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Performance Enhancement Technique through Unequal Channel Allocation Algorithm in Visible Optical Communication

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Abstract

Establishment and focus: Visible light communication system is a communication system that performs communication and lighting functions at the same time. Therefore, the transmission efficiency of communication and the brightness of lighting should be considered at the same time. LED devices have different colors of illumination light depending on the RGB mixing ratio. Depending on this blending ratio, the RGB channel state also changes. In addition, since visible light is used, instantaneous shadowing occurs when the visible light is blocked by an obstacle. In this paper, we propose an optimal channel allocation algorithm to maintain the optimal transmission rate according to the RGB channel condition that changes according to the LED mixing ratio, and to maintain the shadowing phenomenon and dimming level.

System: In this paper, we evaluate the channel condition according to the RGB mixing ratio of LED devices and assign different transmission methods for each channel. The worst channel among the RGB channels allocates and transmits the shadowing detection signal instead of the information data. Since this signal is transmitted continuously as a signal that is always on, instantaneous recognition is possible when the signal is interrupted, and the average dimming level is improved because it is always on. The best channel and the second channel are combined with each other to improve the data rate. In the LED device capable of color control and dimming control, it is difficult to maintain optimal performance of the entire system in the conventional fixed channel allocation method. By applying the proposed technique, it is possible to optimally allocate the channel to the changing RGB channel state and to cope with the shadowing phenomenon which is a problem of visible light communication. Also, since the worst channel is always on, dimming level can be improved and flicker can be prevented. This can improve the performance of the entire system. If the states of the three RGB channels are similar to each other, assigning the worst channel to the shadowing detection signal lowers the overall data rate. Further research on adaptive allocation schemes for these exceptional channel environments is needed.

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1. Introduction

Light-emitting diodes (LEDs) have been widely used in various electronic devices, display devices, traffic signals, indoor and outdoor lighting, etc., due to the development of semiconductor materials and process technologies. In the case of indoor lighting, the replacement of

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conventional incandescent and fluorescent lamps with LEDs with excellent energy efficiency is accelerating. In this context, since mid-2000, studies on optical wireless communication using LEDs in the visible range have been in full swing, and thus, significant technical progress and application fields have been presented. The spectrum of the lighting LED is distributed in the visible light region whose wavelength is mainly 400-700 nm, and the peak wavelength may vary depending on the type. Since it provides a potential bandwidth of about 400 THz, which is much wider than electromagnetic waves, it is drawing attention as an alternative to solve the available frequency limitation and narrow bandwidth problem of existing wireless communication[1-3]. Lighting white LEDs, however, have the disadvantage that the illuminance decays exponentially with limited modulation bandwidth and distance. Focusing on communication technology weakens lighting. There is a problem of flickering or dimming level due to data transmission. In addition, if shadowing occurs due to an obstacle, it is difficult for the receiver to immediately recognize it. Therefore, in this paper, we propose an unequal data transmission technique based on the RGB channel state that changes according to the RGB mixing ratio in LED devices capable of lighting control and dimming control. Through this optimal channel allocation algorithm, shadowing phenomenon and dimming level can be improved. LED devices have different colors of illumination light according to the RGB mixing ratio. In the case of the conventional fixed channel allocation method, it is difficult to maintain optimal performance of the entire system. In order to solve this problem, the worst channel among the RGB channels allocates and transmits the shadowing detection signal instead of the information data. Since this signal is transmitted continuously as a signal that is always ON, instant recognition is possible when the signal is interrupted, and since it is always ON, the average dimming level is improved. In addition, the best channel and the second channel are combined with each other to improve the transmission rate and increase the performance of the whole system[4,5].

