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Improving the performance with Space Wavelength Block Coding – Wavelength Switched Transmit Diversity in visible light communication using LEDs

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Abstract

In this paper, we propose a space wavelength block coding wavelength switched transmit diversity (SWBC-WSTD) scheme for improving the performance in visible light communication (VLC). In a practical indoor environment, there has to install several LEDs for the illuminated. There occurs overlapped the field of view (FOV) due to a plurality of LEDs in VLC. It has the differential propagation time following the location of LED and receiver, which is occurred the interference adjacent LEDs to degrade the performance by superposition of FOV. In order to solve this problem, a spatial modulation scheme was proposed. This modulation scheme can avoid interference between adjacent LEDs by exclusively assigning individual transmission times to each LED. However, when one LED transmits data to the receivers, the remaining LED devices are not operated, so this system can be regarded as a single input single output (SISO) system. In order to improve the BER performance of the system by using multiple LED environment, we propose the SWBC-WSTD scheme. The proposed system can improve the BER performance because the transmit diversity gain can be obtained by using SWBC-WSTD encoding and decoding processes. To demonstrate the effectiveness of the proposed system, the performance of that is compared with the spatial modulation scheme through simulation results.

Keywords: Visible light communication, Multi-input single-output, Space wavelength block coding, Wavelength switched transmit diversity

INTRODUCTION

To move the 4G wireless communication to 5G wireless communication, many researchers have studied faster, more improve, and various communication system than the conventional wireless communication system. 5G wireless communication is approaching not only to transmission of voice, text, and multimedia data between people and people, but also to the Internet of things through communication with objects [1, 2]. And wireless communication using LED lighting, which is one of the Internet of things, has focused the next generation wireless communication [3]. Because, VLC can utilize infinite resources, which is different from the conventional RF wireless communication, and can simultaneously lighting and communication functions [4]. In addition, VLC can also be used in a variety of environments. RF is not available in RF sensitive areas such as airplanes or hospitals, but VLC is available [4]. If it goes out of the FOV, it cannot transmit and receive, so it is more secure than RF wireless communication [5, 6].

In order to maintain the light in the room, it is necessary to install several LED lights instead of one. Several LEDs as a lighting function do not cause any problems. However, several LEDs as a communication function cause FOV superposition phenomenon. Field of view (FOV) superimposition phenomenon causes interference adjacent LEDs, and the performance of the visible light communication system is degraded. In order to solve the problem, spatial modulation is a conventional method [7]. Spatial modulation is used to reduce interference due to FOV superposition phenomenon by transmitting data with different transmission time for each LED [7]. However, the spatial modulation scheme is similar single-input single-output (SISO). Because conventional scheme cannot utilize the several LEDs. According to the conventional scheme is not suitable in practical environments that utilize several LEDs.

Therefore, we propose a VLC using the space wavelength block coding-wavelength switched transmit diversity (SWBC-WSTD) scheme with obtaining the transmit diversity gain to utilize several LEDs and improve the conventional scheme as spatial modulation. The proposed system is based on the multi-input single-output (MIMO) with DC-biased optical OFDM (DCO-OFDM) system according to the indoor lighting environment. SWBC-WSTD and VLC are combined, and several LEDs have a roll as respective transmitter [8]. The proposed system is possible to decrease the interference adjacent LEDs from cyclic prefix (CP) of DCO-OFDM. In addition, the proposed system is obtained the transmit diversity gain by SWBC-WSTD with several LEDs to improve the performance system [9]. The proposed system is possible to decrease the interference of LEDs with CP of DCO-OFDM and improve the performance through transmit diversity gain from obtained several LEDs.

