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Performance Analysis of Wireless OCDMA Systems Using OOC, PC and EPC Codes

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Abstract: To analyze and improve the wireless OCDMA systems performance characteristics such as BER, Q factor and Eye Diagram three distinguishable works have been carried out in this study. Different coding techniques such as OOC, PC and EPC are implemented. The results show that the average BER of EPC, PC, OOC are 7. 01E-12, 4. 64E-10 and 2. 74 E-6 and the average Q factor for EPC, PC, OOC are 22. 12, 21. 254 and 19. 606. From the observed values, it was inferred that EPC is 4% better than PC and 12% better than OOC. Several variations of two dimensional wavelength hoping/time spreading including PC/PC, PC/OOC and PC/EPC OCDMA system codes are implemented and the performance characteristics were analyzed for a user range of 2-20. It was observed that the average BER for PC/EPC, PC/OOC, PC/PC are 1. 01E-12, 6. 06E-8 and 9. 20E-6 and the average Q factor are 22.63, 21.268 and 20.11. From the observed values, it was concluded that PC/EPC performs better than PC/OOC and PC/PC 2D coding techniques. It is proved that using a distance based power allocation algorithm the transmitted power can be saved by 7.85 mW when considered over the distance range of 100-1000 m under high atmospheric turbulence environment.

Key words: OCDMA, prime codes, extended prime codes, optical orthogonal codes, India

INTRODUCTION

Optical Code Division Multiple Access (CDMA) communication systems consolidates immense favorable circumstances, for example, rapid transmission, backing to substantial number of clients when contrasted and Time Division Multiple Access (TDMA) and Wavelength Division Multiple Access (WDMA), adaptability in networking and soft capacity (Chung *et al*., 1989; Stok and Sargent, 2002). The various channel coding techniques in OCDMA such as Optical Orthogonal Code (OOC), Prime Code (PC) and Extended Prime Code (EPC) have their own benefits in different communication scenarios (Yin and Richardson, 2008; Kanmani and Sankaranarayanan 2011, 2012, 2013).

Furthermore, the 2D OCMDA codes exhibits unique compensation like increase in number of users, improved Bit Error Rate (BER) parameter and is secure in nature. However, the wireless OCDMA systems which is under-explored possesses additional profit such as reduced Multiple Access Interference (MAI), accessibility of license free communication channel, high speed transmission with increased bit rate, no multipath fading, electromagnetic compatibility and limited multipath distortion (Ghaffari *et al*., 2008). On the other hand, RF use is limited in sensible environments where high data security and high immunity against interference with other existing RF and electronic devices are required (e.g., Healthcare environments) (Ghaffari *et al*., 2009).

Given the observation in the communication systems especially in wireless optical communication, this research work is motivated and focused towards exploring the benefits of OCDMA systems under various coding schemes and 2D environments (Ghafouri and Karbassian, 2012; Salehi, 2007). Also, the optimization of transmission power remains a challenge in the free space system due to the eye safety requirements and efficiency of the transmission system. To address this issue, a power optimization algorithm is also devised in this research. In optical wireless communication, channel displaying and the connection execution examination are the key points of interest keeping on pulling in innovative work in the type of principal hypothetical examination and practical and also practical execution. The main aim of this study is as follows:

- To examine the performance of the wireless OCDMA systems under OOC, PC and EPC environment
- To design the 2 Dimensional PC/PC, PC/EPC and EPC/EPC codes in wireless OCDMA system
- To analysis PC/PC, PC/EPC and EPC/EPC coding techniques is carried out with respect to BER, Q factor and eye diagram
- To examine OCDMA systems with and without power control algorithms

