

High competence MIMO-OFDM with generalized led index modulation

N. Showme^{1*}, Anush Ramachandran², Nihal Sekhar³, Ravi Shankar⁴

¹Assistant Professor, Department of Telecommunication Engineering, SRM Institute of Science and Technology.

²Student, Department of Telecommunication Engineering, SRM Institute of Science and Technology.

³Student, Department of Telecommunication Engineering, SRM Institute of Science and Technology.

⁴Student, Department of Telecommunication Engineering, SRM Institute of Science and Technology

*Corresponding author E-mail:showme.srm@gmail.com

Abstract

Optical communication in specific the visible light communication (VLC) is the next generation technology in the field of data transmission. This paper proposes an idea of improving the transmission rate of the data via a totally different method of channel using optical light communication. Here, the normal radio frequency waves aren't being used at all. Simple light will give us the required channel medium to send the data over a range. The system that is being proposed separates each data signal and sends it one by one to the light emitting modulation. The real and imaginary part of the complex time domain OFDM signals are taken apart and are sent over a frequency-flat light channel. As a standard it was demonstrated that the performance of the simulation in two different configurations with various numbers of transmitting and receiving antennas.

Index terms: Visible light communications (VLC), multiple-input-multiple-output (MIMO) systems, orthogonal frequency division multiplexing (OFDM), optical-spatial modulation (OSM), LED index modulation, maximum-a-posteriori probability (MAP) estimator [13].

1. Introduction

One of the greatest next generations wireless communication system includes optical wireless communication (OWC) and in particular visible light communication (VLC) operating between 400-800 nm ranges.

This specific range is very much suitable for short distance indoor mobile communication. One of the key factors in visible light communication is that it has wide bandwidth, high energy efficiency and high security compared to existing 4G wireless communication [2].

The frequency selective behaviour of the VLC channels in OFDM systems, gives us medium to high data rate and can easily achieve bit and power loading [1].

Inter symbol interference (ISI) is an advantage in OFDM due to frequency selectivity.

It is not possible to transmit the signal without any alteration. Hence, direct current (DC) bias summation and respective power inefficiency of optical OFDM constitute the motivation for energy conserving optical OFDM models [7].

There are multiple inputs acting in a coherent way to transmit the data to multiple receivers to get in the data.

We arrange these transmitters and receivers in various positions to give us the maximum Signal to Noise Ratio and less Bit Error Rate.

2. Experimental design

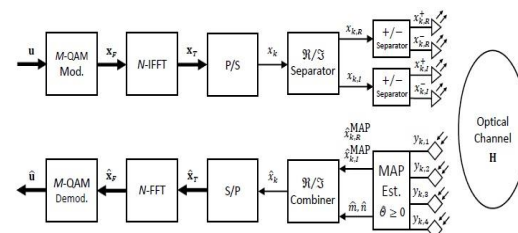


Fig.1: Block diagram of 4x4 GLIM-OFDM MIMO VLC structure

Here, the information bits u enters the M-ary QAM modulator and the Frequency-Flat process takes place. This means that the given message bits are first separated into real and imaginary. For each real valued and imaginary valued parts another type of separation occurs where the positive and negatives values are separated. Then, only the positive values are selected and are transmitted into the optical channel.

This is the transmission part of the system now for the receiving part. Primarily, the signals that are received are in real values and moreover, the transmitted message vector x has a clipped Gaussian distribution. Similarly, the received signal vector y cannot be passed on to the OFDM demodulator straight, for the reason that complex valued signal must first be brought up to get the estimate required to transmit the signal.

In order to solve this issue a simple zero forcing equaliser is added. But, due to this zero forcing a huge noise power is added into this system. Thus, to remove this factor from the system an estimator for the proposed system is taken with the information about the signal vector x . Now, the serial to parallel conversions,

FFT and M ary demodulator is applied to find the estimate of the information bits vector \hat{u}

3. GLIM-OFDM in frequency-FLAT MIMO channels

The $[N \log_2(M)]$ information carrying bits of vector \mathbf{u} for each OFDM block is sent through the GLIM-OFDM transmitter for transmission, where N is the number of subcarriers and M is the magnitude of the measured signal constellation such as M-ary quadrature amplitude modulation (M-QAM). The previous system patterns depend mostly on Hermitian symmetry to produce real time-domain signals after the IFFT operations [11].

