**Data transmission using light (Li-Fi)**

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**Abstract**

Li-Fi is a wireless communication technology which, unlike Wi-Fi, utilises light insted of radio waves to transmit data accross two devices. This term was introduced by the german professor Harald Haas, from the University of Edingurgh, UK, in 2011. Li-Fi data is transmitted in binary form, where “0” is the *OFF* state of the LED, and “1” is the *ON* state of the LED. The experiment is made from two sections, the receiver and the transmitter. The receiver and the transmitter sections contain two Arduino modules that have been programmed through the Arduino IDE. A high-power LED, running on a voltage of 5 volts, is used in the transmitter circuit, and a photoresistor that is part of a voltage divider circuit, is used to detect the light from the LED.

1. **Introduction**

The light fidelity technology (Li-Fi) is a communication technology that transmits data using light instead of radio waves. The ideal implementation of a Li-Fi communication system switches the light source from *OFF* to *ON* and back faster than the human eye can see, making the transmission of data unnoticeable and at the same time reaching very high speeds of transmission. This technology can be used with infrared, visible or ultraviolet light.

The biggest advantages of this technology are the increased speed of transmission over radio waves, which is given by the difference in frequency between visible light and the radio waves used by Wi-Fi, and the reduction in electromagnetic interference, which makes a big difference in radiation sensitive areas such as hospitals and aircrafts. Since light cannot travel through walls, the transmission space is restricted, making the system more resistant to hacking, but also reducing the range of the system. Another advantage that these systems have is the increased bandwidth. The visible light spectrum is 10.000 times wider than the radio spectrum, which means that Li-Fi can reach higher transmission speeds, upwards of 224 Gbit/s, whereas current top of the line Wi-Fi devices can reach a maximum of 9,6 Gbit/s, and it also means that there is a larger number of frequencies that can be used before it is saturated.

One of the disadvantages of using visible light to transmit data is that other sources of illumination, e.g. the sun, regular home lights, will interfere with the data transmitted. Another disadvantage is that to be able to reach the functionality of Wi-Fi, the device that is meant to be the receiver also needs to be able to transmit data, so that communication can be in both directions. This can be partially fixed using Li-Fi just for the downstream signal to a mobile device and using Wi-Fi for the upstream, at least until we can mount strong enough transmitter circuits on our mobile devices.

1. **Method**

A diagram of a computer system

Description automatically generatedIn order to show how data can be transmitted wirelessly with the help of light, the experiment contains two discreet circuits, as shown by Figure 1., connected to each other only by light, the first one, which is driven by an Arduino Mega 2560 compatible board, is the transmitter and it also contains a high power green LED and the second one uses an Arduino Uno compatible board and a photoresistor to read the voltage received from the LED.

Figure 1. Circuit diagram

A yellow rectangular sign with black text

Description automatically generatedFigure 2. Transmitter block diagram

A screenshot of a computer

Description automatically generatedThe above Figure 2. shows the main components of the transmission circuit. The first step in the transmission process is getting the data that needs to be transmitted. Data is transmitted in a serial process, bit by bit, in binary form, “0” being represented by the LED being *OFF* and “1” is represented by the LED being *ON*. The circuit is designed to wirelessly transmit text data, strings or characters, which are inputted from the keyboard of the connected computer into the Serial Monitor of Arduino IDE. From there the data is transferred to the microcontroller using the RS 232 protocol over USB. Each character is transformed into the 8-bit representation of its ASCII code and the microcontroller turns the LED *ON* or *OFF* at a specific period, depending on the state of those 8 bits. For educational purposes, so that the change of state of the LED can be seen, the transmission period is 100ms, too slow for data transmission and noticeable to the human eye.

Figure 3. The transmission of two bytes

In Figure 3, the input to the transmitter is ‘UU’, which is converted to ‘10101010 10101010’ and the bits that signal the start of transmission and the bits that are in between bytes are introduced, after which the LED is commanded with the binary information that was computed.

In addition to the code that transforms the input data into binary information, the microcontroller also has a calibration function, used to synchronize and match the transmission period for the receiving circuit. This is achieved through transmitting a single pulse, a “0” followed by a “1”. The calibration function is activated when the string “calibrate” is inputted from the computer.

A diagram of a computer

Description automatically generatedFigure 4. Receiver block diagram

A diagram of a photoresistor

Description automatically generatedThe receiver circuit is controlled by an Arduino Uno microcontroller, that is the reader and interpreter of the signals received by the photoresistor from the LED. An Arduino cannot read resistance directly, only voltage can be read with its analog input pins, so the photoresistor need to be part of a voltage divider circuit, so that when the resistance of the photoresistor fluctuates with light intensity, the voltage read by the Arduino will also vary, between 0 and 5 volts.

Besides the photoresistor, the Arduino has another input, a button that activates the calibration function, which is essential for receiving the data correctly.

The output devices of the receiver Arduino are a 1-inch, monochrome OLED display that is used to display the received strings after the data was computed and decoded from binary to characters, and a serial RS 232 output stream over USB, which is used for monitoring the receiving of data bit by bit, shown on the Serial Monitor of the Arduino IDE.

As stated above, the circuit includes a temporary button that when pressed will activate a critical calibration function. This function works by firstly setting the reading threshold, the value that differentiates ‘1’s from ‘0’s and that value is calculated with the formula written below this paragraph. The second part of the function calculates the period in which data will be received from the transmitter, using a predefined Arduino function, millis(), a function which returns the time passed from when the board is powered on, in milliseconds.

Because the transmitter is designed to hold the LED fully lit when data is not transmitted, and the LED going *OFF* signals the start of transmission, the receiver circuit is designed to wait until the LED goes *OFF* and then to start listening for data, using the period calculated in the calibration function.

When the character “~” is received from the transmitter, the receiver Arduino resets the OLED screen, clearing it and setting the cursor at the start of the display area.

A group of electronic components

Description automatically generatedA circuit board with wires and wires

Description automatically generated

1. **Conclusion**

The purpose of this circuit is to show how data can be transmitted through light. Because a photoresistor was used, the period of transmission will be limited to around 20 milliseconds, but in a real implementation of Li-Fi technology, the switching time of the LED can be faster than a human eye can see.

There are many challenges with the implementation of Li-Fi communication systems, at least with current technology, but the advantages, the hacking resistance, the increase in the speed of transmission, and the increase in the spectrum of frequencies that can be used, tell us that Li-Fi is the technology to used in the future for wireless communication.

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