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IJLEO-52596; No. of Pages 3
ARTICLE IN PRESS
Optik xxx (2012) xxx–xxx
Contents lists available at SciVerse ScienceDirect
Optik
journal homepage: www.elsevier.de/ijleo

Performance of SAC OCDMA-FSO communication systems

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ARTICLE INFO

Article history:
Received 18 April 2012
Accepted 20 August 2012

Keywords:
Free space optics (FSO)
SAC OCDMA
Khazani–Syed (KS) code
Spectral direct decoding (SDD)

ABSTRACT

In this paper, the performance of free space optical (FSO) communication system employing the spectral amplitude coding optical code division multiple access (SAC OCDMA) technique is presented. SAC OCDMA is one of the multiplexing schemes that have become a research area of interest in optical communication because of its flexibility in allocating channels, ability to operate asynchronously, enhanced privacy and increased network capacity. It utilizes Khazani–Syed (KS) code with spectral direct decoding (SDD) technique. The SAC OCDMA-FSO communication system was compared with the FSO system employing intensity modulation/direct detection (IM/DD) technique. The results of this study show that the performance of the proposed system is better than the system employing the IM/DD technique.

1. Introduction

There are many studies on free space optic (FSO) recently as it has found many applications in the area of communications. FSO is a technology that can provide high speed point to point communication when the location is difficult to communicate using optical fiber. FSO communication can be used in many optical links, such as building-to-building, ship-to-ship, aircraft-to-ground and satellite-to-ground. Optical code division multiple access (OCDMA) has become a popular choice in optical fiber communication for supporting multiple users with a reliable communication link. OCDMA systems have drawn a lot of attention due to its flexibility, scalability, and allow many users share the same transmission medium asynchronously and simultaneously [1]. However, the main factor that degrades the performance of OCDMA is multiple access interference (MAI), especially when large number of users is involved [2].

In this paper, spectral amplitude coding optical code division multiple access (SAC OCDMA) technique employing the Khazani–Syed (KS) code [3] in FSO communication system is proposed. In SAC OCDMA systems, each user is assigned with a sequence code that serves as its address. A user modulates its code with each data bit and asynchronously initiates transmission. Thus, this modifies its spectrum appearance, in a way recognizable only by the intended receiver. Let $\lambda = \sum_{i=1}^{N} x_i y_i$ as the in-phase cross correlation of two different sequences $X = (x_1, x_2, \ldots, x_N)$ and $Y = (y_1, y_2, \ldots, y_N)$. A code with length N, weight w and in-phase cross correlation λ can be denoted by (N, w, λ). Code sequences with fixed in-phase cross correlation λ can be described as when any two of users' sequences are aligned chip by chip, pulses are hit in exactly λ times [4]. The code is considered possess an ideal in-phase cross correlation when $\lambda = 1$. The effect of MAI can also be eliminated by using the spectral direct decoding (SDD) detection technique [2]. The proposed FSO system is compared with the FSO system using the IM/DD technique.

2. Description of the proposed system

Fig. 1 shows the block diagram of the SAC OCDMA based KS code with SDD technique in the FSO communication system. At the transmitter, data with independent unipolar digital signal is optically modulated onto the code sequence using an optical external modulator (OEM). In this study Mach–Zehnder modulator is used. Then the modulated code sequences are combined together and transmitted through the FSO link. At the receiver, an optical splitter is used to separate the different modulated code sequences. The decoder which is based on the SDD technique will only filter the non-overlapping chips. The overlapping chip will be discarded because it may cause interference at the receiver [5]. Then, the decoded signal is detected by the photodetector. In order to recover the original transmitted data, the incoming signal is filtered using low-pass filter (LPF). In this study, optical bandpass filters are used as the encoders and decoders.