In the proposed outline, the complex frequency-domain OFDM frame \mathbf{x}_F is processed by the OFDM modulator directly without requiring Hermitian symmetry. The resulting time-domain OFDM frame: $X_T = [X_0 \dots X_n]^T$, cannot be communicated through a VLC channel because of its complex-valued and bipolar (positive and negative valued) elements. Here a new LED index modulation based MIMO transmission technique has been developed to rectify this issue [6]. After parallel-to-serial (P/S), the real and imaginary parts of the complex signal x_k are split as $x_k = x_k;R + j x_k;I$. Now, the resulting real, but bipolar signals $x_k;R$ and $x_k;I$ are handled by positive-negative (+-) separators. In this outline, $n_r = 4$, for the reason that there are four LED transmitters which are used.

Here, the LEDs transmit the absolute positive values of $x_k;R$ and $x_k;I$ signals and the index of the transmitting LED determines the sign of the corresponding signals[4].

However, this system totally averts the Hermitian symmetry at the input of inverse of the finite fourier transform as well as the associated loss in bandwidth efficiency. Consequently, the spectral efficiency of the proposed outline becomes doubled compared to the old systems, because there is no Hermitian symmetry to produce the real valued OFDM symbols.

4. Experimental graphs

This is the first analytical channel graph that's been processed using the GLIM-OFDM MIMO VLC system. It is an analytical graph for the reason that, all the theoretical values are found and used to generate this output.

Both, in paper and the graphs assisted physical light channel models are found for two different setups. The first, being that the receivers are located in near proximity with each other, with a small distance range from 1cm to 1m, and, the next arrangement being that the receivers are located in further proximity from each other at a distance of 1cm to 8m. The physical VLC channel representations include an accurate light generating device, a receiver where the light is detected and reflection of surfaces of object's losses.

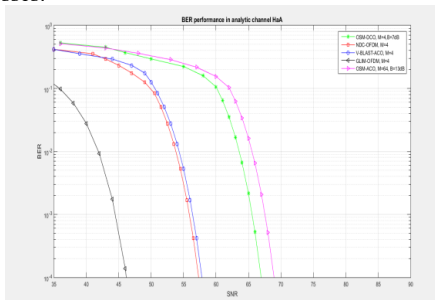


Fig. 4.1: BER performance comparison where M=4, in position A.

Now, in this Fig.4.1, it is seen that for the specific magnitude of the M-ary Quadrature that is 4 the proposed system has a simulated SNR value of 47 with a lesser BER in the ranges of 10^1 bits. Though other old system's has a better SNR compared to this proposed system, the BER has a very significant change. This makes it very reliable to use this system in real time situation.

The receivers are arranged in position A which means that the receivers are in close proximity with each other. As the distance between the receivers are less, the transmission of the signals should be very unidirectional towards the receivers.

In Fig.4.2, it is seen that for the same magnitude that is 4 the proposed system has a simulated SNR value of 22 with a lesser BER in the ranges of -10^1 bits. Though other old systems, has an almost similar SNR compared to this proposed system, the BER has a very significant change when compared in this position. This makes it very reliable to use this system in real time situation.

The receivers are arranged in position B which means that the receivers are further away from each other. As the distance between the receivers are more, the transmission of the signals can be omnidirectional as the receivers are split and pick up lot of signals from a wide range.

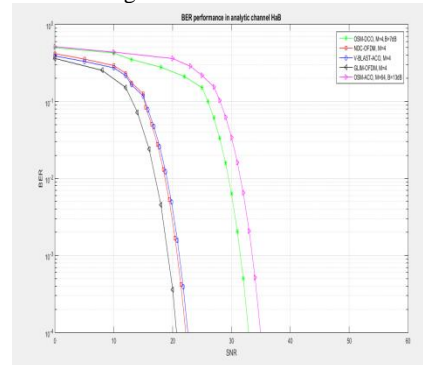


Fig. 4.2: BER and SNR performance where M=4, in position B.

