Analysis of BER Performance for DCO-OFDM in VLC SYSTEM

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Abstract—The overall BER performance evaluation of DCO-OFDM scheme in internal VLC which is Visible Light Communication structures via a different threshold of DC Biased points is proposed in this paper.Presenting the simulation outcomes of DC-biased optical OFDM (DCO- OFDM) performance in AWGN for intensity-modulation and direct-detection systems. However, it is shown that by lowering the dc-biased value or voltage , improves the VLC system performance in terms of BER .

Keywords — OpticalDCO-OFDM, VLC, BER

1. INTRODUCTION

With the rising era of social networking video –on demand and cloud based services. Visible light communication(VLC) has recieved high interest because of the inherent advantage of unregulated huge bandwidth(i.e terahertz band) immunity to Radio frequency(RF) interference, and low cost device which will attain excessive data rate transmission , the VLC technique is commonly used in OFDM system.[1]

VLC refers to an array of OWC which is Optical Wireless Communicationby utilizing spectrum of visible light which varies in the range of 380-780 nm.[2] It provides the capacity for multi-gigabit per-second data rate communication at small distances with ~300 THz of presented visible light spectrum at low power and cost, by using photodiode and some simple LEDs. Further, the VLC systems which use the network for the internal luminous system have been vision as a compact, secure and have an alternative opportunity for the downlink of an internal wireless cellular communique system [3].

Light emitting diode (LED) is recognized as the 4^{th}generation of environmentally friendly lighting products, which has advantages which include less power utilization, long life span and small size. However, LED has highspeed modulation characteristics in comparison with other traditional light sources. Therefore, LED can be utilized for high-speed data communications [4].

OFDM is now broadly used in broadband wired and Wi-Fi communication system to achieve extraordinary data rates in VLC systems because of its resistance to inter symbol interference (ISI) and better spectrum efficiency and it has excellent performance of anti-fading and anti-intersymbol- interference.[5] The VLC systems adopt the intensity modulation and detection (IM/DD) which is direct, the electrical carriers are modulated onto the instantaneous strength of the LED, which means that the transmitted signal have to be non-negative and real-valued. Since the conventional RF time-domain OFDM signals are usually bipolar and complex, the OFDM need a modification in order to become unipolar for VLC systems[5-6]. Hermitian symmetry is normally imposed on the frequency OFDM to realize the output of IFFT (Inverse Fast Fourier Transform) to be real.[6]

The remaining paper is arranged as follows. Section II presents the OFDM system models, simulation and its results are shown in Section III. Finally, conclusion is drawn in Section IV.

2. SYSTEM MODEL

At the system transmitter, OFDM uses IFFT to transform a set of subcarriers which are overlapped and multiplexed in the frequency domain to a signal of its time-domain equivalent form. A single OFDM symbol corporates a set of fixed data symbols, X in the frequency-domain. The OFDM symbol is a vector, which contains a set of N subcarriers.[7] The outcomes of IFFT process the discrete OFDM symbol vector Xtaken in the time-domain is represented as the following equation-

$$x_m = \frac{1}{N}\sum_{k=0}^{N-1} X_k e^{\frac{j2\pi km}{N}} \quad for \quad 0 \le m \le N-1 \qquad (1)$$