3. Results and discussions

Simulation software Optisystem 9.0 is used in order to evaluate and compare the performance of the proposed FSO system with the

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http://dx.doi.org/10.1016/j.ijleo.2012.08.067

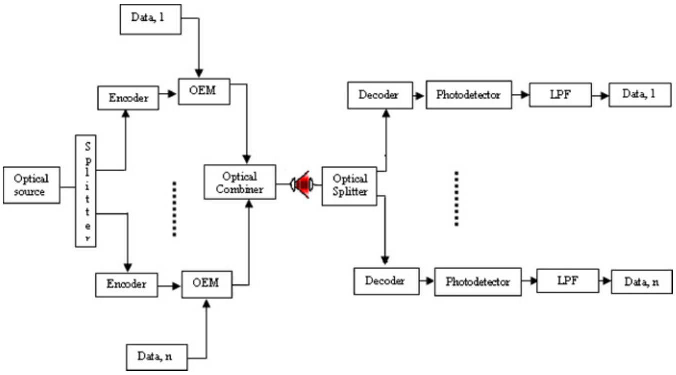

Fig. 1. SAC OCDMA based KS with SDD technique in FSO communication system.

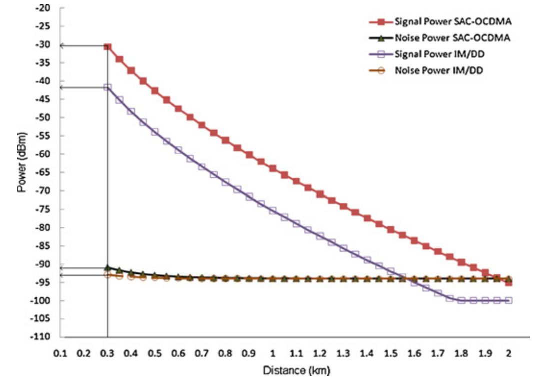

Fig. 3. Signal power and noise power versus distance for the FSO system using SAC OCDMA with SDD technique and the FSO system using IM/DD technique.

FSO system employing the IM/DD technique. In the simulation, the input power, bit rate and attenuation for both systems are 0 dBm, 2.5 Gbps and 8.68 dB/km, respectively.

Fig. 2 shows the BER performance carried out against the transmission distance for two different systems in FSO communication. It can be seen that the BER increases with the transmission distance. A longer fiber provides a larger dispersion and attenuation thus increasing the error rate. The results show that the performance of the FSO system using the SAC OCDMA with SDD technique is better than the FSO system using IM/DD technique. It was found that the FSO system using the SAC OCDMA system could perform sufficiently well up to 0.92 km and the system using IM/DD technique only up to 0.75 km. The result shows that the transmission distance improves by 22.7%.

The effect of distance on electrical signal power and noise power for the FSO system using SAC OCDMA with SDD technique and IM/DD technique is depicted in Fig. 3. The study is important to see the influence of distance on the generation of noise and the loss incurred when using two different techniques. The results show that the signal power decreases with the distance. Additional distance will reduce the signal power level due to dispersion and transmission loss [6]. The signal power for the FSO system using the SAC OCDMA with SDD technique is higher than that using the IM/DD technique. Also shown in Fig. 3 is that the noise power for both systems are almost the same.

From the graph, at 0.3 km, signal power for the FSO system using IM/DD technique is −42 dBm. Its noise power is −93 dBm. Meanwhile for the FSO system using SAC OCDMA with SDD technique, its signal power and noise power are −30 dBm and −91 dBm, respectively. Thus the signal to noise ratio (SNR) for the system using IM/DD technique is 51 dB while the system using SAC OCDMA with SDD technique is 61 dB. The result shows that the SNR improves by 19.6%.

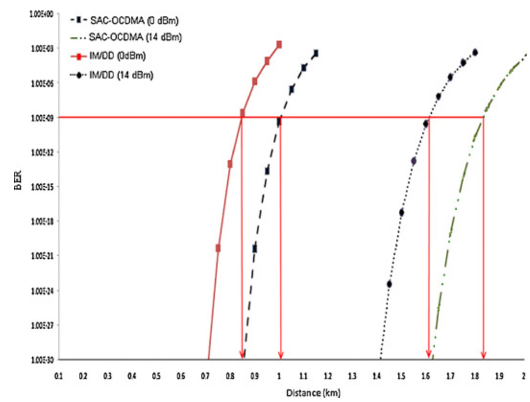

Fig. 4. BER versus distance for the FSO system using SAC OCDMA with SDD technique and the system using IM/DD technique with different value of transmit power.

