Performance Enhancement of OFDM based Visible Light Communication Systems

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Abstract: - Light emitting diodes (LEDs) can be used by the system called visible light communication (VLC) to support communication and illumination at the same time. The main problem high peak-to-average power ratios (PAPRs) is increased in orthogonal frequency division multiplexing (OFDM) signal sent in the system of a VLC but OFDM is used to minimizing the inter-symbol interference (ISI).A hybrid PAPR reduction technique has been proposed depend on the transformation of signal combined with clipping. The minimum threshold of clipping is additionally decided at the same time to decrease the PAPR and enhance the BER of the systems of VLC. Another OFDM structure utilizes the precoding of discrete cosine transform (DCT) before inverse fast Fourier transforms (IFFT) block to additionally enhance the capability of reduction of PAPR and the performance of BER. Some of simulation examples are achieved to trial the proposed technique performance as far as the BER and the complementary cumulative distribution function (CCDF). The got results demonstrate that the proposed system can decrease the PAPR at the same time and accomplish perfect performance of BER compared with the VLC-OFDM system.

Key-Words: - OFDM, VLC systems, PAPR reduction, QAM, DCT, Hermitian symmetry.

1 Introduction

VLC is a rising innovation which utilizes the spectrum of the visible light for indoor wireless communications to send data [1] and release from large open air ecological debasements, for instance, rain, snow and building impact [2]. VLC can allow communication and illumination at the same time by method for LEDs. It provides energy efficient and cheap while guaranteeing rapid, secure transmission and huge transfer speed [3].

The systems of VLC can be utilized as a part of numerous applications, for example, the plane and the hospital since it may to some degree affect electronic tools [4]. The systems of VLC use the method of intensity modulation and direct detection (IM/DD) that give basic and ease information transmission, hence not phase information but it modulated the signal intensity information [5]. The fundamental problem in VLC is the constrained modulation transmission of LED [9]. White LEDs displays the low-pass filter attributes so VLC channel shows up as frequency selectivity channel.

OFDM has been provided for VLC because of its quick data rates, gigantic spectral effectiveness and more heartiness versus frequency selective fading and ISI [6].IM/DD needs the electrical signal should be genuine esteemed and unipolar [7, 8].

The optical signal should be a real value and positive, so Hermitian symmetry is satisfied and bipolar-to-unipolar module should be important [9]. In DC biased optical OFDM (DCO-OFDM) signal, DC bias is utilized to create a positive signals with real value and it isn't efficient as far as of the optical power due to the signal of DCO-OFDM requires a high DC bias [10].

The signal in Asymmetrically Clipped Optical OFDM (ACO-OFDM) is pre-cut at zero or a positive base dimension [11], ACO-OFDM is more efficient to the extent the optical power than DCO-OFDM [12]. The higher order modulation such as QAM must be utilized to accomplish high spectral efficiencies.

One of the principle problems which follow VLC-OFDM systems is the high PAPR that emerges from signals of OFDM which have large Peak and the restricted dynamic range of devices of the LEDs. Large PAPR effects of the performance of the systems of VLC as far as BER, so the reduction of PAPR is vital in the systems OFDM based VLC [13].

There are numerous procedures have been proposed in papers to decrease the large PAPR, also enhance the power effectiveness of RF communication systems [14-16]. Be that as it may, since VLC changes from RF communication in different sides, for instance, system limitation, the characteristic of the nonlinearity of front-end devices and the format of the baseband signal, it isn't evident how the PAPR is identified with the efficiency of conversion communication from illumination.

This paper is composed as follows: Section 2 presents the system of VLC-OFDM model utilizing DCT precoding and the clipping. Section 3 discusses the DCT precoding joined with clipping method. The simulations using matlab is introduced in section 4 and the discussion of results. In section 5, the conclusions are written.

2 System Model

The fantastic property of energy compaction for block of DCT does the vast majority for energy of the signal amassed in the initial some of samples, leaving whatever are left of samples near zero [17]. In the event that the DCT precoding is utilized before information transmission, it is normal that the ISI coming about because of those little sufficiency samples will be little, prompting a superior of the performance of BER.

The system model of VLC-OFDM which discussed here is appeared in Fig.1. The first information is right off the prepared by serial-to-parallel (S/P) then applying QAM before going through DCT block. Hermitian symmetry is forced before IFFT block to ensure the value of the signal must be real. After IFFT, the cyclic prefix (CP) is added after the parallel-to-serial (P/S) operation, the cyclic prefix (CP) is added to remove the inter-symbol interference.

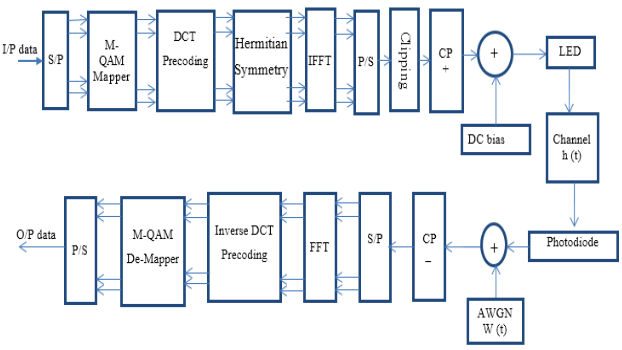

Fig. 1: VLC-OFDM Proposed system.

