Data Rate and External Lighting Variations for Bit Error Rate Measurement on A Simple Single LED Visible Light Communication System

Khalfan Nadhief Prayoga Wicaksono
Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia

Apriono, Catur
Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia

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Khalfan Nadhief Prayoga Wicaksono[1], Catur Apriono[1,*]
[1]Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia, Indonesia

*Author to whom correspondence should be addressed:
E-mail: catur@eng.ui.ac.id

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Abstract: Visible light communication (VLC) system is a promising wireless communication that does not interfere with radio waves. However, it performs different performances in daytime and nighttime due to light as its resource. This research investigates a VLC system using the NRZ-OOK technique by considering external light based on BER measurement. At 10 cm and 100 bps, the bright and low light BER values system are 0.3302 and 0.2504, respectively. Meanwhile, at data rates of 1 kbps and 100 kbps, the BER values are 0.2429 and 0.4387, respectively. This result can become a basis for performance optimization in the future.

Keywords: data rate; lighting variations; bit error rate; LED; visible light communication

1. Introduction

Vehicle-to-Vehicle (V2V) communication is a wireless network system that connects one vehicle with another vehicle or with infrastructure to transmit information in two directions (duplex)[1,2]. Information via V2V communication includes vehicle speed, traffic, location, and much more[3)4)]. Based on the IEEE 802.11p standard, information can be transmitted properly through V2V communication through electromagnetic waves with a frequency range of 5.85 GHz – 5.925 GHz[5)]. The network system of V2V communication is in the form of a mesh, where each node can send and receive information simultaneously[6)]. These nodes can be vehicles or traffic lights integrated with another internet of things systems[7,8)].

Frequency resources are one of the limited resources in telecommunications applications[9)]. Visible light sources can be alternative for telecommunications resources used in V2V communication. Therefore, other telecommunications applications can use the frequency range of 5.85 GHz to 5.925 GHz. Visible light communication (VLC) transmits information using LEDs as an optical signal source to transmit information from one point to another[10-13)]. Before sending information, a modulation process is necessary to modulate electrical information signals into light signals[14)].

The advantages of a wireless VLC system are visible light characteristics, such as its very high frequency, ranging from 400 THz to 800 THz, and free of electromagnetic interferences[15)16)]. Another characteristic is not penetrating thick objects or walls with higher security than radio waves communication systems.

Based on other research on VLC systems, there are visible color spectrum types that have optimal signal transmission performance. The visible light communication system using a monochromatic color spectrum with the best information transmission performance is blue light[17)]. However, from all categories of the light spectrum, the visible light communication system transmission performance is the white polychromatic light spectrum can provide the best information[10)]. In addition, other studies examine the effect of using the number of LED elements on the performance of visible communication systems. The more the number of LED elements used, the better the performance of the communication system[17)].

Before transmission through visible light, coding and modulation processes are needed to transmit information properly. One of the coding and modulation techniques for a VLC system is the unipolar Non-Return to Zero (NRZ) coding technique and the on-off keying (OOK) modulation technique, respectively[15)]. The OOK modulation is simple in analyzing the system performance based on the BER value. The unipolar NRZ coding technique is simple and easy to practice with an LED with a zero voltage and positive bias[18,19,20]. If the NRZ coding technique is used in bipolar, the LED must be operated with a negative voltage (negative biased) and will immediately operate as a photodiode.

Other phenomena must be figured out as an alternative infrastructure for applying VLC, such as how day and night affect the visible light communication system. This research examines the performance of the visible light communication system during the day, representing when the measurement conditions are with bright external light. The visible light communication system's performance at night is represented when the measurement conditions are dark or low light intensity. This research investigates the effect of external light on the performance of visible light communication systems based on the measurement by considering the BER value. In addition, this research also examines the system performance on various data rates to obtain the effect of the amount of data rate. This paper can contribute as the basis of VLC for wireless communication development and optimization, especially the low-cost infrastructure and its characteristics.

