Key Aspects of Infrastructure-to-Vehicle Signaling Using Visible Light Communications

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Abstract. With the appearance of autonomous cars, an infrastructure-to-car communication system can be easily developed by using the visible light communication (VLC). The red and green lights play an important role in the safety of road traffic, being the most significate colors of the traffic light system. The role of the proposed system is to obtain automatic braking if the traffic lights are red and an audio warning in the case of yellow color by modulating the radiation emitted by the traffic light to transmit a code for each of red and yellow lights. A secondary solution is proposed which avoids the modification of the current infrastructure of the traffic light system by adding a supplementary light emission element. The element consists of an infrared emitter used to send either the red color code or the yellow color code depending on the illuminated traffic light.

Keywords: LED · Visible light communication
Infrastructure-to-vehicle system

1 Introduction

In the dawn of the autonomous cars era, the road infrastructure system no longer meets the necessary requirements. A suitable technology that can be used to provide the necessary needs could be the VLC [1, 2].

VLC utilizes a visible light source, i.e. LED, to transmit information. One of the most important situation in which car accidents occur is at crossroads. Forcing the yellow light at crossroads is, unfortunately, a habit which drastically increases the chance of crossing when the red lights switched on.

The next generation, autonomous, cars could be designed to communicate with the signaling infrastructure, reducing the red light crossing to almost zero. This paper

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investigates the key elements of infrastructure-to-vehicle communication and presents the preliminary results of using VLC to implement such system. Onward, the paper is structured as follows: Sect. 2 describes the proposed communication system, Sect. 3 presents the results, and Sect. 4 concludes the paper.

2 Description of the System

The proposed communication system consists of two subsystems, as shown in Fig. 1. The emission subsystem is mounted on the traffic light and is used to transmit a code for the red light and another code for the yellow light by modulating the voltage applied to the radiating element (usually LEDs) [3]. The code must be chosen in such way to prevent flickering. The second subsystem is mounted on the car and is used to receive the code using an optical receiver and decode it. If the received message corresponds to the red code, the braking of the car will occur. If the message corresponds to the yellow code, an audio warning will alert the car driver that the traffic light is about to turn red. If none of these two codes will be received, then no action will take place.

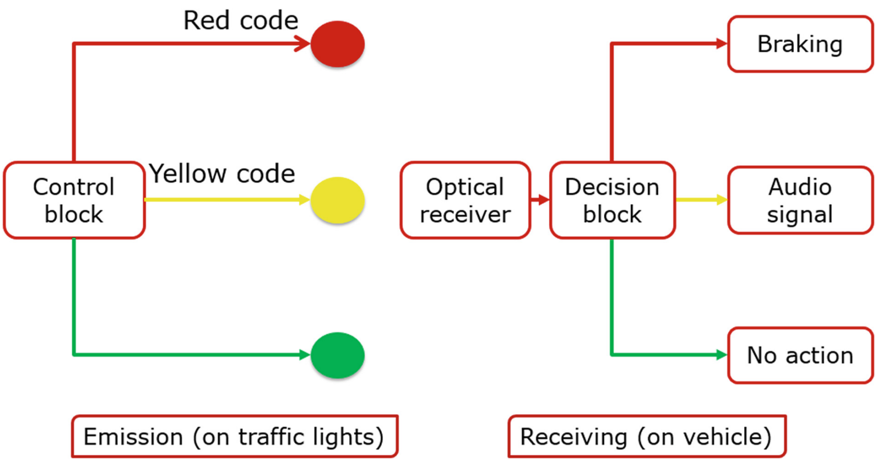

Fig. 1. The block diagram of the infrastructure-to-vehicle signaling system. (Color figure online)

Current signaling system must be modified to permit the modulation of the signal applied to the lamps. A secondary solution which avoids the modification of the current infrastructure of the traffic light system by adding a supplementary emission element to the emission subsystem. The element consists of an infrared emitter used to send either the red color code or the yellow color code depending on the illuminated traffic light. This way the current signaling system must not be modified. Only the information about the light that is on must be extracted, which is a much simpler operation. The receiving subsystem remains the same.

The code consists of synchronization pulses, pulses for logic "0," pulses for logic "1." A word of code is formed by three synchronization pulses and another four pulses representing the four bits carrying the information about the light that is currently on. There were chosen three synchronization pulses for an accurate synchronization (there is a small chance that three synchronization pulses can be obtained by accident. The chances to obtain one synchronization pulse by accident are clearly higher) and four pulses corresponding to the bits to end the code in logic "0". The code would have been ended in logic "0" even if the word would contain only two bits, but four pulses were chosen for possible future expansion of the system. The code is based on the duration between consecutive edges as shown in Fig. 2. The duration between two consecutive edges in case of the synchronization pulse is 50 μs, in case of logic "0" is 200 μs and in case of logic "1" is 100 μs.

