Performance Optimization of Visible Light Communication

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ABSTRACT

This paper focuses to analyze the data rate, bit error rate (BER), flickering & bandwidth of visible light communication (VLC) system. The existing modulation scheme ON-OFF Keying (OOK) is modified and produces the trade-off between these parameters. The modified ON-OFF Keying (MOOK) is proposed in which the variation in the transmitted pulses is investigated. Therefore, the square and rectangular pulses are used to transmit zero and one bits respectively. The duty cycle of square pulse is increased to improve the flickering performance. Moreover, it utilized the bandwidth and deteriorates the BER performance. The differential MOOK (DMOOK) modulation scheme is also proposed in which the ON period of square pulse (zero bits) is removed. Therefore, the data rate of DMOOK is increased because the duration of zero bit pulse is decreased. Similarly, the high bandwidth is utilized and BER performance deteriorates. All performance parameters are evaluated on Arduino based hardware VLC system. We conclude that the BER performance deteriorates by improving flickering performance and data rate of the VLC system.

Key words: Visible Light Communication, Modulation, Flickering, Data rate.

INTRODUCTION

Visible Light Communication (VLC) systems takes advantage of light emitting diodes (LEDs) which can be pulsed at very high speeds without noticeable effect on the lighting output and human eye. VLC system based on the white LED has attracted much attention and becomes a highly potential and valuable method for wireless communication (Liu and Zhang 2014, Lian, Vatansever et al. 2019, Rehman, Ullah et al. 2019).

Many typical modulation methods can be adopted in free space optical (FSO) communication systems, such as ON-OFF keying (OOK), pulse position modulation (PPM), digital pulse interval modulation (DPIM) and dual header pulse interval modulation (DHPIM). The OOK and PPM were firstly proposed in (Kim and Jung 2015, Gao, Li et al. 2017, Ali, Zia et al. 2019, Han, Kim et al. 2019). In this paper the channel information is obtained without any loss of bandwidth efficiency while ensuring illumination quality by reducing the flickering effect of an OFDM based VLC system. A 6.4% low frequency flicker is proposed in(Ali, Zhang et al. 2016, Gao, Li et al. 2017), the light output of LED drivers varies significantly at the double-line-frequency, which not only is considered as a harmful optical flicker, but also greatly affects the effectiveness of data transmission. An OFDM based VLC system with reduced flickering effects is investigated in (Kim and Jung 2015), the results show that the proposed method provides a 6.4% gain in bandwidth efficiency with a 4% reduction in flicker compared to a conventional OFDM-based method. The flicker mitigation performance of different codes is applied and the trade-offs between flicker mitigation, code rate and coding gain, design several codes and compare their error rate and flicker mitigation performance to some codes in the VLC IEEE 802.15.7 standard (Cailean and Dimian 2017). A low flickering code is investigated in(Gao, Li et al. 2017), the performance of code is compared on bases of minimum Hamming distance, peak to average power ratio, run-length, and bit error rate.

The results show that high data rate with low complexity is achieved by proposed code in (Uddin, Cha et al. 2011).Designing a low cost VLC system is a challenge which can provide illumination and communication link at minimum flickering and improved data rate. The aim of this paper to develop a low cost VLC system at minimizes level of flickering at sufficient brightness in the room. The transmitting and detection of high bandwidth pulses is a challenge in low cost hardware like Arduino controller. Therefore, a novel modulation scheme is proposed to reduce flickering. The high bandwidth pulses are produced by using high speed driving circuit and a high efficient photo diode is used for receiving high speed pulses. The flickering problem is improved by reducing the OFF cycle of zero bits. However, the detection of high bandwidth OFF cycle pulse is a challenge; therefore, a trade-off is created between flickering, BER, bandwidth and data rate. The BER performance is deteriorated due increasing bandwidth at cost improved flickering. In a VLC system non-negative pulses are being transmitted which makes dc biasing applicable. It maintains the minimum required brightness when no data is being transmitted.

The remainder of this paper is organized as follows. In Section II we propose a flicker measure used to compare the codes involved in this study. In Section III we introduce the general concepts and present two algorithms to design codes for flicker mitigation to improve coding gain. In Section IV, we compare the designed codes with the standard codes in terms of flicker mitigation and BER performance. Finally, in Section V we conclude.

