

PAPR Reduction in VLC-OFDM System using CPM Combined with PTS Method

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Abstract: One of the primary issues influencing the execution of visible light communication (VLC) system was high peak to average power ratio (PAPR), which depended on the orthogonal frequency division multiplexing (OFDM) technology. The PAPR probability distribution of the OFDM signal in VLC system has been analyzed. The Partial Transmit Sequence (PTS) strategy was modified to reduce the PAPR of OFDM signal in VLC system. PTS was appropriate for transmission in VLC system and combined with continuous phase modulation (CPM) to further reduce PAPR of the optical OFDM signal. The simulation results show that the PAPR of the system is reduced about 3dB, 2.3dB, 2.1dB comparing with the original signal. CPM combined with PTS method has a better PAPR reduction performance.

Keywords: OFDM, VLC systems, PAPR reduction, PTS, CPM.

1. INTRODUCTION

VLC uses the light emitting diodes (LEDs) to send data by the visible light spectrum and it is envisioned to be essential for wireless data transmission in indoor environments for short-range and low-mobility applications [1]. These systems offer some advantages such as the cost of devices used in a VLC system is lower compared with RF systems making it an attractive candidate in a consumer communication system (VLC systems using LEDs are cheaper from those using LDs). There is no law about the regulation of light wave frequencies by any government or organizations worldwide. The VLC frequency spectrum is different than radio frequency, making it convenient in places where electromagnetic interference (EMI) is prohibited (e.g. in hospitals). VLC don't have the ability to pass through walls and other opaque objects and suffer from the inter-symbol interference (ISI) which reduces the signal to noise ratio (SNR) at high data rates [2], [3].

OFDM is utilized widely in a broadband wireless and wired communication systems due to its capacity to accomplish fast information correspondence through a band-restricted channels, effectively mitigate ISI so it has been utilized for VLC [4].

The block diagram of OFDM based VLC system transmitter showed in figure 1. The input serial binary data streams go into parallel transmission then, through the modulation mapping. In VLC, many researchers believe that intensity modulation and direct detection (IM/DD) is a practical system due to its low cost and simple implementation for short-range, indoor applications.

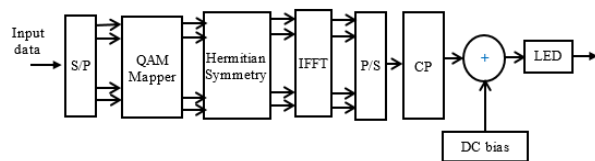


Figure 1. Block diagram of OFDM transmitter based VLC system.

The information is encoded in the power of the optical wave, which can be varied by appropriately changing the current's volume that acts as input to LED but the electric signal demand being non-negative and real-valued, the real OFDM signal has been generated by using Hermitian symmetry then inverse fast Fourier transform (IFFT) is utilized and after the parallel-to-serial (P/S) operation, the Cyclic Prefix (CP) is used to overcome the effect of the ISI. The bipolar OFDM signal



is then converted to a unipolar signal by adding a DC bias, as in DC biased optical OFDM (DCO-OFDM), or by clipping at zero and transmitting only the positive parts of the OFDM waveform as in asymmetrically clipped optical OFDM (ACO-OFDM). Among these schemes, ACOOFDM has been shown to be more efficient in terms of optical power than the systems that use DC-biasing as it utilizes a large dynamic range of the LED [5].

VLC-OFDM acquires the disadvantage of the PAPR from RF-OFDM. Therefore, PAPR reduction techniques are necessary for the VLC-OFDM system that tradeoff complexity and energy inefficiency [6]. Many of techniques have been used to decrease the high PAPR of the OFDM signal such as signal scrambling technique, signal coding technique, companding method and distortion technique reduces the PAPR by clipping the peak signal [7].

PTS procedure has the great execution of PAPR reduction of the system but the procedure has the disadvantage of high computational complexity [8]. Firstly, the input data sequences are divided by the PTS technique into several disjoint sub-blocks with the same length. At that point, the phase factors which utilized for scrambling are multiplied with the signals after IFFT to create a few candidate sequences.

At last, the one with the lowest PAPR from the candidate sequences is chosen as the transmitted signal. OFDM-CPM signals utilize the idea of correlated phase states of a CPM signal have just as of late been presented [10]. The correlation among adjacent OFDM symbols can be deliberately presented by a fitting decision of the modulation index n . The BER in this system can be reduced by this correlation. [11]. One of the advantages of OFDM-CPM signals is that we can systematically introduce correlation among adjacent OFDM symbols by an appropriate choice of parameter (in typical CPM signals is the modulation index). Furthermore, this correlation can be exploited in order to reduce the bit error rate (BER) in such a system.

