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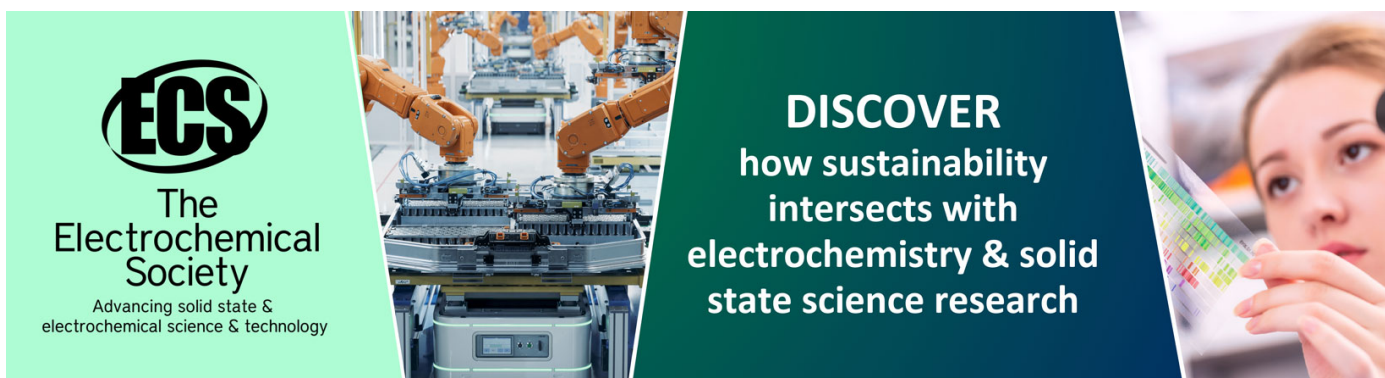
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Energy efficient transmitter for guided indoor navigation using visible light

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Abstract. Visible light communication is one of the wireless communication that transmits information to receiver through lighting. The light-emitting diode (LED) lamp is one of the main components that used to transmit information. Generally, LED lamp used to lighting the room because it has energy saving and long lifetime which makes LED lamp as one of the solutions for an energy crisis. This paper discusses visible light communication using the LED lamp for indoor navigation. The transmitted data contains the identity of the LED lamp was modulated on lighting and received by photo-detector for indoor navigation. Transmitting data from LED lamp to photo-detector examined by the height and distance between the line of sight of the transmitter and a receiver. For 30 cm height and at the line of sight, 3-watt transmitter has illumination level of 180 lux, 6-watt transmitter has 273 lux, and 9-watt transmitter has 288 lux. The transmitter using LED lamp can save energy about 88,3% than a compact fluorescent lamp, halogen light bulb, and an incandescent light bulb. A transmitter using visible light increases the energy efficiency for indoor navigation by using the existing infrastructure of the light system.

1. Introduction

As the growing economy in Indonesia-the largest energy user in Southeast Asia will increase energy demand. Improvements in energy efficiency will create sustainable growth and create the social-economic benefits across Indonesia. Energy efficient transmitter using visible light is one of technology that can save energy by transmitting information through the existing technology.

Visible light can increase efficiency energy by exploiting the illumination to carry information and at the same time using technology that is green in comparison to radio frequency technology while using the existing infrastructure of the lighting systems as the main transmitter [1]. On the other hand, as white LED (Light Emitting Diode) has been developed, LED is expected to be used as illuminations for the next generation. LED has lower power consumption, lower voltage, longer lifetime, smaller size, and cooler operation. Meanwhile, we can use it as a communication device by transmitting a high-speed modulation. By using this, we can perform illuminations and communication at the same time, called visible light communication (VLC) [2]. They have the ability to produce high light levels with low radiant heat output and maintain useful light output for years [3]. The available cost saving in case of compact fluorescent tubes and LED, depending on the daily hours of operation is 26-79% compared to the incandescent light bulb [4].