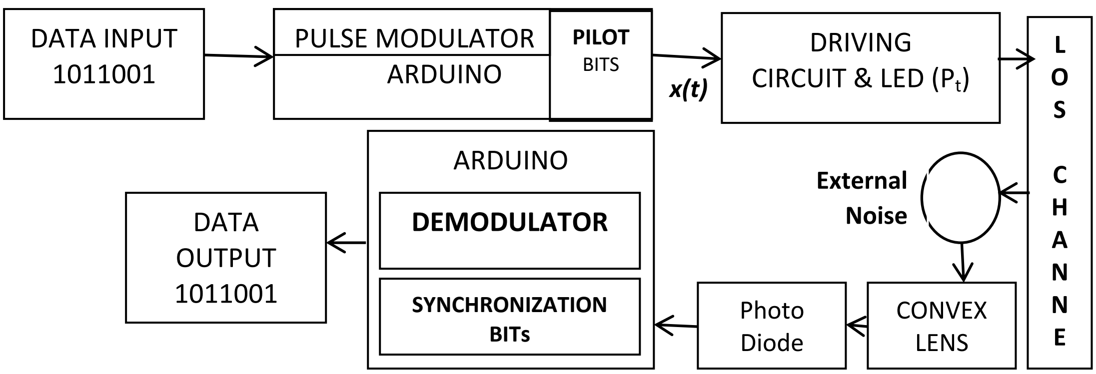

Figure 1 The Proposed VLC Model

THE MODEL OF PROPOSED SYSTEM

Visible Light Communication uses intensity-modulation and direct-detection (IM/DD). Intensity modulation is obtained by varying the bias current of LEDs. A photo-detector in a direct-detection receiver produces a photocurrent that is proportional to the optical power incident upon it. The modulation schemes used in VLC uses power to transmit information. Let *x(t)* and *y(t)* denote the transmitted and received optical signals, respectively as given in Eq(1). The proposed VLC system model only Line of Sight (LOS) channel is considered in Eq(4), transmitted and received power is shown in Eq(2) and Eq(3). The input pulse x(t) is passing through the additive white Gaussian noise (AWGN) *n(t)*(Komine and Nakagawa 2004):

$$y(t) = Rh(t) * x(t) + n(t) \quad (1)$$

y(t) is the photo-detector current, *R* represents the photo responsivity of the photo-detector (in A/W). The time average transmitted optical power is given by:

$$P_t = lim_{T\rightarrow\infty} \frac{1}{2T} \int_{-T}^{T} x(t)dt \quad (2)$$

The average received optical power generally can be determined as Eq(3):

$$P_r = H_{LOS}(0)P_{t(LOS)} \quad (3)$$

where $H(0) = \int_{-\infty}^{\infty} h(t)dt$ is the channel DC gain.

$$H(0)_{LOS} = \begin{cases} \frac{(l+1)A_{PD}\gamma cos^{l}(\varphi)g(\psi)T(\psi)_{cof}cos(\psi)}{2\pi d^2} \\ 0, \ else\ where \end{cases} \quad (4)$$

where d is the distance between the transmitter and receiver, γ is the reflectance factor, l is the order of lambertian emission, APD is the receiving area of photo detector, φ is the irradiance angle, ψ is the angle of incidence, $T(\psi)_{cof}$ is the signal transmission coefficient of an optical filter. The field of view (FOV) in Eq(5) is represented as ψc and *p*, $g(\psi)$ are refractive index and gain of the optical concentrator (Komine and Nakagawa 2004).

$$g(\psi) = \begin{cases} \frac{p^2}{sin^2\psi_c}, & 0 \leq \psi \leq \psi_c \\ 0, & 0 \geq \psi_c \end{cases} \quad (5)$$

