EUROPEAN ACADEMIC RESEARCH
Vol. XI, Issue 7/ October 2023

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

ISSN 2286-4822
www.euacademic.org

BER Performance of Unipolar OFDM Schemes under Dimming Constraints

BIBI HAWA
MUHAMMAD SOHAIL
Dr. JAFAR KHAN KASI
Department of Physics, University of Balochistan, Quetta, Pakistan

Abstract

In the course of time, the demand of higher data rate is escalating. As a result, OWC technology has been proposed as one feasible option for upcoming beyond-5G (B5G) communications. The concept of visible light communication (VLC) involves the modulation of the visible spectrum to transmit data. Orthogonal frequency division multiplexing (OFDM) is a modulation technique applied in OWC because it provides an actual solution to ISI prompted by dispersive channel. The well-known unipolar optical OFDM schemes are DCO-OFDM, ACO-OFDM, Flip-OFDM, and ADO-OFDM. Here the involvement of dimming is mandatory in order to make communication effective with consideration of illumination. VLC system needs to consider dimming control to offer effective communication while illuminating. Since illumination is a crucial component of VLC communications, it is important to consider LED's Dynamic Range while transferring data using LED. Therefore, the performance of BER with regard to dynamic range is analyzed in case of different schemes however; this BER performance may vary under different illumination levels or dimming constraints which was investigated in this paper.

Keywords: OFDM, DCO-OFDM, ACO-OFDM, Flip-OFDM, ISI, Dimming, BER, Visible light communication, dynamic range.

I. INTRODUCTION

In Visible Light Communication VLC, the high light emitting diodes HLED are introduced as VLC transmitters. As LEDs are current controlled devices, i.e. their output light intensity is the function of input current. The current and intensity can be zero or positive for a LED transmitter, however, it cannot be negative. Conventionally, the OFDM, used in RF, is bipolar. However when utilized in VLC it should be made unipolar. The well-known unipolar optical OFDM schemes includes DCO-OFDM, ACO-OFDM, Flip-OFDM, and ADO-OFDM [4].

Furthermore, one of the most important factors that people should consider when it comes to reducing their energy consumption is LED dimming. This technology can help them adjust their light levels based on their personal preference. Continuous current reduction (CCR), an analogue dimming approach, is used in general to dull the LEDs mounted inside. The brightness of CCR is controlled by diminishing the forward current flow by means of the LEDs. In contrast, however, Pulse Width Modulation (PWM), a digital dimming technology, is another option. PWM controls the lighting intensity by varying the forward current's flow through adjusting the duty cycle of the pulse. PWM is the recommended method for dimming LEDs because it preserves linearity between light output and duty cycle [3]. Since illumination is a crucial component of VLC communications, it is important to consider the DR of LED while transferring data using LED. Therefore, the BER performance with regard to dynamic range is analyzed for different schemes however, this BER performance may vary under different illumination levels or dimming constraints, which is to be investigated in this paper. Furthermore, the dynamic range for ADO was not designed and its BER performance remains to be investigated which is the primary motivation of this work compare the performance of ADO with other schemes that whether it supersedes the other schemes or not.

II. BER and DR Expressions

The results of Dynamic range equations and BER expressions of DCO, ACO, and ADO-OFDM are taken from the (2) and (8).

DCO-OFDM

$$DR_{DCO} = 2\text{K}\sqrt{2R(1+N_{CP}/N)E_b} \quad (1)$$

$$BER_{DCO} \approx \frac{2(M-1)}{(N/2-1)Mlog_2M} \times \sum_{k=1}^{N/2-1} Q\sqrt{\frac{6\beta_r^2\beta_s^2\, N\left|H_{k,DCO}\right|^2 log_2M}{(1+N_{CP}/N)(M^2-1)RN_0}\frac{DR_{DCO}}{2K}} \quad (2)$$

ACO-OFDM

$$DR_{ACO} = \text{K}\sqrt{2R(1+N_{CP}/N)E_b} \quad (3)$$

$$BER_{ACO} \approx \frac{8(M-1)}{NMlog_2M} \times \sum_{k=1,3....}^{N/2-1} Q\sqrt{\frac{6\,\beta_r^2\beta_s^2N\left|H_{k,ACO}\right|^2 log_2M}{(1+N_{CP}/N)(M^2-1)RN_0}\frac{DR_{ACO}}{2K}} \quad (4)$$

ADO-OFDM

$$DR_{ADO} = 2\text{K}\sqrt{2R(1+N_{CP}/N)E_b} \quad (5)$$

BERADO = BERDCO + BERACO (6)

III. BER PERFORMANCE OF DCO, ACO, AND ADO-OFDM UNDER DIMMING CONSTRAINT

Dimming is a crucial factor for visible light communication. In this section, the dimming factor is taken into consideration when discussing the BER performance of various OFDM schemes.