Usually, the industrial warehouse has existing light infrastructure that using LED as the lighting system and also has a navigation system to determine the location of the product and guide to the destination point. GPS is one of technology to determine position based on satellite, so obstacles such as mountains and buildings block relatively weak GPS signals. VLC based positioning using LED lamps and image sensor has been proposed in [5]. This system performs the optical intensity modulation of the LED illumination for data transmission and receives the light by using image sensor. Energy efficient transmitter in the form of LED sent an information to be modulated by the emitted light. Information sent in the form of light identity that can guide the mobile robot for navigation purposes in the warehouse.

The transmitter converts electrical signals into optical signals, while the receiver or detector serves to convert optical power into electric current. Data transmission can be done by changing the level of LED illumination on the transmitter side to determine high or low logic. The photo-detector on the receiver side generates a linear pulse to the received illumination level. The LED illumination level setting and information signal modulation are controlled by the microcontroller device.

The purpose of this research is to implement energy efficient transmitter with visible light, utilize transmitter with existing technology for improving energy efficiency, and to guide mobile robot for indoor navigation while using visible light as the indoor lighting system.

2. Methods

This section is using experiment study which aims to implement energy efficient transmitter using the existing infrastructure of the lighting system. The transmitter guide a mobile robot as the navigation system. Transmitter and receiver communication design implemented in the system using visible light. The stage that will be done in this methods is designed the transmitter, design the receiver, and scenario test of experiment in the laboratory

2.1. Transmitter design

The transmitter design is using 3 Watt, 6 Watt, and 9 Watt of LED. The room used in this experiment is a laboratory with an illumination level about 6-11 lux. Information signal will be modulated by the LED with the controller. Then, the signal went through the LED driver. The LED driver is divided into two parts, linear LED driver and switch mode LED driver [6]. Switch mode LED driver working with outages or conditions '0' and lit or condition '1'. The switch mode LED driver is suitable for digital modulation, while linear LED drivers have low efficiency but can support analog modulation. In this research is using a switch mode LED driver.

2.2. Receiver design

The receiver using photo-detector that implemented with the mobile robot for indoor navigation purposes. The component of the receiver is a light-to-voltage photo-detector with the following specifications below.

Table 1. Receiver specification.

Parameter	Value
Type	TSL 251R-LF
Input Voltage	3 - 9 Volt
Output Voltage	1 - 3 Volt
Supply Current	900 - 1600 μ A
Output Current	± 10 mA

Photo-detector TSL 251R-LF type has an input voltage of 3-9 Volt derived from the controller. It produces 1-3 volt and 900-1600 μ A current (Table 1). The photo-detector also has a trans-impedance amplifier (TIA) consisting of an OP-AMP and resistor feedback (Rf). The output of TIA circuit is by multiplying resistor feedback value and the current that generated by the photo-detector. The receiver is

implemented with capacitor feedback and parallels with resistor feedback to compensate the noise due to amplification by OP-AMP.

2.3. Experiment scenario

The visible light system has transmitter circuit to send the identity of the lamp to the mobile robot for navigation purpose. Energy efficient transmitter tested by comparing the percentage daily hours operation with the other. As shown in Figure 1, the transmitter circuit contains the controller, LED driver and LED to transmit information via visible light. The information is received by photo-detector that is implemented with a mobile robot and controlled by the controller, motor driver and DC motor. In Figure 2, the system tested with the different height between the transmitters and receiver. The illumination intensity according to the variation in distance between the Tx and Rx in the y direction was measured using a Luxmeter while keeping the radiation and incidence angles at 0° [7]. The test is in the laboratory with a room illumination level of 6-11 lux.