This paper discusses a hybrid technique between PTS with CPM for VLC-OFDM to reduce the PAPR of the system with different modulation index and different sub-blocks. The rest of the paper is organized as follows. Section 2 describes OFDM-CPM based on VLC system. Section 3 introduces the principles of PTS in VLC. Section 4 introduces the CPM-PTS method to reduce the PAPR of VLC-OFDM system. The PAPR probability distribution of OFDM signal is briefly presented in VLC system in section 5. Simulation Results are presented in Section 6. At last, conclusions are presented in Section 7.

2. OFDM-CPM BASED VLC

In the OFDM system, the mapper is BPSK, QPSK or M-QAM. CPM mapper has been applied in this paper. Multi-amplitude CPM in single carrier communications is

a generalization of conventional CPM in which the signal amplitude is permitted to change over a set of amplitude values while the phase of the signal is compelled to be continuous [12].

Two-component CPM constellations in the mapper have been used in this paper to reduce PAPR where the signal amplitude is permitted to take one of the two conceivable values. The signal is decoded in view of the phase of complex number at the receiver, so there is no need to send any extra data about the amplitudes of complex numbers to the receiver.

Figure 2 demonstrate that the input serial data is changed over into blocks of N bits shown by $x_{m,p}$; $m=0, 1, 2, \dots$ and $p=0, 1, 2, \dots, N-1$.

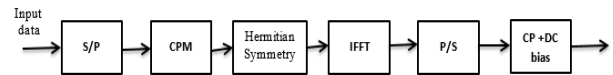


Figure 2. Block diagram of OFDM-CPM transmitter based VLC system.

Where N refer to the number of carriers. The incoming $\{x_{m,p}\}$ are transformed into suitable complex numbers $\{y_{m,p}\}$ by the CPM mappers, i.e.

$$y_{m,p} = \cos(\theta_{m,p}) + \sin(\theta_{m,p}) \quad (1)$$

With

$$\theta_{m,p} = \begin{cases} x_{m,p}\pi n + \pi n \sum_{l=0}^{m-1} x_{l,p} + \phi; & m \geq 1 \\ x_{0,p}\pi n + \phi; & m = 1 \end{cases} \quad (2)$$

Where n is the parameter which knows the CPM mapper and the first mapping point demonstrated by ϕ and expected zero without loss of generality. The angles $\theta_{m,p}$ rely on upon the present information and the past information. The complex numbers from the output of the CPM mappers are gone through Hermitian symmetry block then have been converted to time domain by IFFT, then CP and DC bias are adding and finally go through LED.

At the receiver side, direct detection (DD) is employed. The incoming optical power signal has been converted into the amplitude of an electrical signal by The PIN photodetector (PD). The propagated OFDM signal goes through the wireless optical channel with impulse response $h(t)$ is given by:

$$y_r(t) = \mathcal{R} x(t) \otimes h(t) + w(t)$$

\mathcal{R} is the photodetector responsivity, \otimes denotes the circular convolution and $w(t)$ which added in the electrical domain refer to the additive white Gaussian noise (AWGN). The encompassing signals are for the most part at DC and can be filtered out, in any case, they cause shot noise in the detector, which is precisely

demonstrated as AWGN. The performance in a flat channel, therefore, we suppose that $\mathcal{R} = h(t) = 1$ has been considered in this paper.

3. PARTIAL TRANSMIT SEQUENCE

PTS has been introduced in 1997 by S. H. Muller and J. B. Huber. The PTS strategy is received to carry out random phase weighting to the signal to reduce the OFDM signal peak value probability signal appears, accordingly decreasing the PAPR of OFDM signal. The block diagram of the principle of the PTS method based VLC system has been shown in figure 3 [13]. The frequency domain information vector set to be modulated transmission is $X = [X_0, X_1, \dots, X_{N-1}]$, the information length is N .

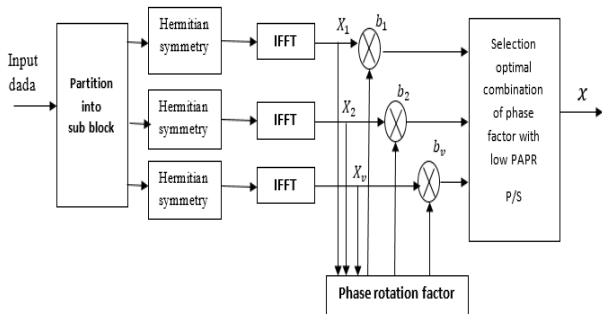


Figure 3. The block diagram of the PTS scheme in VLC OFDM system [13].