2. System design

A wireless visible light communication system has two interrelated parts to function properly: the transmitter and the receiver. If the information to be sent is still analog at the transmitter, it needs to be converted into digital form. Furthermore, the information that has been in digital form is encoded and digitally modulated. These processes are necessary to carry information signals transmitted by light through free space[17].

A photodiode detects information signals at the receiver and converts signals in an optical signal into an electrical signal. Next, the electrical signals are processed by a suitable demodulation technique and converted back into analog information similar to those transmitted.

2.1 Electronic components

Fig. 1 and Fig. 2 show a schematic of the system designed with the components used in this research. These components can be categorized as simple components that the general public can access because they are commercially available. This research uses the Arduino UNO microcontroller component, with a maximum clock speed of 16 MHz, to carry out the modulation and coding process[21,22,23]. In addition, other components used are a blue LED as an optical signal source, an LM35CZ temperature sensor to capture the information to be transmitted, a 1,000-ohm resistor to limit the electric current, and a BPW34 PIN photodiode to capture the transmitted optical signal[17].

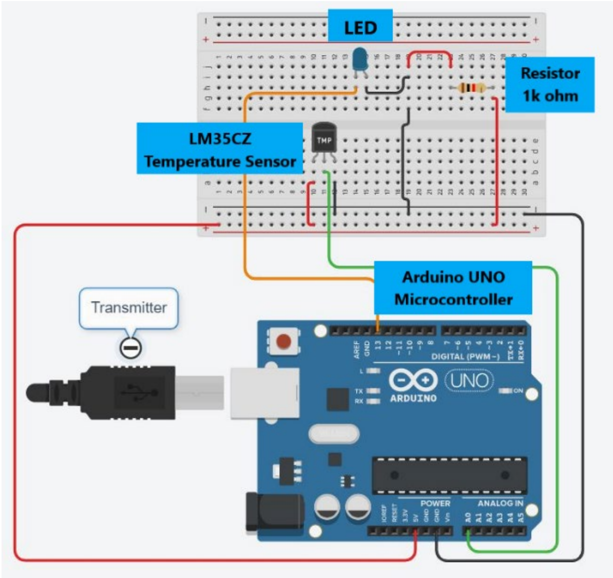

Fig. 1: Schematic of Transmitter Circuit.

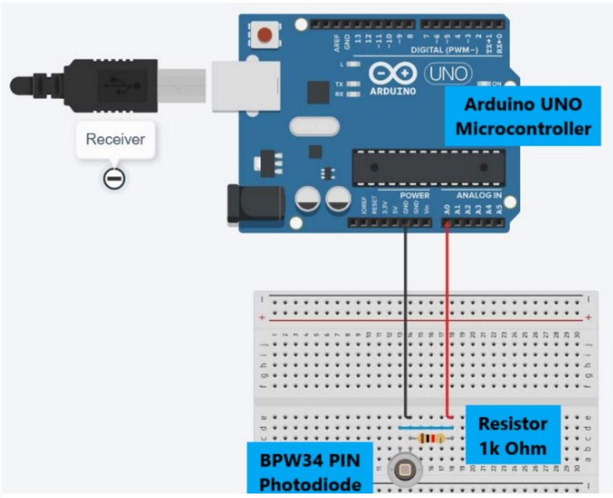

Fig. 2: Schematic of Receiver Circuit.

2.2 Transmitter and receiver

After the transmitter and receiver parts of the system are assembled according to Fig. 1 and Fig. 2, the settings are made so that the assembled system can function properly. The setup is conducted by applying the unipolar NRZ coding and OOK modulation techniques. The unipolar NRZ coding technique converts bits of information into two voltage levels, 0 and +V [24]. Meanwhile, the OOK modulation technique regulates that every bit represented as voltage levels become an LED blink. The BER measurement in this research refers to Eq. 1, which states the BER value in the OOK modulation technique[25].

$$BER_{OOK} = Q\left(\frac{P}{\sqrt{N_0 R_b}}\right) \quad (1)$$

In the OOK modulation technique, three aspects affect the performance of the visible light communication system. These aspects are optical signal power, the rate of information data transmission, and interference that enters the system[17]. At a glance, Eq. 1 shows the optical signal power value, which is directly proportional to the BER value. The noise power value and the data rate are proportional to the BER value. However, Eq. 1 has a non-complementary q-function variable which makes the meaning of the variables in the equation inversely proportional to the original. This condition has implications for the optical signal power value, becoming inversely proportional to the BER value. In addition, the data rate and noise power become directly proportional to the BER value.