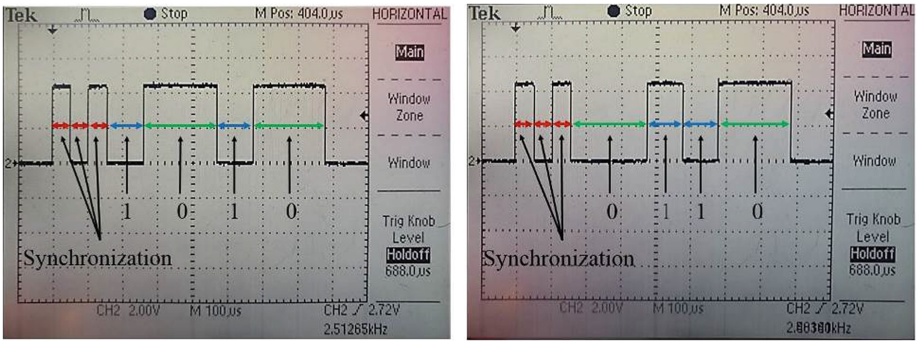

Fig. 2. The waveform of the "1010" (red) and "0110" (yellow) codes at the emitter side. (Color figure online)

On emission, the subsystem consists of a development board that transmits the code "1010" by modulating the red light and the code "0110" by modulating the yellow light. The duration for each word of code is 750 μs and the maximum duration of the code, in case of sending "0000", is 950 μs. In the infrared solution, the development board transmits either the code "1010" or code "0110" through the light emission element depending on the lighted color of the traffic light. Each word is repeated after 775 μs, assuring that flickering will not occur.

The receiving subsystem consists of an optical receiver that captures the light from the traffic lights, transforms it into voltage and, depending on the decoded code, sends the command to brake the car or to transmit an audio warning.

3 Results

The system discussed in the above section was implemented. The emission subsystem consists of a red LED, a yellow LED and a microcontroller. The receiving subsystem consists of an optical receiver (TSL14S), a red LED, a yellow LED, a blue LED and a microcontroller.

In Fig. 3, the microcontroller modulates the voltage applied to the yellow LED with the waveform for the code "0110", therefore, and the TLS14S receives the code from the light emitted by the LED, and if the message was correctly decoded and it corresponded with the code used for the yellow light, the yellow LED who plays the role of the audio warning lights up. A supplementary blue LED is used to determine if the receiving subsystem is powered up.

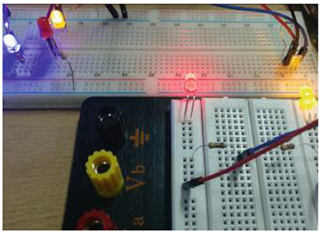

Fig. 3. The system transmits the code for yellow light ("0110" – right side of the picture) and the receiver successfully decodes it by turning on the yellow LED on its side (upper left side of the picture). (Color figure online)

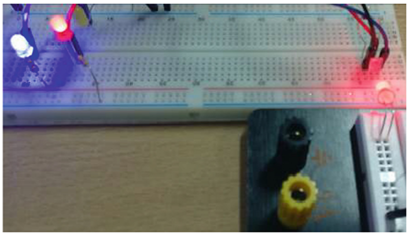

Fig. 4. The system transmits the code for red light ("1010" – right side of the picture) and the receiver successfully decodes it by turning on the red LED on its side (upper left side of the picture). (Color figure online)

In Fig. 4, the same situation presented above is repeated for the red LED.

In Fig. 5, the infrared solution is implemented and the microcontroller transmits the code "0110", and if the TSL14S received the code corresponding with the yellow light, the yellow LED lightens up.

In Fig. 6, the infrared solution is implemented and the microcontroller transmits the code "1010", and if the TSL14S received the code corresponding with the red light, the red LED lightens up.

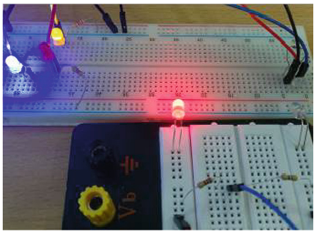

Fig. 5. The infrared LED transmits the code for the yellow light and the receiver successfully decodes it (the yellow LED is lit on the receiver side – upper left of the image). (Color figure online)

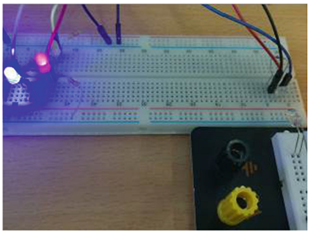

Fig. 6. The infrared LED transmits the code for the red light and the receiver successfully decodes it (the red LED is lit on the receiver side – upper left of the image). (Color figure online)

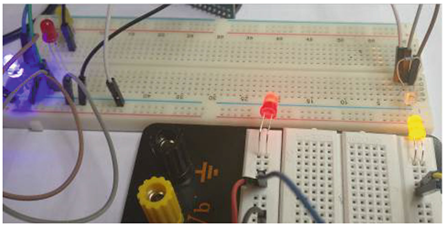

Fig. 7. The system transmits the yellow code, but because of the strong ambient light, the receiver is blinded and unable to decode. (Color figure online)

