Performance analysis of multilevel dual polarization OCDMA based modulation using different codes in MDM-OWC system

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In this paper, performance investigation of multilevel dual polarization-based modulation is addressed in optical wireless communication system for security enhancement. The proposed system investigates different codes such as DDW code, MD code and ZCCRW code and compares their performance on the basis of distance and receiver pointing error angle. This system uses Optical code division multiple access code to improve security, data rates and minimize multiple access interference. Results revealed that out of the three codes, ZCCRW code shows better performance using multilevel dual polarization modulation followed by DDW and MD code. It provides quality factor of 29 and minimum BER of 10^{-160} at the distance of 25000 km. Also, performance has been evaluated on the basis of receiver pointing errors. It is observed that ZCCRW code shows quality factor of 27 and BER of 10^{-160} followed by 10 and 8 quality factors of DDW and MD code respectively. The receiver optical power 7 dBm for a distance of 15000 km and as the pointing error increases form 1.1 µrad to 2.5 µrad, the ROP ranges from 3 dBm to 1 dBm.

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Keywords: - ZCCRW, MD, DDW, IS-OWC, BER, Q-factor, OCDMA, MDM

1. Introduction

The emergence of optical wireless technology which is called Inter-satellite optical wireless communication system (IS-OWC) technology is capable of providing huge data rates, high transmission speed, high modulation bandwidth and large capacity of channel. In present era, there is greater demand of 5G services as RF and microwave links that seems to be insufficient. With optical wireless communication, high data rates upto 100 Gbps has been achieved. In IS-OWC system communication takes place in the outer space that has no attenuation losses, thus leading to 0Db /km signal losses in the IS-OWC channel [1]. In spite of these advantages, the efficiency of IS-OWC system is degraded for long distances because of equipment disturbances, vibrations and backend noise radiations thus leading to complete channel failure [2-4]. Hence, the selection of desired modulation technique and operational wavelength is important to obtain optimum speed results for long distance.

Further, to improve the spectral efficiency and speed of transmission, mode division multiplexing technique (MDM) has been integrated [5]. MDM is spectrum efficient multiplexing method which is used to transmit multiple information channels simultaneously over different spatial modes by varying the eigen modes [6, 7]. It is spectral efficient technology which is cost effective to transmit high speed information [8]. It incorporates the use of linear polarized modes which comprises of light intensity profiles and helps in eliminating crosstalk. MDM is considered better than WDM because it is cost efficient and uses single laser source. The works in [9-13] discusses about the integration of MDM scheme in FSO links and optical fiber. Many of the researches have reported the fulfilment of high capacity with MDM systems but MDM in IS-OWC is yet to be analysed. One of the major preferred techniques used to multiplex data is OCDMA (Optical code division multiple access) which allows multiple users to send data where all users share same bandwidth simultaneously [14-15]. OCDMA technique has proven to reduce multipath interference and improve security of communication system [16]. One major advantage of the technique is that it allows better management of resources and originality of code sequence that will reduce interference which is affecting performance of this technique [17]. Polarization modulation has variety of applications in wireless communication like overcome the use of radio resource domain [18]. Polarization modulation has exceptional features like it is insensitive to noise and non-linearity of the power amplifier. Therefore, it is helpful in improving energy efficiency and capacity of channel. It uses polarization of carrier signal as its parameters are gaining more attention [19].

Polarization modulation starts from optical communication. Analysis of binary polarization shift keying was discussed in [20] where two orthogonal polarizations are switched abruptly to constitute different bits. But it has bandwidth widening problem created by abrupt switching of polarizations, hence multilevel dual polarization method overcomes this issue by improving spectral efficiency. Combining amplitude and phase modulation, polarization modulation is helpful in increasing energy efficiency of power amplifier and it works normally even with distortion in non-linear region. Multilevel continuous dual polarization scheme aims to provide continuous signal waveforms in narrow bandwidth and gives continuous polarization. It also provides high symbol error rate performance and high spectral efficiency [21]. In this research article, dual polarized OCDMA based IS-OWC transmission system is presented using different codes. In [22] the impact on optical power when the distance and pointing error is varied. The Section 1 comprises of introduction, Section 2 consists of the proposed set up. Afterward Section 3 analyses and discusses the simulation results of the proposed code along with the existing codes. Finally, conclusions are drawn in Section 4.