This research focuses on applying variations in data rates and system disturbance variations. The disturbance can be described by external light entering the system. A comparison between the number of incorrectly received bits and the number of sent bits is used to get the BER value from the measurement results of the designed system. Eq. 2 represents the BER value based on the measurement results.

$$BER = \frac{Error\ Bits}{Total\ Bits} \tag{2}$$

2.3 Experimental setup

Fig. 3 is an experimental setup of the visible light communication system, which shows the transmitter and receiver sections. The propagation method is a direct line of sight (direct LOS). In the direct-LOS method, the transmitter part of the system is directed directly to the receiver. In addition to the direct-LOS method, there are other propagation methods, such as non-directional-LOS and hybrid-LOS[25]. Fig. 4 illustrates the propagation methods of a visible light communication system.

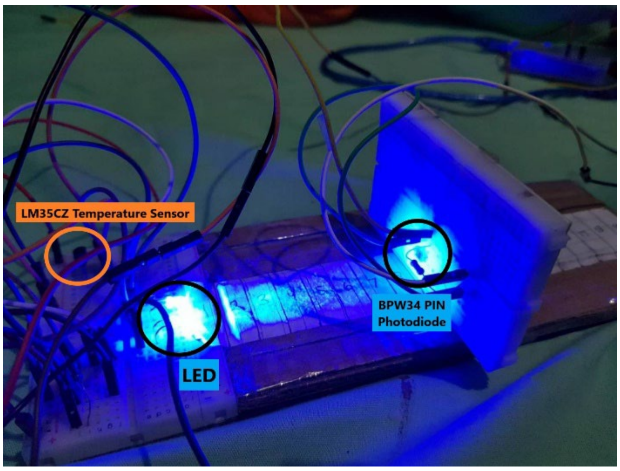

Fig. 3: Propagation Link Modes of Visible Light Communication[17].

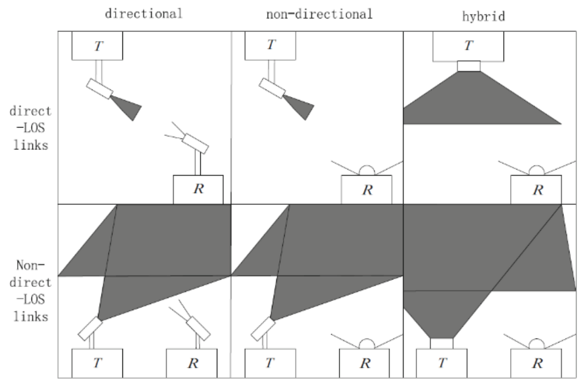

Fig. 4: Line of Sight Experimental Setup.

3. Results and analysis

Data measurement was carried out at least three times for each sample in this research. This procedure was to obtain the data's consistency to describe the existing phenomenon. The data in this experiment were the BER value with data rates of 1 bps to 100 kbps. In addition, this research also compares the performance of visible light communication systems in bright and low lighting. The purpose of doing these two things is to determine the effect of the magnitude of the data rate used and the influence of external light on the performance of the visible light communication system.

The considered tolerated BER value in this research is 0.5. Suppose the BER value is greater than 0.5. The visible light communication system has a performance where the chance of receiving incorrect bits is greater than the correct information bits. The desired performance target of the system is a BER value that is getting closer to 0. A BER value close to 0 means that the system receives fewer incorrect bits.