2. System model

Figure 1 shows the VLC system model. The visible light communication environment in the room is an optimal space because it can be hardly influenced by outdoor light, and the space where people live or live is mostly a shape of a hexahedron. Indirect lighting techniques are also being used as part of emotional lighting that enriches human life. Indirect lighting refers to lighting a wall or ceiling with light reflected thereon, rather than directly illuminating the subject. Since the light is reflected more than once, the illuminance is uniform, and there is no glare or shade. Visible light communication starts when the data that has undergone electrical signal processing in the transmitter module is changed from LED to optical signal. Then, the photon particles starting from the LED move linearly in the room and then move to the receiving part (PD), and the optical signal is changed into the electric signal, so that the communication is completed by the decoding process in the receiving module. The characteristics of the photon moving in the room is the visible light communication channel model. A photon reflected by reaching a wall, ceiling, or floor changes its direction, its energy is reduced, and its energy is reduced by the distance it travels, to the square of the distance. Also, since the photodiodes are photographed around every corner of the room, there is a characteristic that arrives with a time difference[6,7].

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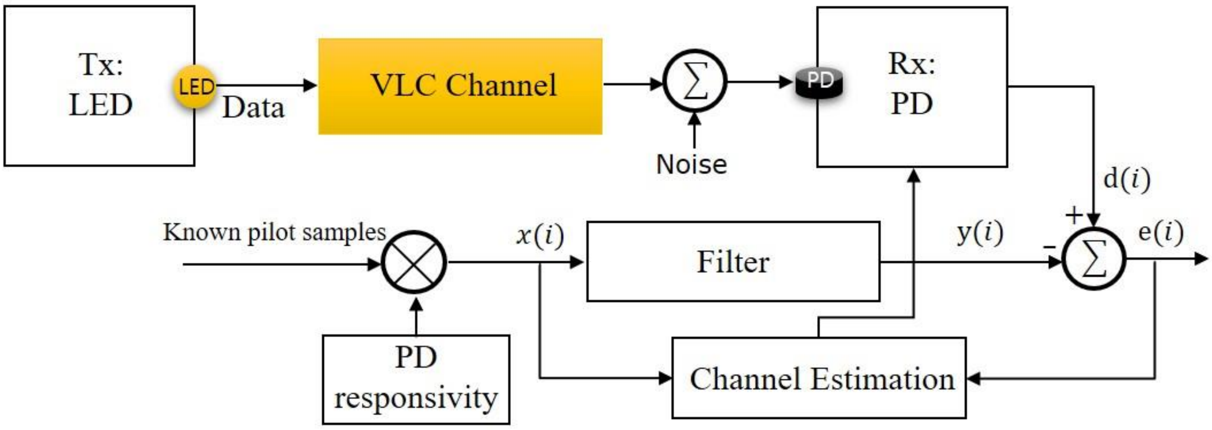

Figure 1. VLC system model

$$\bar{\tau} = \frac{\sum_j e_j^2 \tau_j}{\sum_j e_j^2} = \frac{\sum_j P(\tau_j)\tau_j}{\sum_j P(\tau_j)} \quad (1)$$

$$\sigma_\tau = \sqrt{\overline{\tau^2} - (\bar{\tau})^2} \quad (2)$$

$$\overline{\tau^2} = \frac{\sum_j e_j^2 \tau_j^2}{\sum_j e_j^2} = \frac{\sum_j P(\tau_j)\tau_j^2}{\sum_j P(\tau_j)} \quad (3)$$

$$B_c = \frac{1}{\alpha \sigma_\tau} \quad (4)$$

The delay spread by multipath is expressed as Mean Excess Delay $\bar{\tau}$, rms delay spread σ_τ, Mean Square Delay $\overline{\tau^2}$. The average excess delay is averaged by multiplying the signal power of the multipath and the delay time, and the rms delay spread is an indicator of how spread the signal is. The coherence bandwidth, which is not affected by the selective frequency fading, is calculated as shown in Equation (4). Assuming 50% frequency correlation, α is 5, and α is 50 assuming 90% correlation[8-10].

