ES-116 (2024) Course Project Laser Based Wireless Communication System

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***Abstract*—This project aims to develop a laser-based wireless communication system using LiFi (Light Fidelity) principles. The system comprises an Arduino-based transmitter and receiver. The transmitter performs a two step encoding, converting characters, to ASCII values (numerical values in range 0 to 255), then to binary (8 bit). Consequently, in the reverse sequence of steps, this is decoded at the receiver. The receiver, housed in a cardboard casing, utilizes a solar panel to detect the transmitted light pulses. A threshold analog value is used to decode the message, which is then displayed on the serial monitor. Through this project, we aim to explore the practical implementation of LiFi technology for wireless communication.**

I. Aim

TO develop a laser based wireless communication system, based on the principle of LiFi (Light Fidelity).

II. Theoretical Descriptions

A. Laser Diodes and Laser-Based Communication

Laser diodes emit light through stimulated emission, producing intense, narrow-bandwidth, and directional light ideal for applications like laser-based communication systems. In our project, we send binarized data via the laser diode as light pulses, representing ”ON” (1) or ”OFF” (0). Each bit's duration is 10 milliseconds, with a 100-millisecond gap between consecutive bits.

> Example: For a 2-bit binary number like ’10’, the laser pulse is on for 10 ms to represent ’1’, followed by 100 ms off, then another 10 ms off. Thus, the total transmission time for 2 bits is 120 ms.

Laser-based communication uses modulated light pulses from laser diodes to convey information. These pulses travel through optical fibers or free space, enabling fast and reliable data transmission over long distances. Our project involves transmitting data through the air.

Laser diodes in communication systems typically have three main pins: positive, negative (ground), and signal. At the receiver end, photo-detectors (such as a solar panel in our case) capture the transmitted light pulses and decode the encoded information.

B. ASCII based 8-bit encoding

ASCII (American Standard Code for Information Interchange) assigns numerical values to characters, enabling computers to represent text using binary code. Each character has a unique 8-bit binary code, allowing it to be transmitted and decoded. This method facilitates sequential sending and communication of text-based information.

> Example: In ASCII, the letter ’A’ is represented as the binary number 01000001. At the receiving end, the binary data is decoded back into its original ASCII characters, allowing the transmitted message to be understood. This is shown by the binary representation of ’A’ as 01000001.

C. LiFi (Preliminary)

LiFi, or Light Fidelity, is a wireless communication technology using light to transmit data, like how Wi-Fi uses radio waves. It employs light, often from LED bulbs or laser diodes, to send and receive data. Information is encoded into light pulses and decoded by photosensitive receivers like photodiodes or solar panels. LiFi offers high-speed data transmission, security, and immunity to electromagnetic interference, making it useful for indoor wireless communication and internet connectivity.

III. Instruments Required

Following is the list of instruments used in the project:

- Red Laser diode (5mW, 5V, 650mm)
- Arduino Uno board (for both transmitter and receiver)
- Solar panel (for receiver)
- Breadboard and jumper wires
- Cardboard casing for the receiver
- Laptop (for encoding and decoding using Arduino IDE)

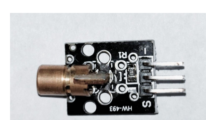

Fig. 1: Laser Diode

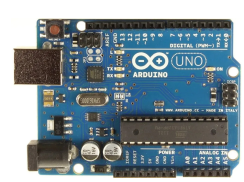

Fig. 2: Arduino Uno Board

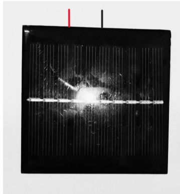

Fig. 3: Solar Panel

IV. Procedure

A. Steps by step methodology employed :

1) Mount the laser diode on a breadboard (we performed without a breadboard but for stability a breadboard is essential) and connect its pins to the Arduino for transmission.
2) Set up the solar panel in a cardboard casing (self made casing) and connect it to the other Arduino for receiving signals.
3) Connect both of these Arduino's to an IDE (Integrated Development Environment) software, on two separate Laptops.
4) Run the code to observe the readings from the solar panel when exposed to light (laser) and when not, in order to establish the appropriate threshold.
5) Run the code in C (Encoding-Decoding Algorithm), compile it and then upload it on the appropriate port, and view the serial monitor.
6) Ensure proper alignment between the laser diode and the solar panel for proper transmission and reception. (This is a challenging step, discussed further).
7) Write a message on the transmitter and send it. View it being decoded in real time on the receiver's serial monitor.