2. Proposed dual polarized OCDMA based IS-OWC system using different codes

OCDMA codes are preferred due to its economical operation in Inter-satellite optical wireless communication system. In this proposed set up, three different codes namely ZCCRW, DDW (Diagonal double weight code} and MD (Multi-diagonal code) have been implemented. Dual polarization modulation is implemented on these coding schemes.

2.1. System set up

In this paper, we emphasized on dual polarized OCDMA based Inter satellite communication system using ZCCRW code. The salient features of ZCCRW code includes bandwidth efficiency, less multiple access interference and simple construction.

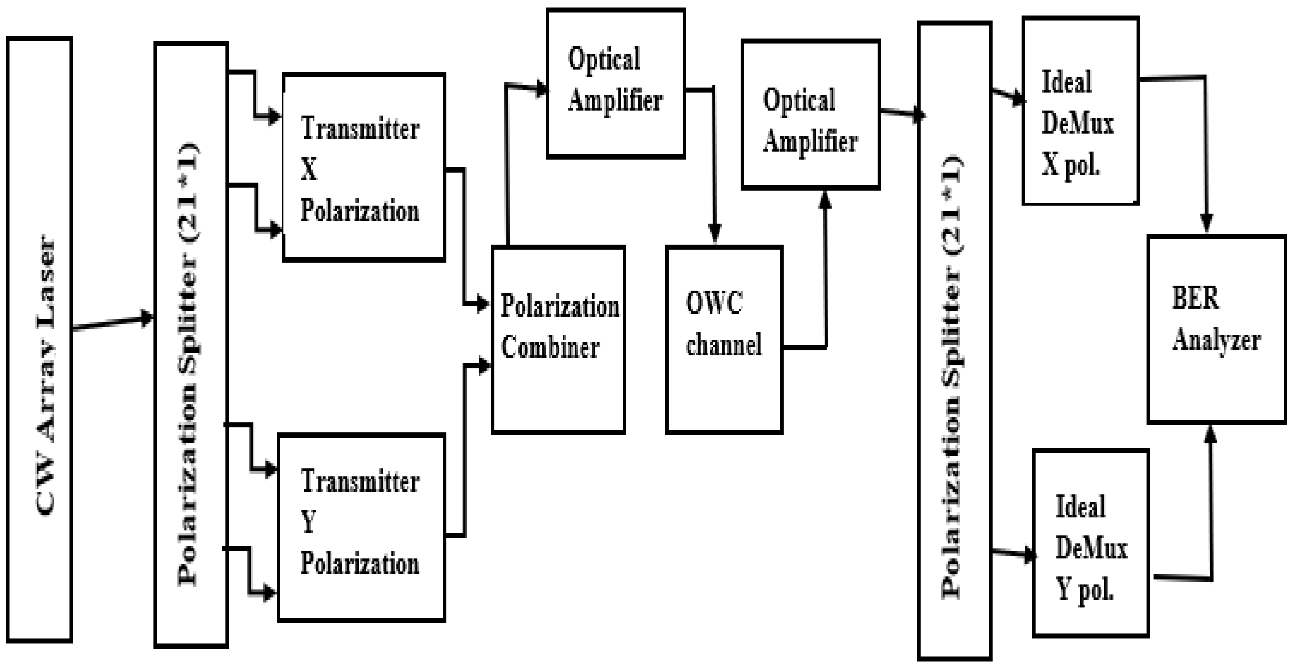


Fig. 1. Proposed set up of dual polarized OCDMA based IS-OWC system

In this proposed set up given in Fig. 1, continuous wave laser of frequency 193.1 THz having input power 30 db is used and simulation is done using Optisystem software 18.0. This circuit consists of 21 active users as 21 input ports. These CW lasers are employed at the source and fed to the polarization splitter. Polarization splitters are used to split light into transmitted X. polarization and transmitted Y. polarization. Transmitter X. polarization consists of 21 multiplexers to combine multiple input signals and provide to ideal demultiplexers. These are again fed to WDM seven multiplexers each having three input ports. Wavelength division multiplexing is used as it is easy to configure and increase channel capacity as well as bit rate of point-to-point systems.