LED INTERFERENCE MODEL

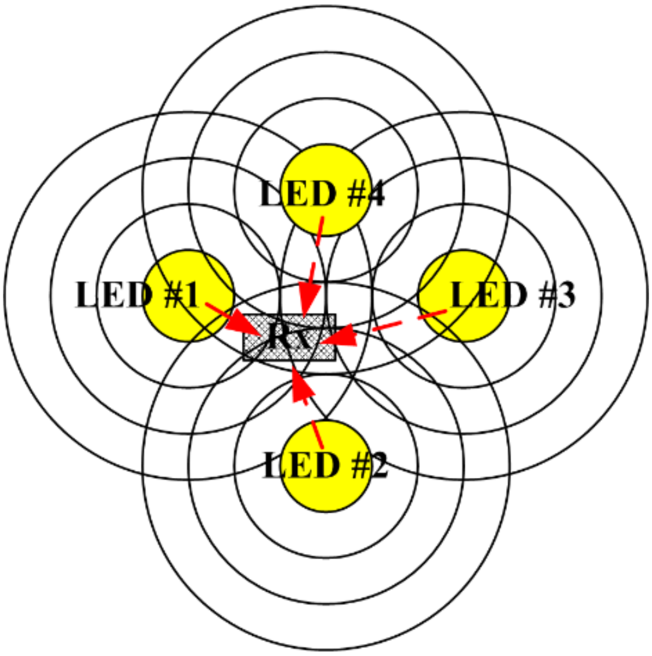

Figure 1. Interference model of several LEDs.

Fig 1 represented the interference model of several LEDs. By the installed several LEDs and location of the receiver, it is occurred the interference adjacent LEDs. In case of fig 1, the receiver and each LED have the different transmitted power by differential propagation time. LED #1 has the strongest transmitted power. Because of LED #1 and the receiver have the closest distance.

Therefore, the transmitted power is defined by distance and location of transmitted LEDs and the receiver [10].

$$P_r = H(0) \cdot P_t \tag{2.1}$$

Where, P_r is the received optical power. P_t defines the transmitted optical power. $H(0)$ is derived the wireless optical link, the channel DC gain as follows [10, 11];

$$H(0) = \begin{cases} \frac{(m+1)\mathrm{A}}{2\pi d^2} \cos^m(\phi) T_s(\psi) g(\psi) \cos(\psi), & 0 \le \psi \le \Psi_c \\ 0, & 0 > \Psi_c \end{cases} \tag{2.2}$$

Lambertian radiant intensity is $\frac{(m+1)}{2\pi}\cos^m \phi$ [10]. The order m is related to $\Phi_{1/2}$, the transmitted semi-angle (at half power), by $m = -\ln 2 / \ln(\cos \Phi_{1/2})$ [11]. For example, $\Phi_{1/2} = 60^\circ$ (Lambertian transmitter) corresponds to $m = 1$, $\Phi_{1/2} = 15^\circ$ (typical directed transmitter) corresponds to $m = 20$ [12]. Where, A is the physical area of the detector in a photo diode (PD) of receiver, d is the distance between a LED and a receiver, ψ is the angle of incidence, ϕ is the angle of irradiance, $T_s(\psi)$ is the gain of an optical filter, and $g(\psi)$ is the gain of an optical concentrator. Ψ_c is defined the range of FOV at a receiver [12]. The optical concentrator $g(\psi)$ can be given as [11]:

$$g(\psi) = \begin{cases} \frac{n^2}{\sin^2 \Psi_c}, & 0 \le \psi \le \Psi_c \\ 0, & \psi > \Psi_c \end{cases} \tag{2.3}$$

where n denotes the refractive index.

From the difference P_r of each LED with different distance and location to receiver, which is occurred the interference adjacent LEDs. It can be defined as the desired to undesired signal power ratio (DUR) from adjacent LEDs. The DUR can be given as [10, 13]:

$$DUR[dB] = 10\log\left(\frac{P_{desired}}{\sum_{k=0, k\neq desired}^{K-1} P_k}\right) \tag{2.4}$$

where, P_k is the received optical power from k^{th} LED. The value of DUR is decreasing, while the optical power of adjacent LEDs is increasing, also the optical power of desire signal is decreasing from eq. (2.4). Therefore, the value of DUR is decreasing, which is degraded the performance of system by increasing the interference of adjacent LED.