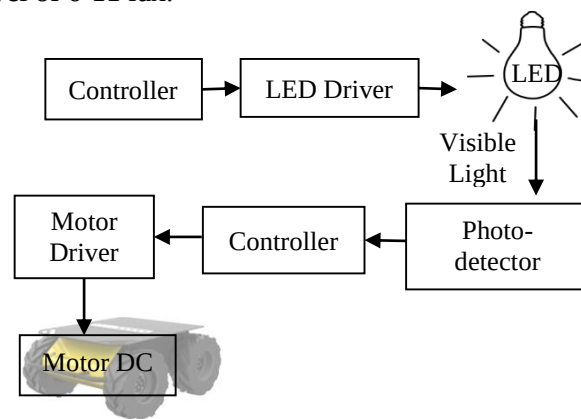


Figure 1. The system of an energy-efficient transmitter by using visible light.

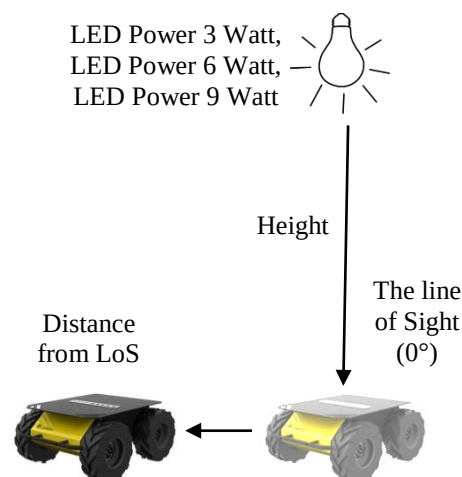


Figure 2. Experiment system using the different power of a transmitter, height and distance from LoS.

3. Results and discussion

The results of this experiment include the level of transmitter illumination with different power, maximum transmitter communication distance to the receiver for mobile robot guide, and efficiency by using LED as the main transmitter. In this experiment, the illumination levels of different LED power also cause differences in the maximum distance of communication. The distance of communication is

adjusting to the height of the warehouse to guide the mobile robot. When comparing the energy efficiency of LED as the main transmitters with other technologies LEDs have low power consumption. By using LED as the transmitter will increase energy saving by utilizing infrastructure lighting system to guide the mobile robot.

3.1. Energy efficiency of the transmitter

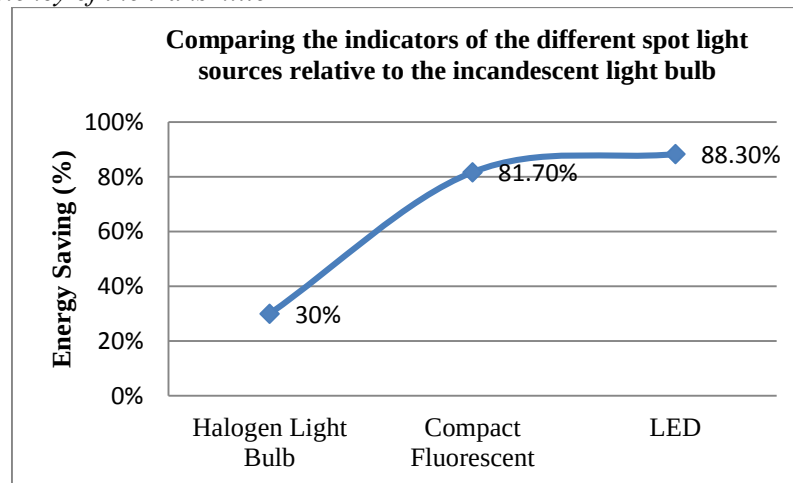


Figure 3. Energy efficiency of LED as the main transmitter.

Energy efficiency by using LED as a transmitter in visible light communication can store energy as much as 88.3% rather than using halogen light bulb and compact fluorescent (Figure 3). In case of spotlighting LED have been better than those observed. The available cost saving in case of fluorescent tubes and LED depending on the daily hours of operation is 26-79% [4].

Table 2. Comparing the power consumption.