Fig. 4 depicts the BER performance evaluated with respect to distance with different value of transmit power for both FSO systems. The transmit power used in this simulation is the default value 0 dBm and the enterprise value in the market today, 14 dBm [7]. It can be observed that the performance of the system is better when the transmit power is larger. The higher the transmit power, the higher is its SNR, hence the better is its performance or the lower the BER. For BER $\leq 10^{-9}$, the FSO system using SAC OCDMA with SDD technique and the FSO system using IM/DD technique could perform up to 1.02 km and 0.85 km, respectively, when the transmit power was set at 0 dBm. When the transmit power was set at 14 dBm, both systems could perform up to approximately 1.85 km and 1.6 km, respectively. The higher transmit power gives more energy for the signal power to propagate further.

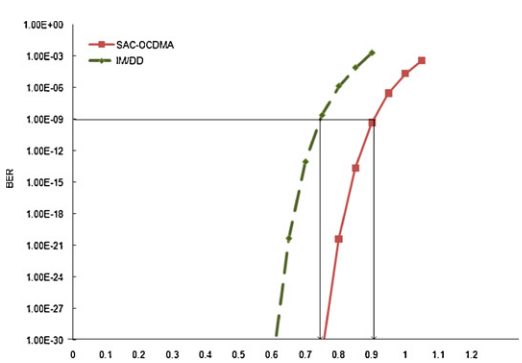

Fig. 2. BER versus distance for the FSO system using SAC OCDMA with SDD technique and the FSO system using IM/DD technique.

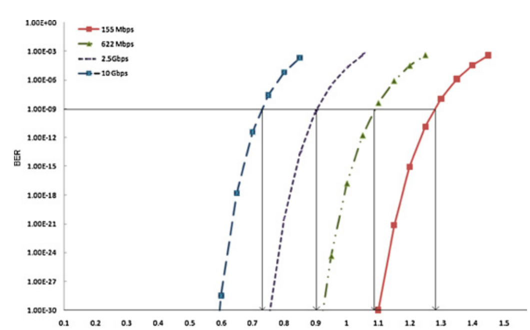

Fig. 5. BER versus distance for the FSO system using SAC OCDMA with SDD technique for different bit rates.

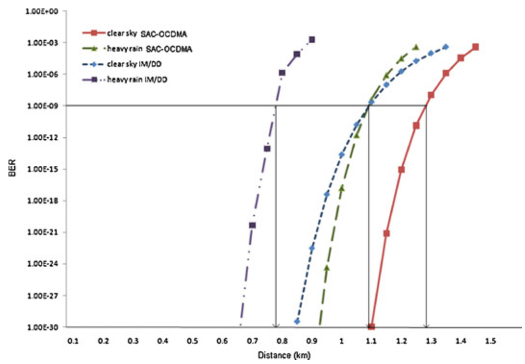

Fig. 6. BER versus distance for the FSO system using SAC OCDMA with SDD technique and the system using IM/DD technique with different weather conditions.

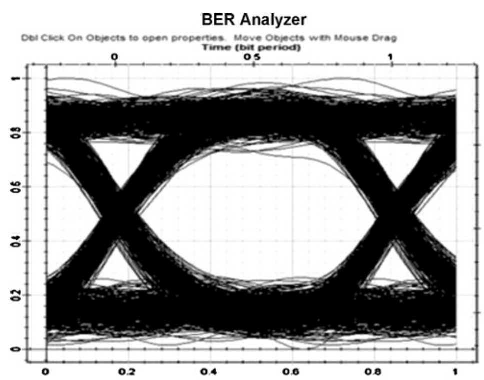

Fig. 7. Eye diagram of FSO system using SAC OCDMA with SDD technique, BER = 10^{-21}.

Fig. 5 shows the transmission distance for the FSO system using SAC OCDMA with SDD technique for different bit rates. The code weight for the KS code and the number of users were set to 2. In this study, four main bit rates were considered, those are the STM-1 (155 Mbps), STM-4 (622 Mbps), STM-16 (2.5 Gbps), and STM-64 (10 Gbps). It can be seen that the distance decreases as the bit rate increases. This is expected as increasing the bit rate will decrease the pulse width, making the data more sensitive to dispersion, thus degrades the system performance [8].

In Fig. 6, BER performance against transmission distance is illustrated for different weather conditions. In this simulation, the attenuation was set to 3 dB/km and 8.68 dB/km which correspond to clear sky and heavy rain, respectively [9]. Other parameters are not changed. The results indicate that at the same transmission distance, BER is higher when the value of attenuation is higher. Moreover, BER is growing with the increasing transmission distance. When the weather is clear and dry, the FSO system using the SAC OCDMA with SDD technique can transmit farther as compared to when it is in a heavy rain condition. This shows that FSO system is vulnerable to the weather.

