Implementation of Unipolar OFDM based VLC Transmission System under Dimming Constraint for High Speed Data through FPGA

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Abstract— Visible light communication is an emerging indoor communication technology which simultaneously is used for data transmission and illumination. Dimming is an essential aspect of indoor illumination. This work was carried out to implement Unipolar OFDM based VLC transmission system with dimming constraint. The software system design was obtained using Simulink and hardware was designed using DE0-nano FPGA board and LED based VLC panel. The system was tested for 2m range and results were obtained for software and hardware systems.

Keywords—*Optical OFDM, PPM, Visible light communication*

I. Introduction

Visible light communication (VLC) has emerged as an alternate to conventional radio frequencies indoor communications. VLC transmitters comprises of LEDs, a non-coherent source with high efficacy and low power consumption. Unlicensed large transmission bandwidth, fast switching rate and readily available to use made them a viable candidate for indoor wireless communication [1], [2]. As the light from an LED can be confined inside the building or room so they are more secure compared to radio frequencies. For transmission intensity modulation and direct detection is used for positive and real signal. Due to the variation of transmitted light source current, the IM is achieved and DD is obtained by using photodiode at receiver which generates a current proportional to the received instantaneous optical [3], [4]. Whenever data rate increases, it causes inter symbol interference (ISI) due to the multipath propagation which limits the transmission performance. In order to reduce the effect of ISI a multiplexing and modulated scheme known orthogonal frequency modulated multiplexing (OFDM) have been used for OWC. In OFDM technique for high data speed the carriers are orthogonal to each other which give high spectral efficiency. OFDM is based on fast Fourier Transform (FFT). Practically it is based on Discrete Fourier transform which can be easily implemented using Field Programmable Gate Array (FPGA) board [2]. OFDM implementation provided simple and easy reprogramming of FFT and IFFT, to obtain design with high performance and high-speed data. In FPGA the designer can programmed the functionality of FPGA rather than the device maker. Conventional OFDM generates bipolar signal containing real and imaginary parts [6] and cannot directly applied to VLC. To overcome these constraint unipolar Optical-OFDM (O-OFDM) schemes explicitly DC-biased Optical OFDM (DCO-OFDM), flip-OFDM and Asymmetrically Clipped Optical OFDM (ACO-OFDM) have been suggested [7]. In DCO-OFDM, a biased is added to make OFDM signal unipolar. For ACO-OFDM, data is mapped on odd subcarriers and negative part is clipped. In flip-OFDM, the negative parts of signal are flipped and added after the positive part. Implementation of ACO-OFDM and DCO-OFDM requires FPGA followed by a digital to analog converter [8]. With the dimming consideration, the performance of ACO-OFDM, DCO-OFDM and flip-OFDM can significantly affect. Dimming is one of the important aspects of lightening devices [9]. The dimming controller selects the OFDM symbols i.e. high and low. High means maximum LED current subtracted the unipolar signal and low means the minimum LED current is added to the signal. Dimming can be controlled by continuous current reduction CCR in which the reduction of forward current dims the light and this method is very simple and cost effective while in pulse width modulation PWM the square pulse modulation controls the illumination of LED by varying duty cycle. Dimming along with unipolar OFDM schemes may be used for visible light communication. In case of examination halls, restaurants and conference room needs light level maximum brightness for comfort. For office tasks the brightness of 300 lux (lumens /meter square) is required [10].

The basic methods to dim LEDs are analog dimming and digital dimming. In analog dimming the amplitude modulation and continuous current reduction can control the dimming while in digital dimming pulse width modulation PWM is used to control the dimming level by varying the duty cycle in which the time period of PWM signal is fixed. For low speed data transmission, Pulse Position Modulation (PPM) is suggested for dimming and data transmission.

Dimming is one of the essential parameter for eye safety as well as for energy saving. It is required to overcome heat losses and to make the illumination level compatible with the required value for indoor use. Implementation of unipolar optical OFDM scheme in FPGA requires different dimming requirements for reliable and efficient data transmission. Under the dimming, the comparison of different optical OFDM schemes may result in different BER performance

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which needs an investigation by implementing dimming in Optical-OFDM using FPGA.

This paper deals with the transmission design of Optical-OFDM system with dimming support. The paper consists of system model, software and hardware system design results and conclusions.

II. System Model

The system model of OFDM based VLC system, incorporating dimming is depicted in Fig. 1. Initially random bits are generated and are mapped to 4-QAM. To make the signal real at the output of IFFT, Hermitian symmetry is used. The output is then incorporated with cyclic prefix to avoid ISI. The signal is formerly clipped to make it unipolar. Finally, the output from transmitter FPGA board is added with dimming current from PWM or PPM. The output of adder is applied to the Digital to Analog Converter (DAC). The signal from DAC is used to derive the current of VLC based transmitter.

