmission [8].

Shivaleela et al. describes the design principles of wavelength/time (W/T) multiple pulses per row (MPR) codes for incoherent fiber optical CDMA networks [9]. Mendez et al. addressed the design of eight matrix codes set for 2.5 Gbps operation estimating the propagation over an existing 214 km network connection [10]. Recently, Jain et al., addressed performance analysis of 2D (W/T) codes on different modulation formats (NRZ and RZ) [11]. Sahbudin et al. presented performance analysis of spectral amplitude coding, optical code division multiple access-free space optics (SAC OCDMA-FSO) communication system compared with FSO system employing intensity modulation direct detection (IM/DD) using Khazani-syed (KS) code [12].

The paper is structured as follows. Section II discusses the proposed 2D MGC code, Section III contains the proposed system description, Section IV discusses the result and simulation part and finally, Section V summarizes and concludes this paper.

II. TWO DIMENSIONAL MGC CODE [7]

These codes, are uniquely referred to as, wavelength time hopping codes, and multiple wavelength codes. For the production of pseudo orthogonal matrix codes for 64 bits, which is primarily based on the “folding” of spanning rulers or optimal Golomb rulers is implemented in this work. An ideal Golomb ruler is a (0, 1) pulse array where the distances between any pulses is a non-recurring integer. The Golomb rulers are shifted, which shows that the outcome ought to be a matrix of dimensions of r*C, where r*C > L. Here “r” is the number of rows, “C” is the number of columns and L is the length of the Golomb ruler. The possible number of shifts are [(r*C) – L], which is equal to the number of ‘zeros’ attached to the modified ideal Golomb ruler before shifting it. The number of new matrices relies on upon the two parameters, first is the basic Golomb ruler length L and second is the number of shifts. In an effort to assure that the matrix code set size M is equivalent to the number of rows in the matrices the following condition should also be satisfied.
The distance between any pulses is non-recurring integer that is \((r \times C) - L \geq r - 1\), where “\(r\)” is the number of rows, “\(C\)” is the number of columns and \(L\) is the length of the Golomb ruler [7]. The Pseudo orthogonal (PSO) matrices are converted 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.

### TABLE I. [7]

| Wavelength (W) | Time slots |
|---------------|------------|
| 1             | 1,2,6,8,9  |
| 2             | 1,2,3,7,9,10 |
| 3             | 2,3,4,8,10,11 |
| 4             | 1,3,4,5,9,11,12 |
| 5             | 2,4,5,6,10,12,13 |
| 6             | 1,3,5,6,7,11,13,14 |
| 7             | 2,4,6,7,8,12,14,15 |
| 8             | 11,3,5,7,8,9,13,15,16 |

III. PROPOSED SYSTEM DESCRIPTION

![Block diagram of SAC OCDMA-FSO system using 2D MGC code.](image-url)
As shown in Fig.1, the transmitter part consists of 8 laser arrays with 0 dBm input power each. The wavelength ranging for the input laser is 1550.0 to 1550.7 with 0.1nm interspacing between channels. The binary data are fed to a Non return to zero (NRZ) encoder for encoding and it is further optically modulated by Mach-Zender modulator. The outputs of 8 channels are given to a multiplexer, which is directly connected to a 1:8 fork. Each of the signals is being encoded by the encoder. Each 8 encoded data are combined by using another 8:1 fork that is connected to an EDFA amplifier. Then the signal propagates through the FSO channel. At the receiver part, the output signal is passed through a 1:8 fork. Each of the 8 data bits are decoded by a decoder followed by a photo detector for direct detection purpose. Then the resultant electrical signal from the detector is passed through a low pass filter and a BER analyzer, which estimates the BER value, and Q value.

IV. RESULTS AND DISCUSSION

The study is executed by distinguishing four cases: case (1) different modulation technique NRZ and RZ formats, case (2) different input powers 1mW, 2mW, 3mW and 4Mw, case (3) different beam divergences 0.25mrad, 0.50mrad, 0.75mrad and 1mrad and case (4) effect of MAI in OCDMA over FSO communication system. The parameters used in this case are shown in Table II. Figs. 2(a) and (b) show the comparative graph between BER and Q values with respect to FSO range using 2D MGC and PSO matrix code respectively. From the graph we noticed that the Q values reduces while BER increases significantly for FSO range from 1 km to 10 km in case of NRZ and RZ modulation formats respectively. From the plot, it is observed that the BER and Q values of the 2D MGC is better compared to the existing PSO matrix code [13]. Figs. 3(a) and (b) plot the comparative graph between BER and Q values with respect to FSO range using 2D MGC and PSO matrix code respectively for different input powers. It is observed that in this case also, the BER exhibited by the 2D MGC outperforms the PSO matrix code for all the input powers ranging from 1 mW to 4 mW, in steps of one mW [13].

| Parameter         | Value  |
|-------------------|--------|
| Range             | 8km    |
| Data rate         | 10Gbps |
| Input power       | 3mW    |
| Gain              | 30 dB  |
| Attenuation       | 1 dB/ km |
| Beam divergence   | 0.25mrad |

Table II (Simulation parameters) [13]

Fig. 2. (a) Estimation of BER versus FSO range with NRZ and RZ (b) Estimation of Q value versus FSO range with NRZ and RZ.
Figs. 4(a) and (b) show the comparative graph between BER and Q values with respect to FSO range using 2D MGC and PSO matrix code respectively [13]. The plot 2D MGC exhibits a better BER and Q factor compared to that of PSO matrix code for different beam divergence values such as 0.25mrad, 0.50mrad, 0.75mrad and 1mrad, respectively. It is also observed that the BER of the 2D MGC remains zero up to FSO range of 10 km distance, while the beam divergence values are fixed at 0.25mrad, 0.50mrad.

![Graph](image1.png)  

(a)

![Graph](image2.png)  

(b)

**Fig. 3. (a)** Estimation of BER versus FSO range with different power **(b)** Estimation of Q value versus FSO range with different power.
Figs. 5(a) and (b) depict the comparative graph between BER and Q values versus FSO range without MAI and with MAI for (two users) in OCDMA over FSO network using 2D MGC and PSO matrix code respectively. For a single user using the BER exhibited by the 2D MGC code remains zero up to 10 km distance. As is shown in the plot, the 2D MGC exhibits better BER and Q value compared to that of the PSO matrix code both with MAI and without MAI.

**Fig. 4.** (a) Estimation of BER versus FSO range with different Beam divergence (b) Estimation of Q value versus FSO range with different Beam divergence.
V. CONCLUSION

A proposed OCDMA over FSO communication system using modified 2D Golomb code is modelled at bit rate of 10 Gbps of 10 km range and further compared with 2.5Gbps OCDMA over FSO communication system using PSO matrix code. The performance analysis on this modelled OCDMA over FSO is executed using different modulation formats (NRZ and RZ), different input powers (1mW, 2mW, 3mW and 4mW), different beam divergence (0.25mrad, 0.50mrad, 0.75mrad and 1mrad) and without MAI and with MAI (two users). Finally, it is concluded that OCDMA over FSO communication system using 2D MGC code provides desirable values than PSO matrix code and it is observed that NRZ provide satisfactory result than RZ, transmission range is directly proportional to input power and inversely proportional to...
beam divergence and the system performance is poorly affected by the increasing number of users.

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