This is processed by pseudo random bit sequence generator. Pseudo random bit sequence generator is used for encryption and simulation of data streams. These are further encoded to different NRZ pulse generators. Mach-Zehnder modulator is used for modulation of data having extinction ratio of 30 db. These signals are modulated and fed to ideal multiplexers. Transmitter Y. polarization contains same simulation set up with transmitter X. Polarization. Transmitter X. polarization and Transmitter Y. polarization are combined at Polarization Combiner.

Optical amplifiers are used between optical wireless channels to amplify the signal.

At the receiver part, optical amplifiers are demultiplexed through polarization splitter. Polarization splitter split the signal into ideal Demux X. polarization and Ideal Demux Y. polarization. At the output section, low pass Bessel filter is used to suppress the unwanted signal and the output reaches to optical receiver. It works as 3R regenerator. Thus, output is obtained at BER analyser to visualize the signal and observe eye diagrams. Eye diagrams are used to measure the quality factor and observe bit error rate. The simulation parameters have been discussed in Table 1.

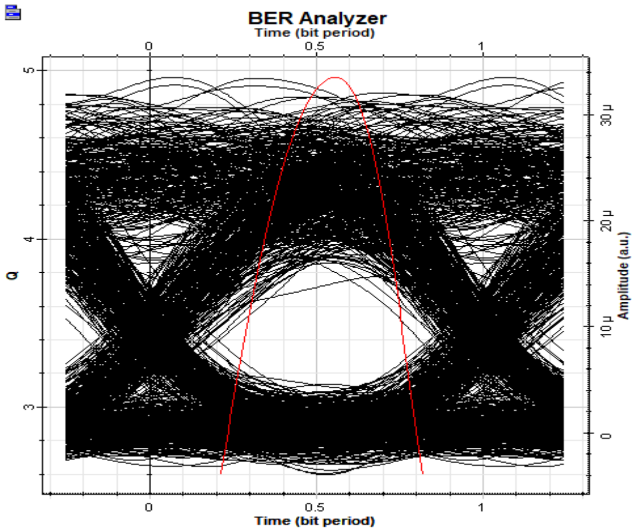
3. Results and discussion

The simulation parameters which are used in dual polarization-OCDMA based IS-OWC communication system are given in Table 1. These parameters are used in proposed set up to measure out quality factor and efficiency of system.

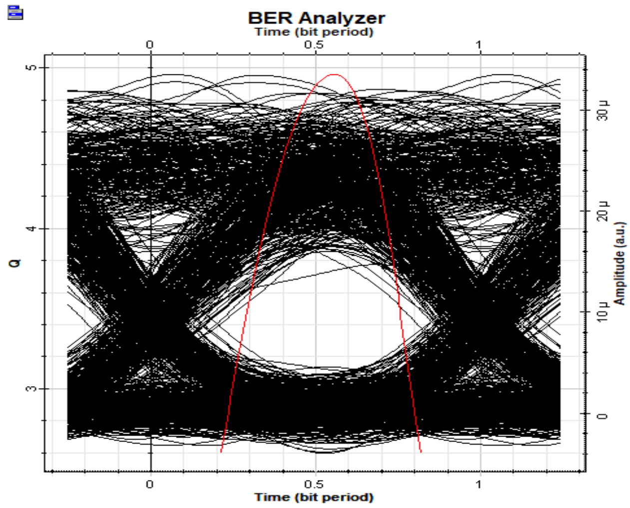
Table 1. Simulation parameters of proposed ZCCRW-OCDMA based IS-OWC system

Simulation Parameters	**Values**
Frequency of CW laser	193.1 THz
Power	30 dBm
Frequency spacing	100 GHz
Gain of optical amplifier	30 db
Channel	OWC
Noise figure	4db
Frequency of OWC channel	1550 nm
Range of OWC channel	3000 km
Bandwidth of Bessel optical filter	20 GHz
Bit rate	10 Gbps
No of input and output ports	21
Distance	25000 km