Device	Power consumption in 1 hour (kWh)
Linksys WLAN	0.011
D-LINK switch	0.01
Incandescent Lamp (60 Watt Mirabella)	0.053
Energy-saving LED	0.001

Table 2 provides the power consumption of an average American household. It shows devices that have potential to use VLC in the future. Using Energy-saving LED has power consumption 0.001 kWh which saves energy than other transmitter devices [8]. A joint brightness and data transmission control scheme was presented to minimize the power consumption while satisfying light and communication requirements [9]. For VLC, the energy is consumed for at least two purposes: illuminations and data transmissions [10].

3.2. Maximum communication distance

The transmitter with different power produces the different maximum communications distance. Based on different illumination level experiments on the transmitter will affect the highest distance communication using visible light. Transmitter with 9-watt LED produces high illumination level and highest communication distance that is 4.07 meters, while the lowest using a 3-watt transmitter is only 1.7 meters (Figure 4).

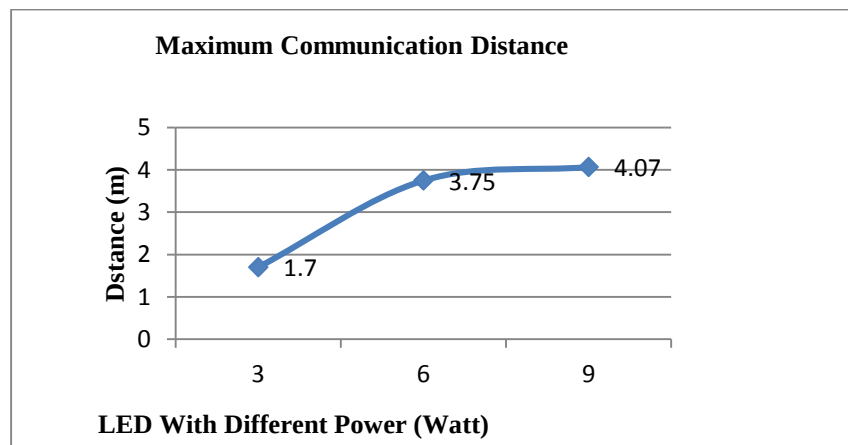


Figure 4. Maximum communication distance by using the different power of a transmitter.