3. Unequal Channel Allocation Algorithm in Visible Optical Communication

3.1. LED Mixing Type

LED generate a light source by mixing three color elements Red, Green, and Blue. Table 1 shows the color mixing ratios and efficiencies of the red, green, and blue constituting the white LED. The LED device also changes the RGB channel state depending on the RGB mixing ratio. This mixing ratio greatly affects the performance of the system. In this paper, we use R, G, B mixing ratios of four types [Type 1, 2, 3, 4] that make up White LED. If you only use LEDs as lights, the efficient Tpye 4 works best. However, when communication and lighting are used at the same time, there is a problem in that the performance of each channel is different due to a large output power difference of each device. This characteristic adversely affects the average BER performance of the system. In this paper, we proposed the Using Unequal Data Transmission Ratio Algorithm according to the RGB channel state that changes according to the LED mixing ratio.

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Table 1: Red, Green, Blue Mixing Ratio Efficiency

	RED	Green	Blue	Efficiency (1m/W)
Type 1	0.68	0.60	1.71	291
Type 2	0.53	1.40	1.05	317
Type 3	1	2.62	1.96	391
Type 4	1	11.17	7.19	413

3.2. Unequal Data Transmission Ratio Algorithm

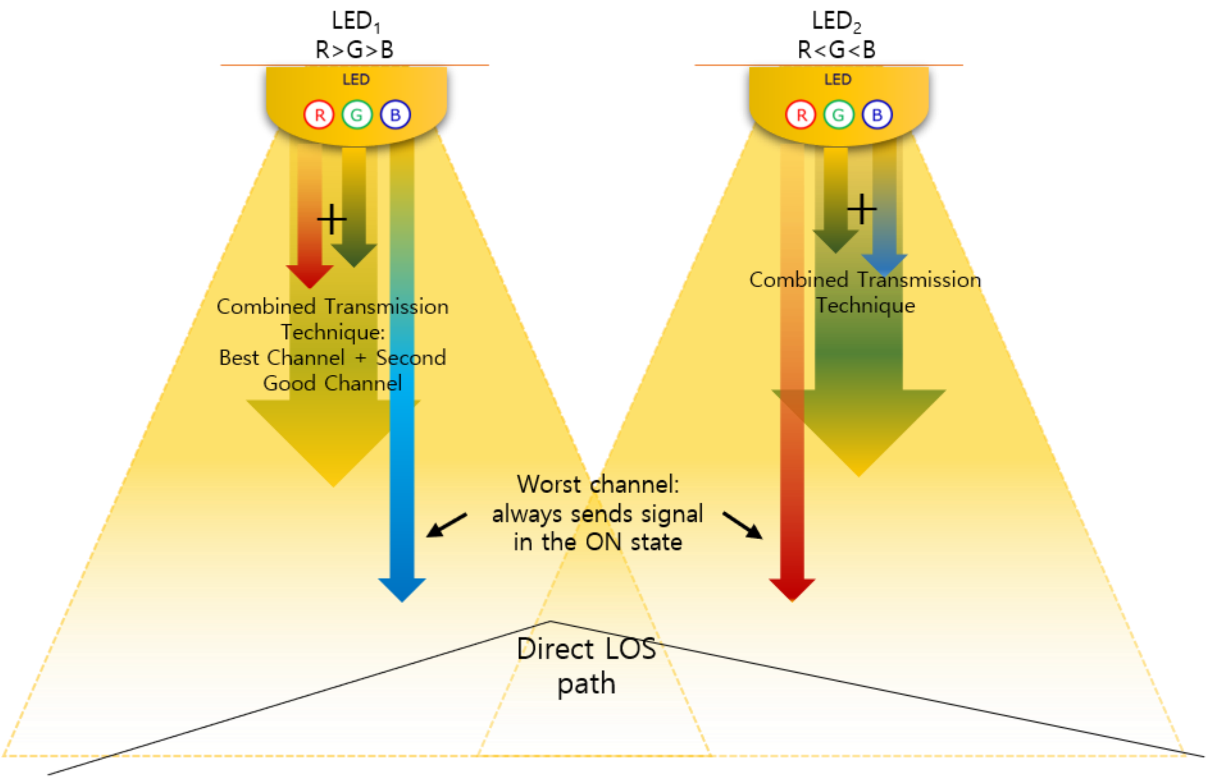

Figure 2. Proposed system model design

The proposed system is a visible light communication system using OOK. The LEDs used in the transmitter have several RGB mixing values. The performance of each channel varies according to the RGB mixing values. In this paper, four types of typical LED mixing values are used. Figure 2 shows the proposed system model. It consists of a mixing type selector and data rate regulator to find the worst channel depending on the RGB mixing value. First, determine the mixing type of the LED. After that, the worst channel always transmits a signal of 1 without transmitting data. This reduces the transmission rate by 66.7% because three channels are reduced to two channels. If this is expressed as an expression, it is as follows.