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PROPOSED SYSTEM MODEL

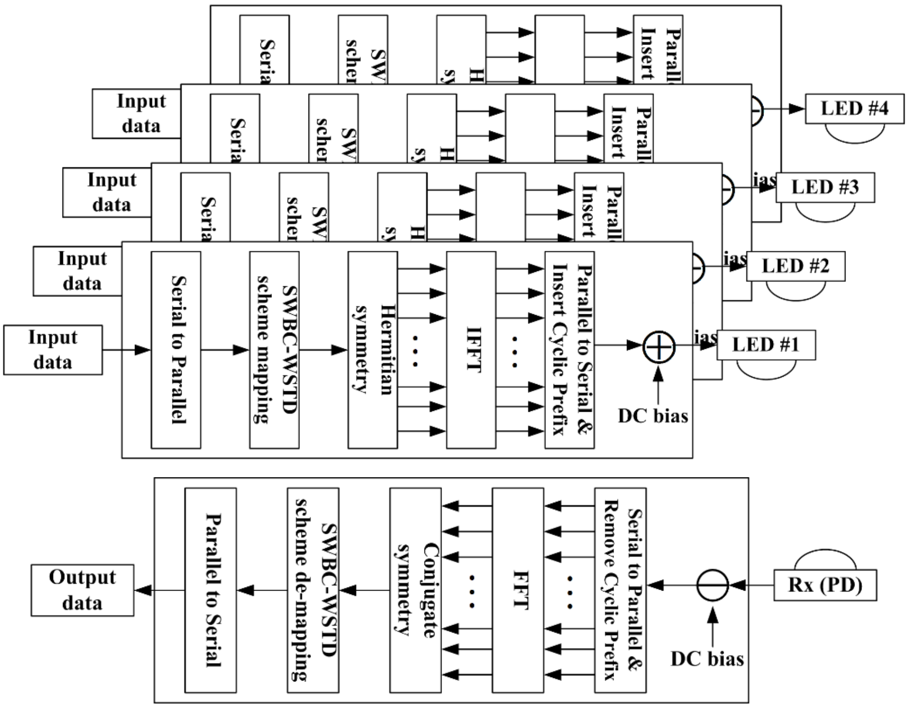

Figure 2. Structure of proposed system.

Fig 2 represented the structure of proposed system. The proposed system is based on 4x1 multi-input multi-output (MIMO) system with DC-biased optical OFDM (DCO-OFDM). To transmit the DCO-OFDM of sub-carrier, it has to process the inverse fast Fourier transform (IFFT). However, optical signal has to process the Hermitian symmetry unlike the conventional OFDM, because there is no imaginary number. The input signal is converted from parallel to serial (P/S) with inserting a cyclic prefix (CP). After, the resulting signal added the DC bias. There is possible to convert the negative signal to zero from DC bias [14].

The optical signal received through the PD of the receiver subtracts the DC bias and goes through the reverse process of the transmission process. The transmitted signal is converted from serial to parallel (S/P) with removing a CP. After the resulting signal is converted from FFT. Then the conjugate symmetric is performed to remove the generated imaginary number by the transmitter to restore the original signal. The output signal can be estimated through P/S [14].

The proposed system adds SWBC-WSTD scheme before going through Hermitian symmetric and conjugate symmetric from fig 2. The proposed scheme as SWBC-WSTD is based on the four LEDs. In the WSTD scheme a pair of modulated symbols are transmitted using SWBC scheme over two LEDs, whereas the other two LEDs are not transmitting [15]. In other words, in the WSTD scheme, the transmission is switched between a pair of LEDs at each wavelength slot. This means that in the first wavelength slot the first two symbols are transmitted through first LED and third LED, whereas nothing is transmitted on second and fourth LEDs. Then, in the next frequency slot for transmission of next two symbols, second and fourth LEDs, where first and third LEDs are not transmitting [16].

SIMULATION RESULTS AND DISCUSSION

Table 1 summarizes the main simulation parameters to evaluate the proposed system.

