An MIMO–OFDM System Implementation Using Visible Light Communication

R. Sindhuja, Arathi R. Shankar, and Subhashini Gopinath

Abstract In recent years, the demand for data has exponentially increased by a considerable rate which increases the dependency of bandwidth in the RF spectrum. So there is a need to look for an alternate spectrum which can serve the purpose and facilitate the customer with better quality of service. In order to achieve this performance, visible light spectrum is considered for communication purposes. An attempt has been made by the authors to simulate visible light communication based on MIMO–OFDM system. OFDM provides better spectral efficiency as compared to any other single-carrier modulation techniques.

Keywords Multiple input multiple output (MIMO) · Orthogonal frequency division multiplexing (OFDM) · Visible light communication (VLC)

1 Introduction

The motivation for usage of VLC was provided by the evolution in the solid-state lighting. This leads to the replacement of florescent lamps by LEDs. It is challenging to achieve high data rate transmission, though the visible light spectrum has a wide range of frequency of about THz due to the limited bandwidth of the off-the-shelf LED [1]. To overcome this drawback in a single room multiple LEDs are installed. Therefore to boost the data rate the MIMO techniques are employed in indoor atmosphere and investigation of various MIMO techniques is undertaken. In this paper, the primary concern is to achieve better performance in indoor environment using VLC. It has been shown in the paper that combining OFDM and MIMO fading can be largely reduced and yields frequency-flat MIMO channel by spatial diversity [2]. The effect of increasing the number of LEDs on the fixed-sized environment is also analysed.

R. Sindhuja · A. R. Shankar (✉)
BMS College of Engineering, Bengaluru, India
e-mail: arathi.ece@bmsce.ac.in

S. Gopinath
RBEI, Bengaluru, India

G. R. Kadambi et al. (eds.), *Emerging Trends in Photonics, Signal Processing and Communication Engineering*, Lecture Notes in Electrical Engineering 649,
https://doi.org/10.1007/978-981-15-3477-5_5

2 Methodology

2.1 MIMO–OFDM Transreceiver System Using VLC

Figure 1 presents the block diagram of the proposed transmitter. The proposed transmitter is a combination of three technologies, namely MIMO, OFDM and VLC.

The data to be transmitted over the visible light is in binary format. Binary data is represented by series of 0s and 1s. The output binary data is the input to the serial/parallel (S/P) block. S/P block converts the data in serial format into parallel format. The resulting signal is given as input to the OFDM modulator. Within the OFDM modulator the data is mapped using different mapping techniques such as BPSK, QPSK or QAM. According to the analysis, 16-QAM gives a better performance for OFDM. So QAM is selected as the mapping technique. Further cyclic prefix (CP) is added to the signal. Now to make the signal compatible for VLC the negative parts of the signals have to be removed. So the signal is DC-biased. Only the positive and real part is retained for further communication. DC-biased optical OFDM (DCO-OFDM) is the modulation technique used. The electrical signal is converted into optical signal using LEDs. LEDs are the transmitters in case of VLC. The data is transmitted in the form of light [3].

In VLC the medium of propagation is light. MIMO configuration is incorporated based on the number of LEDs used. Multiple LEDs are used to improve the performance of the system. The MIMO configuration at the front end of the receiver is maintained by incorporating multiple LEDs.

Figure 2 presents the block diagram of the proposed receiver. Photo detector (PD) is used for the reception of light. It converts the optical signal into electrical signal. In VLC system PD is the receiver. Number of PDs at the receiver depends on the number of LEDs. The output of the analogue to digital converter (ADC) is fed as

