Implementation of Vehicular-Visible Light Communication for motorcycle platooning

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Abstract. In this research, we explain the use of visible light communication technology for communication systems between motorbikes, where so far motorcycle lights have only been used for lighting or speed markers. But now, with visible light communication we can use it as a medium to communicate between vehicles, especially motorbikes. Visible light communication (VLC) is a communication system using visible light as an information carrier. VLC has many advantages including in terms of safety, speed, and ease of application to the user to send various types of information including digital data such as text and images. The VLC transmission section will use the LED motorcycle headlamps to send information to the receiver i.e. Light-to-Voltage Sensors are mounted on the back of a motorcycle when several motorbikes are in convoy or platooning. This study describes the use of VLC Vehicle-to-vehicle technology so that motorbikes can communicate with each other so that the motorcycle itself can adjust the distance with other motorbikes in front of him without being under or semi-controlled by the rider. From the results of measurements with the selected transmitter and receiver system, communication between motorbikes can be done up to 130 cm during the day and 180 cm at night. The potential of this technology is that it can truly support communication systems between vehicles such as self-driving motorcycles in the future.

1. Introduction

Vehicles platooning carried out by a group of people on a trip together, or what we have known as Convoys, is an activity that involves many vehicles and is carried out on the highway; therefore, safety is a top priority. Platooning cannot be carried out without proper preparation and clear communication between drivers in a convoy group, miscommunication between motorcycle riders is often a major problem that must be faced. This miscommunication occurs because communication between motorists is assessed with less effective after all. It still used conventional methods such as using a mobile phone or Handy Talky which is prohibited when driving since it can endanger the driver and other people as illustrate on Figure 1.

Management in convoys is also very important, so that between drivers can monitor and know important things, therefore fast communication between vehicles is needed to overcome the problem [1]. As we already known that LEDs are not only be used as illumination but can also be used as transmission media. It also works for LEDs on headlamp of motorcycles. While on the receiver, we can use photodiode which can change the lights into an electrical signal.
Visible Light Communication is a wireless communication system that conveys information by modulating visible light. In this study, we use the head and tail LED motorcycle lights as the transmitter and the light-to-voltage sensors as the receivers. The focus is to realize the communication system between vehicles based on Visible Light Communication. A set of modulators and demodulators communication system will be realized using devices that are easily available on the market so that the target of transmitting and receiving information at a certain distance can be realized by actual environmental conditions. In order to define vehicle communications, one must first differentiate the different types of communication that may occur. Mainly, there are two types of vehicle communication: Intra-vehicle communication reference communications that occur within a vehicle and Inter-vehicle communication represents communications between vehicles or vehicles and sensors placed in or on various locations, such as roadways, signs, parking areas, and even the home garage [2,3].

The primary modes of communication in inter-vehicle communications are the Vehicle to/from roadside communication mode requires using roadside transponders. Vehicle to/from roadside communication supports both vehicle-specific data as well as locally relevant data broadcast to vehicles. This category is referred to as Vehicle-to-Infrastructure (V2I) communication and Vehicle to/from vehicle communication mode includes in-line communications with neighbouring vehicles (including those travelling in the opposite direction and those travelling in the same lane). This category is referred to as Vehicle-to-Vehicle (V2V) communication [4]. Visible light communication (VLC) is an attractive complementary communication technology for vehicular applications such as platooning. Although data rates around 100 kbps are enough for crucial data transmission, it may be useful to reach a few megabits per second for other applications like networking [5]. In addition to the radio frequency (RF)-based dedicated short range communication (DSRC) and long-term evolution (LTE) communication technologies, vehicular visible light communication (V2LC) is proposed as a complementary solution, utilizing readily deployed vehicle light emitting diode (LED) lights as transmitter with image sensors such as photodetector (PD) and camera as the receivers [6]. A vehicular VLC channel model for V2V setting was proposed where an off-the-shelf scooter taillight is used at the transmitting end. Since the Lambertian pattern adopted in the LOS channel model is not able to capture the automotive lights pattern accurately, a piecewise Lambertian channel model was proposed to reflect the asymmetrical intensity distribution of scooter taillight. The analytical results obtained by this model were confirmed with empirical measurements [7,8]. Vehicular VLC (V2LC) between vehicle lighting and smartphone cameras has the potential to enable a great number of applications with low cost. The system utilizes rolling shutter cameras as the receiver and takes advantages of its characteristics to improve the receiving performance. An off-the-shelf vehicle LED taillight is used as the transmitter. The performance evaluation results demonstrate that the communication prototype is robust and can resist common optical interferences and noises within the image [9]. In case of vehicles deployed with V2LC system, most of researcher implement the systems on the car [10-12] to exchange the ECU data each other. In order to broaden the application, motorcycles as mentioned before has another unique implementation such as communicating its distance to prevent safety [13].
2. Vehicular VLC system design

Figure 2 shows a Vehicular VLC system design that is used to send information in the form of motor ID and the distance between motors measured using ultrasonic sensors. The LED motorcycle headlamp and the taillight lamps type used are shown in Figure 3.

![Vehicular VLC System Design](image)

**Figure 2.** White LED Motorcycle Headlights and LED taillight used to send information among motorcycles.

![VLC Circuit](image)

**Figure 3.** VLC transmitter, receiver, and distance measurements circuit.

Before carrying out the measurement scenario, first set the placement of the tool so that the information entered to be processed is accurate data. Tests carried out on the prototype and on the results of the implementation to compare the sensitivity of the installed light-to-voltage sensors.