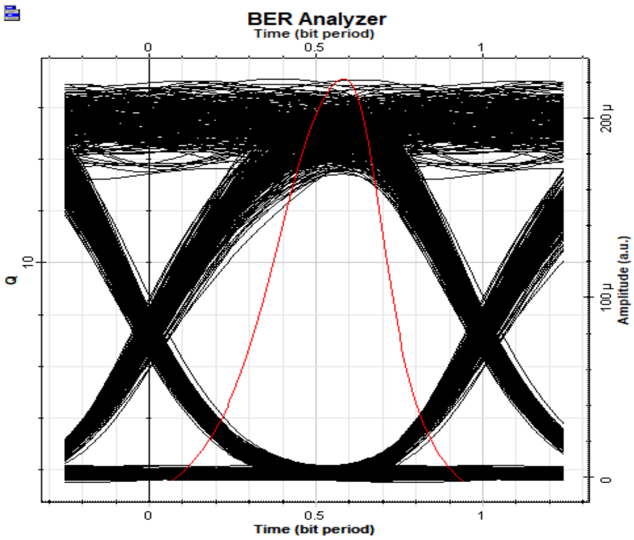
Also, comparison has been done between different codes such as ZCCRW code, MD code and DDW code to evaluate the performance of the designed system. Quality factor has been calculated and BER has been evaluated with increasing IS-OWC distances. Upon implementation of proposed system, eye diagrams have been observed at 25000 km distance for DDW code, MD code and ZCCRW code as given in Fig. 2.



(a)



(b)



(c)

Fig. 2. Eye diagram at 25000 km distance for (a) DDW (b) MD (c) ZCCRW code

It has been observed that ZCCRW codes high quality factor around 29.2 and BER of 10^{-160} followed by DDW code having quality factor of 10.6 and MD code 8.7. ZCCRW code shows better performance in comparison with MD Code and DDW code in Dual polarization OCDMA IS-OWC system. Also, BER is minimum in case of ZCCRW code because of error control. Fig. 3 shows the graph of comparison of different codes with increasing IS-OWC distances.

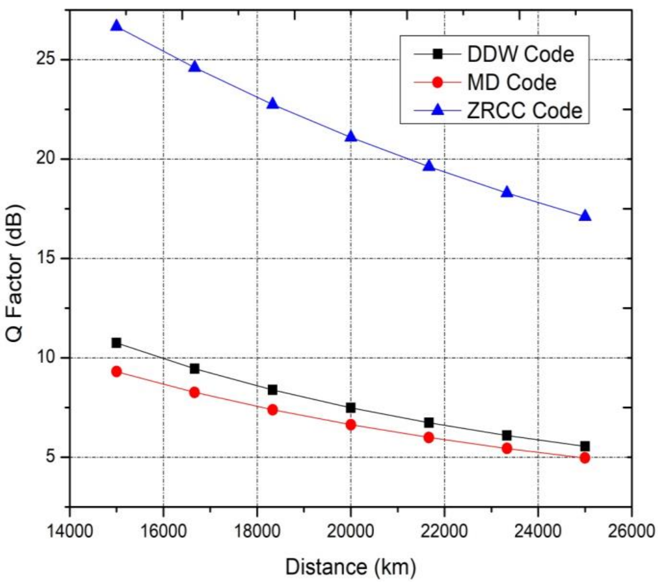


Fig. 3. Comparison of different codes with increasing distances (color online)

Further, as shown in Fig. 4, performance has been evaluated with increasing receiver pointing error angle in order to calculate efficiency of proposed system using pointing errors. Distance is taken around 25000 km and range of receiver pointing error angle varies from 1.0 to 2.6 to measure out eye diagram and bit error rate.