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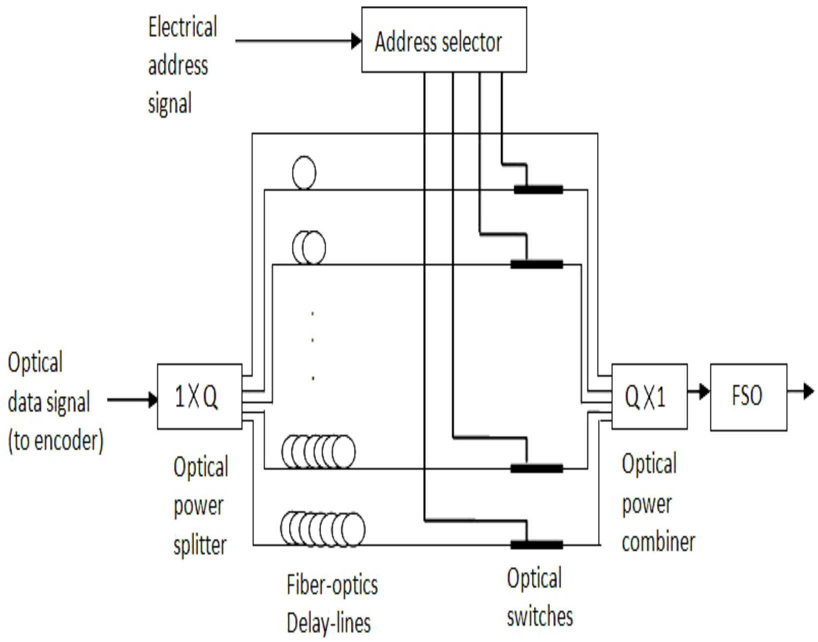

Fig. 1: Encoder system of OCDMA transmitter

MATERIALS AND METHODS

Implementation of prime code families in wireless ocdma under differential channel charecteristics: The architecture of Wireless OCDMA system includes a transmitter, a transmission channel and a receiver (Kanmani and Sankaranarayanan, 2012). Each user's information sequence is fed into the Forward Error Correcting (FEC) encoder. The FECs are applied as error-correcting codes in this system, both encoding and decoding are performed in electrical domain. There are a large number of FEC codes available, each with different properties that are related to how the codes are generated and consequently how they perform. In this work, the Reed-Solomon (RS) (255,239) code is used. RS codes are described as (N, K) where N is the total number of symbols (bits) per code word is the number of information symbols (data bits) and R is the number of check symbols (N-K). The overhead of the code is simply the ratio of the check symbols to code-word symbols. For example, the Reed-Solomon codes used (255, 239) so will consist of a 239 information symbols and 16 check symbols with about 6.7% overhead.

OCDMA encoder: The optical data signal out of the modulator is fed into the encoder circuit as shown as in Fig. 1. The encoder consists of a optical power splitter, an optical power combiner and a set of parallel fiber-optic delay lines. At the input of encoder, optical data signal is split into pulses by the power splitter. The optical switch delay line is used to control the passage of the delayed pulses at its input upon closing of the switch. An electronic address selector controls the opening and closing of the optical switch. The 'w' properly delayed pulses, according to the chip position of binary ones in the address signature of its intended receiver, are selected by closing the corresponding 'w'optical switches. These 'w' properly delayed optical pulses are then recombined at the power combiner to form the desired code sequence. The resulting OCDMA waveform is then combined with the code sequences from other stations and they are transmitted through the free space optic channel.

Receiver side: In receiver side, the optical decoder is built with a similar setup to optical encoder. The decoder is used to correlate the incoming waveform by accumulating the properly delayed signal to give high autocorrelation peak for the correct address signal. Otherwise, a low cross-correlation function results Fig. 2.

The correlated signal is then photo detected. The photo detector converts optical signal into electrical signal. In the threshold detector, all the weighted chips of the desired sequences are summed to form a decision variable. This decision variable is compared to a threshold to detect the data bit 1 or 0. These data bits are entered into FEC RS decoder to implement the error correcting technique. The corrected data bits are entered into the end user.