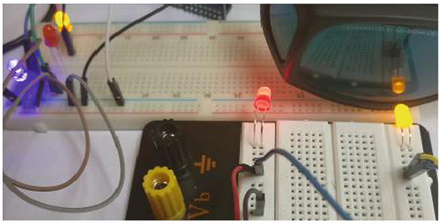

Fig. 8. An optical filter (Thorlabs LG4) placed in front of the receiver solves the blinding problem, ensuring proper decoding. (Color figure online)

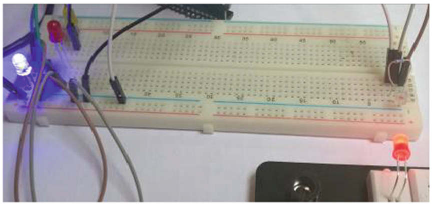

Fig. 9. The system transmits the red code, but because of the strong ambient light, the receiver is blinded and unable to decode. (Color figure online)

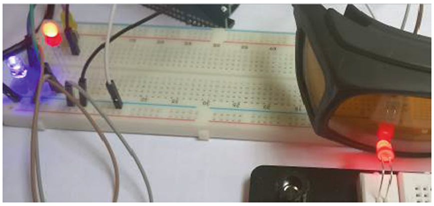

Fig. 10. An optical filter (Thorlabs LG10) placed in front of the receiver solves the blinding problem, ensuring proper decoding. (Color figure online)

In real situations, the receiver could be blinded by the ambient light during the day or by flashlights during the night. These situations were investigated in small scale conditions. In Fig. 7, the system transmits the code for the yellow light, but because of the strong ambient light, the receiving subsystem is not able to decode the received message and the yellow LED remains off to indicate this. To solve this problem an optical filter (Thorlabs LG4 glasses [4]) is placed in front of the receiver. In Fig. 8, the system transmits the code and the receiving subsystem is now able to decode the code properly because the ambient light was filtered and the TSL14S receives the incoming message.

In Figs. 9. and 10, the system transmits the code for the red light. In Fig. 9 the system it is not able to decode the received message, and in Fig. 10 an optical filter (Thorlabs LG10 [5]) was placed in front of the receiver to insure the correct decoding of the transmitted message.

The objective of this paper was to present the key elements of infrastructure-to-vehicle signaling. All the experiments in this paper were done using low power LEDs to highlight only the principles. High power LEDs [6] are to be used in real situations to assure a sufficient range.

4 Conclusions

The paper proposes an optical communication system used for the transmission of the messages between vehicles and the automotive infrastructure. The system consists of two subsystems, one for the transmission of the codes for the red and the yellow lights, and another for the receiving and the decoding them. A secondary solution was developed to avoid the modification of the current infrastructure of the traffic light. The supplementary light emission element consists of an infrared emitter used to send either the red color or the yellow color code depending on the illuminated traffic light.

The code consists of synchronization pulses, pulses for logic “0,” pulses for logic “1”. A word of code is formed by three synchronization pulses and four bits, but any even number of bits can be used to assure the return to zero, for further development. The duration of the pulses must be scaled accordingly to avoid flickering. The code is based on the duration between consecutive edges. The duration for each of the code is 750 μs and the maximum duration of the code is 950 μs.

It was seen that the system could not work in strong lighting condition, therefore an optical filter solution was proposed to filter the ambient light and to ensure the properly decoding of the received message. The next steps of the research includes measuring the optical responsiveness of power LEDs to determine their suitability for visible light communications.

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References

1. Pathak, P.H., Feng, X., Hu, P., Mohapatra, P.: Visible light communication, networking and sensing: a survey, potential and challenges. IEEE Commun. Surv. Tutorials **17**, 2047–2077 (2015)
2. George, J.J., Mustafa, M.H., Osman, N.M., Ahmed, N.H., Hamed, D.M.: A survey on visible light communication. Int. J. Eng. Comput. Sci. **3**, 3805–3808 (2014)
3. Ionescu, C., Vasile, A., Codreanu, N., Negroiu, R.: Comparative studies on dimming capabilities of retrofit LED lamps. In: Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies, pp. 100102Z–100102Z-10. International Society for Optics and Photonics, Constanța (2016)
4. Thorlabs LG4 glasses datasheet. https://www.thorlabs.com/drawings/13f86c35c264a5c9-7DC5C175-F09C-1A63-77480014951A8907/LG4-SpecSheet.pdf. Accessed 14 June 2017
5. Thorlabs LG10 glasses datasheet. https://www.thorlabs.com/drawings/13f86c35c264a5c9-7DC5C175-F09C-1A63-77480014951A8907/LG4-SpecSheet.pdf. Accessed 14 June 2017
6. Ionescu, C., Drumea, A., Codreanu, N.D., Vasile, A.: Thermal investigations on high power LEDs. In: Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies, pp. 84112Y–84112Y-10. International Society for Optics and Photonics, Constanța (2012)