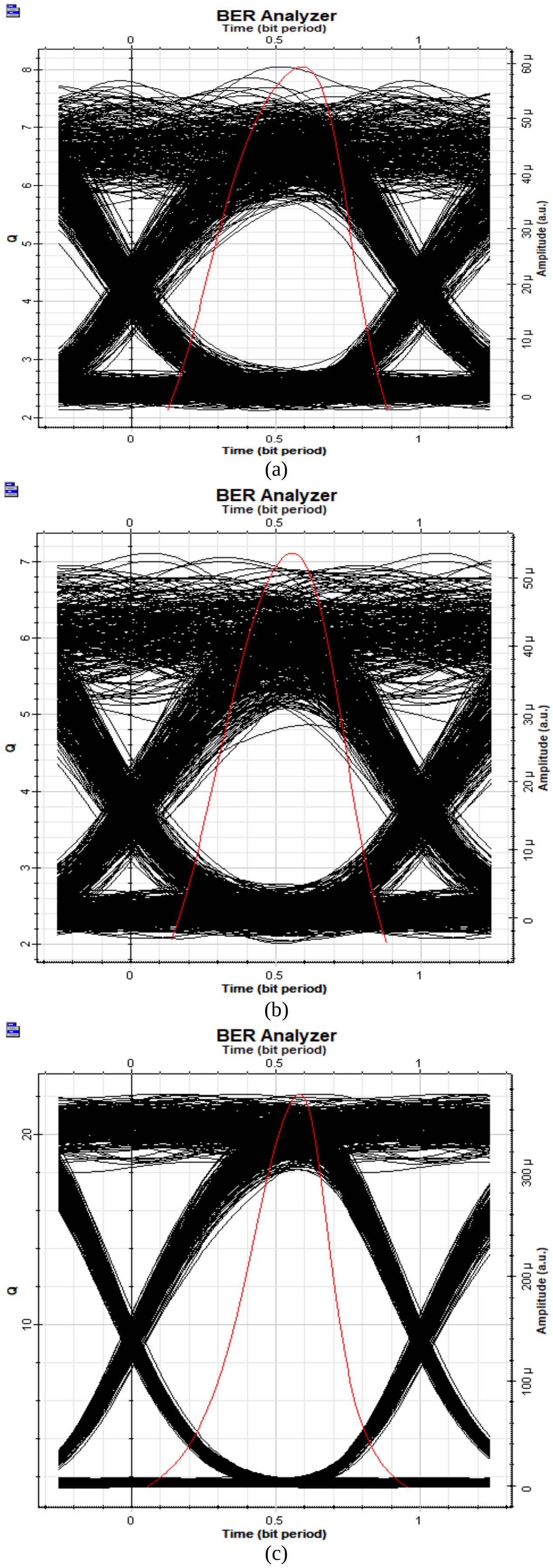


Fig. 4. Eye diagram at 2.5 µrad pointing error angle for (a) DDW (b) MD (c) ZCCRW code

Also, performance comparison is shown in Fig. 5 with increasing receiver pointing errors. It has been observed that around quality factor of 27 has been obtained in case of ZCCRW code followed by MD code (multi-diagonal code) and DDW code (Diagonal double weight code). MD Code possesses quality factor around 8 and DDW code around 11.

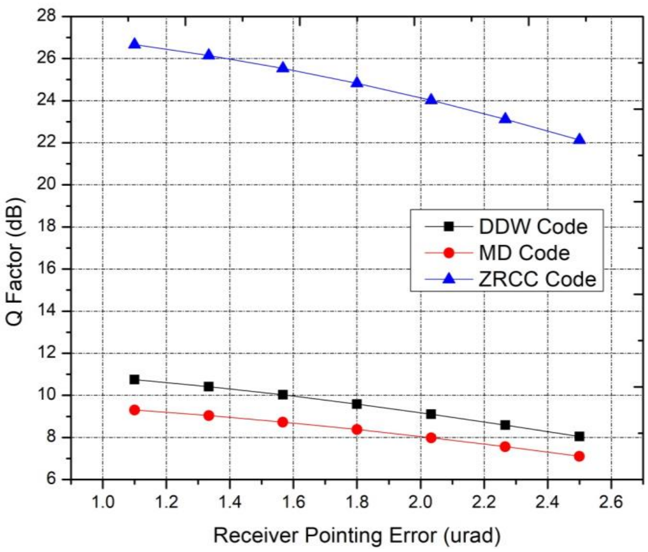


Fig. 5. Quality Factor versus Pointing error (color online)

The performance of system is analysed by observing the impact of distance on the receiver optical power. When the distance is varied from 15000 km to 25000 km the power corresponding to it ranges from 7 dBm to 3 dBm in case of proposed ZCCRW code. The ROP is minimum in case of MD code followed by DDW code reaching upto -3.5 dBm and -2.8 dBm respectively as depicted in Fig. 6.