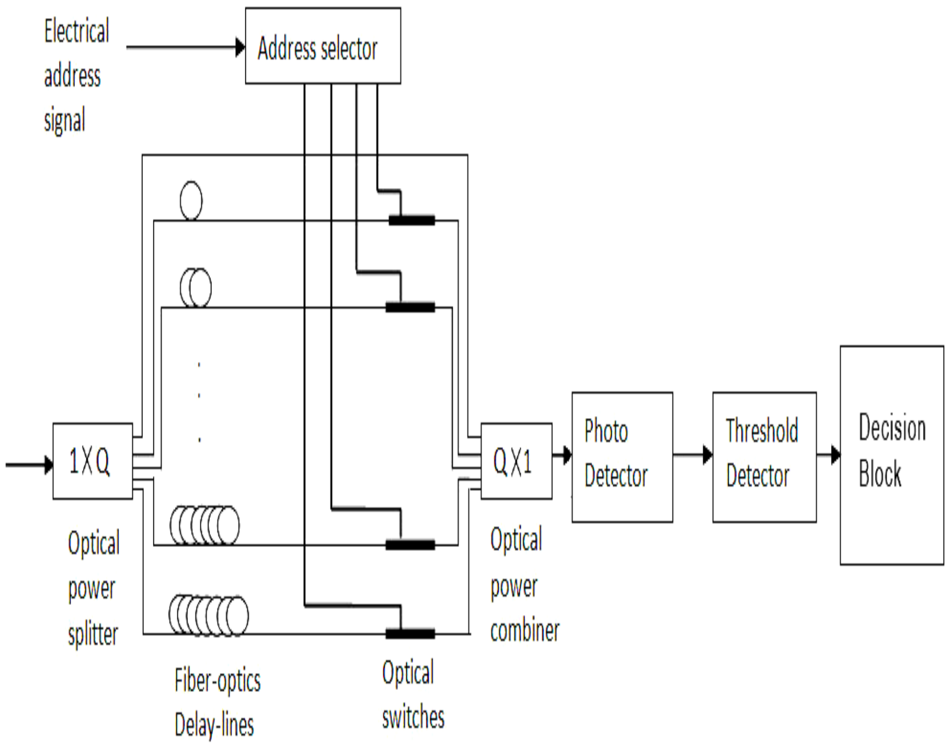

Fig. 2: Wireless OCDMA receiver employing prime codes

RESULTS AND DISCUSSION

Performance analysis of wireless OCDMA systems using OOC, PC and EPC: The performance of three different coding techniques such as OOC, prime codes and extended prime codes used in Wireless OCDMA. To accurately quantify the performance of the coding techniques, the channel characters such as attenuation, transmission wavelength, bitrate and divergence angle are varied one at a time keeping the other parameters a constant. The performance is contrasted with respect to BER, Q-factor and eye diagram.

Simulation setup: LASER is used at the transmitter end with a wavelength of 1550 nm with each user having bit rate of 1.25 GB/s and power of 1.3 dBm. The receiver is designed with an aperture area of 180 cm^{-2}. The link range is fixed as 500 m and the beam divergence angle is set as 3 mrad. To simulate a weak turbulence environment that is considered for the experiment, the environment attenuation is set as 1 dB km^{-1}. Prime code P = 7, extended prime code P = 7 and OOC (41, 3, 1, 1) are used here. Number of users are 7.

Comparison of ber with varied attenuation: To effectively differentiate the performance of the coding techniques with the increase in attenuation, the attenuation is varied in the experimental setup in steps of 1 on a scale from 10 d B-1 dB. In each of the steps, the BER for extended prime code, prime code and OOC is observed and the results are represented graphically by plotting them on Fig. 3. From the Fig. 3, it can be inferred that the extended prime code has a very low BER for various levels of attenuation. Comparison of Q-factor with varied attenuation.

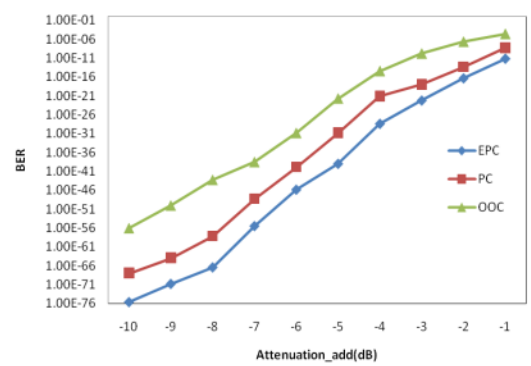

Fig. 3: Variation in BER with change in attenuation

The performance of extended prime code, prime code and OOC is compared as a measure of Q-factor with change in attenuation. The attenuation is varied in the in

