32nd URSI GASS, Montreal, 19-26 August 2017

Visible Light Communication Based On Offset Pulse Position Modulation (Offset-PPM) Using High Power LED

Mostafa H. Ahfayd; Martin J. N. Sibley, Peter J. Mather, and P. I. Lazaridis
Department of Engineering and Technology, University of Huddersfield, Huddersfield HD1 3DH, UK
E-mail: M.ahfayd@hud.ac.uk

Abstract

In this paper, the performance of a visible light communication (VLC) system based on offset pulse position modulation (Offset-PPM) has been demonstrated using a commercial high power white single LED (30 W) and the new coding scheme. Data at a speed of 11 Mbps has been successfully transmitted over a distance of 1 m with zero bit error rate (BER), and 18 Mbps with 1.15×10^{-6} of BER through the simplest transceiver circuits.

Keywords- bit error rate; offset pulse position modulation; visible light communication.

1. Introduction

The study related to visible light communications (VLC) along with a proposition of applying LEDs on data communications as well as lighting has increased in the last couple of years. The chief technological reinforcement for this comprises extensive durability of high-brightness LEDs over other artificial sources of light such as incandescent light bulbs, growing popularity of lighting of solid-state, data security, higher rate of data/bandwidth minimum power consumption and zero health issues. A successful demonstration of transmitting audio signal with the help of a mirror vibrated through the voice of a person was made by Alexander Graham Bell in 1870s. Bell and his assistant Tainter used the light source of sunlight for making a successful communication being 213 meters apart from each other in 1880.

In recent years, owing to the launch of optical electronics, particularly in regards to light sources, the communications through optical wireless has evolved again [1]. Optical communication is expanding with visible light communications (VLC) particularly focusing on visible part of electromagnetic spectrum to humans [2-5]. Both communications and related illumination should be accounted as a VLC standard [6]. Most of the other standards of communication are different from it [2, 7]. A VLC standard should be included for both communications and associated illumination [8]. Some vital issues have already been noted in relation to the practical line-of-sight (LOS) seen in the design of light communication system where channel model, receiver front-end and transmitter are included [9]. A white light emitting diode has been implemented in several research works to acquire higher transmission of data in optical wireless system, several Mbps [8, 10, 11], and illumination. As opined by Chow (2015), investigation has been conducted over the visible light communication. The highest achieved bit rate was 190 Mb/s at high illuminance [12]. For the improvement and mitigation of transmission quality and the effects of inter symbol interference (ISI) respectively investigation was conducted using Dicode pulse position modulation technique (DiPPM) [13].

This paper proposes a novel modulation scheme (Offset–PPM) based on visible light communication using a commercial high power LED.

2. The Offset pulse position modulation (Offset-PPM)

The offset PPM is a novel version of digital pulse position modulation (PPM) which operates at half the line rate of digital PPM and offers an increase in sensitivity [14]. The offset PPM gives >3.1 dB improvement in sensitivity over digital PPM at low bandwidths, also has a better sensitivity than multiple PPM[14]. The Maximum Likelihood Sequence Detector (MLSD) is unnecessary with offset PPM. However, offset PPM gives a discrete line at the frame repetition frequency, which has a stronger frame component than DPPM [15]. Initially, all positions of code-word are reset to zero to the first sequence. For the second sequence, the least significant bit (LSB) is replaced to the one. The subsequent code-words in sequence will product by removing the one from the least significant bit to the most significant bit (MSB). The most significant bit is kept one simultaneously with the formation of the following code-word by replacing the least significant bit to one as shown in table 1[14].