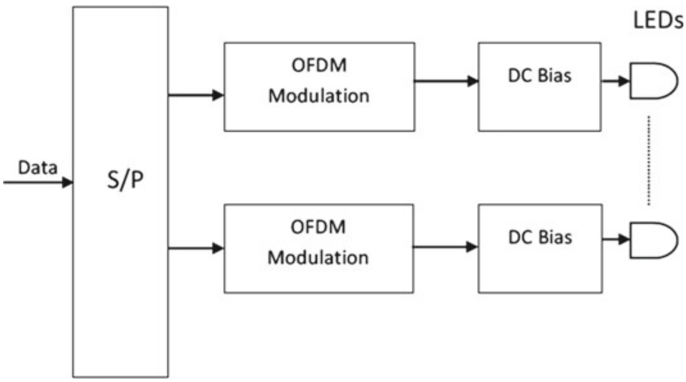

Fig. 1 MIMO–OFDM VLC transmitter

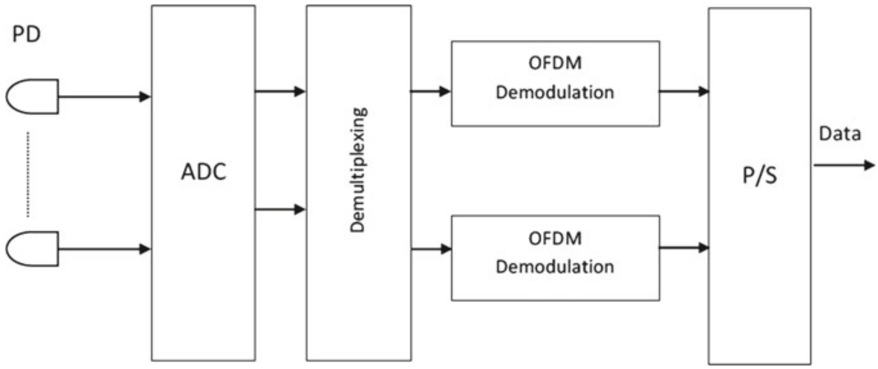

Fig. 2 MIMO–OFDM VLC receiver

input to the demultiplexer. The further processing of the signal is performed by giving the output of the demultiplexer as input to the OFDM demodulator.

Figure 3 explains the block diagram of OFDM. The incoming serial data is converted to a block of specific size to process it block by block. Serial to parallel converter is used, which will be mapped using signal mapper corresponding to the chosen modulation technique. IFFT is carried out on the output of signal mapper and ISI cyclic prefix is added to the IFFT output. After adding cyclic prefix the output data is serialized using parallel to serial converter, which can be up-converted and transmitted to the wireless channel. Information signal will be affected depending on channel noise. At the receiver the incoming serial data is converted to a block of specific size that was followed during modulation. The cyclic prefix which was

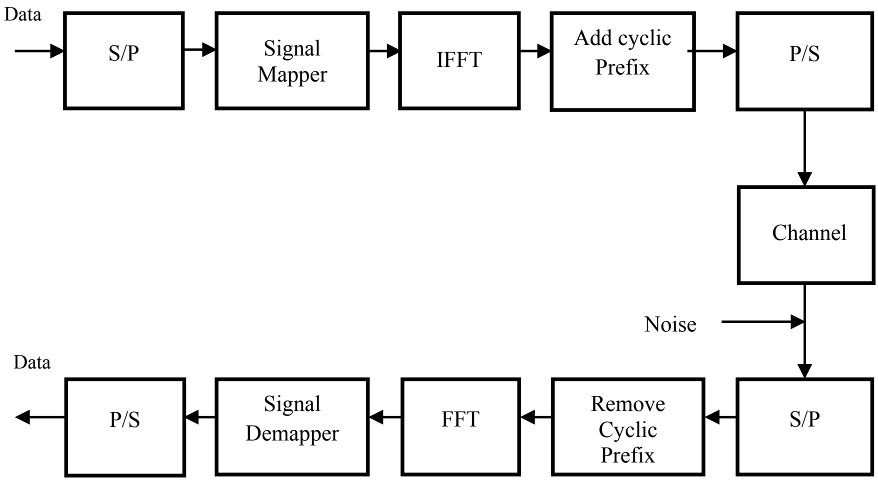

Fig. 3 OFDM block diagram

added during modulation is removed for further processing. The FFT is carried out on the data block and applied to signal de-mapper. The de-mapped data symbols are converted from parallel data to serial data using serial to parallel converter.