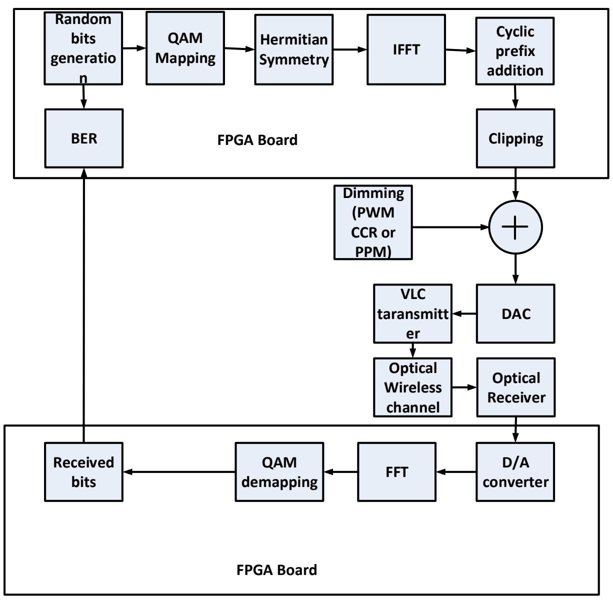

Fig. 1 Block diagram of system model for OFDM-based VLC system with dimming support

The system model is divided into software and hardware system designs

III. Software System Design

The software system is designed using MATLAB Software. In particular, Simulink is used to generated the system model. The random integers are generated for and are mapped on 4-QAM. The output is divided in two parts. 1st part is stored and the same version of output is then flipped using and zero-padded before applying to IFFT block of Simulink. Finally, the signal is made unipolar by clipping asymmetrically. Similarly the receiver part is constructed in Simulink. To obtain Verilog code, HDL coder in Simulink is used which is needed for the hardware system.

IV. Hardware System Design

The Hardware is composed of DE0-nano board from Altera, depicted in Fig. 2., and a VLC based optical transmitter Fig.3. The dimming is achieved using 4-PPM, which is based on constant width pulses. In 4-PPM frame, which is expressed in terms of time frame, there are 8 slots where either bit ‘0’ or bit ‘1’ is allocated to its assigned positions. To achieve illumination of 50 %, two cases were considered. In the first case, preselected bits were (0000). which can be seen in Fig. 4 that the PPM frame is for bits (0000). For second case, preselected bits were (1111) and again 50% illumination was obtained. Which can be seen in Fig. 5 that now the bits are (1111) finding the alternate positions in the PPM frame.

Fig. 2 DE0-nano used for hardware system design

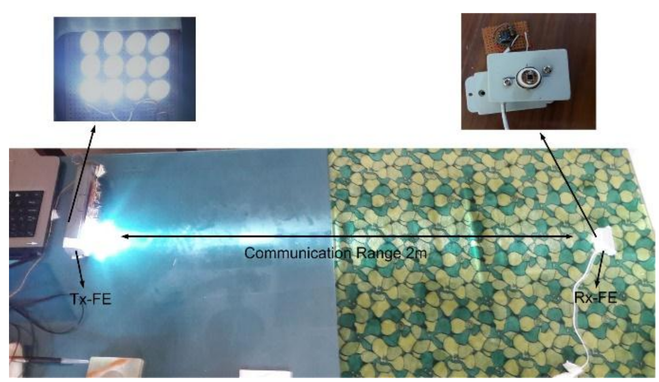

Fig. 3 VLC based transmission system

V. Results and Discussion

In this section, we present results of Optical- OFDM based system with dimming support. Fig.4 gives the output of generated integers from Simulink. The result is generated for 4 m-ary with amplitude ranges from 0 to 3V. These values corresponds to the input decimal points of 4-QAM. Result depicted in Fig. 5 is the output of QAM modulator clearly indicating 4-QAM in constellation diagram. In Fig. 6, the output of IFFT is shown which is real and bipolar. The output is converted into unipolar OFDM and is applied to dimmer. The generated 4-ppm, obtained from MATLAB, is depicted in Fig. 7 and Fig. 8.