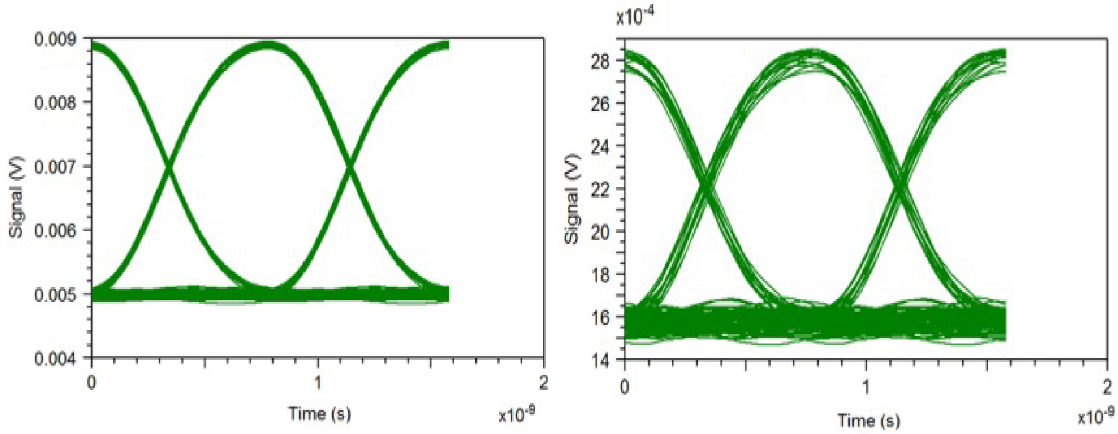

Fig. 4: Variation in eye diagram with varied attenuation: a) 10dB; b) -5 dB

Table: 1 Observation of change in Q-factor with varied attenuation

Attenuation (dB)	EPC (Q-factor)	PC (Q-factor)	OOC (Q-factor)
-10	25.31	24.84	24.10
-9	24.82	24.50	23.53
-8	24.73	24.13	22.82
-7	23.81	23.32	22.42
-6	23.93	22.54	21.50
-5	22.53	21.51	20.41
-4	21.43	20.42	18.41
-3	19.52	18.95	15.95
-2	18.47	17.12	13.82
-1	16.72	15.21	13.10

steps of 1 on a scale from 10-1 dB. In each of the steps, the Q-factor for various coding schemes is observed and is tabulated as shown in Table 1.

It can be clearly inferred that extended prime code performs better than prime code and OOC with increase in attenuation. Hence, extended prime codes are suitable for environments with high range of attenuation.

Comparison of eye diagram with change in attenuation: The effect of attenuation on received signal is studied with the help of eye diagram. The eye diagrams for EPC is observed with varied channel characteristics to stand as proof for the results obtained in the previous sections (Fig. 4).

Analysis of wireless optical CDMA using 2D PC/PC, PC/EPC AND PC/OOC CODE: Construction of 2D codes can be done in many different combinations. In this study, three 2D codes that are widely being used in OCDMA communication namely, PC/PC, PC/EPC and PC/OOC are selected (Yin and Richardson, 2008). It is implemented for wireless OCDMA and the performance of each of these 2D codes is measured using the standard performance measuring metrics.

The BER for the above setting is measured for the three different codes for different number of users such as

Table 2: Setting of variables for PC/PC, PC/EPC and PC/OOC codes

Parameters	2D WH/T scodes	No. of available wavelength	λ	Cardinality	Code length
(5×25, 5 ,0, 1)	PC/PC	5	1	20	25
(5×49, 5, 0, 1)	PC/EPC	5	1	20	49
($5\times n_{OOC}$, 3, 1, 1)	PC/OOC	5	1	20	$n_{OOC} = 7$

Table 3: Comparison of Q-factor for various 2D codes with variable number of users

No. of users	PC/PC Q factor	PC/EPC Q factor	PC/OOC Q factor
2	25.12	26.91	26.10
5	24.72	25.82	25.31
10	20.99	23.22	22.31
15	18.31	20.99	19.01
20	11.41	16.21	13.61

2, 5, 10, 15 and 20. The results tabulated in Table 2 are plotted on as graph and is shown in Fig. 5. It can be seen that when the number of users is 5, the BER of PC/PC is 2.36E-69, the BER of PC/EPC is 1.67E-86 and that of PC/OOC is 8.33E-76. When the number of users is greater than 10, PC/PC is inferior to other two codes but PC/EPC and PC/OOC have adjacent values of BER. In total, it can be inferred that BER of PC/PC is the highest for all range of users. The BER of that of PC/OOC is lesser than PC/PC code but it is considerably high when compared to PC/EPC codes, especially when the number of users is >10. Therefore PC/EPC is the ideal choice when the number of users is less.