The primary vector is divided into V non-overlapping set, appeared on $\{X_v, v = 1, 2, \dots, V\}$, in particular to meet:

$$X = \sum_{v=1}^V X_v \quad (3)$$

Every sub-block contains an equal number of data symbols. There are various types of division strategy of data symbols, for example, interlacing segmentation, adjacent segmentation, and random segmentation. In the IFFT contribution of every parcel information vector can be represented as:

$$X_v' = [0, x_1, x_2, \dots, x_{N-1}, 0, x_{N-1}^*, x_{N-2}^*, \dots, x_1^*] \quad (4)$$

At that point get OFDM time domain signal is:

$$Z_v = \text{IFFT}\{X_v'\} \quad (5)$$

Then they V groups respectively with the weighted coefficient are multiplied by $b_v (v = 1, 2, \dots, V)$, V output sequence hence got can be represented as:

$$Z_v' = b_v Z_v, v = 1, 2, \dots, V \quad (6)$$

In the weighted coefficient of b_v otherwise called the phase rotation factor, it fulfills:

$$b_v = \exp(j\varphi_v) \quad (7)$$

The output sequence income speculation v packet and the weighted coefficient multiplied is

$$Z_v' = b_v Z_v \quad (8)$$

Then every group got back together and then output time domain signal is:

$$x' = \sum_{v=1}^V Z_v' \quad (9)$$

By selecting the suitable phase rotation factor $b_v (v = 1, 2, \dots, V)$, makes the OFDM time domain signal with the least conceivable estimation of PAPR. Meet the OFDM time domain signal values of PAPR phase rotation factor optimal can be represented as:

$$\{b_1', b_2', \dots, b_v'\} = \arg \min_{[b_1, b_2, \dots, b_v]} \left(\max_{1 \leq n \leq N} |x'|^2 \right) \\ = \arg \min_{[b_1, b_2, \dots, b_v]} \max_{1 \leq n \leq N} \left(\left| \sum_{v=1}^V Z_v' \right|^2 \right) \quad (9)$$

4. THE PROPOSED OFDM-CPM WITH PTS BASED VLC SYSTEM

In this paper, the technique which utilizes multi-amplitude CPM signals and PTS to reduce the PAPR of OFDM signals has been studied. Not at all like other PAPR reduction procedures such PTS; this method does not require side data to be sent to the recipient. The PAPR decreasing technique is then connected which gives drive execution at lower cost and intricacy.

As shown in Figure 4, the CPM-PTS technique that used to reduce the PAPR value of OFDM signals in VLC system. In this way, this will be the CPM strategy consolidated with PTS to enhance the complexity of the system, additionally has more excellent performance PAPR inhibitory properties.

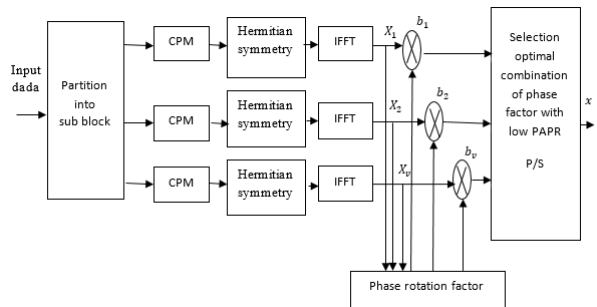


Figure 4. The block diagram of the PTS scheme in VLC OFDM-CPM system.

5. PAPR PERFORMANCE OF OFDM BASED VLC

The PAPR of the continuous time OFDM signal based VLC is known as the proportion of the maximum instantaneous power to the average power. The saturation of the power amplifier and increasing error probability happens in OFDM techniques because of high PAPR.

The PAPR of discrete time OFDM signal in VLC system \hat{x}_n is expressed as [14]:

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

$E[\cdot]$ means statistical expectation. The Complementary Cumulative Distribution Function (CCDF) of the PAPR is a standout amongst the most frequently utilized performance measures for PAPR reduction methods which expressed as [15]:

$$CCDF = Prob(PAPR > PAPR_0) \quad (11)$$

The probability that the PAPR of a data block exceeds the threshold value defined as CCDF.

6. SIMULATION RESULTS

In this part, the PAPR reduction capability with proposed scheme has been evaluated by MATLAB program which is utilized with computer simulations. The performance of proposed scheme in the CCDF of the PAPR of OFDM signals based VLC is evaluated in comparison with other conventional reduction PAPR techniques.

TABLE 1. SIMULATION CONDITIONS.