3.3. Illumination level using different power transmitter

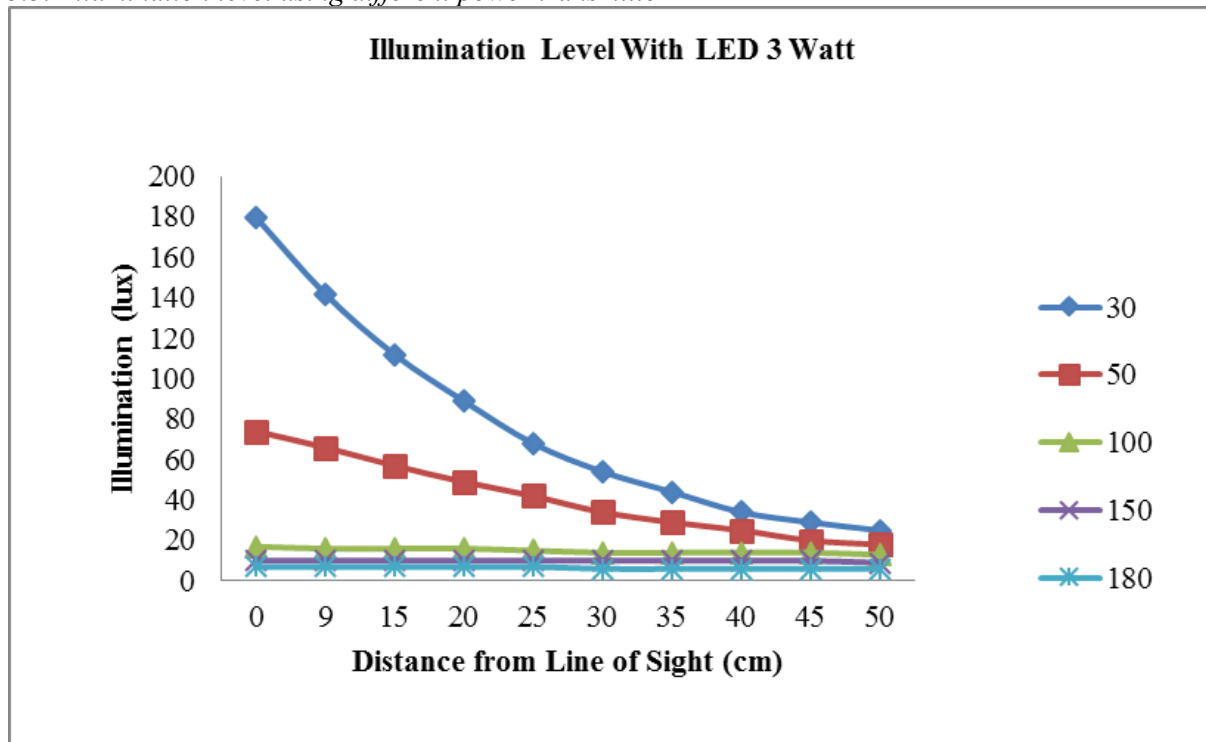


Figure 5. Illumination level by using 3-watt power transmitter.

In Figure 5, the maximum transmitter distance of 3 Watt is 1.7 meters to send information with the highest illumination level at 30 cm height with 0 cm distance from the line of sight is 180 lux. The lowest illumination level at 170 cm height with 50 cm distance front line of sight is 6 lux equivalent to the light intensity of the room.

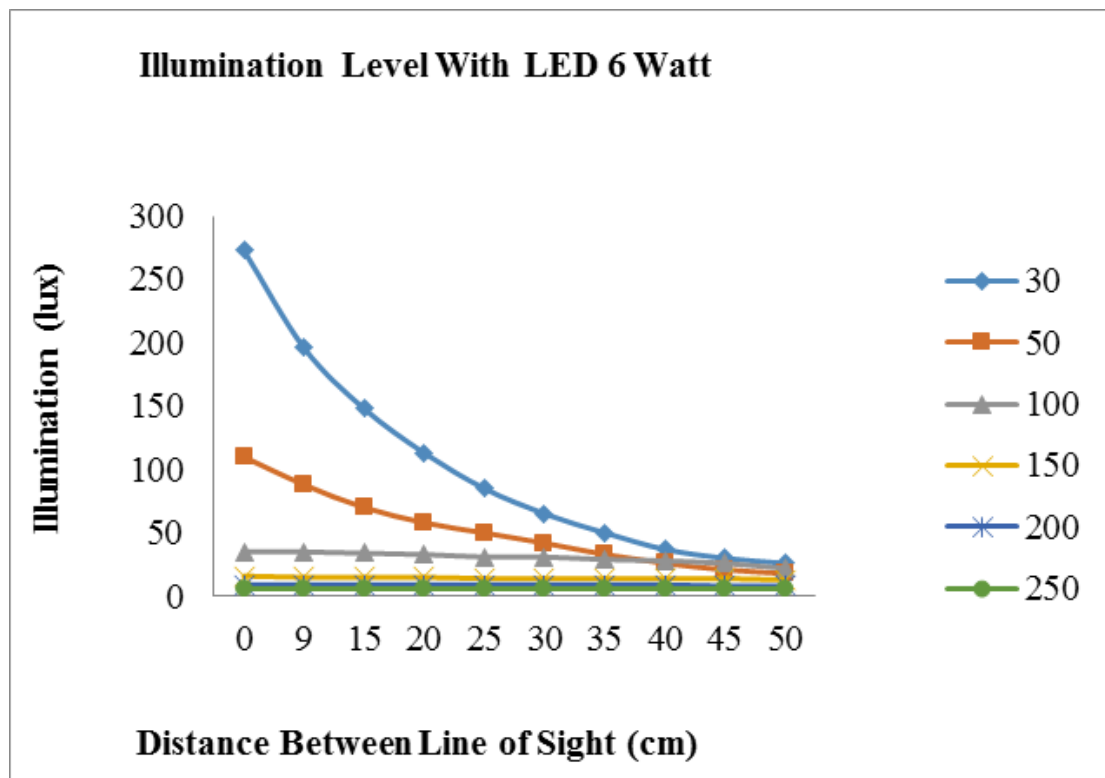


Figure 6. Illumination level by using 6-watt power transmitter.

