Short range visible light communication for high-speed data transfer using low-cost optoelectronic components

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Abstract. High-speed wireless communication is required to carrying out high-quality data. It can be realized by increasing data capacity with enlarging operational bandwidth. As we know, light has very large operational bandwidth with a drawback of large propagation loss in free-space (air). Therefore, high-speed communication can be realized using light with short coverage area. Light has wide spectrum include visible light region. The visible light is used as a lamp for lighting in a room. The lamp with laser emitting diode (LED) is widely used due to its characteristics of low electric power consumption with bright light. Visible light for communication is promising for smart home. In here, we report our research activity to realize and demonstrate visible light communication with low-cost optoelectronic devices such as laser diodes and photo detectors. Demonstration of the short range visible light communication to carry out digital data is reported.

1. Introduction

Nowadays, electromagnetic-wave is widely used for many applications such as sensing, communication, and so on [1]. Electromagnetic-wave have very wide spectrum between radio and optical bands. Therefore, certain specification such as cost, resolution, speed, and so on can be realized using the wide electromagnetic spectrum. In communication, the electromagnetic wave can propagate through wired with a metal cable or optical cable and wireless in air space.

Based on the Cisco report for traffic forecasting, global IP traffic in 2016 stands at 96 EB per month and will nearly triple by 2021, to reach 278 EB per month. Consumer IP traffic will reach 232.7 EB per month and business IP traffic will be 45.5 EB per month by 2021 [2]. In order to facing the problem, high speed and high quality communication should be provided through wired and wireless links. In wired link, optical fiber can be used for carrying out the data with lightwave as the carrier with low propagation loss characteristics [3]. In wireless link, bandwidth for carrying data should be enhanced in the used radio or optical bands [4]. Since mobile devices are widely used for communication, therefore wireless link with high-speed and high-quality is required in the future to anticipate future traffic bottleneck problems.

Wireless optic link is one candidate to solve the problem. Optical bands have large bandwidth to carrying the data since it has very high operational frequency. Light has wide spectrum include visible light region. The visible light is used as a lamp for lighting in a room. The lamp with laser emitting diode (LED) is widely used due to its characteristics of low electric power consumption with bright light. Visible light for communication is promising for smart home [5].

In here, we report our research activity to realize and demonstrate visible light communication with for data transfer using simple optoelectronic circuits with laser diodes/ laser emitting diode and photo detectors. The proposed visible light communication is designed with low cost optoelectronic devices. Demonstration of the short range visible light communication to carry out digital data is also reported.
2. Visible Light Link

Figure 1 shows the basic structure of visible light links with optical transmitters and receivers. Optical transmitters are using laser diode or light emitting diode as conversion device from electrical to optical signals. The transmitting module requires a driving circuit with broadband and high-speed operation. Optical receivers are used photodiode as conversion device from optical to electrical signals. The receiving module requires a signal conditioning to identify the received data. The light propagates through air space for a distance.

![Figure 1. Basic structure of visible light links.](image)

Figure 2 shows the proposed visible light link with simple optoelectronic circuits for experiment which consist mainly of a single white LED and a single photodiode. The electronic driver circuit is controlled using a microcontroller unit to generate logical data. Therefore, the generated logical data can be modulated to the light from the LED as a carrier-wave. The modulated light is transmitted to the free-space then received and converted to electrical signal by the photo-diode and not gate conditioning. The converted electrical signal is sent to a PC through a serial to USB converter. As a result, the logical data can be displayed on the PC display. An oscilloscope is also used for observing the electrical logical data close to the LED and photodiode.

![Figure 2. Proposed visible light link with simple optoelectronic circuit.](image)

3. Experiment

Figure 3 shows the experiment setup for the proposed visible light link using simple optoelectronic circuits. The transmitted and received signals were observed electrically by an oscilloscope to identify that the data can be transferred through lightwave wirelessly. The distance between the white LED and photodiode in the measurement was set up to 0.1m. The digital data was generated electrically by microcontroller. The generated data was passed through driving circuit for LED. As a result, the
driving circuit can drive the LED with on-off to indicate the digital data. Based in this, we can observed the electrical transmitted signals using oscilloscope. Then the modulated lightwave propagates through air space and detected by photodiode. In order to identify the transferred electrical data, we can use simple signal conditioning with not gate logic. As results, the received signal has opposite logic with the transmitted signal. Finally, we sent the electrical signal to personal computer using RS232 to USB converter for communication and displayed the data.

Figure 3. Experiment setup.

Figure 4. Measurement of the transmitted signal (top) and received signal (bottom) for several distances (a) about 10cm, (b) about 20cm and (c) about 30cm.
In measurement, the transmitted and received signals were observed using oscilloscope as reported in Figure 4 for several distance variation. Based on the results, the digital data were successfully transferred wirelessly through lightwave. When the distance between optical transmitter and optical receiver is changed, amplitude of the electrical received signal was changed also. It mean, propagation characteristics of optical signals in air space with the distance.

In this current experiment, we used single LED and single photodiode. Therefore, short distance visible light communication can be realized. Based on this, we believe that large distance visible light communication can be realized using array of LED and array of photodiode to improve sensitivity of the wireless optical link. Furthermore, it can be used for indoor communication in smart home application with a distance of ~5m.

4. Conclusion

Visible light communication with for data transfer using simple optoelectronic circuits was realized with laser diodes/ laser emitting diode and photo detectors. The realized visible light communication was demonstrated for transferring digital electrical data. The electrical data was successfully transferred through lightwave wirelessly in the link. Lightwave propagation in air space can be also observed using the link since the received electrical signal is changed for different distance. Sensitivity of the visible light link can be also increased furthermore using array structure of optical transmitters and receivers.

We are attempting to realize visible light link for high speed communication to transfer high quality data. It can be applied for indoor communication in the future.

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