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Impact of hybrid OTDM/WDM implementation on VLC performance

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Abstract

Parallel to the development of technology, the interest in different protocols in communication systems is increasing. In this context, visible light communication (VLC) systems that promise high data rate, unused spectrum and high data security attract attention and are promising for the future. The main problem to be overcome in visible light communication systems is known as the necessity of increasing the channel capacity in order to spectrally overlap the Light emitting diodes (LEDs) used as transmitters and to serve many users. Wavelength Division Multiplexing (WDM) and Optical Time Division Multiplexing (OTDM) techniques can be suggested as solutions to VLC problems. In this study, the advantages of WDM and OTDM techniques were investigated and a reference hybrid OTDM/WDM VLC system was designed. The performance of the system designed using the OptySystem 14.0 simulation software was analyzed over the Eye diagram, Q factor and Bit Error Rate (BER) values.

Introduction

With the technological developments, the interest in communication systems has increased in the last century. Today, wireless communication systems serve in a wide area, from the transmission of single-bit messages to multimedia sharing, which requires high bandwidth. With the developing technology, different communication protocols have been developed for reasons such as restrictions in the frequency spectrum, insufficient data rate, and inability to provide data security. Visible light communication systems are promising for the future with their high data rate, low loss and wide usage area in the frequency spectrum. VLC systems aim to transmit a message signal to the receiver over free space by modulating it on a carrier at visible light wavelengths (400-700 nm) [1]. In VLC systems, which are technically similar to optical communication systems, it is aimed to get rid of the disadvantages of wired communication and to realize wireless communication by using free space instead of fiber channels [2].

In VLC systems, LED is used as the transmitter and photodetectors are used in the receiver unit. The basic expectation from communication systems is to provide high speed and quality service to multiple users without any interference or deterioration. At this point, it is inevitable to use multiplexing technologies. Multiplexing technologies such as WDM, Code Division Multiple Access (CDMA) and Non-Orthogonal Multiple Access (NOMA) are widely used to increase the data rate and capacity of the VLC system [3]. On the other hand, the number of channels should be increased in line with the goal of increasing the number of users, which leads to an increase in the effect of channel crosstalk. To solve this problem, the use of a secondary multiplexing technique may be beneficial. Hybrid Optical Time Division Multiplexing (OTDM) over WDM system will be a potential solution and a possible alternative for future VLC systems.

There are various studies on multiplexing techniques that can be used for VLC systems in the literature. Saeed et al [4] designed a system using RayLab simulation software to optimize wavelength allocation in multi-user WDM VLC systems. Chen et al. [5] examined the use of MIMO-NOMA in visible light communication systems in their study.

In this study, the advantages of OTDM multiplexing technique integration were investigated in order to increase the scope and efficiency of a WDM-VLC system with RGB LED transmitter with different wavelengths (Red-Green-Blue), then a Hybrid WDM/OTDM visible light communication system was designed using OptiSystem 14.0 simulation software. and system efficiency were analyzed using Q factor, eye diagram and BER. Section-2 includes Materials and Methods, Section-3 includes results.

Material and Method

Mathematical Model

WDM, which works on a similar basis with frequency division multiplexing (FDM) and is frequently used to provide multi-user support in optical communication systems, is a technique that allows to transmit a series of optical signals over a single channel by using carrier signals of different wavelengths [6].

OTDM, which is another technique used to provide multiplexing in communication systems, is a technique that uses different carriers over a single channel by providing the transmission of signals sent from the transmitter unit and coming from multiple users in different time slots [7]. The mathematical expression [8] for the signal obtained at the multiplexer output in the Hybrid WDM/OTDM system is given Eq. (1). Multi-user support, which is one of the main problems in VCL systems, signals from each group of users spread over time are multiplexed according to wavelengths in the WDM mux unit and sent to space. In this way, the number of users and service quality are increased by providing double-layer multiplexing.

$$s_j = \sum_{n=1}^{n=i} \sum_{k=-\infty}^{\infty} P(t-(n-1)\,\mathrm{Ts}-\mathrm{kT})\cos\left(\frac{2\pi c}{\lambda_j}t\right) \qquad (1)$$

where P(t) denotes an RZ-OOK pulse of duration Ts, the kT data bit of the nth user transmitting at wavelength λj, and Ts the time slot corresponding to the nth user.

Simulation Study

The ability to serve multiple users, which is one of the main purposes of communication systems, is also a challenge for VLC. In this regard, it is necessary to increase the system efficiency by using different multiplexing techniques in VLC systems. For this purpose, in the system in Figure 1, designed using Optysytem 14.0 simulation software, a two-step multiplexing is carried out by using RGB LEDs with different wavelengths and by spreading the wavelengths with the WDM technique before the signals leaving the transmitter by spreading time with the TDMA technique. targeted.