B. Essential code and it's explanation

The following is the link to the GitHub repository.
(Please read the README file for reference.)

V. Time Analysis of Signal Communication

We calculated the BIT Rate of our data transfer:

- Let's assume we're sending "N" characters from the transmission side of our project.
- For each character we send, we require 8 bits.
- So, for "N" characters, we need to send 8*N bits.
- To transmit each bit, we need 10 milliseconds of time, as that's the minimum delay time for our laser diode to blink.
- Therefore, for 8*N bits, we need 80*N milliseconds of time.
- To reduce errors in sending large characters, we are taking a 100-millisecond delay between each letter of our sentence.
- Since there are "N" letters, the overall delay will be 100*N milliseconds.
- So, the overall time taken to send an "N" character sentence will be 80*N milliseconds + 100*N milliseconds.

If we are transmitting **N characters**, then the time taken will be **0.18 * N seconds** or **180 * N milliseconds**

VI. Images (Transmitter, Receiver and casing)

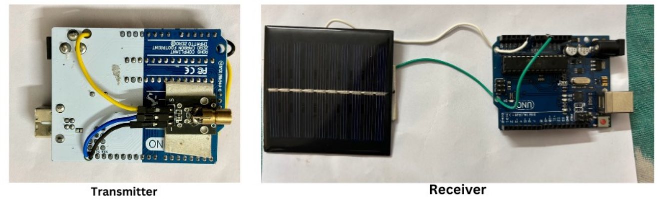

Fig. 4: Laser attached to the back of an Arduino UNO (Left) and Solar Panel connected to an Ardunio UNO (Right)

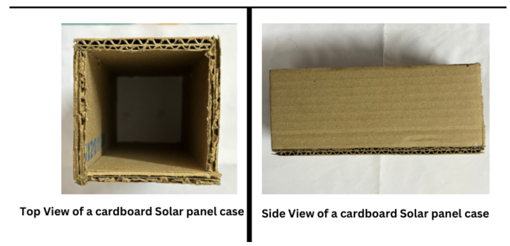

Fig. 5: Cardboard casing to block ambient light at recevier.

Note: In order to view the practical setup and demonstration at the Indoor Volley Ball Court, IIT-GN, refer to the YouTube Video.

VII. Challenges Faced and Potential Scope of Improvement

A. Challenges Faced

1) Initially, utilizing a photodiode with limited surface area hindered our ability to effectively focus the laser diode for long-distance transmission.
2) Transitioning to a solar panel at the receiver end introduced challenges related to ambient light sensitivity, causing fluctuations in our threshold value. Mitigation involved enclosing the panel within a cardboard box.
3) Aligning the laser diode for optimal transmission distance posed significant hurdles. Even minor adjustments resulted in notable displacements of the laser pointer at greater distances. Additionally, the insufficient power output of our 5mW, 650nm, 5V laser diode led to intensity reduction over extended ranges due to scattering effects, requiring constant threshold recalibrations.

B. Potential Scope of Improvement

1) **Range:** Clean data transmission was constrained to approximately 10 to 12 meters due to limitations in laser intensity and beam divergence. Overcoming these limitations through the adoption of higher-quality lasers and more sensitive sensors could enhance both the range and precision.
2) **Memory:** The Arduino Uno's 32 KB flash memory, while suitable for basic data, proved inadequate for transmitting

large datasets such as image pixels. Upgrading to a microcontroller with expanded memory capacity could help.

3) **Transmission Channel:** We were unable to test our laser and sensor underwater due to logistical constraints. Exploring alternative transmission channels such as water or glass could provide valuable insights and expand the application scope.