Considering component tolerances, assuming that highest attainable DR, represented by DR_{max}, is 0.8 $I_{max.}$ Furthermore, corresponds to the range of the linear modulation, which is well contained between [0.1 I_{max}, 0.9 I_{max}]. On the other hand, the minimum limit for DR is should be 0.1$I_{max;}$ consequently, the lower limit's minimum dimming level corresponds to 20%.

DCO-OFDM

The expression of DR for DCO-OFDM in terms of illumination level is

$$DR_{DCO}(x) = \frac{(x-20)}{100} I_{max}, \qquad x \in [20,100]$$

ACO-OFDM:

The expression of DR for DCO-OFDM in terms of illumination level as pointed in (14)

$$\frac{0.1I_{max}+\frac{1}{\sqrt{2\pi K}}(0.9I_{max}-0.1I_{max})}{0.5I_{max}}100 = 20+\frac{160}{\sqrt{2\pi K}}$$

$$x = 20+\frac{160}{\sqrt{2\pi K}} \qquad (8)$$

Based on x, the lowest limit of the DR, indicated by I', is calculated as

$$I' = \frac{\left(\frac{\sqrt{2\pi K}}{200}x-0.9\right)}{(\sqrt{2\pi K}-1)}\mathrm{I}_{\mathrm{max}}$$

Based on x, the upper most limit of the DR, indicated byI', is calculated as

$$I' = \left[\frac{\sqrt{2\pi K}}{200}x-0.1\left(\sqrt{2\pi K}-1\right)\right]\mathrm{I}_{\mathrm{max}}$$

As a result, the DR is written as follows in concerning x:

$$DR_{ACO/Flip} = \begin{cases} \frac{\sqrt{2\pi K}}{200}(x-20)I_{max}, & x\in\left[20,20+\frac{160}{\sqrt{2\pi K}}\right] \\ \frac{(180-x)}{200\left(1-\frac{1}{\sqrt{2\pi K}}\right)}I_{max}, & x\in\left[20+\frac{160}{\sqrt{2\pi K}},100\right] \end{cases} \qquad (9)$$

***ADO-OFDM*:**

As the ADO, based OFDM scheme is the crossover of both DCO and ACO schemes of OFDM, so its means also does not lie at the center. we can find the expression at which the maximum DR occurs by adding the above mentioned expression given in case of DCO and ACO i.e. () and () and then taking its half.

So, the maximum DR will be achieved at the illumination level of

$$\frac{1}{2}\left[\left(\frac{0.1I_{max}+\frac{1}{\sqrt{2\pi K}}(0.9I_{max}-0.1I_{max})}{0.5I_{max}}+0.5I_{max}\right)100\right] = 35+\frac{80}{\sqrt{2\pi K}} \qquad (10)$$

The maximum furthest reach of the DR is kept up at $0.9\mathrm{I}_{\mathrm{max}}$ for $x > 35+\frac{80}{\sqrt{2\pi K}}$, as shown in Figureure (7). Based on x, the lowest limit of the DR, indicated by I', is calculated as

$$I' = \frac{1}{2}\left[\frac{(180-x)}{200\left(1-\frac{1}{\sqrt{2\pi K}}\right)}+\frac{(x-20)}{100}\right]I_{max} \qquad (11)$$

And

$$I' = \frac{\sqrt{2\pi K}x+140\sqrt{2\pi K}-2x+40}{400(\sqrt{2\pi K}-1)}\mathrm{I}_{\mathrm{max}}$$

The minimum furthest reach of the DR is maintained at $0.1\mathrm{I}_{\mathrm{max}}$ for $x \le 35+\frac{80}{\sqrt{2\pi K}}$, as shown in Figureure (7). Based on x, the maximum furthest reach of the DR, indicated byI', is calculated as

$$I' = \frac{1}{2}\left[\frac{\sqrt{2\pi K}}{200}(x-20)+\frac{(x-10)}{100}\right]I_{max}$$

And

$$I' = \frac{\sqrt{2\pi K}(x-20)+2x-20}{400}\mathrm{I}_{\mathrm{max}}$$

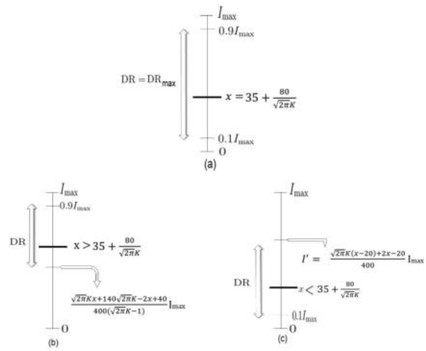


Figure 7: Dynamic range for various illumination levels in ADO-OFDM

As a result, the DR is written as follows in concerning x:

$$DR_{AD0} = \begin{cases} \frac{\sqrt{2\pi}K(x-20)+2x-20}{400} I_{max} , & x \in \left[20{,}35 + \frac{80}{\sqrt{2\pi}K}\right] \\ \frac{\sqrt{2\pi}Kx+140\sqrt{2\pi}K-2x+40}{400(\sqrt{2\pi}K-1)} I_{max} , & x \in \left[35 + \frac{80}{\sqrt{2\pi}K}, 100\right] \end{cases} \qquad (12)$$