$$D_{total} = D_R + D_G + D_B \tag{5}$$

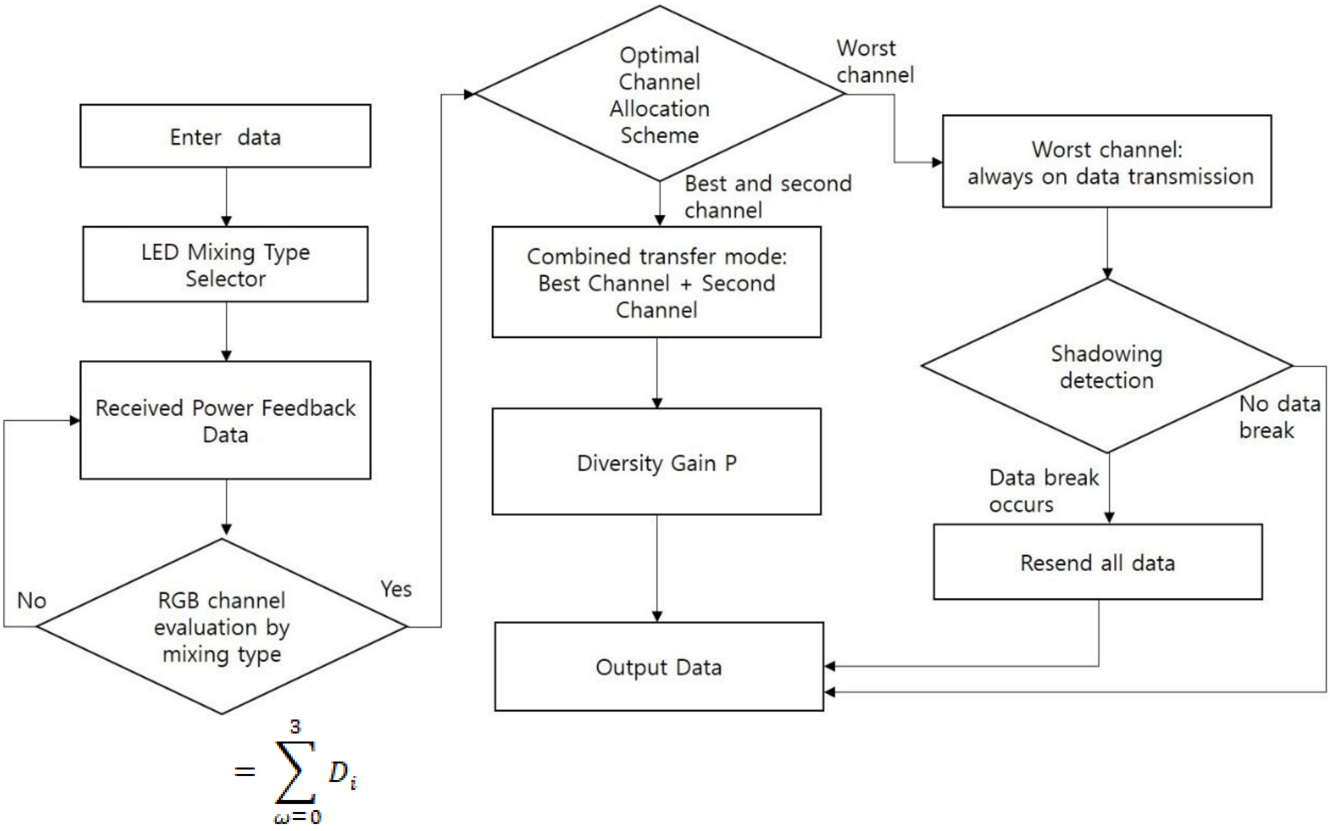

Figure 4. Flow chart of proposed system

Here, if the BER performance is R <G <B, the RED channel is always ON, and transmits 1 signal. Data is transmitted through the remaining two channels, G + B. In the above formula, since $D_{total} = D_R + D_G + D_B$, if the data rate of each LED is equal to K, then $D_{total} = 3K$. Here, if one channel is always on, $D_{total} = 2K$, which reduces the transmission data rate by 66.67%. However, using only the best channels improves average BER performance and raises the lighting dimming level. In addition, the data rate can be expressed as the following equation.

$$D_{total} = \alpha D_R + \beta D_G + \gamma D_B \qquad (6)$$

$$f\ \alpha = 0, K(\beta + \gamma) = 3K \qquad (7)$$

$$\beta = (3 - \gamma) \qquad (8)$$

Therefore, even if you give up the data transmission of the worst channel, you can adjust the transmission speed of the entire system by adjusting the data transmission speed of the other channel. In addition, the signal transmitted on the worst channel is used as a detection signal that detects that shadowing occurs immediately at the receiver when the receiver does not receive it.