Modulation Type	QPSK & CPM
Modulation index	1/2 & 2/3
OFDM symbols	10,000
No. of data subcarriers	48
FFT size	128
Guard interval	16 samples times
Total subcarriers	144

The simulation conditions shown in Table 1 are: system subcarrier number is 128, using CPM modulation with modulation index 1/2 or 2/3, the subcarriers are divided into 2 or 4 sub-block in the PTS algorithm, the number of allowed phase factors is 2, 4.

Figure 5 shows PAPR reduction performance of OFDM-CPM with PTS based VLC with subcarriers of 128. The red curve is the simulation results of the original VLC-OFDM with QPSK modulation type and other curves with CPM modulation type with modulation index 1/2 and 2, 4 sub-blocks. The simulation results are obtained by the 10,000 OFDM blocks. As can be seen from the figure, the OFDM-CPM based VLC can obtain 2 dB PAPR reduction compared with the original VLC-OFDM system with CPM modulation type When the CCDF value

is 10^{-3} . From the figure can be seen that the CPM-PTS algorithm is better than other methods, PAPR is reduced about 2.3 dB, 3 dB than the original VLC-OFDM signal when $v=2, 4$ respectively at the CCDF value is 10^{-3} .

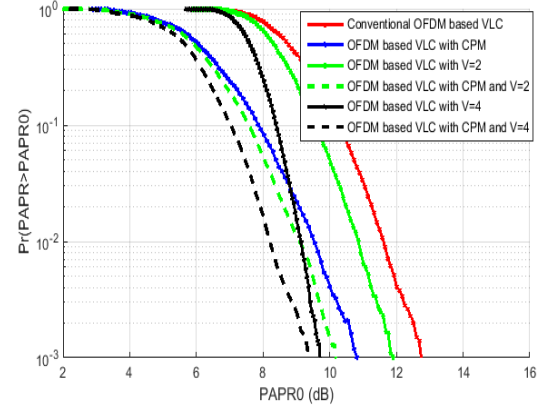


Figure 5. Comparison of the PAPR of VLC OFDM-CPM system Different sub-block and $h=1/2$ at subcarriers = 128.

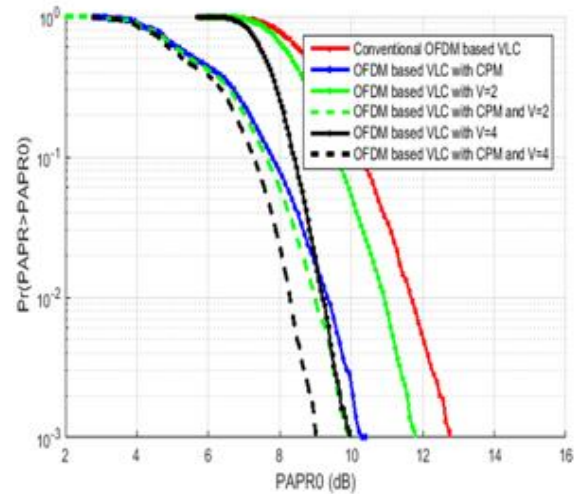


Figure 6. Comparison of the PAPR of VLC OFDM-CPM system Different sub-block and $h=2/3$ at subcarriers = 128.

Figure 6 shows PAPR reduction performance of OFDM-CPM with PTS based VLC with modulation index 2/3 and 2, 4 sub-blocks. As can be seen from the figure, the OFDM-CPM based VLC can obtain 2.1 dB PAPR reduction compared with the original VLC-OFDM system with CPM modulation type When the CCDF value is 10^{-3} . From the figure can be seen that the CPM-PTS algorithm is better than other methods, PAPR are reduced about 2.2 dB, 2.7 dB than the original VLC-OFDM signal when $v=2, 4$ respectively at the CCDF value is 10^{-3} .



7. CONCLUSION

The high peak to average power ratio in VLC OFDM system is a big problem and LED nonlinear devices will have a serious distortion of PAPR signals. Accordingly, how to reduce the high PAPR must be very important in OFDM system. It is observed from simulation results that the proposed scheme which combination of CPM with PTS method and by choosing the parameter h may obtain significant PAPR reduction in VLC OFDM system instead of using individual CPM or PTS methods. The performance of an OFDM-CPM system depends upon the type of signaling used at the transmitter and the observation interval employed at the receiver. At CCDF = 10^{-3} , proposed scheme may achieve about 3dB PAPR reduction than the original signal PAPR in VLC OFDM system at $h=1/2$ and PAPR reduction about 4dB at $h=2/3$.

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