Table 1. Simulation parameters

Parameters	Values
Electrical modulation	OFDM with QPSK
Optical modulation	Intensity modulation – Direct detection
Number of subcarriers	512
Number of IFFT/FFT size	512
Data rate	100 Mbps
Number of data and pilot symbols	60 and 4
Length of guard interval	25% of a symbol duration
Optical to electrical efficiency	0.53 A/W
Optical channel model	LOS channel with inter-lighting interference

In Table 1, QPSK is applied by the complex modulation technique, and the number of subcarriers and IFFT / FFT points is set to 512, respectively. In addition, the channel model is the LOS channel model from each LED to a receiver, and the inter lighting interference is modeled by the DUR values.

Fig. 3 shows the BER performance results according to the DUR value in the SISO (i.e. one transmitter and one receiver) system, where the same data was transmitted by using a repetition coding (RC) scheme from each transmitter (i.e. LED). The simulation results can demonstrate that the BER performance is degraded, as the value of the DUR decreases.

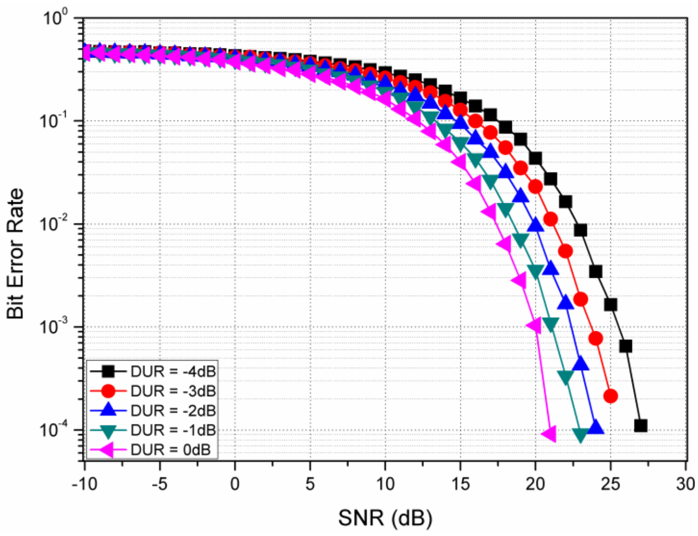

Figure 3. Comparison of the BER performance according to several DUR values in SISO system

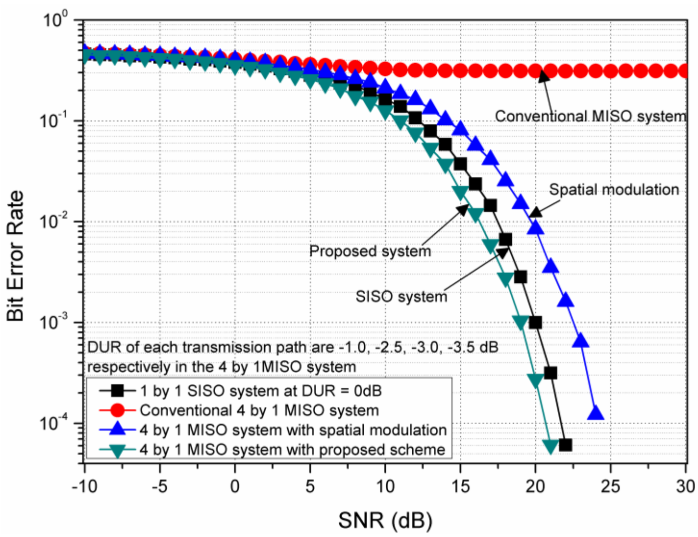

Figure 4. Comparison of the BER performance according to several DUR values in SISO system

Fig. 4 shows the BER performance results for several transmission types. In Fig. 4, the conventional MISO system means that different data is transmitted from each LED to a receiver, simultaneously. In the case of that, the interference occurs in the entire data durations, so information of the received signal cannot be detected. Also, the BER performance of the proposed system can be improved than the spatial modulation scheme. This is because the proposed system can obtain the space diversity gain and time diversity gain by transmitting the encoded signals at the same time from each LED. In addition, the simulation results demonstrate that the BER performance of the proposed system is also improved compared to the SISO system which is no interference between LEDs.