Table 1. Generation of offset PPM, DPPM, from equivalent three bits of PCM [14]

PCM	DPPM	Offset PPM
000	0000 0001	0 000
001	0000 0010	0 001
010	0000 0100	0 010
011	0000 1000	0 100
100	0001 0000	1 000
101	0010 0000	1 001
110	0100 0000	1 010
111	1000 0000	1 100

3. RECEIVER DESIGN

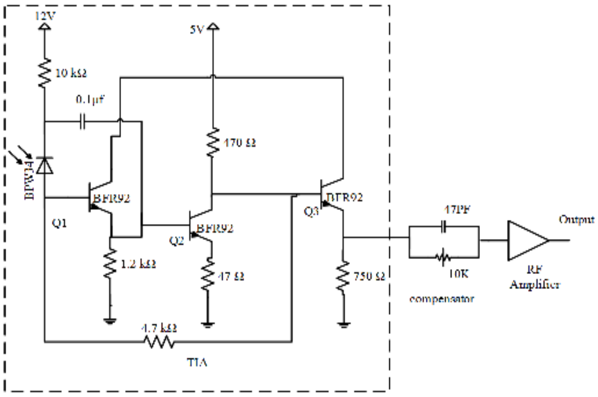
The TIA has been designed and developed by adding an RC lead compensator in order to improve system response by reducing the rise time as shown in figure 1. The resistor and capacitor in the RC lead compensator has been chosen and calculated in order to increase the bandwidth above 2 MHz according to the equation:

$$f_c = \frac{1}{2\pi RC} \quad (1).$$

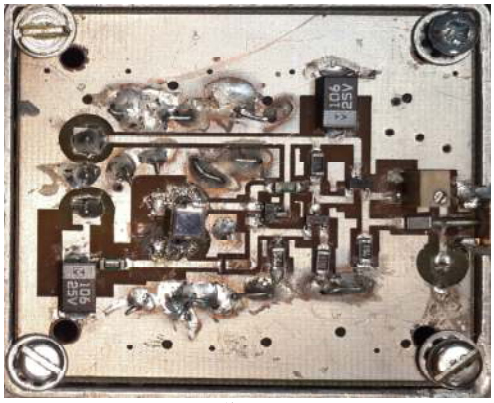
The capacitor of 47 pf has been selected in order to match 50 ohm load resistor for a wide bandwidth. Then, the resistor R will be calculated according to 2 MHz bandwidth and 47 pf.

$$f_c = \frac{1}{2\pi RC} \quad (2).$$

$$R = \frac{1}{2\pi \times 2\times 10^{6} \times 47 \times 10^{-12}} = 1.69\ K\Omega$$



(a)



(b)

Figure 1. Receiver circuit a) circuit diagram. b) PCB Printed circuit

4. EXPERIMENTAL SETUP

Figure (2) depicts the experimental setup. For this purpose, the coding system was programmed into the Field Programmable Gate Array board (FPGA) type (Cyclone IV GX-EP4CGX150DF31C7) through the Quartus II software using Very high Speed Integrated Circuits (VHSIC) Hardware Description Language (VHDL), which requires how the device functions.