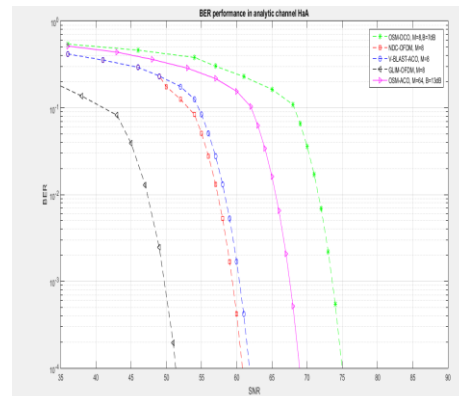


Fig. 4.3: BER and SNR performance where M=8, in position A.

In this Fig.4.3, it is seen that for the specific magnitude of the M-ary Quadrature that is 8 the proposed system has a simulated SNR value of 51 with a lesser BER in the ranges of -10^{08} bits. Though other old system's has a better SNR compared to this proposed system, the BER has a very significant change. This makes it very reliable to use this system in real time situation. The receivers are arranged in position A which means that the receivers are in close proximity with each other. As the distance between the receivers are less, the transmission of the signals should be very unidirectional towards the receivers.

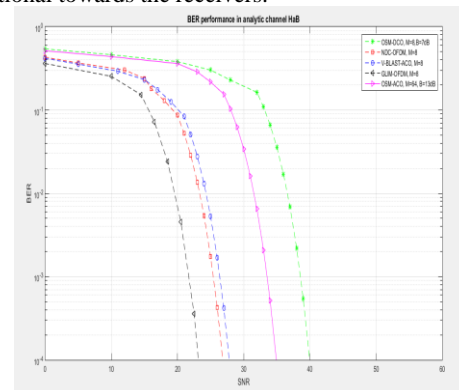


Fig. 4.4: BER and SNR performance where M=8, in position B.

In Fig.4.4, it is seen that for the same magnitude that is 8 the proposed system has a simulated SNR value of 24 with a lesser BER in the ranges of -10^1 bits. Though other old systems, has an almost similar SNR compared to this proposed system, the BER has a very significant change when compared in this position. This makes it very reliable to use this system in real time situation.

The receivers are arranged in position B which means that the receivers are further away from each other. As the distance between the receivers are more, the transmission of the signals can be omnidirectional as the receivers are split and pick up lot of signals from a wide range.

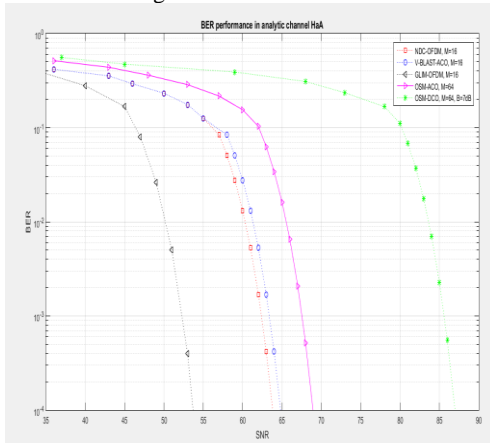


Fig. 4.5: BER and SNR performance where M=16, in position A.

In this Fig.4.5, it is seen that for the specific magnitude of the M-ary Quadrature that is 16 the proposed system has a simulated SNR value of 54 with a lesser BER in the ranges of -10^{04} bits. Though other old system's has a better SNR compared to this proposed system, the BER has a very significant change. This makes it very reliable to use this system in real time situation.

The receivers are arranged in position A which means that the receivers are in close proximity with each other. As the distance between the receivers are less, the transmission of the signals should be very unidirectional towards the receivers.

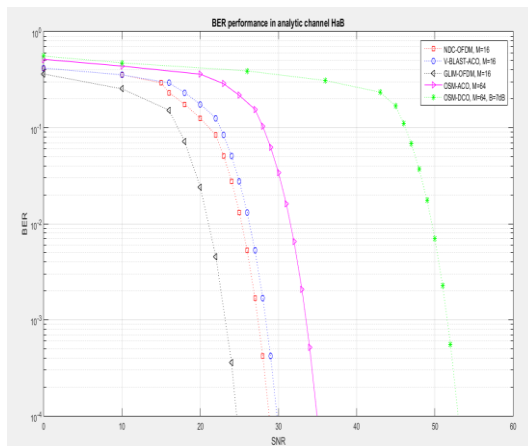


Fig. 4.6: BER and SNR performance where M=16, in position B.