CONCLUSION

We proposed a SWBC-WSTD in VLC using LEDs to obtain the transmit diversity gain for improving the performance. Several LEDs is installed the indoor by lighting function, by which are caused the superposition of FOV to decrease the performance. To solve the superposition of FOV, the proposed system implemented SWBC-WSTD, which is possible to obtain the transmit diversity gain from MISO-VLC for improving the performance system. Therefore, the proposed system can be implemented the practical environment as installed several LEDs, where is possible to transmit efficiency.

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REFERENCES

[1] S. Park, Y. Choi, Analysis of Standardization Trend and Marketability with Tele-screen Service Platform for Smart City Foundation. *The Journal of the Convergence on Culture Technology (JCCT)*, Vol. 1, No. 2 (2015), 71-75.

[2] S. Y Chae, J. H. Park, A Design and Implementation of Testing and Management System for IoT sensors. *The Journal of the Institute of Internet, Broadcasting and Communication (JIIBC),* Vol. 16, No. 5 (2016), 151-156.

[3] Z. Chuluunbaatar, N. Y. Kim, Optimization of Thermal Performance in Nano-Pore Silicon-Based LED Module for High Power Application. *International Journal of Internet, Broadcasting and Communication (IJIBC),* Vol. 7, No. 2 (2015), 161-167.

[4] Y. Tanaka, T. Komine, S. Haruyama, M. Nakagawa, Indoor visible communication utilizing plural white LEDs as lighting. *Personal, Indoor and Mobile Radio Communications, 2001 12th IEEE International Symposium on*, (2001).

[5] S. J. Kim, H. R. Lee, M. Lee, A Study of 4G Network for Security System. *International Journal of Advanced Culture Technology (IJACT)*, Vol. 3, No.2 (2015), 77-86.

[6] Y. S. Chung, S. H. Jung, J. W. Kim, J. H. Lee, J. S. Cha, LED-QR Authentication Technology for Access Control and Security. *International Journal of Advanced Smart Convergence (IJASC),* Vol. 4, No. 2 (2015), 69-75.

[7] Raed Y. Mesleh, H. Haas, S. Sinanovic, C.W. Ahn, S. B. Yun, Spatial Modulation. *IEEE Transactions on Vehicular Technology*, Vol. 57, No. 4 (2008), 2228-2241.

[8] M. Torabi, A. Jemmali, J. Conan, Analysis of the Performance for SFBC-OFDM and FSTD-OFDM Schemes in LTE Systems over MIMO Fading Channels. *International Journal on Advances in Networks and Services,* Vol. 7, No.1 & 2 (2014), 1-11.

[9] N. Nguyen, B. Tran, V. D. Nguyen, A code scheme SFBC on 3GPP Channel Model in Correlated MIMO-OFDMA system. *The 2014 International Conference on Advanced Technologies for Communication,* (2014), 245-250.

[10] T. Komine, M. Nakagawa, Fundamental Analysis for Visible-Light Communication System using LED Lights. *IEEE Transactions on Consumer Electronics*, Vol. 50, No.1 2004, 100-107.

[11] J. R. Barry, Wireless Infrared Communications. *Kluwer Academic Press*, Boston, MA, (1994).

[12] F. R. Gfeller, U. Bapst, Wireless in-house data communication via diffuse infrared radiation. *Proc. IEEE,* Vol. 67, No. 11 (1979), 1474-1486.

[13] H. Elgala, R. Mesleh, H. Haas, Indoor Optical Wireless Communication: Potential and State-of-the-Art. *IEEE Communications Magazine*, Sep., (2011), 56-62.

[14] S. C. Saju, A. J. George, Comparsion of ACO-OFDM and DCO-OFDM in IM/DD Systems. *International Journal of Engineering Research & Technology (IJERT),* Vol. 4, Issue 04 (2015), 1315-1318.

[15] E. Dahlman, S. Parkvall, J. Skold, 4G LTE/LTE-Advanced for Mobile Broadband. *Academic Press*, (2011).

[16] H. Bolckei, A. J. Paulraj, Space-Frequency Coded Broadband OFDM Systems. *IEEE Wireless Communications and Networking Conference (WCNC)*, (2000), 1-6.