VLC is typically characterized by a nonnegative and non-coherent signal transmission. The block diagram of the proposed VLC transmitting and receiving systems is shown in Fig.1. The binary input data is inserted in Arduino controller (AC) at IDE port. The AC modulates the binary data into pulses then pilot bits are inserted for synchronization of transmitter and receiver. The AC provide low power signal, therefore, the driving circuit is used to provide sufficient power to LED. The light is transmitted to LOS channel and received by small scale solar panel via lens. The receiver uses AC for demodulation and synchronization. An ON–OFF keying (OOK) transmitter emits a rectangular pulse of duration T_s intensity to signify a one bit and no pulse to represent a zero bit. The OOK signal *is* $x(t)=2P_b rect(t/T_s)$ as shown in Fig 1. The T_s shows the symbol time, the shape of the $x(t)$ is rectangular pulse and P_b is bit power. The OOK modulation is modified in proposed model in which the digital input one bit is modulated by a high pulse and zero bit is sub-divided into high and low ($T_S = t_H + t_L$) pulse. In order to improve flickering, high pulse t_H duration keep high then low pulse t_L duration $t_H > t_L$ as shown in Fig 2(b). Moreover, the flickering can be improved more by increasing t_H then t_L ($t_H >> t_L$). The flickering is depending upon the OFF cycle t_L of the pulse, the OFF cycle increases the flicking in the room increases. However, the bit error performance decreased due to decreasing of t_L. The decreasing of low pulse duration t_L utilize high bandwidth therefore, there is a trade-of between flickering, BER and bandwidth. The BER performance is also improved by using convex lens at receiver. The differential modified OOK modulation (DMOOK) scheme is also proposed to improve the data rate. The low duration time t_H=0 is removed only t_L pulse duration exist in zero-bit of binary inputs as shown in Fig 2(c).

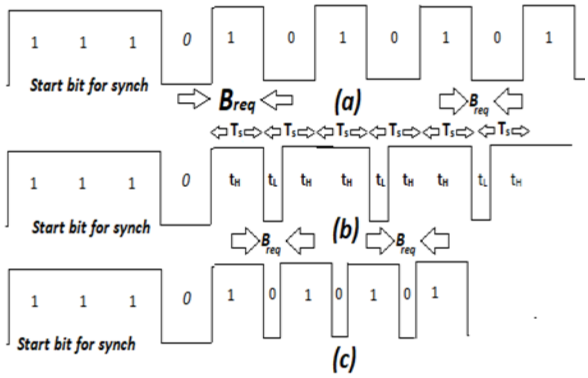

Figure 2 Signaling scheme (a) Binary input (b) MOOK (c) DMOOK

In this scheme only the width of the low pulse is varied in accordance with the data rate = $1/T_s$. The data rate is depending on T_s and symbol time of OOK, MOOK and DMOOK are not same.

ANALYSIS

The BER and flickering and bandwidth performances are analyzed of proposed MOOK and DMOOK modulation schemes. The flickering performance increasing if the t_H greater than t_L. The MOOK has t_H high then t_L therefore, MOOK has highest flickering performance then OOK and DMOOK. The total eight bits are transmitted in Fig 2 which is transmitted in 8ms. The off duration t_L of zero bit is measured 2.4ms in MOOK as shown in Fig 2(b). Similarly, the DMOOK duration of eight bits is 5.2ms and OFF duration t_L of zero bit is measured 1.2ms. This analysis shows that MOOK has less flickering then DMOOK. However, DMOOK transmit eight bits in 5.2ms, therefore, the data rate is greater than MOOK. The Flickering performance can be obtained by Eq(6) equation,

$$Flickering\ \% = \frac{t_H - t_L}{t_H + t_L} \times 100 \qquad (6)$$

The Bandwidth is defined as the inverse of minimum time duration of ON or OFF pulse duration as shown in Fig 2(Ali, Zhang et al. 2016).

$$B_{req} = \frac{1}{t_L} \qquad (7)$$

The bandwidth of MOOK and DMOOK are same. However, the minimum time duration t_L of zero bit is varying with bandwidth utilization. The high bandwidth pulses have low BER performances and better flickering performance.

The BER performance of MOOK and DMOOK can be derived from constellation diagram as shown in Fig 3. As depicted in Fig. 3 the zero bit ('n' point) location is varying between 'm' to 'o' point and BER performance is also varies. The high distance between 'o' and 'n' points obtain the better BER performance and utilize less bandwidth and produce high flickering in MOOK. However, in DMOOK the t_H is zero only duration of t_L is varying. Similarly, the higher distance between obtain better BER performance.