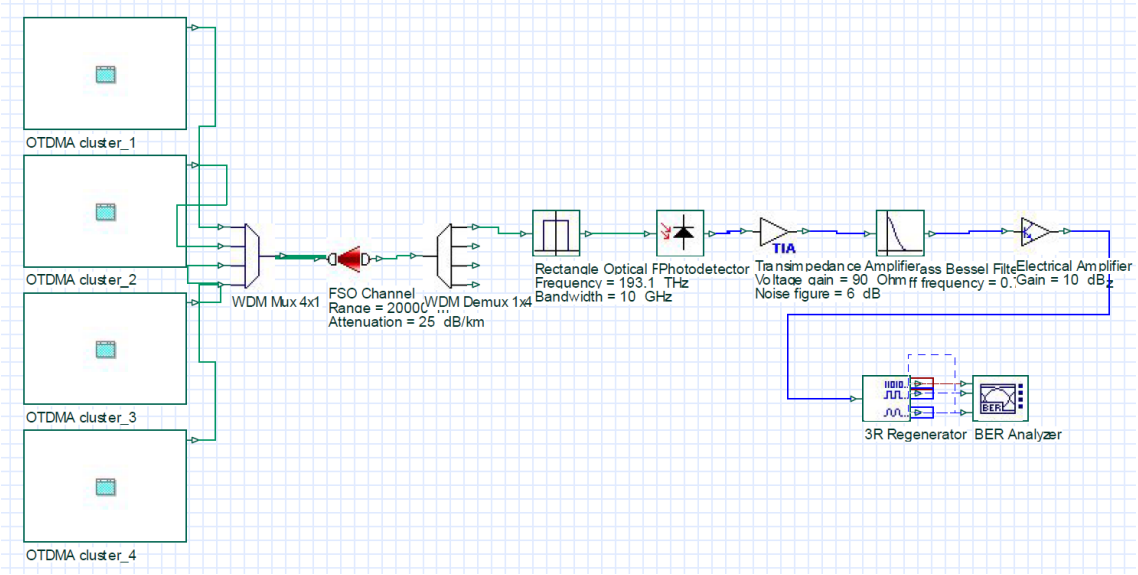

Figure 1. Hybrid OTDM/VLC System

Four different user sets are designed, each of which uses LEDs of different colors and therefore of different wavelengths as transmitters, and the contents of which are shown in Figure 2 (a). Signals with OTDMA technique applied in user clusters are spread over wavelengths via WDM Mux. Thus, it is aimed to provide multiple data transmission from a single channel by paving the way for data transmission at every point of time and at every wavelength of the relevant spectrum region. The signal obtained at the WDM multiplexer output is given to the

Free Space Optic (FSO) channel with a length of 2000m and an attenuation of 25 dB/km. The signal reaching the receiver unit is reduced to previous wavelengths by the WDM Demultiplexer and digitized with the help of the photodedector. Afterwards, the signal, which undergoes the necessary filtering and amplification processes, is made ready for use by the end user.

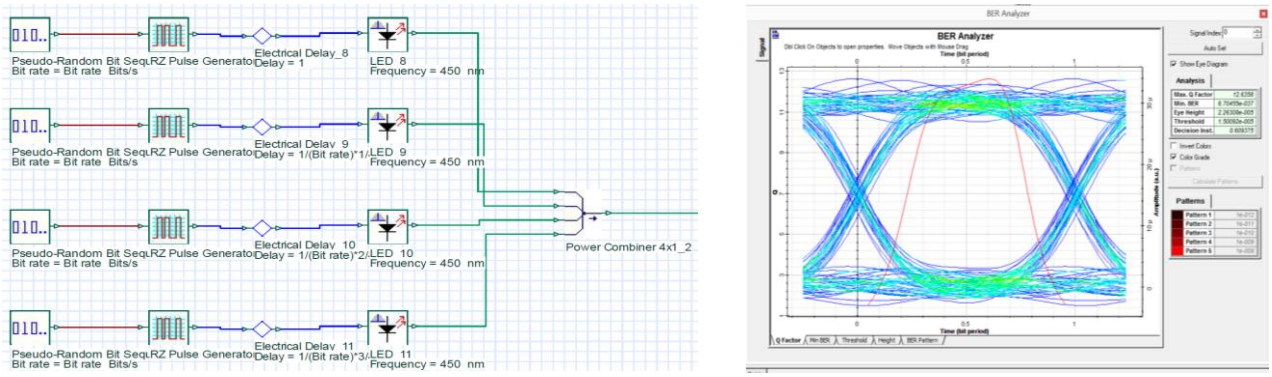

Figure 2. (a) OTDM Clusters (b) Eye Diagram

OTDMA technique is realized by adding a time delay based on Bit Rate for each user in user clusters, each of which uses LEDs of different wavelengths as transmitters. The Eye diagram obtained as a result of the simulation study and containing the value of the Q factor is given in Figure 2 (b). The most important performance evaluation parameters in optical and visible light communication systems are the Q factor, the BER value and the symmetry of the Eye diagram. Looking at Figure 2 (b), it is seen that a relatively symmetric eye diagram and a smooth Q factor curve are formed.

Conclusion

With the development of technology, societies have become completely data-oriented, triggering the development of high-speed, multi-user and high-security communication systems. In this regard, VLC systems, which have attracted attention with their successful applications in recent years, are promising for the future. In this study, an innovative dual-stage architecture is proposed for multi-user support, which is one of the main problems of VLC systems. In this context, two-stage multiplexing was performed by spreading over the wavelength with the WDM technique, before the signals spread over time with the OTDM technique in the transmitter unit were transmitted to the FSO channel. The system output was observed with the BER Analyzer in the reference Hybrid OTDM/WDM VLC system designed using the OptiSystem 14.0 simulation software. Max. Q factor value and Min BER value are given in Table 1.

Table 1. Simulation Results

Max. Q factor	12,6358
Min. BER	$6.7x10^{-37}$
Eye Diagram	Symetric

While the Q factor of 12.6358 was obtained in the designed system, the Min BER value was determined as $6.7x10^{-37}$. It has been concluded that the system, whose eye diagram symmetry is close to ideal, can produce a solution to the multi-user support problem in VLC technology.

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