A microcontroller is used as an OOK modulator, placed in a motorized frame that is directly adjacent to the source of the supply (Accumulator), positioned in the upper part of the frame with a horizontal state and installed using special adhesive/insulation. Next, we used a male-male jumper cable along the 2 meters, this cable is used to connect components located outside the motor framework to microcontroller that is inside the motor frame. The cable installation process is arranged in a motorized frame, so as not to interfere when driving.

Furthermore, the component for the indicator, is placed inside the front of the motor framework, this component is placed inside because it protects from environmental factors (rain, etc.). The LED will be placed inside the existing enclosure, this is also intended to protect the LED from environmental factors as well as to make the driver's vision clearer with the color indicator shown by the LCD. The LCD component will be placed on the outside of the speedometer precisely at the bottom of the speedometer. The distance sensor will be placed in the front of the motor and attached to a cover to measure the distance of the front motorcycle. Figure 4 shows the distance sensor placement.
Figure 4. Implementation of VLC transmitter and distance sensor on motorcycle.

Figure 4 shows the measurement of light intensity sent by the transmitter VLC with 20 cm for the closest to 180 cm at the farthest distance. When is done at night-time conditions at 20:00 using a Lux meter shows a decrease in light intensity of 1697 lux with 20 cm to 68 Lux at 180 cm. The decrease in the intensity of light is directly proportional to the distance between the transmitter and the receiver.

3. Experiment and results
In subsequent experiments testing the performance of the VLC receiver, testing the implementation of the vehicle is done by testing it on a motorcycle that is on and while running at an average speed of 10 km/h, with an average distance of between vehicles of 100 cm, and has been equipped with all supporting components, such as protective cases, lenses, etc.

Table 1. VLC receiver performance test results on a running motorcycle.

| No. | distances (cm) | Measurement from distance sensor (cm) | Measurement displayed on LCD (cm) | Notification on LCD |
|-----|----------------|--------------------------------------|----------------------------------|---------------------|
| 1.  | 48             | 48                                   | 48                               | Danger              |
| 2.  | 91             | 91                                   | 91.92                            | Save                |
| 3.  | 92             | 92                                   | 92                               | Save                |
| 4.  | 95             | 95                                   | 95.95                            | Save                |
| 5.  | 95             | 95                                   | 95                               | Save                |
| 6.  | 93             | 93                                   | 93.93                            | Save                |
| 7.  | 104            | 104                                  | 103.2                            | Save                |
| 8.  | 98             | 98                                   | 98                               | Save                |
| 9.  | 101            | 101                                  | 100.8                            | Save                |
| 10. | 103            | 103                                  | 102                              | Save                |

From the VLC Receiver performance testing on a running motorcycle, the test results described on table 1.
The results indicate that transmitting and receiving data between motorcycles can only be done at a distance of about 98 cm, if the distance is too far, then the data transmission will be error, or the data received cannot be read. In the next experiment, testing the angle of light containing the receiver's VLC information is carried out. Experiments on the illumination angle are carried out to find out which angle that makes data can be received perfectly. This is because in real condition, motorcycles platooning not always in straight line with others. In the experiment using motorcycles where the environment light intensity was around 58 lux, the angle of receiving are special angle and some testing angle are 0°, 5°, 10°, 30°, 45°, 60°, 90°. The distance between the transmitter and receiver are kept 1m with the trial duration is 60 seconds with the lens has been installed.

![Figure 6. Receipt angle of light measurements when VLC Receiver of front motorcycle receiving information.](image)

From the light receiving angle experiment when transmitting information on the motorcycle, table 2 show the test results.

| No. | Angle of Irradiance (°) | Receiving Angle (°) | Information displayed on LCD |
|-----|-------------------------|---------------------|-----------------------------|
| 1.  | 85                      | 5                   | 101                         |
| 2.  | 80                      | 10                  | 10°                         |
| 3.  | 60                      | 30                  | ???                         |
| 4.  | 45                      | 45                  |                             |
| 5.  | 30                      | 60                  |                             |
| 6.  | 0                       | 0                   | 100                         |
| 7.  | 90                      | 90                  |                             |

The results indicate that the angle of light receiving by light-to-voltage sensor with a lens mounted will be successful at angle of 0°, or when the transmitter and the receiver are on a straight path. In addition, it is still possible for the light-to-voltage sensor to receive information at a receiving angle of 5° to 10°, even though the quality of the data received is not optimal.

4. Conclusion and suggestion
Based on the results of a series of tests and analysis on the device, we conclude that in its application, this communication between motors uses a motor LED as a transmitter that sends data containing information that has been tested at a distance of 20cm to 130cm can be received by the photodiode, and at the next distance the data sent data cannot be received. The sending process for the visible light communication system uses a motorcycle LED with 130 cm. The angle of sending information by the transmitter device on communication between motorbikes works well at an angle of 0° to 10° because of its implementation, the position between motorbikes changes not in a straight line because it is very
influential for the quality of information to be sent. For the light intensity of the transmitter during the day the motorcycle LED lights are higher around 1700 lux at a distance of 20cm to 180cm and compared with the night LED motorcycle that is sent around 1697 Lux to 68 Lux this happens because there is no sunlight. In future researches, it can be developed, especially for another Visible Light Communication (VLC) application in daily life, different type of vehicle-to-vehicle communication and vehicle to infrastructure communication. With the series specifications that have been made, the next development is expected to examine the next layer (after the Physical layer). So that in the future communication using VLC technology especially for vehicle-to-vehicle can be even safer or encrypted so it is not easily hacked and can be used for military spy purposes or so on.

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