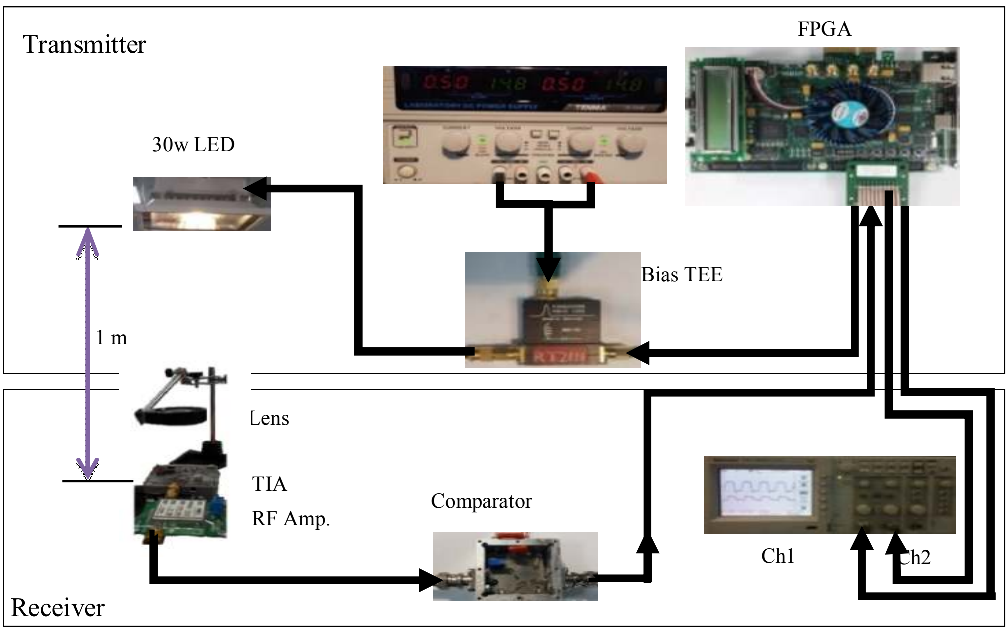


Figure 2. Experimental link

The PRBS signal was generated by FPGA overlaid onto the LED bias current through a Bias-T (Picosecond Pulse Labs 5575A). The output of the Bias-T was directly delivered to a high power white LED (30w LED floodlight, LED lighting, waterproof IP65). A 1m free space length has been taken between the LED and PD, where an optical convex lens (6cm focal length) was fixed in front of the PIN photodiode (BPW34) which has been built into the trans-impedance preamplifier (TIA) board. Lastly, a low power, high speed comparator (MAX942) has been applied in order to standardize the receiver output, where the receiver output is either zero volts or 5 volts. The comparator output was sent to the board of the FPGA to compare with the signal at the input and then showed the result on the PC through the USB cable via the signal tap II of the logic analyser. Furthermore, the signals have been plotted by using a digital storage oscilloscope with a two channel (Tektronix TDS 1002B 60 MHz).

5. Implementation of offset pulse position modulation (offset-PPM)

The block diagram in figure 3 describes the complete design of the Offset-PPM through VHDL programming language and Altera Quartus II software. First and foremost, the 50 MHz clock was connected to the Phase-Locked Loop (PLL) in order to control the selection of the appropriate frequency up to 50MHz, fed to 3bit/4bit clock signal via C0, which fed the pseudorandom bit sequences (PRBS) and offset-PPM (coder/decoder). The PRBS signal was sent to the Offset-PPM coder to generate Offset-PPM signal (convert from 3 bit to 4 bit), which was then sent to the high-power LED through the bias-T via pin (G26).

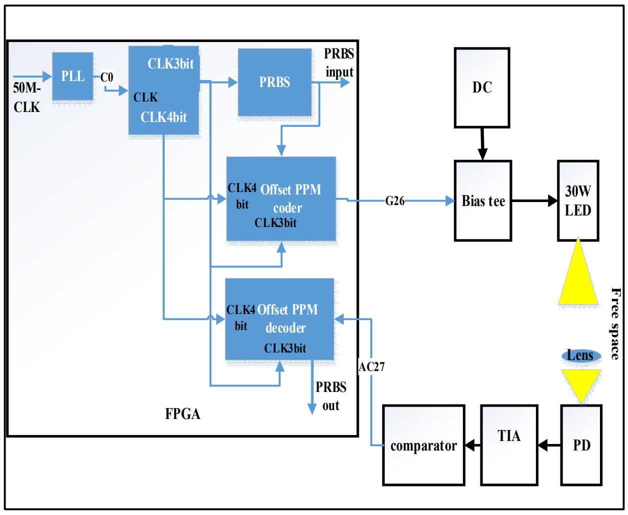


Figure 3. Block diagram of the Offset-PPM based on VLC

Running the simulation of the Offset-PPM system with clock and the PRBS input waveforms is illustrated on the timing diagram of the simulation in Figure 4.

The wave form of the input, output, and coder signals are illustrated and there is matching between the input signal and the output signal including delay. There is also similarity between the transmitted coded signal (which was sent via LED) with the received coded signal (received from the receiver through the comparator output), where zero bit error rate has been achieved at a speed of 11 Mbps through the offset PPM scheme. Figure 5 depicts the real signals via the oscilloscope at 18 Mbps PRBS and 24 Mbps coder signal, with BER1.15×10^{-6}.