In Fig.4.6, it is seen that for the same magnitude that is 16 the proposed system has a simulated SNR value of 24 with a lesser BER in the ranges of -10^{07} bits. Though other old systems, has an almost similar SNR compared to this proposed system, the BER has very less change when compared in this position but this is the best compared all other signals. This makes it very reliable to use this system in real time situation.

The receivers are arranged in position B which means that the receivers are further away from each other. As the distance between the receivers are more, the transmission of the signals can be omnidirectional as the receivers are split and pick up lot of signals from a wide range.

The more the SNR the better the signal is but in this proposed system the BER value is less such to an extent that the SNR value can be overseen and can be used in a real time system comfortably. The graphs show us that for increase in M-QAM modulation values, the GLIM-OFDM SNR increases making it a better system to use in real time situation.

The GLIM-OFDM system's BER performance is vastly reliant on the connection between diagonal that is line of site also direct and off diagonal that is non-line of site also indirect features of the channel matrix. The channel matrix has an excellent BER functioning when it is near the line of site. There is a coefficient which can be related to the rows and columns of this channel matrix. The more the close the coefficient is to the diagonal, stronger the relation is to the channel matrix.

5. Conclusion and enhancement

Visible Light Communication is clearly the next big technology in the next decade. Already, fiber optics are being used to get maximum speed for data, video and voice network and it's only a matter of time before the normal data starts to get transmitted over light. One of the key elements for the light communication is that the unbelievable speed that it offers for a wide range of traffic that it can handle.

The proposed system gives double the bandwidth efficiency which is nothing but, sending out the message in bits by using LED in the form of light channel. This gives the proposed system a fair bit of advantage over the previously existing system. Finally, it can be understood that from the simulated graphs that the Bit Error Rate (BER) and the Signal to Noise Ratio (SNR) performance of the proposed system is not affected by selecting specific frequency for transmission, while retaining its bandwidth efficiency of sending messages in bits, advantage over other MIMO-OFDM systems which uses light communication for transmission of data. Furthermore, this system can be drastically improved if the LOS can be extended to a wider area. Also by not restricting the device just to be an LED instead out of all the devices that emit light can be used to transfer data.

References

- [1] Miramirkhani F & Uysal M, "Channel modeling and characterization for visible light communications", *IEEE Photon. J.*, Vol.7, No.6, (2015), pp.1–16.
- [2] Fath T & Haas H, "Performance comparison of MIMO techniques for optical wireless communications in indoor environments", *IEEE Trans. Commun.*, Vol.61, No.2, (2013), pp.733–742.
- [3] Dimitrov S & Haas H, *Principles of LED Light Communications: Towards Networked Li-Fi*. Cambridge University Press, (2015).
- [4] Ertugrul B, Erdal P, Murat U & Harald H, "Generalized LED index modulation optical OFDM for MIMO visible light communications systems", *IEEE International Conference on Communications (ICC)*, (2016).
- [5] Chvojka P, Zvanovec S, Haigh PA & Ghassemlooy Z, "Channel characteristics of visible light communications within dynamic indoor environment", *J. Lightw. Technol.*, Vol.33, No.9, (2015), pp.1719–1725.
- [6] Basar E, "Index modulation techniques for 5G wireless networks", *IEEE Commun. Mag.*, Vol.54, No.7, (2016), pp.168–175.
- [7] Armstrong J & Lowery AJ, "Power efficient optical OFDM", *Electron. Lett.*, Vol.42, No.6, (2006), pp.370–372.
- [8] Fernando N, Hong Y & Viterbo E, "Flip-OFDM for optical wireless communications", *IEEE Inf. Theo. Workshop*, (2011), pp.5–9.
- [9] Azhar AH, Tran TA & O'Brien D, "A gigabit/s indoor wireless transmission using MIMO-OFDM visible-light communication", *IEEE Photon. Technol. Lett.*, Vol.25, No.2, (2013), pp.171–174.
- [10] Islim MS, Tsonev D & Haas H, "On the superposition modulation for OFDM-based optical wireless communication", *IEEE Global Conf. on Signal and Inform. Process.*, (2015), pp.1022–1026.
- [11] Anil Y, Ertugrul B, Farshad M, Erdal P, Murat U & Heral H, "Optical MIMO-OFDM with Generalised LED Index Modulation", *IEEE Transactions on Communications*, (2017).