The PAPR of the OFDM signal can be decreased by using the clipping block. DC biased is used to guarantee the signal positive and not complex. At transmitter block, the electric input signal y (t) is converted to optical signal by the LED and intensity modulation has been utilized but direct detection is used at the side of receiver, the optical power is converted again to an electrical signal by using the PIN photo detector (PD). CP is deleted, After FFT stage an Inverse DCT is used and the signal is demodulated by M-QAM demodulator. Finally, information signals are viably gotten after the conversion of P/S.

The got OFDM signal engendered through the wireless optical channel with impulse response $h(t)$ is offered as:

$$y(t) = \mathcal{R}\, x(t) \otimes h(t) + w(t) \qquad (1)$$

R is the responsivity of the photodetector, $\otimes$ means the circular convolution and $w(t)$ is the AWGN which included the electrical domain. This is the model normally utilized as a part of the system of infrared wireless communication where the fundamental weakness is because of abnormal state radiation of ambient infrared. The signals of ambient are mostly at DC and may be filtered, be that as it may they cause shot noise in the receiver, which is precisely demonstrated as AWGN. The performance in a flat channel consequently has been expected that R=h(t)=1 in this paper.

3 Prepare DCT Precoding Combined with Clipping Technique

Real transform block DCT make the modulated data,X_M changes to other signal utilizing K × KDCT matrix F shown as [18]
(2) Where i and j illustrate the row and column

$$F_{i,j} = \begin{cases} \frac{1}{\sqrt{K}} & i = 0,\ 0 \le j \le K-1 \\ \sqrt{2/K}\cos\left[\frac{(2j+1)i\pi}{2K}\right] & 1 \le i \le K-1,\ 0 \le j \le K-1 \end{cases}$$

elements, individually. The new groupings $\hat{X}_{M-DCT}$ after the DCT matrix can be characterized as:

$$\hat{X}_{M-DCT} = F\, X_M \qquad (3)$$

The information succession after M-QAM is specified by $X = [X_1, X_2, X_3, \ldots, X_M]^T$, the groupings $\hat{X}_M$ after the DCT precoding can be characterized as:

$$\hat{X}_M = H_M X_M \qquad (4)$$

After N-point IFFT, the signal $\hat{X}_M$ might be characterized as:

$$\hat{x}_M = \mathrm{IFFT}\left(\hat{X}_{M-DCT}\right) \qquad (5)$$

Utilizing the clipping technique the signal is restricted to the limit when the top of the input signal surpasses a specific esteem. Something else, the signal goes through specifically. In the proposed clipping technique, clipping procedure is characterized as:

$$y_c = \begin{cases} -A & (\hat{x} < -A) \\ \hat{x} & (-A \leq \hat{x} \leq A) \\ A & (\hat{x} > A) \end{cases} \quad (6)$$

The yield of IFFT signal is $\hat{x}$, A is the clipping threshold and y_c signifies the yield signal subsequent to cutting task. The clipping ratio (CR) is a fundamental parameter which is used to choose the cut-out limit C. It is characterized as:

$$CR = 20log\frac{A}{\sqrt{\bar{P}}} \ dB \quad (7)$$

$\bar{P}$ is the OFDM average power, since about a half of the cut examples are negative genuine and the base esteem is – A no less than, an bias of A esteem is added to each OFDM symbols to make the send signal non negative. With the above procedures, the dynamic range of the amplitude can be smothered to under 2A. Besides, cutting without filtering makes the bias is consistent for each OFDM symbol.

The succession X from the QAM block is changed by the DCT precoding as in Equation 4. The changed grouping is changed over to time domain utilizing IFFT as in Equation (5). The clipping threshold C is calculated, utilizing equation (7) and produce the sequence y_c by clipping $\hat{x}_n$ utilizing equation (6). In last, DC biase of A is added to each OFDM symbol to transmit non negative signal.

The ratio between the maximum instantaneous power to the average power is defined as PAPR of the continuous time OFDM signal. The PAPR of VLC-OFDM signal $\hat{x}_n$ is described as:

$$PAPR(dB) \triangleq 10\ log_{10} \frac{\max_{0 \leq n \leq N} |\hat{x}_n|^2}{E[|\hat{x}_n|^2]} \quad (8)$$

Where E [·]
connotes estimate value want.

The Complementary Cumulative Distribution Function (CCDF) of the PAPR is a champion among the most as frequently as conceivable used execution measures for PAPR decrease systems; it is characterized as [19]:

$$CCDF = Prob(PAPR > PAPR_0) \quad (9)$$

where is the given limit esteem. CCDF signifies the likelihood that the PAPR of an information block surpasses the limit value.

4 Simulation Results and Discussion

A lot of simulation examples have been implemented in this part to show the proposed techniques performance as far as the BER and CCDF. The parameters of Simulation are appeared in Tab. 1. Bias values equivalent to the absolute value of the optimum value has been added in the state of conventional VLC-OFDM system.