IV RESULTS:

For similar bit rate of 10 Mbps, the channel gains K, j, and H are plotted in Figures (8), (9), and (10) respectively. As can be observed from the graphs, DCO-OFDM has larger channel gains than ACO-OFDM. These channel gains are a requirement for the BER performances. The superior BER performance is a result of the larger channel gains for DCO-OFDM . However, when we compare the channel gain of these abovementioned schemes with ADO scheme so it has significant better channel gain as compared to others.

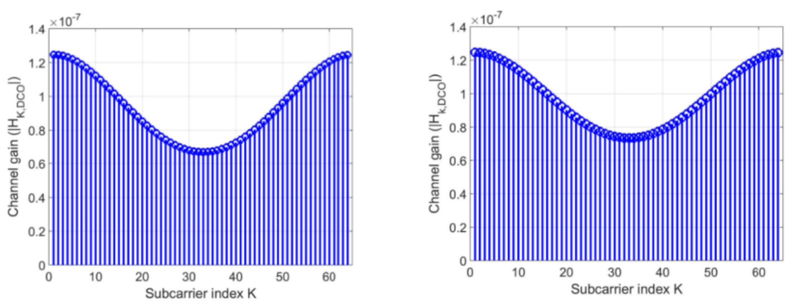


Figure 10: ADO-OFDM channel gain at 10Mbps and 20Mbps respectively

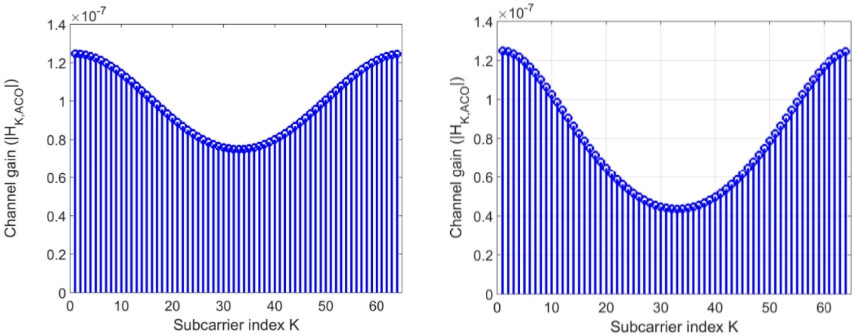


Figure 8: DCO-OFDM channel gain at 10Mbps and 20Mbps respectively

In the case of BER performance under dimming constraints, the Figureure compares the BER performance for various illumination level at different transmission rate of, 10Mbps and 20Mbps respectively.

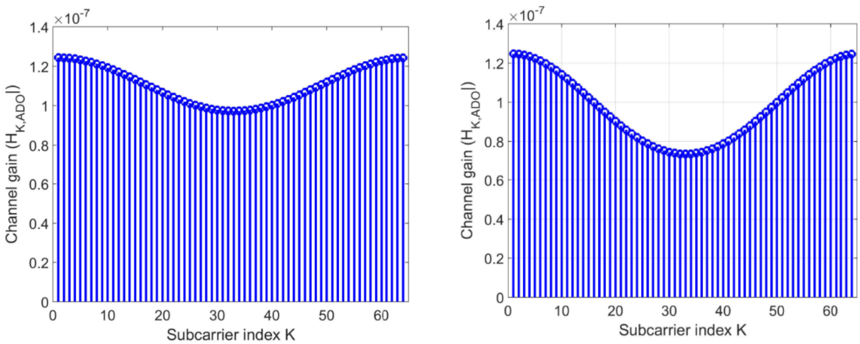
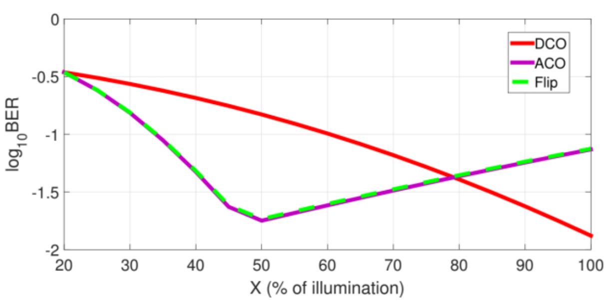
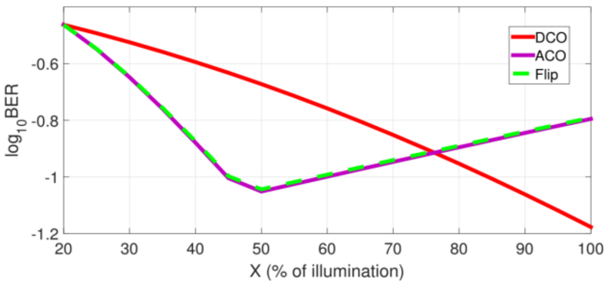