To confirm the inference obtained using the BER analysis of the three codes, Q-factor is measured. The three codes are simulated in the same environment that was used for analyzing the BER and the Q-factor is observed for individual codes when the number of users is 2, 5, 10, 15 and 20. The observations are tabulated in Table 3.

With the results of BER and Q Factor observation, it was concluded that PC/EPC performs better than PC/OOC and PC/PC 2D coding techniques. Therefore, PC/EPC is the ideal choice especially when the number of users is <20.

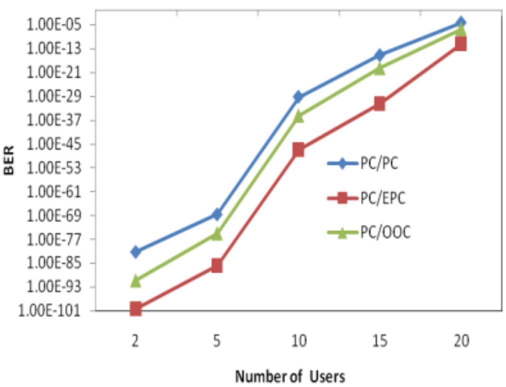

Fig. 5: Comparison of BER with varied number of users

Distance based power allocation algorithm in FSO channel: To analyze the effect of distance based power allocation algorithm, it is necessary to determine the received power using various coding schemes (Kanmani and Sankaranarayanan, 2011). Hence, the receivers are placed at various distances from the transmitter and the received power is measured at each receiver. All the three major coding techniques namely OOC, prime codes and extended prime code are individually used to transmit the signal. The transmission channel environment is set as a strong turbulence environment with environmental attenuation of 9 dB km^{-1}.

An average minimum output power of 1.3 dB m is fixed to be transmitted with an input signal having power 0.0013 W. The variation of the power consumed in the three schemes is evaluated using BER and Q-factor. To determine the BER for the various coding schemes, the signal is transmitted individually using the respective coding technique. From the Fig. 6, it can be seen that extended prime code outperforms prime code and OOC. It can also be inferred that the BER is directly proportional to the link distance i.e., the BER is comparatively small when the link distance is small and increases as the link distance increases.

Similarly, to the analysis of BER for various receivers placed at various distances, the Q-factor is also measured and tabulated in a strong turbulence environment. The transmission power is maintained to be 1.3dbm with a base transmit power of 0.0013 mW. The environment settings for a strong turbulence environment remain unchanged as in the previous case of attenuation. The observations are tabulated in Table 4.

The observation in Table 4 is plotted as a graph in Fig. 7 From the Fig. 7, the Q-factor performance of extended prime code, prime code and OOC are observed. The figure stands a proof for the previous inference in analysis of BER stating that Q-factor is inversely proportional to the link distance.

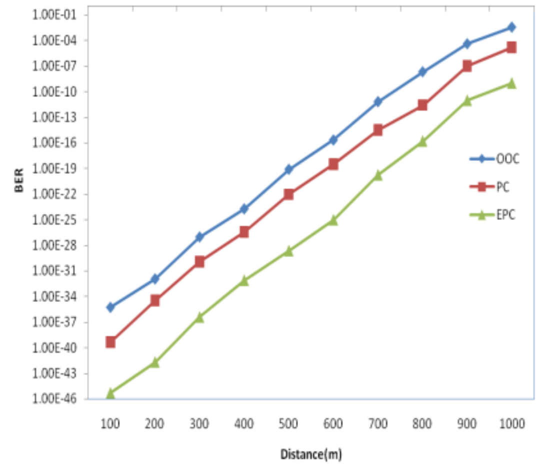

Fig. 6: Comparison of BER for various coding schemes without applying distance based power allocation algorithms