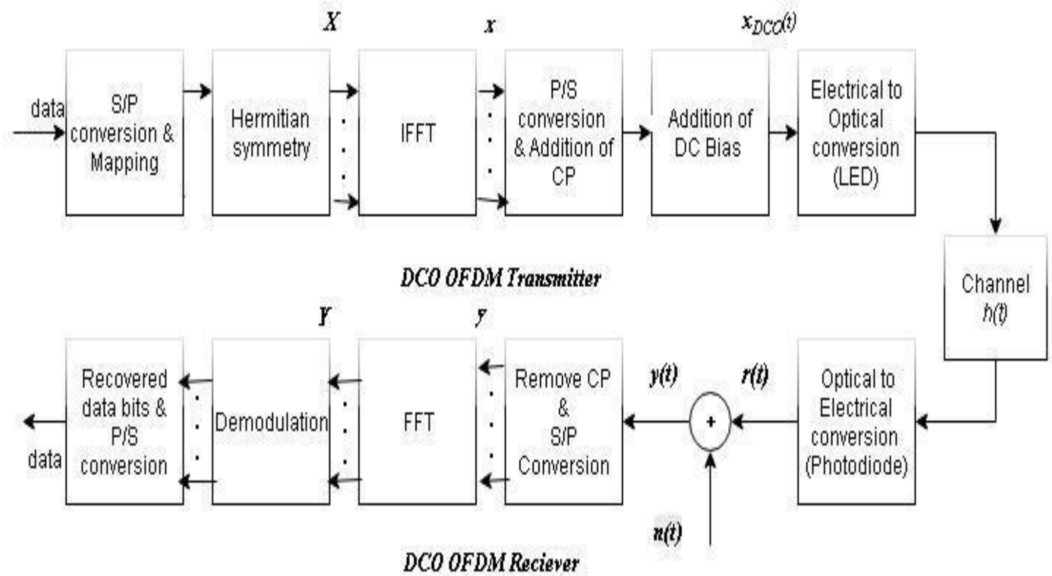

Fig 1. System Model of DCO-OFDM

Here, the magnitude of IFFT is denoted by N and X_K is the k^{th}subcarrier symbol. The equivalent FFT transformation can be defined as-

$$X_k = \frac{1}{N}\sum_{m=0}^{N-1} x_m e^{-j\frac{2\pi km}{N}} \quad for\, 0 \leq k \leq N-1 \quad (2)$$

The outcome of the equation (1) is a complex signal and it cannot be utilized in an IM / DD system which is an LED center VLC technique. Hermitian symmetry is utilized to get an IFFT output in real form [8]. It is a transpose-conjugate replica of fixed, mobile subcarriers, that's delivered or introduced to the second half of the IFFT frame, IFFT input vector, X_H is defined as

$$X_H = [X_0, X_1, X_2 .....X_{N-1}, X_N, X^*_{N-1}, X^*_{N-2}......, X^*_2, X^*_1] \quad (3)$$

The input of the inverse fast fourier transform (IFFT) is the complex data signal $\mathbf{X_H}$, and the DC element, $X_0=X_N=0$. This outcome is a 2N-point IFFT output of the OFDM symbol. Equation (1) is amended as

$$x_m = \frac{1}{N}\sum_{h=0}^{2N-1} X_{H,h} e^{j\frac{2\pi hm}{N}} \quad for\, 0 \leq m \leq 2N-1 \quad (4)$$

Because of the input of Hermitian symmetry, the outcome of IFFT, x is real not complex, here in (4)

h is the hth-subcarrier symbol of X_H. The OFDM symbol has a cyclic characteristic with time interval, $Tp=1/\Delta f$, and Δf is the range of frequency or subcarrier presented as

$\Delta f=B/(N-1)$

Where modulation bandwidth is denoted by B.

Now signal x_m is transformed from (P/S) parallel to serial, a cyclic prefix (CP) is affixed. The benefit of transmission of OFDM is that it can minimize the ISI drawback through the use of a cyclic prefix (CP) which is added to the OFDM frame at the beginning. The CP is a cyclic replica of the last part of a frame of OFDM. The prefix is prolonged than the predicted delay in the channel; It alleviates the destructive effect which is created by the dispersive channel. The optical OFDM symbol spectrum in time domain is real and bipolar. To satisfy IM/DD necessities, a DC threshold is added in the DCO-OFDM technique to generate unipolar signal. The creation and restoration of the DCOOFDM technique is simple. A DC- biased points (applied in an experiment as a DC-bias current to operate the LED) is introduced to the produced signal to uplift the signal into a unipolar area and after that it is transmitted [9].

For DCO-OFDM, the total data rate transmission is given by

$$R_{DCO-OFDM} = \frac{B}{N}\sum_{k=1}^{N-1} log_2 M_k \quad (5)$$

Here B is termed as a bandwidth of modulation and $\log_2 M$ indicates the number of bits per symbol of an M-pulse amplitude modulation (M-PAM) scheme. While, the actual-valued OFDM signal in the time-domain is still marked by a large PAPR [10]. The PAPR is expressed as

$$PAPR = \frac{max x_m^2}{E[x_m^2]} \quad (6)$$

Where max $x_m^2$is defined as the OFDM signal power with maximum value and E [x_m^2] is the mean of these maximum values of x_m^2. For larger values, the signal sub carriers can be designed as a Gaussian random variable with mean equal to zero and variance of these signals is defined by $\sigma_D^2 = E[x_k^2]$..