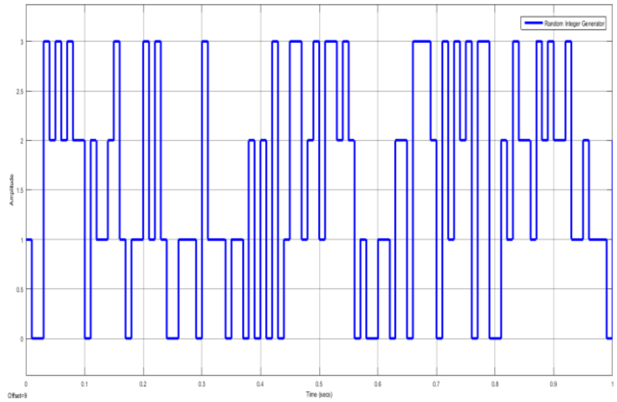

Fig. 4 4 level signal representing decimal input to QAM

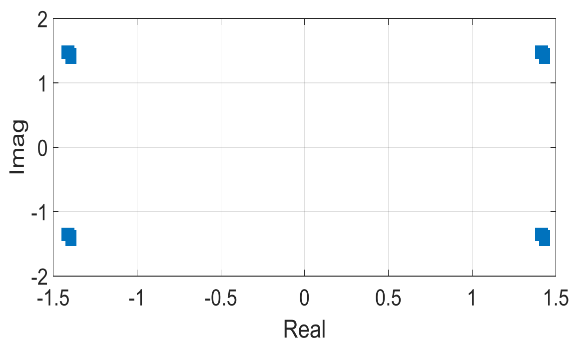

Fig. 5 4-QAM Constellation

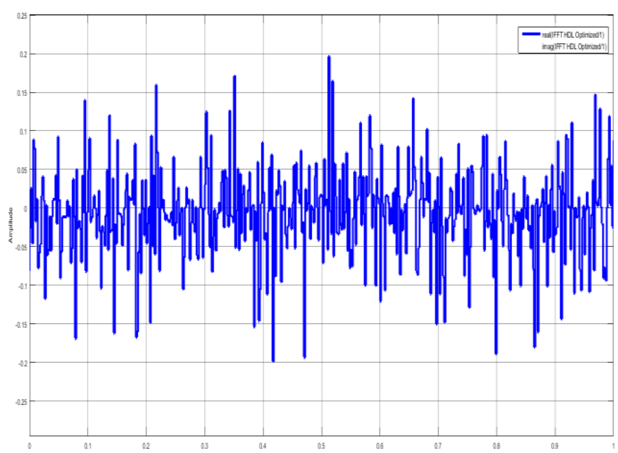

Fig. 6 Bipolar OFDM signal from IFFT

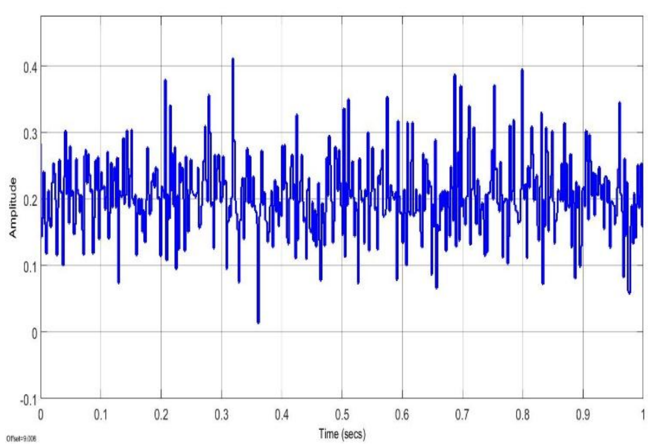

Fig. 7 Unipolar OFDM signal

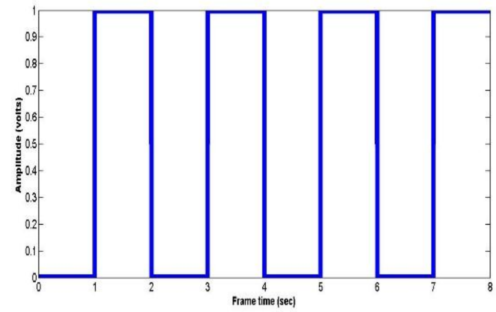

Fig. 8 4-PPM frame for dimming using bits 0000

VI. CONCLUSION

Using Simulink the Optical-OFDM system with dimming support is designed. For hardware, Verilog code was generated using HDL coder. The code was implemented and transmission system was tested. The result from Simulink clearly indicated the generation of OFDM signal. The different dimming levels, which is added using PWM and PPM dimmer gives the different dynamic rang. The complete transmission system may be used to give a better BER performance, which is the content of ongoing research.

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