The sum of error probability function of zero and one bit is given below

$$P_b = \frac{1}{\sqrt{\pi\sigma}} e^{-\frac{(y+\sqrt{E_n})^2}{\sigma^2}} + \frac{1}{\sqrt{\pi\sigma}} e^{-\frac{(y+\sqrt{E_o})^2}{\sigma^2}}$$

$$P_b = \frac{1}{2}\left(erfc\left(\sqrt{\frac{E_n}{\sigma}}\right) + erfc\left(\sqrt{\frac{E_o}{\sigma}}\right)\right) \qquad (8)$$

$$E_m < E_n < E_o$$

$E_m = E_n$ condition define OOK and $E_n < E_o$ is define MOOK, however, in DMOOK the

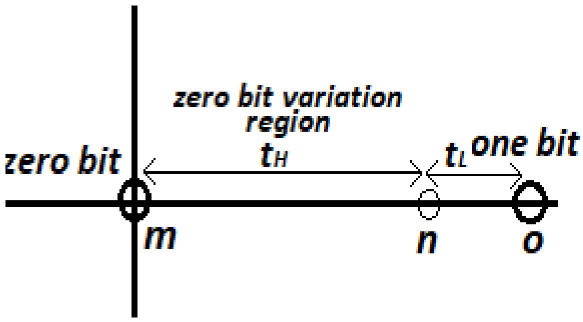

Figure 3 Constellation diagram

error performance is same as MOOK.

RESULTS AND DISCUSSION

In this section various results regarding performance of different parameters using OOK, MOOK and DMOOK different modulation schemes are discussed. Fig 4 shows the BER performance against different data rate. The results show that OOK modulation has better BER performance then MOOK and DMOOK. BER and flickering performances are inversely proportional to each other. However, in Fig 5 the lower flickering values is considered as better performance then higher flickering values and, in BER performance the lower values are higher performance and Higher values are considered as low BER performance. The result shows in Fig 5, the BER performance of OOK is better than MOOK and DMOOK because the constellation distance is high in case of OOK. However, the higher constellation distance produce high flickering in the room. Therefore, the flickering performance of MOOK and DMOOK is better than OOK. The bandwidth performance of proposed scheme and OOK scheme is obtained in Fig. 6. The results show that the OOK utilized low bandwidth but high flickering due to equal pulse duration of one and zero bits. However, the high bandwidth pulse is used in MOOK and DMOOK but better flickering performance is obtained. The bandwidth performance is also inversely proportional to BER performance as shown in Fig. 7. As depicted in Fig. 7 the OOK utilized low bandwidth resources and high constellation distance between one and zero bits. Therefore, the high BER performance than MOOK and DMOOK.