Now an appropriate DC bias is introduced and clipped residual negative peaks in signal $\boldsymbol{x_{DCO}}$**(t)**. Because of large peak-to-average power ratio in OFDM signals, a very large DC bias value is necessary to get rid of the negative peaks. After linear scaling (LS) and a biasing operation in DCO-OFDM the positive onward signal ***x_{DCO} (t)*** that operates the LED should be acquired from *x(t)* as

$$x_{DCO}(t) = \alpha x(t) + \beta_{DC} \quad (7)$$

Where α and β_{DC} are both real-valued. β_{DC} is set corresponding to the standard deviation of x(t). The DC bias level is denoted by β_{DC}.

$$\beta_{DC} = \mu\sqrt{Ex(t)^2} \quad (8)$$

in which proportionality constant is denoted by μ. β_{DC} is described as a bias of $10\log_{10}(1+\mu^2)$dB. [11] Remaining negative peaks are clipped at zero value after adding β_{DC}. Signal $\boldsymbol{x_{DCO}}$(t) is taken as input to the optical modulator (LED). Here in the paper, we suppose an ideal optical modulator, so the intensity of the outcome of the optical signal is directly proportional to input of electrical current. The forward signal *y(t)*operates the LED which transforms the electrical signal into optical intensity. The iris of the human cannot understand high-speed varying intensity of light, and can acknowledge only to the mean light intensity. Meanwhile, linear scaling as well as biasing model is observed to make the onward signal in the kinetic variation of the LED [12]. The biasing point β_{DC} introduced to *x(t)* to make certain OFDM signal at the input of the LED is unipolar, and α is the factor to amount *x(t)* for the variations of LED. The scalar part should be properly selected to labor with the limitation of the LED. However, a large value of α can be the reason of clipping of the optical signal.

The consequential signal is sent through an AWGN channel. Shot noise act as dominant source which influences the signal and formed as AWGN [13], η_{AWGN} introduced in the electrical domain. A photodiode is utilized at receiver to alter the obtained optical intensity to the electrical signal amplitude.

The Signal passes through the channel, the obtained signal is received as $y(t)=h(t)*r(t)+\eta_{AWGN}$ where in *y(t)* indicates the acquired distorted duplicate of the sent signal *r(t),* and here * denotes discrete linear convolution The distorted signal is convolved to the impulse response of the channel, *h(t),* and transmitted signal is distorted by means of AWGN ,i.e.$n_{AWGN}(t)$, at the receiver. Here, * denotes linear convolution. As OFDM is primarily centered on IFFT and FFT process, and its DSP implementation is straightforward. It is essential to express that the noise is appended in the electrical signal; thus, the gained signal can be positive as well as negative. That's why, the gained signal is bipolar in its place of unipolar. First of all, CP is eliminated and the linear convolution is transformed to circular convolution, then the demodulation of signals is done by utilizing FFT.

At the receiver, an FFT function executes the action of transforming from domain in time to the domain in frequency. And each element of the FFT output Y_h is determined by

$$Y_h = \sum_{m=0}^{2N-1} y_m e^{-j\frac{2\pi hm}{N}} \quad for\, 0 \le h \le 2N-1 \quad (9)$$

here y is vector contains a fixed set of amplitudes of the acquired of length $2N$ time-domain signal. The transmitted and the gained signal in AWGN channel are determined by

$$y(t) = r(t) + \eta_{AWGN} \quad (10)$$

here, $r(t)=h(t)*x_{DCO}(t)$ is substituted in (10) then y(t) is expressed as

$$y(t) = h(t) * x_{DCO}(t) + \eta_{AWGN} \quad (11)$$

Now by substituting (11) in (9), the equation becomes see(12)

$$Y_h = \sum_{m=0}^{2N-1} x_m e^{-j\frac{2\pi hm}{N}} + \sum_{m=0}^{2N-1} \eta_{AWGN} e^{-j\frac{2\pi hm}{N}} \quad for\, 0 \le h \le 2N-1 \quad (12)$$

After demodulating the signal by the usage of FFT. Then, symbols are withdrawing from the FFT outcome and demodulation of PAM is attained. After serial-to-parallel conversion data bits are restored in its original form.