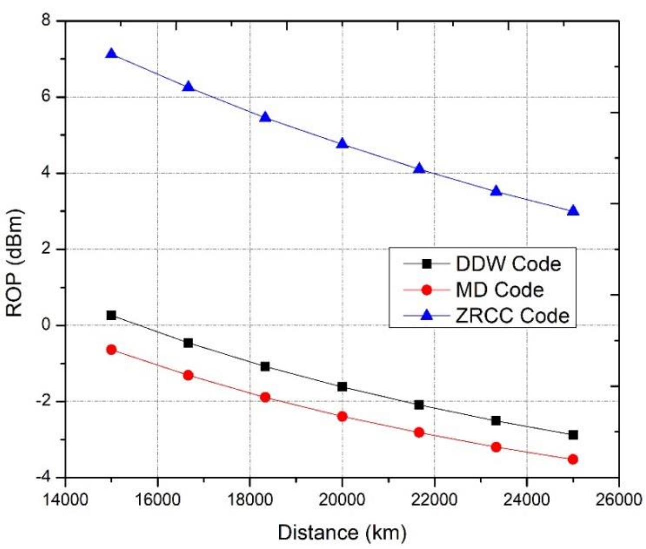


Fig. 6. Received optical power versus distance (color online)

The ROP is reduced maximum in case of MD code followed by DDW code due to misalignment of pointing angle at receiver side. Fig. 7 reveals that the ZCCRW code has the highest value of output power i.e. 3 dBm when pointing error is 1.1 μrad and it reduces to 1dBm as the error increases to 2.5 μrad.

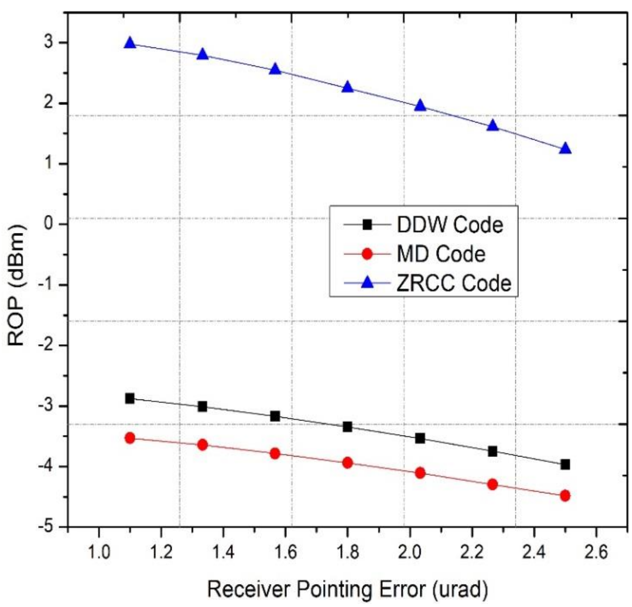


Fig. 7. Received optical power versus pointing error (color online)

4. Conclusion

In this paper, a novel approach has been performed by using ZZRCW code in dual polarization optical code division multiple access technique in IS-OWC based transmission system. For this approach, transmitter X. polarization and transmitter Y. Polarization subsystems are proposed at distance of 25000 km using bit rate of 10 Gbps and power of 30 dBm. Here, ZCCRW code has been compared with MD and DDW code to evaluate its performance in proposed set up. Results have been taken with respect to OWC channel distance and receiver pointing error angle. It is observed that ZCCRW code provides better efficiency, eye quality of 29 and less BER of 10^{-160} due to minimum multiple access interference whereas DDW code and MD Code shows less performance than ZZRCW code. DDW code contains multiple access interference and quality factor of 10.6. MD code contains less MAI but more SNR and quality factor of 8.7. The receiver optical power for proposed ZCCRW code is 3 dBm corresponding to pointing error of 1.1 μrad. Dual polarization OCDMA technique using ZCCRW Code IS-OWC system is proposed for the first time as per author's best knowledge.

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