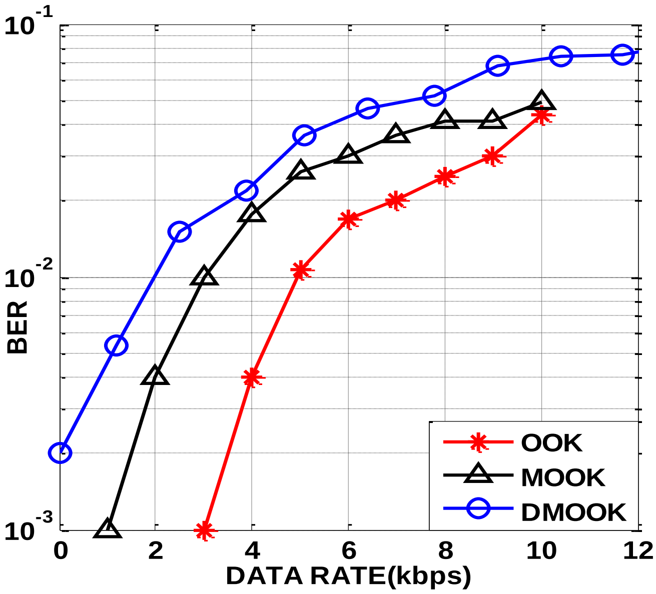

Figure 4 BER vs data rate performance of OOK, MOOK and DMOOK

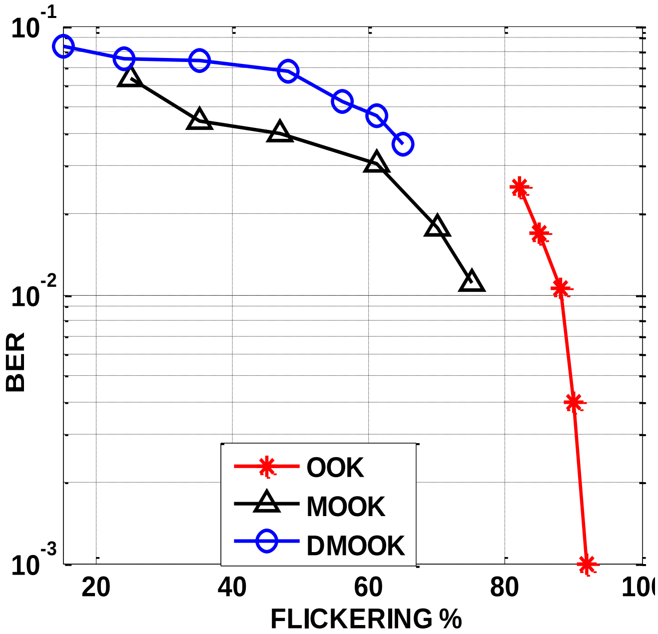

Figure 5 BER vs flickering performance of OOK, MOOK and DMOOK

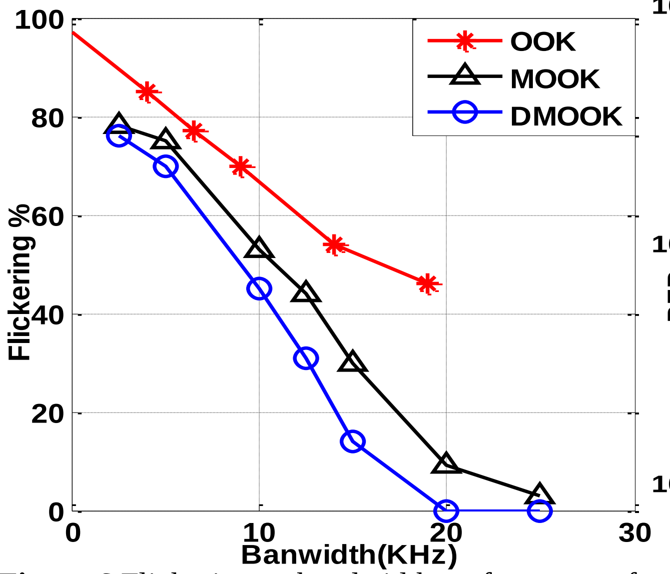

Figure 6 Flickering vs bandwidth performance of OOK, MOOK and DMOOK

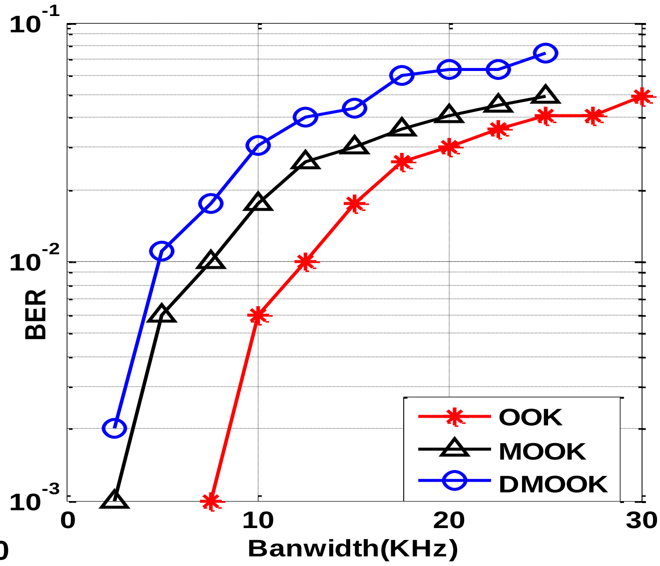

Figure 7 BER vs bandwidth performance of OOK, MOOK and DMOOK

CONCLUSION

The flickering problem is mainly investigated in this study. Therefore, the proposed technique mainly devoted to reduce the flickering in the room. The high bandwidth pulses are utilized in proposed scheme MOOK and DMOOK to reduce the flickering significantly. The BER performance is deteriorated by utilizing high bandwidth pulses. Moreover, high speed controllers are required to detect the high bandwidth pulses. Therefore, we provide a trade of between bandwidth and BER performance. The data rate performance is improved in DMOOK as compare to OOK and MOOK because the t_L(zero bit)<<t_H(one bit) pulse duration of zero bit is reduced. The BER performance is improved by using convex lens.

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