Figure 10: ADO-OFDM channel gain at 10Mbps and 20Mbps respectively



(a)



(b)

Figure 12: BER under dimming constraint for ACO, DCO, and FLIP-OFDM at transmission rates of 10MBPS, and 20Mbps respectively.

The optimal performance of DCO-OFDM is attained at x = 100, which relates to DRmax. It can be noticed, DCO-OFDM works better than flip-OFDM and ACO-OFDM at illumination levels greater than about 70%. It is important to note that, at high illumination level for all transmission bit rates, DCO-OFDM significantly lead ACO-OFDM and flip-OFDM, whose performances decline when the illumination level reaches 100%. (10).

However, when we include the BER performance of ADO-OFDM too and compare it with other schemes so the result's scenario gets change. Furthermore, it is worth noting that as we increase the transmission bit rate, the performance of ADO gets aligning with the Exhibition of DCO-OFDM.

V CONCLUSION:

In this paper the four schemes of OFDM are discussed particularly DCO-OFDM, ACO-OFDM, Flip-OFDM and ADO-OFDM. The expressions of DR for the signals DCOOFDM, ACO-OFDM, and flip-OFDM were first determined. Then, among other system characteristics, for each OFDM scheme the BER equation was determined regarding DR.

Based on common VLC system specifications, numerical BER statistics for indoor transmissions at 5, 10, and 20 Mbps were produced. Signal clipping beyond the DR was used in simulation to produce the desired outcomes. Analytical and simulation findings were found to be nearly identical in both situations, proving the accuracy of the generated analytical BER expressions and the lack of significant signal distortion caused by the investigated DRs.

Then again, the BER performance of these schemes were compared and is found that DCO is more attractive as compared to other schemes as the transmission rates escalates. However, When DCO- OFDM compared with ADO-OFDM so the results were quite in matching interestingly the ADO-OFDM superseding up to some extent. However, the results of both get align at high transmission rates.

REFERENCES

1. J. M. Kahn and J. R. Barry, ”Wireless infrared communications,” in Proceedings of the IEEE, vol. 85, no. 2, pp. 265-298, Feb. 1997, doi: 10.1109/5.554222.
2. Ullah, H., Sohail, M., & Bokhari, M. (2022). Dynamic range of LED in optical OFDM for PAPR performance analysis. *Optical and Quantum Electronics*, *54*(11), 742.
3. Namdeo, Sahasha, and Reena Rani. ”Designing and Performance Evaluation of 64 − *QAM* OFDM System.” IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN (2013): 2278-2834.
4. Jyoti, Amar Prakash, and Sumita Mishra. ”MASSIVE MIMO TECHNOLOGY FOR VISIBLE LIGHT COMMUNICATION (VLC).”
5. Yu, Zhenhua, Robert J. Baxley, and G. Tong Zhou. ”Brightness control in dynamic range constrained visible light OFDM systems.” 2014 23rd Wireless and Optical Communication Conference (WOCC). IEEE, 2014.
6. S. D. Dissanayake and J. Armstrong, ”Comparison of ACO-OFDM, DCO-OFDM and ADO-OFDM in IM/DD Systems,” in Journal of Lightwave Technology, vol. 31, no. 7, pp. 1063-1072, April1, 2013, doi: 10.1109/JLT.2013.2241731.
7. J. Armstrong, “OFDM for optical communications,” *Jour. of Lightwave Tech.*, vol. 27, no. 3, pp. 189–204, Feb. 2009.
8. M. Sohail, P. Saengudomlert, and K. L. Sterckx. ”Performance analysis of dynamic range limited dco-ofdm, aco-ofdm and Flip-ofdm transmissions for visible light communication.” IEICE Transactions on Communications 97.10 (2014): 2192-2202.
9. J. Armstrong and B.J.C. Schmidt, “Comparison of asymmetrically clipped optical OFDM and DC biased optical OFDM in AWGN,” *IEEE Comm. Letters*, vol. 12, no. 5, pp. 343–345, May 2008.