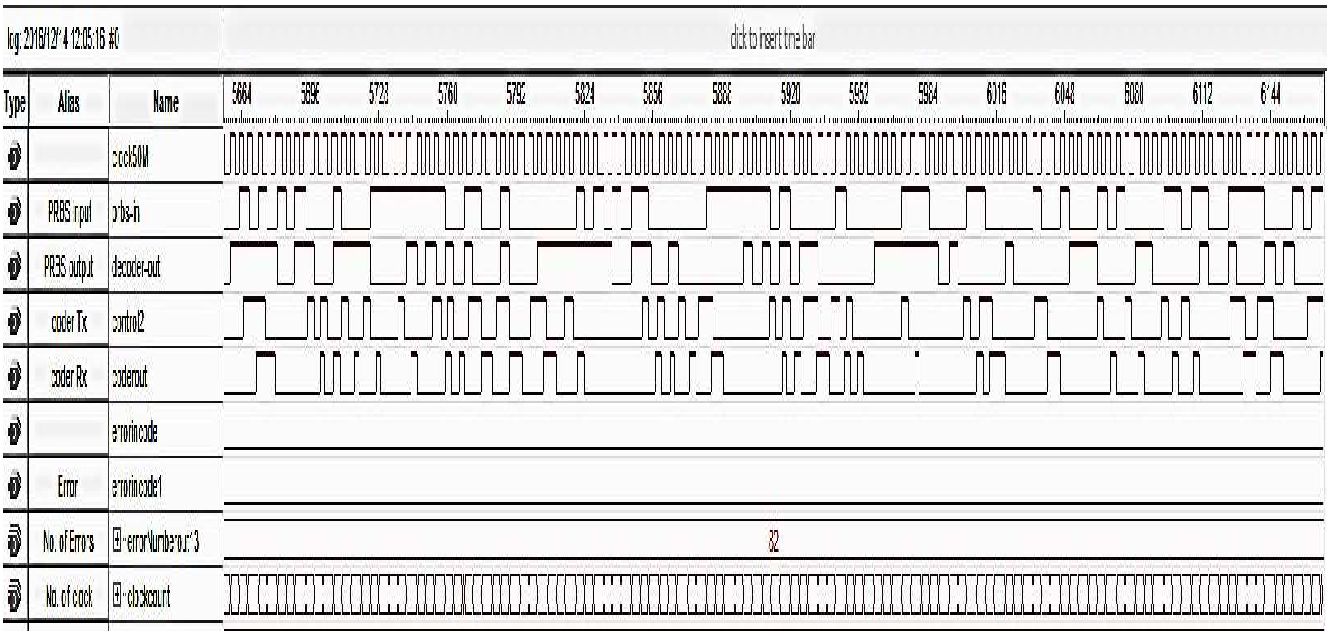
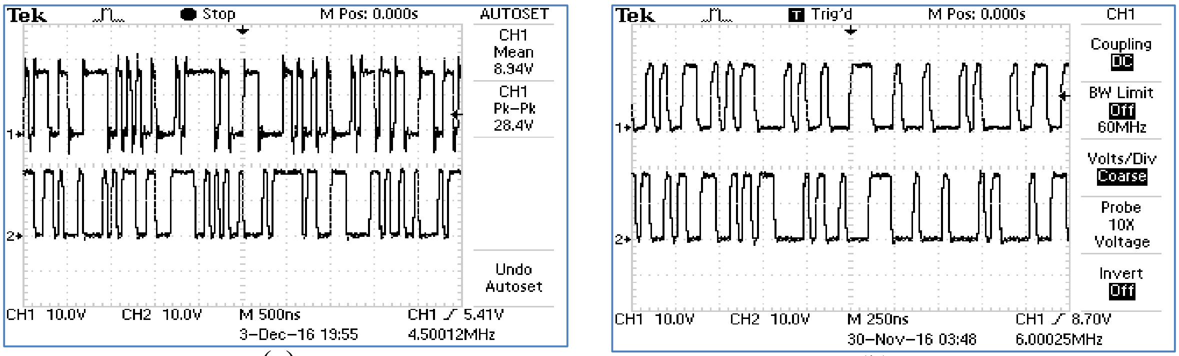


Figure 4. Waveforms of the Offset-PPM simulation.