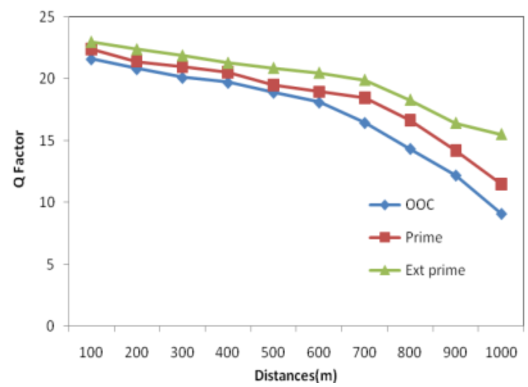

Fig. 7: Comparison of Q-factor for various coding schemes without applying

Table 4: Q-factor observation of various coding schemes without using power control algorithm

Distances in (m)	Q factor OOC	Q factor PC	Q factor EPC
100	21.60	22.40	23.0
200	20.80	21.40	22.4
300	20.10	20.99	21.9
400	19.70	20.51	21.3
500	18.90	19.50	20.9
600	18.10	18.95	20.5
700	16.45	18.47	19.9
800	14.35	16.67	18.3
900	12.20	14.20	16.4
1000	9.10	11.50	15.5

Distance based power allocation algorithms: From the experimentations conducted without applying distance based power allocation algorithm, it is observed that when equal power is transmitted to receivers at various link distances, the signal strength decreases with distance and the receiver at the farthest end will receive deficient signal

Table 5: Received signal strength for receivers placed at different link distances

Distance in (m)	Received power (dBm)
100	-30
200	-34
300	-37
400	-41
500	-45
600	-49
700	-53
800	-57
900	-61
1000	-65

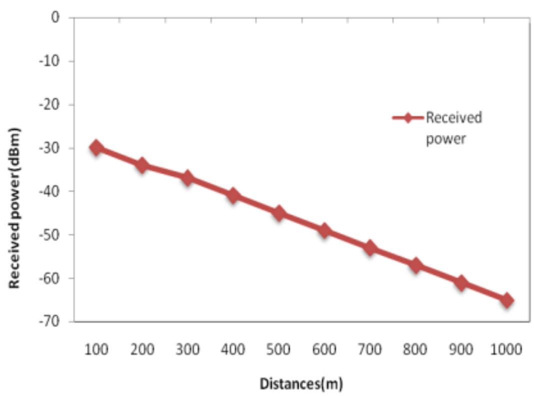

Fig. 8: Received signal strength by receivers placed at different link distances when signal with equal power is transmitted

strength whereas the receiver closest to the transmitter will receive excess signal strength. These results are tabulated in Table 5 and the observation is plotted on a graph in Fig. 8.

To overcome the above problem, the transmission power has to be varied for each receiver based on the distance of the receiver from the transmitter. Consider the scenario where the received power is -61 dBm, the BER for extended prime code is 10^{-12}. Assuming that the BER range is tolerable for the application, the transmitted power should be varied depending on the distance of the receiver from the transmitter. Here, the acceptable received power is fixed. When the distance between the transmitter and the receiver is less, low power signal should be transmitted. Accordingly, when the distance increases, the transmitted power should also be increased. By applying distance based power allocation algorithm, for the setup in Table 5, when the link distance is 200 m the transmitter transmits at -26 dBm power whichh is sufficient to receive-61 dBm in the receiver side.

When the link distance is 400 m, -18 dBm transmitter power is only needed to receive -61 dBm in the receiver. Hence, 8.91 dBm power is saved in the transmitter side. This design effectively illustrates that a significant

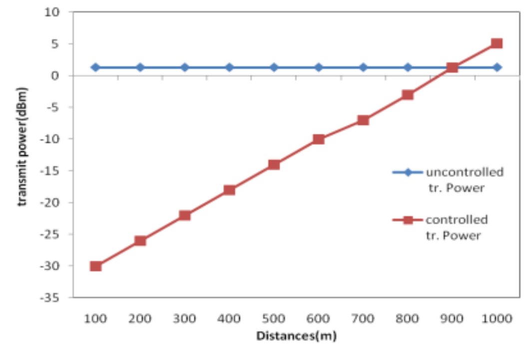

Fig. 9: Comparison in terms of transmission power between conventional scheme of transmission and new design with dista

