International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com, Special Issue 42 (AMBALIKA) (March 2017), PP. 57-60

REVIEW OF OFDM MODULATION SCHEME FOR INDOOR VISIBLE LIGHT COMMUNICATION SYSTEM

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***Abstract*— Visible light communication (VLC) system for small range transmission uses visible spectrum which provides illumination simultaneously. Designing cost of light emitting diodes was reduced in order to make this communication possible. A modulation technique which can effectively employ the bandwidth is orthogonal frequency division multiplexing (OFDM) technique. This technique has a unique form of subcarrier modulation scheme because in this all the subcarrier frequencies are orthogonal in nature. Orthogonal Frequency Division Multiplexing scheme are able to attain high throughput in the restricted bandwidth requirement. On the other hand, the major demerit of OFDM has a high peak-to-average-power- ratio (PAPR) which requires a high dynamic variety. High PAPR also causes nonlinear distortion which mostly affects the OFDM scheme in VLC system.**

***Index Terms*—** Visible Light Communication, OFDM, PAPR.

I. INTRODUCTION

With the growing demand of technologies visible light communication system become an alternative to radio frequency technology which is mostly used for indoor conditions. Visible light communication provides highly appealing features like higher bandwidth capability, more security, lower cost and more prone to electromagnetic disturbances [1-6]. Different sources present in a room cause a dispersion of the optical signals that can widely affect the system due to multipath distortion.

Intensity modulation and direct detection (IM-DD) are the techniques which can be used for recent implementations of visible light communication system where intensity of light is modulated. Visible light communication systems have real and non negative signal structure restricted in dynamic range of Light Emitting Diodes. In VLC system, multi-level pulse position modulation and on-off keying modulations schemes are directly used. Though, spectral efficiency is limited because of the ISI [3]. In order to attain the high-speed communication orthogonal frequency division multiplexing (OFDM) modulation scheme is more suitable due to their information rates and cost effectiveness.

The modulation technique of orthogonal frequency division multiplexing (OFDM) has been used to reduce the effect of inter- symbol interference (ISI) caused by multipath reflections in any environment [7-11]. VLC systems have different OFDM modulation techniques that uses intensity-modulation direct-detection (IM/DD) are DC-clipped OFDM [12], asymmetrically clipped optical OFDM (ACO-OFDM) [10], Flip-OFDM [13] and uni-polar OFDM (U- OFDM) [14], [15].
Both communication and illumination combination is used in visible light communication (VLC) system for the reason of high dimming control or low dimming level is necessary. In spite of this, DCO- OFDM has critical performance deprivation in high or low optical power levels which in turn limits its effectiveness [16],[17].
Nowadays visible light communication system uses orthogonal frequency division multiplexing (OFDM) techniques which can broadly and effectively used in RF system in order to reduce the multipath distortion and data rates increases without any power and bandwidth extension [18-23]. In Orthogonal Frequency Division Multiplexing-Visible Light Communication system, the wireless channel receives the distorted signal. The channel consequences can be predicted and compensated in order to improve the transmitted information [24]. The simplest method to find the channel frequency response (CFR) is least square (LS) technique by inserting a training series at the transmitter side. An adaptive channel estimation algorithm and discrete Fourier transformation (DFT) method are used in order to improve the system functioning of the orthogonal frequency division multiplexing system. [25-26]. Depending on the training series, the LS , the correlation and MMSE techniques are used for investigation of orthogonal frequency division multiplexing system. [27]. In spite of this, the above methods are mainly results based without any experimental verifications [28, 29]. Maintenance of a broadband and reliable VLC links are the main design challenges which restricts the commercialization of visible light communication system in the lighting industry, also OFDM has a higher power and spectral effectiveness. Particularly, the challenge is the expansion of hybrid modulation methods incorporates the pulse-width modulation (PWM) for dimming control and the Orthogonal Frequency Division Multiplexing (OFDM) signal for information transmission [30].

II. SYSTEM MODEL

In indoor visible light communication system, different methods are used to calculate the receiver coordinates. In one scheme, the received signal strength can be detected by a photo diode (PD). Depending on the power attenuation transmitter and receiver distance is predicted, and by using lateration technique the receiver coordinates are designed. [31], [32].

For Indoor OFDM technique, consider a standard room whose dimensions are 6 m × 6 m × 3.5 m and Light Emitting Diode bulbs are situated at a height of 3.3 m through a rectangular arrangement. Data transmissions are done from these LED lights and after transmission driver circuit is modulated.

In optical wireless communication system various Orthogonal Frequency Division Multiplexing techniques were developed in the past few years. For the briefness of the system, Asymmetrical Clipped Optical – Orthogonal Frequency Division Multiplexing (ACO-OFDM) has a large active range of Light Emitting Diodes and is more effective in response of optical power as compared with the DC biasing techniques. In spite of this, the other techniques are very simple. The information and Light Emitting Diode ID policies are joint as the input bits which is parsed into a set of N/4 complex information symbols defined as

I = [I0, I1,………..IN/4-1]T

where (:)T gives the transpose of a vector in a system. A real value signal is necessary for modulation of light emitting diode in VLC systems which use IM/DD techniques. Therefore, Hermitian symmetry is required for Asymmetrical Clipped Optical – Orthogonal Frequency Division Multiplexing (ACO-OFDM) subcarriers. In ACO-OFDM, destruction from clipping noise is neglected by mapping of the complex source symbols onto an N _ 1 vector S is given as

S = [0, I0,0, I1,……,0, IN/4, 0,……,I *, 0,……..I *, 0]T

where (.)* defines the complex conjugate of a vector of the system. For creating a time domain signal x an N-point Inverse Fast Fourier Transform is applied. To make suitable and unipolar optical communication the entire negative values are clipped off of the transmitted signal. The clipping process reduces the amplitude precisely to half and does not change the data-carrying signals [10]. The signal which is clipped is firstly converted into an analog form and then modulates with the intensity of an light emitting diode. On the other side, the signal is received by a photodiode and converted again into digital signal. Channel estimation and synchronization is done by using a training series [33].