In Figure 6, the highest illumination level at 30 cm height and line of sight is 273 lux. The lowest at 210 cm height and line of sight is 6 lux equivalent to the light intensity of the room. The maximum of 6 Watt transmitter distance communication is 3.75 meters.

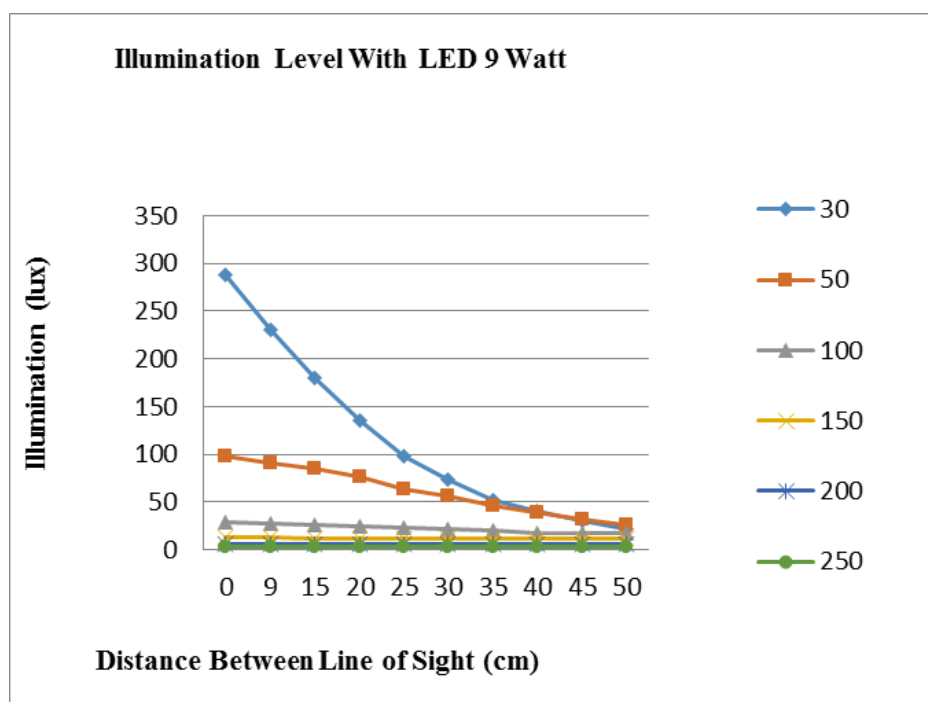


Figure 7. Illumination level by using 9-watt power transmitter.

At Figure 7, the highest illumination level is 288 lux at 30 cm height. The lowest illumination level at 230 cm height with 35 cm distance from the line of sight is 6 lux equivalent to the intensity of the room. The maximum distance of 9 Watt transmitter is 4.07 meters.

4. Conclusions

Energy efficient transmitter using LED can save energy about 88,3% than the one with incandescent light bulbs, halogens or even compact fluorescent light bulbs. It has low energy consumption to transmit the information through visible light. The different power of transmitter can transmit the information at a different distance to guide mobile robot for indoor navigation. Visible light can save energy by exploiting the illumination that contains information at the same time while using the existing infrastructure of the lighting systems.

5. Future work

It could be interesting if visible light can be developed in the warehousing of Indonesia and other sectors that can minimize the use of power by utilizing existing lighting system.

Acknowledgements

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