Table 1: Simulation Parameters.

Modulation Type	4 QAM
OFDM symbols	10,000
No. of data subcarriers	64
FFT size	128
Guard interval	1/8
Total subcarriers	144

Fig. 2 demonstrates the probability that the PAPR will be larger than the value of a threshold PAPR0 comparison between the main and the proposed system utilizing DCT precoding and variables values of the clipping ratio.

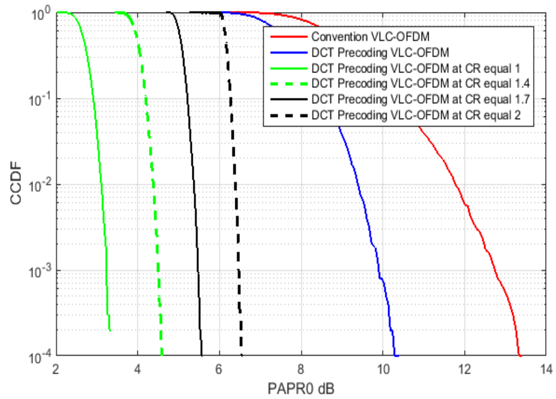

Fig. 2: The CCDF performance of the proposed VLC-OFDM system with different CR.

It tends to be seen that at CCDF = 10^{-3} contrasted with fundamental system, the PAPR is reduced by 2.7 dB while applying only DCT precoding without clipping.

Table 2 shows the effect of using DCT with different values of the clipping ratio on the CCDF performance at CCDF=10^{-3}, for example at CCDF = 10^{-3}, when the proposed technique is used, the PAPR of OFDM based VLC system can be reduced by 6.3 dB, 7.3 dB, 8.3 dB and 9.4 dB at CR = 2, 1.7, 1.4 and 1, respectively.

The reduction in PAPR is over 9.4 dB at using the proposed technique with CR=1 so the peak power can be reduced. This recorded reduction in the peak signal value directly means avoidance of signal clipping and reduction in the amount of DC bias need to make the OFDM signal unipolar but BER performance will be affected.

Table 2: The effect of utilizing DCT Precoding on the performance of CCDF at CCDF=10^{-3}.

	PAPR Reduction
Convention VLC-OFDM	…..
DCT Precoding VLC-OFDM	2.7 dB
DCT Precoding VLC-OFDM at CR equal 2	6.3 dB
DCT Precoding VLC-OFDM at CR equal 1.7	7.3 dB
DCT Precoding VLC-OFDM at CR equal 1.4	8.3 dB
DCT Precoding VLC-OFDM at CR equal 1	9.4 dB

The BER performance of the proposed VLC-OFDM system with different CR is shown in Fig.3.

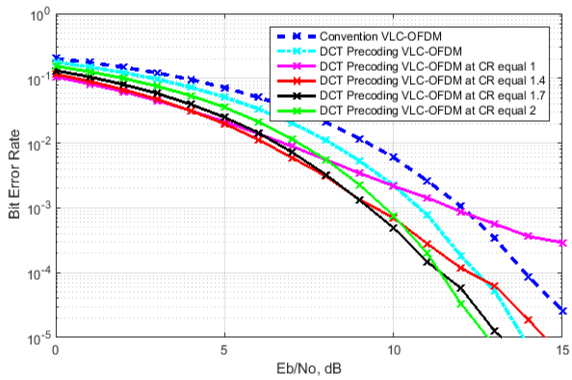

Figure 3: BER performance of the proposed VLC-OFDM system.

At BER $=10^{-3}$, the proposed VLC-OFDM system can accomplish about 1.2 dB enhancement in E_b/N_0 contrasted with fundamental system. Table 3 shows the effect of using DCT with different clipping ratio on the E_b/N_0 performance at BER=10^{-3}.

Table 3: The effect of utilizing DCT Precoding on the E_b/N_0 performance at BER=10^{-3}

	E_b/N_0 Improvement
Convention VLC-OFDM	…..
DCT Precoding VLC-OFDM	1.2 dB
DCT Precoding VLC-OFDM at CR equal 2	2.2 dB
DCT Precoding VLC-OFDM at CR equal 1.7	2.7 dB
DCT Precoding VLC-OFDM at CR equal 1.4	2.4 dB
DCT Precoding VLC-OFDM at CR equal 1	No Improvement

Likewise take note of that t, the performance of E_b/N_0 is reduced round 2.2 dB at a CR of 1.4 contrasting to the fundamental system. This decrease winds up 2.7 dB when the CR becomes 1.7 and 2 at BER=10^{-3}.

5 Conclusion

The hybrid methods have been proposed to decrease the PAPR and enhance the performance of BER of VLC-OFDM systems. The proposed system combined the DCT matrix with cut-out strategy. The minimum clipping value at which we can decrease the PAPR and enhance the BER of VLC-OFDM systems was likewise assessed. The performance of fundamental VLC-OFDM system, the proposed VLC-OFDM system with different CR was determined and thought about as far as CCDF and BER. It was exhibited that, the proposed VLC-OFDM with clipping method has the minimum PAPR and best BER performance contrasted with regular system.

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