Figs. 7 and 8 show the eye diagrams for the FSO system. For both cases, the input power, bit rate, attenuation, and number of users were set to 0 dBm, 2.5 Gbps, 8.68 dB/km and two users, respectively. The distance was set to 800 m. It is clearly shown that the eye opening for the FSO system using SAC OCDMA with SDD technique is relatively larger than the FSO system using the IM/DD technique. The corresponding simulated BER for the FSO system using SAC OCDMA with SDD technique is 10^{-21}, in contrast with the FSO system using the IM/DD technique's 10^{-6}.

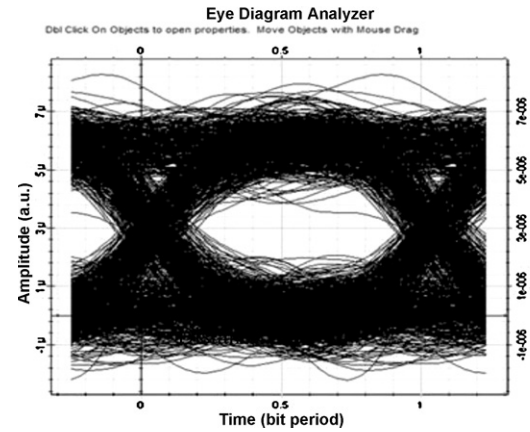

Fig. 8. Eye diagram of FSO system using IM/DD technique, BER = 10^{-6}.

4. Conclusion

In this paper, the performance of SAC OCDMA-FSO communication systems with SDD technique has been introduced. The performance comparison between the FSO communication systems employing the SAC OCDMA with the FSO system using the IM/DD technique has been performed. Obviously, the proposed FSO system described in this paper presents an appealing performance compared to the FSO system using the IM/DD technique and the transmission distance improves by 22.7%.

Acknowledgments

The work described in this paper is funded by Research University Grant Scheme (RUGS) of Universiti Putra Malaysia (Vote no. 91985). The authors would like to thank all parties which have contributed toward the success of this project.

References

[1] Z. Wang, A. Chowdhury, P.R. Prucnal, Optical CDMA code wavelength conversion using PPLN to improve transmission security, IEEE Photon. Technol. Lett. 21 (2009) 383–385.
[2] R.K.Z. Sahbudin, M.K. Abdullah, M. Mokhtar, Performance improvement of hybrid subcarrier multiplexing optical spectrum code division multiplexing system using spectral direct decoding detection technique, J. Opt. Fiber Technol. 15 (2009) 266–273.
[3] M.K. Abdullah, S.A. Aljunid, M.D.A. Samad, S.B.A. Anas, R.K.Z. Sahbudin, Unified KS-Code, Encyclopedia of Multimedia Technology and Networking, vol. III, O-Z, 2nd ed., 2009, pp. 1473–1479.
[4] M. Noshad, K. Jamshidi, Novel codes family for modified spectral-amplitude-coding OCDMA systems and performance analysis, IEEE/OSA J. Opt. Commun. Netw. 2 (2010) 344–354.
[5] S. Khaleghi, M.R. Pakravan, Quality of service provisioning in optical CDMA packet networks, J. Opt. Commun. Netw. 2 (2010) 283–292.
[6] J. Capmany, B. Ortega, D. Pastor, A tutorial on microwave photonic filters, J. Lightwave Technol. 24 (2006) 201–229.
[7] J. Liao, J. Zeng, S. Deng, V. Joyner, A. Boryssenko, K. Connor, Z.R. Huang, Packaging of optoelectronic and RF components with shared elements for dual-mode wireless communications, Electron. Lett. 45 (2009) 411–412.
[8] D.R. Goff, Fiber Optic Reference Guide: A Practical Guide to Communications Technology, Focal Press, Massachusetts, USA, 2002.
[9] N. Cvijetic, D. Qian, J. Yu, Y.-K. Huang, T. Wang, 100 Gb/s per-channel free-space optical transmission with coherent detection and MIMO processing, in: Proceedings of the European Conference on Optical Communication (ECOC 2009), Vienna, Austria, September 20–24, 2009.