3.PERFORMANCE ANALYSIS

A. Simulation Setup

The flowchart of our simulation analysis is shown in Fig.2. Data bits are generated arbitrarily and transformed from (s/p) serial to parallel in symbols form for PAM. The PAM symbols are modulated by the usage of IFFT to change the symbols into time-domain. Before the (P/S) parallel to-serial conversion takes place a CP is merged. After adding CP, symbol-to -symbol DC bias is affixed to follow with the positive limit. The consequential signal is modulated by a light source and is sent through the WOC channel. After eliminating the DC bias the inverse procedure is done at the receiver.

TABLE I. SIMULATION PARAMETERS

Simulation Parameters	**Value**
OFDM	
IFFT Length	32
CP Length	8
Length of OFDM Symbol	40
Data Symbols	16
LED	
Responsitivity	0.54
Biasing Points	1-4 V
No. of LED's	2500

B. Results and Discussion

This section presents and investigates, the variable or constants that affect the DCO-OFDM performance of VLC system. In realistic OFDM structures, a CP is appended to keep up the orthogonality among channels. Additionally, a linear scaling has been followed in our simulation to make the OFDM signal work in the confined VLC system. At the same time as a DC bias is amended to theOFDM signal which is bipolar to comply with the constraint of being non- negative as shown in Fig.3.

In order to the impact of DC bias at the BER overall performance, simulations are conducted with M=16 for distinct DC Bias value as seen in Fig.4 and it is shown that as the DC bias value increases, BER enhance simultaneously.