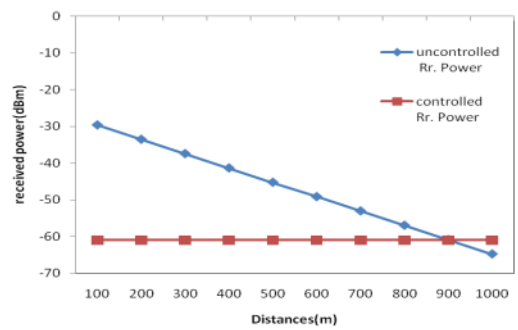

Fig. 10: Comparison of received signal strength by the receivers with distance based power allocation and conventional systemnce based power allocation

amount of power 7.85 mW can be saved in transmission in free space optical channel communication if the transmission power is allocated based on the link distance.

By applying the distance based power allocation scheme, it can be seen that significantly low transmission power is used for transmission when the receivers are at close distance and no power is wasted. When compared with the conventional method, the design with distance based power allocation shows drastic savings 7.85 mW in terms of power. The comparison in terms of transmission power between orthodox scheme of transmission and the new design proposed is shown in Fig. 9.

It is clearly visible from Fig. 10 that in the traditional system, the receivers close to the transmitter receive very high power unnecessarily. However, when distance based power allocation is applied equal power is transmitted to all the receivers even though they are at different distances from the transmitter.

CONCLUSION

In this study, three distinguishable works have been carried out to analyze and improve the wireless OCDMA systems' performance characteristics in wireless medium, by making use of the performance characteristics of FSO communication systems such as BER, Q factor and eye diagram. Though this study presents several works on improving the efficiency of the wireless OCDMA systems, this can be further enhanced, especially at the receiver side with an improved receiver design.

REFERENCES

Chung, F.R., J.A. Salehi and V.K. Wei, 1989. Optical orthogonal codes: Design, analysis and applications. IEEE. Transac. Inf. Theor., 35: 595-604.

Ghaffari, B.M., M.D. Matinfar and A.S. Jawad, 2008. Wireless optical CDMA LAN Part I: Digital design concepts. IEEE. Transac. Commun., 56: 2145-2155.

Ghaffari, B.M., M.D. Matinfar and J.A. Salehi, 2009. Wireless optical CDMA LAN: Digital implementation analysis. IEEE J. Sel. Areas Commun., 27: 1676-1686.

Ghafouri, S.H. and M.M. Karbassian, 2012. Optical CDMA networks: Principles, analysis and applications. John Wiley and Sons, Hoboken, New Jersey, USA., ISBN: 978-0-470-66517-6, Pages: 387.

Kanmani, R. and K. Sankaranarayanan, 2011. Using prime codes analysis of power control for indoor wireless optical CDMA networks. Int. J. Emerg. Technol. Sci. Eng., 5: 21-27.

Kanmani, R. and K. Sankaranarayanan, 2012. BER Analysis Of Wireless Optical CDMA LAN using prime codes and extended prime codes. Networking Commun. Eng., 4: 427-433.

Kanmani, R. and K. Sankaranarayanan, 2013. Study of wireless optical cdma lan in indoor environment. Int. J. Adv. Res. Comput. Eng. Technol. Syst., 2: 2278-1323.

Khangura, S.K., K. Kaur and R.S. Uppal, 2010. Power control algorithms in wireless communication. Int. J. Comput. Appl., 1: 82-87.

Mendez, A.J., R.M. Gagliardi, V.J. Hernandez, C.V. Bennett and W.J. Lennon, 2003. Design and performance analysis of wavelength/time (W/T) matrix codes for optical CDMA. J. Lightwave Technol., 21: 25-24.

Salehi, J.A., 2007. Emerging optical CDMA techniques and applications. Internat. J. Opt. Photon., 1: 15-32.

Stok, A. and E.H. Sargent, 2002. The role of optical CDMA in access networks. IEEE. Commun. Mag., 40: 83-87.

Yin, H. and D.J. Richardson, 2008. Optical code division multiple access communication networks. chap, 1: 36-37.