Fig. 5 shows the BER comparison between two different external lighting conditions. The bright lighting condition has a relatively higher BER value when compared to the low lighting condition. This result is because ambient light enters the system in a bright lighting condition and is considered a noise system. If the ambient light factor is omitted, in the sense of making the condition darker condition, then the BER value will be better. This condition is in line with Eq. 1 regarding the BER value in the OOK modulation technique.

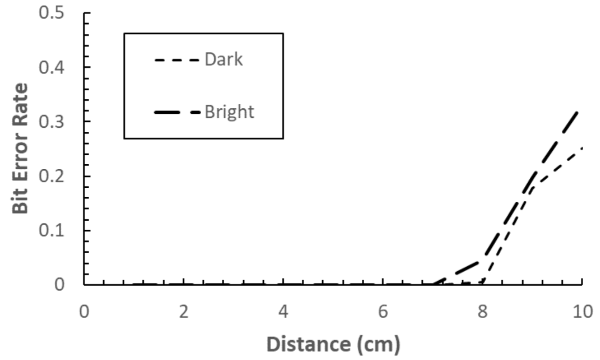

Fig. 5: BER Comparison Between Two Different External Light Conditions.

Fig. 6 shows the measurement of BER values with data rates ranging from 1 bps to 1 kbps. There is a tendency where the increasing data rate of information transmission using visible light communication systems, the system performance decreases. This condition is evidenced by the measurement results of the BER value, where for data rates of 1 bps, 10 bps, and 100 bps, the BER value of the system is still 0 for a transmission distance of 7 cm, which means that the information bit is received perfectly. These results indicate that the wide pulses can maintain BER performances because the dispersion effects still do not yet meet their limits. However, the measurement of BER values with data rates of 1 kbps and 100 kbps shows that the BER values are not perfect even for a transmission distance of 1 cm, where at data rates of 1 kbps and 100 kbps, the BER values are 0.2429 and 0.4387.

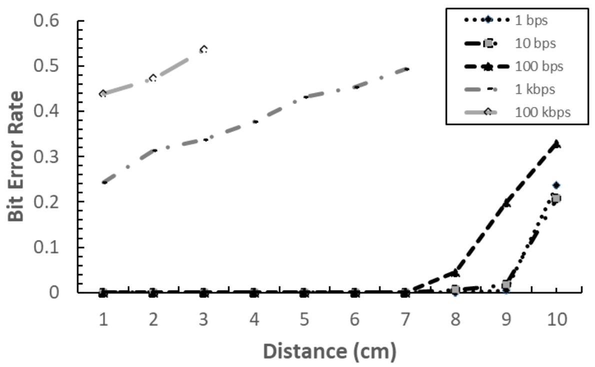

Fig. 6: BER Comparison Between the Variations of Data Rate for Visible Light Communication.

The experimental results align with Eq. 1 regarding the BER value in the OOK modulation technique. Eq. 1 shows that because of the non-complementary Q-function factor, the information transmission data rate has a quadratic relationship that is directly proportional to the BER value in the OOK modulation technique. Therefore, it is possible to find phenomena such as the reduced transmission distance on the performance of visible light communication systems based on the measurement of the BER value, as shown in the experimental results.

4. Conclusion

This research results that external light can affect system performance based on BER measurement value with visible light communication system infrastructure using the OOK modulation technique and unipolar NRZ encoding. At a distance of 10 cm and a data rate of 100 bps, the BER values in bright and low light are 0.3302 and 0.2504, respectively. Based on the experiments, the application of the visible light communication system is relatively more optimal in terms of the BER value in low-lighting conditions (night). In addition, the increase in the data transmission rate also affects the performance of the visible light communication system. As the data transmission rate increases, the system performance decreases relative to the BER measurement value. BER values with data rates of 1 bps, 10 bps, and 100 bps still have a BER value of 0 (perfect) at a transmission distance of 7 cm. Meanwhile, at data rates of 1 kbps and 100 kbps, the system performance is not optimal in terms of its BER values, respectively, 0.2429 and 0.4387.

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