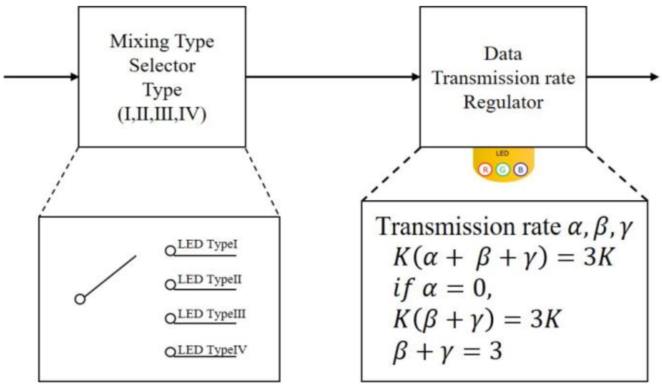

Figure 3. Propose system structure

Figure 3 shows the Propose system structure. First, select the transmission type according to the mixing type of the LED in the Mixing Type Selector. After that, assign the shadowing detection signal to the worst channel as described above, and determine the transmission rate of the other two channels in the data transmission regulator. Since the worst channel is left out of the transmission band, the transmission regulator takes steps to compensate for the existing speed. dimming levels. In addition, due to the shadow detection signal sent continuously, the receiver can detect the moment of data disconnection and wait for data retransmission. Figure 4 shows the system flow in more detail.

Table 2: Simulation parameter

Modulation Scheme	IM-DD
Pulse Modulation	OOK
Multiplexing Method	WDM
Symbol rate	100 Mbps
Noise Model	AWGN
Background light noise	0 dBm
O/E convert efficiency	0.52

4. Performance evaluation

Table 2 shows the parameters required for the simulation. The modulation scheme for the light source is IM-DD and convolutional coding. The symbol rate is 100 Mbps.