A multicarrier system, such as FDM, is used to transmit multiple carriers in parallel to the total available bandwidth in the spectrum into sub-bands. By placing carriers closely in the spectrum high data rate can be achieved. However, due to lack of spacing separating the carriers leads to inter-carrier interference (ICI). Guard bands need to be placed in between any adjacent carriers in order to reduce ICI, which results in lowered data rate.

2.2 Software Specifications

An indoor room environment is simulated using MATLAB and the room dimensions and other specifications are listed in Table 1.

The user can decide the number of LEDs to be placed in the specified dimension. DCO-OFDM is simulated for 16-QAM and the output of this is given as the input to VLC. Here LEDs are the transmitters and PDs are the receivers. From the received input, the received power, intensity of LEDs and effect of reflectivity are calculated. These parameters are further used to calculate the performance parameters like SNR in dB, capacity of the channel and received power. Here, the information carrier is a light wave whose dimensions are in the order of thousands of wavelengths, leading to spatial diversity, which prevents multipath fading. For these reasons multipath fading can be ignored and only AWGN channel is considered. Based on the SNR values 3D plots are generated and the results are analysed.

Table 1 System model specifications

Specifications	Value
Room size (meters)	$5 \times 5 \times 3$
Distance between Tx and Rx (meters)	1.5
R (photodiode responsivity)	0.4 (A/W)
Single LED power	50 mW
Ba (amplifier bandwidth)	4.566 (Hz)
Reflectivity due to ceiling	0.8
Reflectivity due to floor	0.15
Reflectivity due to wall	0.9

Table 2 SNR values for different number of LEDs

No. of LEDs	SNR value (dB)
4	9.202
32	45.33
128	69.41

Table 3 AWGN channel value for different number of LEDs

No. of LEDs	AWGN channel capacity (bits/s/Hz)
4	0.9694
32	4.533
128	6.941

3 Results and Discussions

3.1 Analysis of SNR Value

The spectrum infers that at 0.5 m^2 the value of SNR is high around 69.41 dB for 128 LEDs. At the corners of the room the value of SNR decreases and this mainly depends on the distribution of LEDs.

From Table 4 it is shown that by analysing different SNR spectra for different number of LEDs in an indoor environment, it can be observed that as the number of LEDs increases the SNR value increases.

3.2 Analysis of Capacity of AWGN Channel

From Table 3, by analysing different channel capacity spectrum for different number of LEDs in an indoor environment, it can be observed that as the number of LEDs increases the value of channel capacity also increases.

3.3 Analysis of Received Power

From Table 4, it can be analysed that as the number of LEDs increases the value of

Table 4 Receiver power for different number of LEDs

No. of LEDs (in Tx and Rx)	Receiver power in dB
4	−31.81
32	−11.02
128	−2.846

received power increases and for lesser number of LEDs the difference between the received and transmitted power is high.

4 Conclusion and Future Scope

VLC is considered advantageous than the existing RF communication because of the abundant range of spectrum available. As per the result obtained in this paper, multicarrier modulation technique like OFDM shows better performance than single-carrier modulation. To attain high spectral efficiency 16-QAM is used as the mapping technique over QPSK. To check the performance of VLC for indoor environment different parameters like SNR, channel capacity and received power is analysed. As per the results obtained, as the number of LEDs increases in a closed room, SNR, channel capacity and received power show better performance. In this paper binary data is considered for communication and it can be further analysed for QoS of audio and voice data. This paper explores only spatial diversity of MIMO. Spatial multiplexing of MIMO is yet to be explored. Performance analysis in outdoor environment is to be simulated.

References

1. Panwara N, Sharma S, Singh AK (2016) A survey on 5G: the next generation of mobile communication. Phys Commun 18:64–84
2. Tayade PP, Rohokale VM (2015) Enhancement of spectral efficiency, coverage and channel capacity for wireless communication towards 5G. In: IEEE international conference on pervasive computing (ICPC), ISBN: 978-1-4799-6272-3
3. Feng L, Hu RQ, Wang J, Xu P, Qian Y (2016) Applying VLC in 5G networks: architectures and key technologies. IEEE Netw, ISBN: 0890-8044