(a) (b)

Figure 5. (a): PRBS, (b): Offset PPM coded signals, transmitted signal (top trace) and received signal (bottom trace)

6. Conclusion

In this paper, the performance of an indoor real-time VLC based on a 30W white LED has been reported on. For the first time, the Offset PPM code has been implemented and the speed has successfully reached 11 Mbps with a BER of zero. A BER of 1.15×10^{-6} has been achieved with 18 Mbps.

9. References

[1] Z. Ghassemlooy, W. Popoola, and S. Rajbhandari, Optical Wireless Communications: System and Channel Modelling with MATLAB vol. 1. GB: CRC Press Inc, 2013.

[2] S. C. Lo, "Visible Light Communications," IEEE Transactions on Consumer Electronics, vol. 50, 2004.

[3] N. Chi, H. Haas, M. Kavehrad, and T. D. Little, "Visible light communications: demand factors, benefits and opportunities [Guest Editorial]," Wireless Communications, IEEE, vol. 22, pp. 5-7, 2015.

[4] S. Arnon, Visible light communication: Cambridge University Press, 2015.

[5] S. Rajagopal, R. D. Roberts, and S.-K. Lim, "IEEE 802.15. 7 visible light communication: modulation schemes and dimming support," Communications Magazine, IEEE, vol. 50, pp. 72-82, 2012.

[6] F. Zafar, D. Karunatilaka, and R. Parthiban, "Dimming schemes for visible light communication: the state of research," Wireless Communications, IEEE, vol. 22, pp. 29-35, 2015.

[7] D. C. O'Brien, L. Zeng, H. Le-Minh, G. Faulkner, J. W. Walewski, and S. Randel, "Visible light communications: Challenges and possibilities," in Personal, Indoor and Mobile Radio Communications, 2008. PIMRC 2008. IEEE 19th International Symposium on, 2008, pp. 1-5.

[8] D. O'Brien, H. Le Minh, L. Zeng, G. Faulkner, K. Lee, D. Jung, Y. Oh, and E. T. Won, "Indoor visible light communications: challenges and prospects," in Optical Engineering+ Applications, 2008, pp. 709106-709106-9.

[9] K. Cui, G. Chen, Z. Xu, and R. D. Roberts, "Line-of-sight visible light communication system design and demonstration," in Communication Systems Networks and Digital Signal Processing (CSNDSP), 2010 7th International Symposium on, 2010, pp. 621-625.

[10] T. Komine, J. H. Lee, S. Haruyama, and M. Nakagawa, "Adaptive equalization system for visible light wireless communication utilizing multiple white LED lighting equipment," Wireless Communications, IEEE Transactions on, vol. 8, pp. 2892-2900, 2009.

[11] H. Sugiyama, S. Haruyama, and M. Nakagawa, "Brightness control methods for illumination and visible-light communication systems," in Wireless and Mobile Communications, 2007. ICWMC'07. Third International Conference on, 2007, pp. 78-78.

[12] C. Chow, Y. Liu, C. Yeh, J. Sung, and Y. Liu, "A practical in-home illumination consideration to reduce data rate fluctuation in visible light communication," Wireless Communications, IEEE, vol. 22, pp. 17-23, 2015.

[13] A. M. Buhafa, B. M. Al-Nedawe, M. J. Sibley, and P. J. Mather, "VLC system performance using Dicode Pulse Position Modulation over an indoor diffuse link," in Telecommunications Forum Telfor (TELFOR), 2014 22nd, 2014, pp. 605-608.

[14] M. J. Sibley, "Analysis of offset pulse position modulation-a novel reduced bandwidth coding scheme," IET optoelectronics, vol. 5, pp. 144-150, 2011.

[15] I. Ray, M. J. Sibley, and P. J. Mather, "Spectral characterisation of offset pulse position modulation," IET optoelectronics, vol. 9, pp. 300-306, 2015.