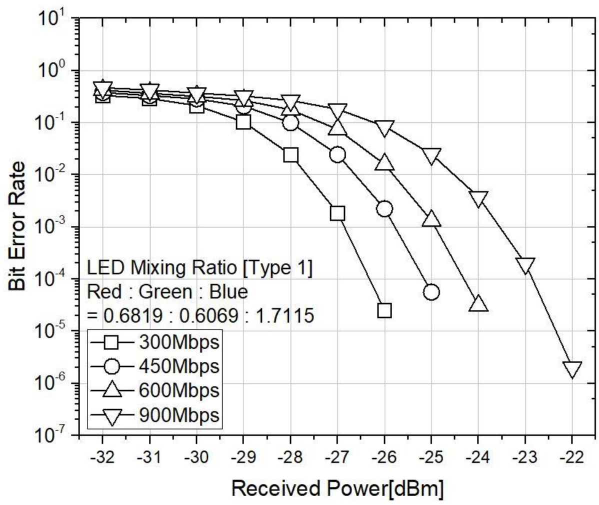

Figure 5. BER performance according to transmission speed of Type 1 LED

In addition, since the noise model uses a visible optical communication system indoors, the AWGN model is used and the communication distance is 1m. The four mixed types of LEDs in Table 1 were simulated. The proposed system assigns users the optimal channel according to the mix ratio.

Figure 5 shows the typical BER performance of a Type1 LED. The BER performances were compared at 300Mbps, 450Mbps, 600Mbps and 900Mbps respectively. At 300Mbps, the BER performance is best and the faster the data rate, the worse the BER performance is.

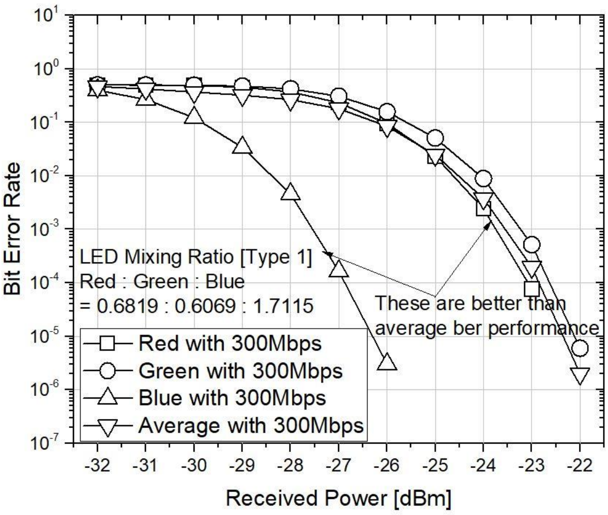

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Figure 6. BER Performance for RGB Channels of Type 1 LEDs

Figure 6 shows the BER performance for each channel of Type1 leds at 300Mbps. The mixing ratio of Type1 LED is R: G: B = 0.6819: 0.6069: 1.7115, the best performance is Blue channel. Therefore, as shown in the figure, the BER performance of the B channel is the best.

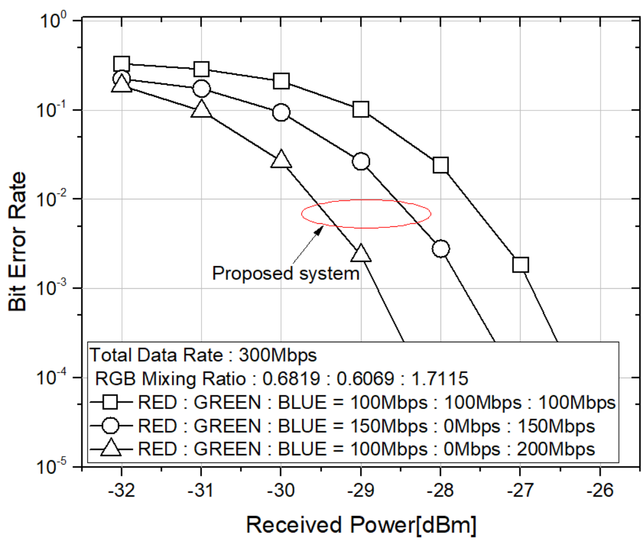

Figure 7. BER performance with Unequal transmission in Type1 LED

Figure 7 shows the performance of the proposed system. Compared to the case of sending fixed data to Type1 LED like conventional method and the case of channel allocation by applying proposed system. As shown in the figure, the performance is better when the channel is allocated except the green channel, which is the worst channel, than when the RGB channel is fixedly assigned to each 100Mbps. In addition, it can be seen that performance is better when the best channel transmission rate is unevenly assigned to 200Mbps and the second channel to 100Mbps, compared to 150Mbps for the best channel and the second channel.