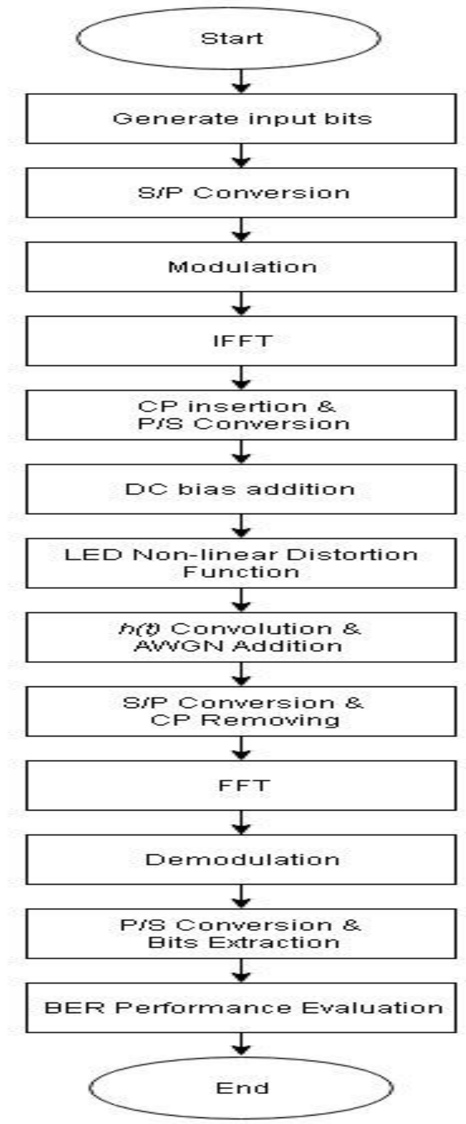

Fig 2. Simulation Flowchart

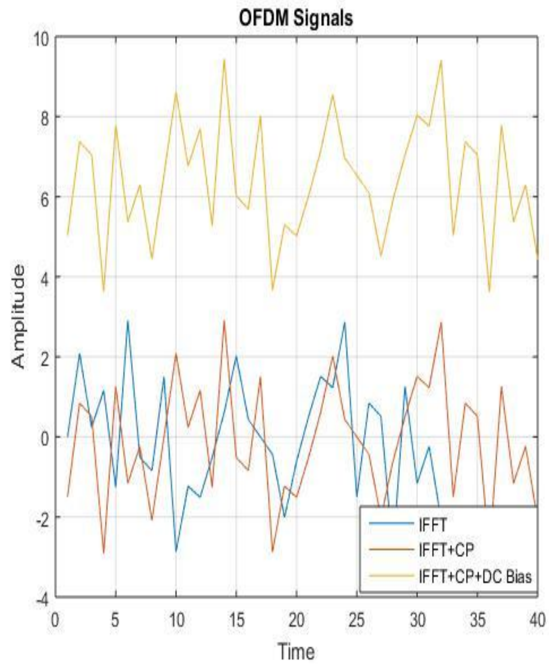

Fig 3. OFDM Signals

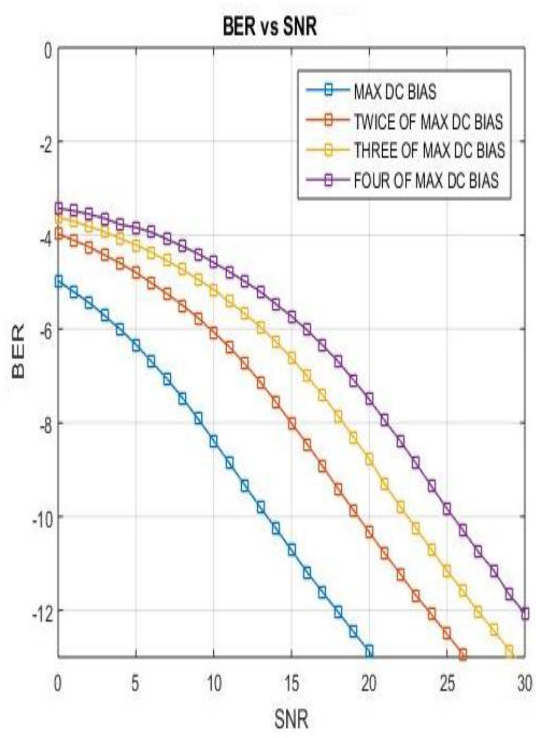

Fig 4.. BER vs. SNR for DC bias points in DCO-OFDM VLC system

TABLE II. BER Data for DC Bias points

S.No	SNR	BER at MAX DC BIAS	BER at 2*MAX DC BIAS	BER at 3*MAX DC BIAS	BER at 4*MAX DC BIAS
1	0	-4.973	-3.974	-3.620	-3.423
2	1	-5.208	-4.110	-3.704	-3.482
3	2	-5444	-4.250	-3.819	-3.552
4	3	-5.721	-4.427	-3.932	-3.648
5	4	-6.009	-4.599	-4.073	-3.738
6	5	-6.332	-4.798	-4.209	-3.806
7	6	-6.697	-5.019	-4.361	-3.957
8	7	-7.066	-5.249	-4.548	-4.067
9	8	-7.475	-5.496	-4.727	-4.239
10	9	-7.921	-5.765	-4.944	-4.397
11	1	-8.381	-6.066	-5.158	-4.583
12	11	-8.860	-6.382	-5.418	-4.789
13	12	-9.333	-6.744	-5.675	-4.908
14	13	-9.808	-7.134	-5.958	-5.206
15	14	-10.255	-7.557	-6.273	-5.473
16	15	-10.718	-8.010	-6.618	-5.720
17	16	-11.187	-8.452	-7.002	-6.026
18	17	-11.613	-8.925	-7.408	-6.346
19	18	-12.037	-9.408	-7.850	-6.693
20	19	-12.466	-9.874	-8.315	-7.094
21	20	-12.879	-10.338	-8.772	-7.539
22	21	-13.357	-10.790	-9.316	-7.967
23	22	-13.755	-11.225	-9.790	-8.389
24	23	-14.077	-11.682	-10.245	-8.681
25	24	-14.436	-12.089	-10.708	-9.362
26	25	-14.787	-12.507	-11.160	-9.834
27	26	-15.094	-12.929	-11.581	-10.285
28	27	-15.437	-13.319	-12.030	-10.740
29	28	-15.718	-13.673	-12.430	-11.198
30	29	-16.006	-14.042	-12.850	-11.648
31	30	-16.218	-14.422	-13.224	-12.466

4. Conclusion

The paper presents the evaluation of the performance of DCOOFDM schemes of VLC. Some challenges of VLC design in practice are discussed covering the BER performance. The results of simulation indicate that as the DC bias value increases BER increase in VLC system. If a large DC bias is used, the optical energy per bit to single sided noise power spectral density, E_{bopt}/No, becomes very large, in that way the scheme will become inefficient or unproductive based on optical power. So in order to keep low BER, DC bias must be low but DC bias is important as discussed above, so the conclusion is, a moderate value of DC bias is recommended.

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