Recovery of transmitted signal and reduction of channel distortion is employed by using a single tap equalizer and is denoted by

Î = [Î0, Î1, …….., ÎN/4 -1]T

The visible light communication system contains shot noise and thermal noise that model in an additive white Gaussian noise (AWGN) channel [7]. The receives signal for a flat fading channel can be defined as

R(n) = ghXt(n) + w(n)

where gh gives the optical path gain coefficient, and w(n) defines the Additive White Gaussian Noise. While gh is a feature which scales the received signal-to-noise-ratio (SNR) [34]. The signal which is received performs a converse transform after the conversion of optical signal to electrical signals. The converse transform output can be given as

y(n) = $r\ n - B$
a

At the receiver side the scaling factor can be predicted as a division of channel state information for equalization purpose. From these equations it is cleared that for large scaling factor channel noise is smaller after the converse transform but at the transmitter it cause a high clipping distortion.

III. OPTICAL OFDM TECHNIQUE FOR VISIBLE LIGHT COMMUNICATION SYSTEM

The transmitted signals are modulated in a various ways in an optical communication method. Implementation of intensity modulation is very easy which become one of the advantage, in accordance with the modulating signal the output power of the optical signal is changes. The generated optical signals are easily detected and with the output of PD and modulating signal are simply recovered. This is the technique of direct-detection (DD). The consequence for the easiness of intensity modulation - direct detection (IM-DD) technique is a decrease in sensitivity, and the susceptibility to error – on comparison with coherent detection techniques. OFDM become a perfect choice due to their in-built strength where large numbers of transmitters are used at the same time and path differences between receivers present [35].

Optical orthogonal frequency division multiplexing (O-OFDM) becomes an attractive modulation technique in a VLC system. For higher spectral effectiveness and lower complication direct-current O-OFDM (DCO-OFDM) is mostly employed method. As Visible Light Communication is a combination of communication and illumination, various optical powers is used to get a definite intensity of illumination [36].

Peak-to-average ratio (PAPR)

In order to get the perfect use of modulation bandwidth of light emitting diode, VLC system requires an orthogonal frequency

division multiplexing (OFDM) method. Like in radio frequency transmission high peak-to-average power ratio (PAPR) is also present in visible light communication system. Visible Light Communication-OFDM system is different from radio frequency- OFDM system in which peak-to-average power ratio are of two types

– upper PAPR and lower PAPR and the baseband signals are also real- valued. Upper PAPR and lower PAPR become a topic of asymmetric constraints because of their not independently distribution. Orthogonal frequency division multiplexing modulation technique is widely used in VLC system in order to achieve higher data rates and uses all the available bandwidth of Light Emitting Diodes [37-38].

Like Radio Frequency-OFDM, Visible Light Communication-OFDM also has the demerit of high peak-to- average power ratio (PAPR) [39]. In Visible Light Communication-OFDM the IM/DD wants the baseband signal to be unipolar and real valued which is the major difference between radio-frequency-OFDM. In order to make the optical system power ineffective, it is necessary to convert the bipolar OFDM to unipolar OFDM which require biasing of high peak-to- average power ratio [40]. Consequently, in visible light communication-OFDM system it is crucial for reduction of PAPR.

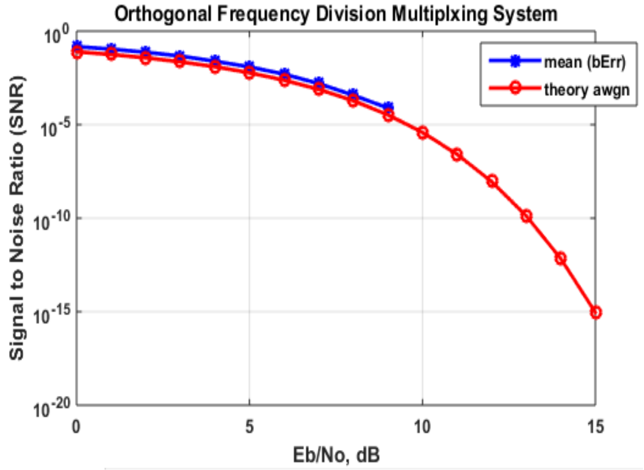

Figure 1: Generation of OFDM signal.

The OFDM modulation technique has been extensively used for radio and digital Television and for Wi-Fi also. The above plot represents the generation of OFDM signal in which signal-to-noise ratio is given. Customized OFDM can be employed in free space optics system. There are a number of advantages including good spectral effectiveness but this method is very complex to design.

CONCLUSION

Optical orthogonal frequency division multiplexing (O-OFDM) becomes an attractive modulation scheme in a Visible Light C communication system. The high peak-to-average ratio (PAR) in OFDM is a major disadvantage of the OFDM modulation technique in visible light communication system. The high PAPR of the Orthogonal Frequency Division Modulation signal can be decreased by combining the non-uniform. In VLC-OFDM system it is very crucial for reduction of PAPR.

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