Northumbria Research Link

1 Mb/s Data Transmission Employing NRZ-OOK in a Visible Light Communication System

Joon-Ho Choi[1], Eun-Byeol Cho[1], Z. Ghassemlooy[2], Chung Ghiu Lee[1]
[1]*Dept. of Electronic Engineering, Chosun University, South Korea*
[2]*NCRLabs,CEIS, Northumbria University, United Kingdom*

Corresponding author: clee@chosun.ac.kr

Abstract: We report 1 Mb/s data transmission using NRZ-OOK signal format in a visible light communication system. The data signal is independently controlled and transmitted upon PWM dimming signal. The eye diagram of the received optical signal diagram has been measured and the technical issues are discussed.

1. Signal format

According to development of illumination LEDs, the application of illumination LEDs to communication system are proposed and analyzed [1-3]. However, due to limited modulation bandwidth of illumination LEDs, the efforts to enhance the data rate have been reported [4-6]. Previously, we suggested a signal format for data transmission based on the PWM dimming for the VLC system [4].

While it provides the illumination control by changing the duty cycle of the PWM signal, the data transmission is required to a data rare to accommodate a communication service. Now, the modulation bandwidth of illumination LEDs are not so high, it is natural to utilize the whole PWM period. Also, a simple data format is recommended to use low-cost electronics for illumination infrastructures. From these points of view, we propose and experiment the NRZ-OOK signaling, based on PWM dimming control signal.

Other data modulation formats needs higher bandwidth or more complex circuits, for example, RZ-OOK or subcarrier modulation schemes. In this signaling scheme, NRZ-OOK data is loaded during ‘OFF’ states as well as ‘ON’ states of PWM dimming periods.

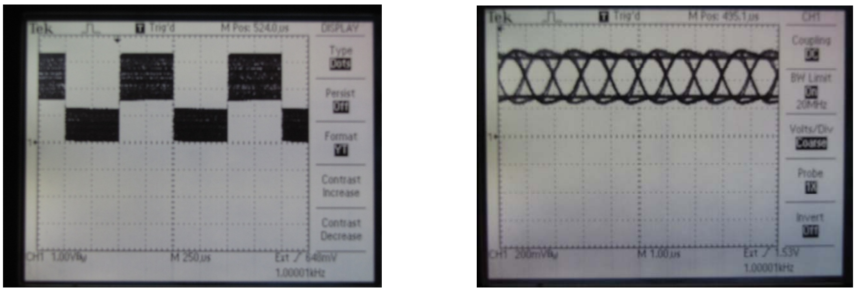
2. Experimental setup

The transmitter mixes up the PWM dimming signal and the 1 Mb/s NRZ-OOK pseudorandom binary sequence (PRBS) data signal. The signal drives an LED through an op-amp to support appropriate signal level. The two signals are generated independently and synchronized for clear recovery of data from the mixed signal..

The transmitted signal is detected in a receiver module at a distance of 10 cm. The optical receiver is equipped with a gain selectable transimpedance amplifier, which is set to be a 20 dB gain. No other optical element for focusing is used.

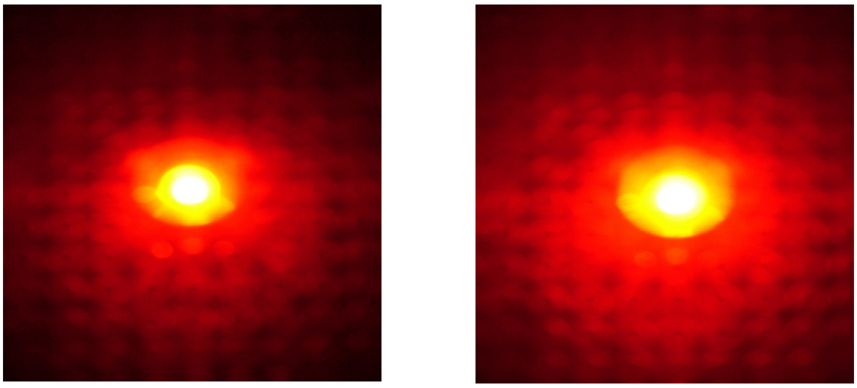
3. Measurement data and Conclusion

Fig. 1 shows the waveform of the received optical signal and the magnified eye diagram of the part during “ON” state of PWM dimming. The PWM dimming frequency is 1 kHz and the data rate of NRZ-OOK is 1 Mb/s. Since the data rate is too high to seem to be dark area. It is shown that if Figs. 1(a) and 1(b) make it possible to transmit NRZ-OOK signal over PWM at 1 Mb/s



(a) (b)

Fig. 1. (a) Waverform of the signal (duty cycle = 50%). (b) Eye diagram of PWM “ON” state.



(a) (b)

Fig. 2. Snapshots for different PWM duty cycles. (a) 30 % and (b) 70 %.

Fig. 2 shows the snapshots for different PWM duty cycles of 30 % and 70 %. The dimming control is independent of the data rate. However, the relative amplitudes must be controlled in relation to each other. To enhance communication performance, the amplitude of the data signal must be sufficiently high. To enhance illumination performance with precise dimming control, the amplitude of the data signal must be sufficiently small.

We reported 1 Mb/s data transmission using NRZ-OOK signal format in a visible light communication system. By controlling the relative amplitude levels of the data signal compared to that of the PWM dimming signal, the total dimming level can be controlled.

References

[1] T. Komine, M. Nakagawa, "Fundamental analysis for visible-light communication system using LED lights," IEEE Transactions on Consumer Electronics, vol. 50, no. 1, pp. 100-107, 2004.

[2] H. L. Minh, D. O'Brien, G. Faulkner, L. Zeng, K. W. Lee, D. K. Jung, and Y. J. Oh, "80 Mbit/s visible light communications using pre-equalized white LED," Proc. European conference on Optical communications (ECOC), Brussels, Belgium, pp. 5-223/224, 2008.

[3] H. L. Minh, D. O'Brien, G. Faulkner, L. Zeng, K. W. Lee, D. K. Jung, Y. J. Oh, and E. T. Won, "100-Mb/s NRZ visible light communications using a postequalized White LED," IEEE Photonics Technology Letters, vol 21, no. 15, pp. 1063-1065, 2009.

[4] J.-H. Choi, E.-B. Cho, T.-G. Kang, and C. G. Lee, "Pulse width modulation based signal format for visible light communications," Technical Digest of 15th Optoelectronics and Communications Conference (OECC 2010), Sapporo, Japan, pp. 276-277, 2010.

[5] J. Vucic, C. Kottke, S. Nerreter, K.-D. Langer, and J. W. Walewski, "513 Mbit/s visible light communications link based on DMT-modulation of a White LED," Journal of Lightwave Technology, vol. 28, no. 24, pp. 3512-3518, 2010.

[6] H. Sugiyama, S. Haruyama, and M. Nakagawa, "Brightness control methods for illumination and visible-light communication systems," Proc. the third International Conference on Wireless and Mobile Comm. (ICWMC 2007), pp. 78, 2007.