In Figure 8, the proposed system was evaluated using Type2 LEDs. The mixing ratio of Type 2 LEDs is R: G: B = 0.5376: 1.4086: 1.0538. When the proposed system is applied to the type2 LED, it shows better performance than the fixed channel allocation system. Also, in case of type2 LED, there is no big difference between G channel and B channel. Therefore, even if the transmission rate is assigned differently, it can be seen that there is no significant difference in BER performance.

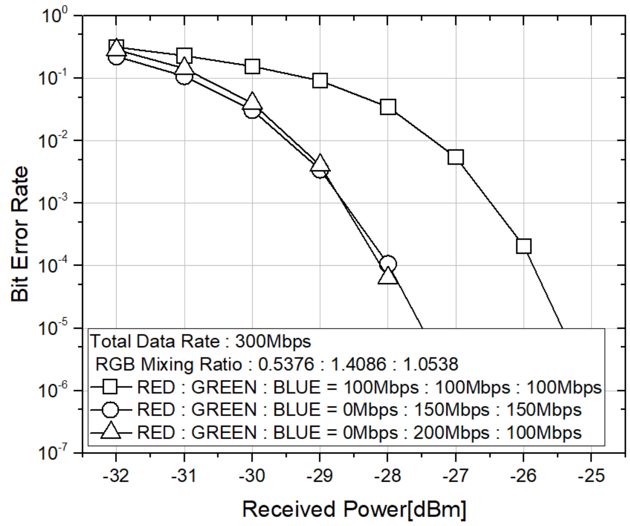

Figure 8. BER performance with Unequal transmission in Type2 LED

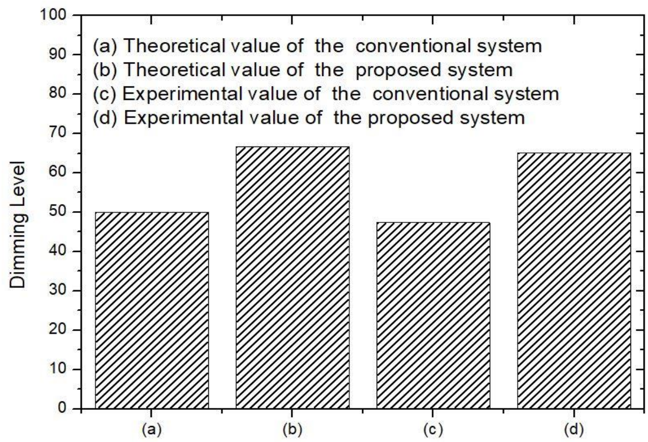

Figure 9. Comparison of Dimming Level Performance of Existing System and Proposed System

Figure 9 shows the dimming level change of the existing system and the proposed system. The proposed system always turns on the worst

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channel and assigns it to the shadowing detection channel. As a result, the ON / OFF sequence of the LED is reduced compared to the existing system, thereby improving the dimming level. As shown in the figure, when the proposed system is applied at the dimming level of 50%, about 10% is increased.

5. Conclusion

As VLC systems evolve, securing communication reliability and increasing data rates in the service area is a fundamental research issue. In this paper, we studied the technique to improve the dimming level and BER performance by applying the unequal data rate algorithm in visible light communication system. Visible light communication provides both lighting and communication at the same time, so both must be considered. The proposed technique improves dimming level and overall BER performance. In addition, dedicated channel assignments to improve shadowing, a problem in visible light communication, provide an environment in which the receiver can immediately respond to shadowing. This can improve the QoS of the entire system. However, when the states of the three RGB channels are similar to each other, assigning the worst channel to the shadowing detection signal decreases the overall transmission speed. Further research on adaptive allocation schemes for these exceptional channel environments is needed.

6. Acknowledgment

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