EEP3010

Communication Systems Lab

Introduction to LiFi And BER analysis of end to end optical wireless communication system

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Abstract:

Li-Fi (Light Fidelity) is a data transmission technique that uses Illumination for transmitting data using light as a medium of transmission. Here data is transmitted by varying the intensity of light produced by LEDs. Li-Fi, also known as Optical Wireless Technology, provides better bandwidth, higher efficiency and security, and high speed. In this experiment, a simple setup of Li-Fi is made and tested in variable conditions such as with noise(in sunlight) vs without noise, the variable distance between transmitter and receiver, and variation of sound quality with distance.

This experiment explores the fundamentals of Li-Fi technology, a wireless communication system utilizing light for data transmission. The setup involves LEDs and pen LASERs as transmitters, solar panels as receivers, and various configurations to analyze sound quality. Additionally, the experiment delves into the Bit Error Rate (BER) analysis of an end-to-end optical wireless communication system employing Free Space Optical (FSO) communication.

The Li-Fi experiment investigates the impact of a dark box on sound quality, varying distances between the transmitter and solar panel, and altering the light source from LED to pen LASER. Multiple scenarios, such as blocking the link between LED and solar panel and using LED arrays, are explored to understand the nuances of Li-Fi communication.

In parallel, the BER analysis experiment examines the FSO system's components, including an optical power meter, attenuator, Erbium-doped fiber amplifier (EDFA), Bit Error Rate Tester (BERT), and collimators. The goal is to measure the BER under different conditions, adjusting transmitted power and using attenuation to simulate real-world scenarios.

Objective:

The primary objective of this experiment to familiarize the students with Li-Fi technology, a wireless communication system utilizing light for data transmission. In this experiment we set up a Li-Fi setup and transmit audio signals and observe how different parameters affect sound quality. The main parameter considered are distance , different light sources (LEDs and pen LASERs), the number of LED arrays and the with noise and without noise.

In this experiment we also observe about BER Analysis of Optical Wireless Communication System. We analysis Bit error rate(BER) of an end-to-end optical wireless communication system. We investigate the effects of different parameters, such as transmitted power and attenuation, on the BER in a Free Space Optical (FSO) communication setup.

Experimental Procedure:

LI-FI Experiment : In this experiment we need to determine the signal noise ratio or the affect of the quality of the sound by varying the number of LED arrays as (2,4,8) and varying distance(10 cm, 20 cm,30 cm) . The same experiment will do under two condition one with noise and other without noise. In this experiment we also find the effect of quality of sound at distance from start of LED 1 , mid of LED1 and LED2 , end of LED2 and at last.

The equipment required are:

- LEDs(3)
- Pen LASER
- solar panel (1)
- aux cables (2)
- breadboard (1)
- voltage source (1)
- speaker (1)
- No of LED arrays (2,4,8)

The circuit diagram we initially need to connect is:

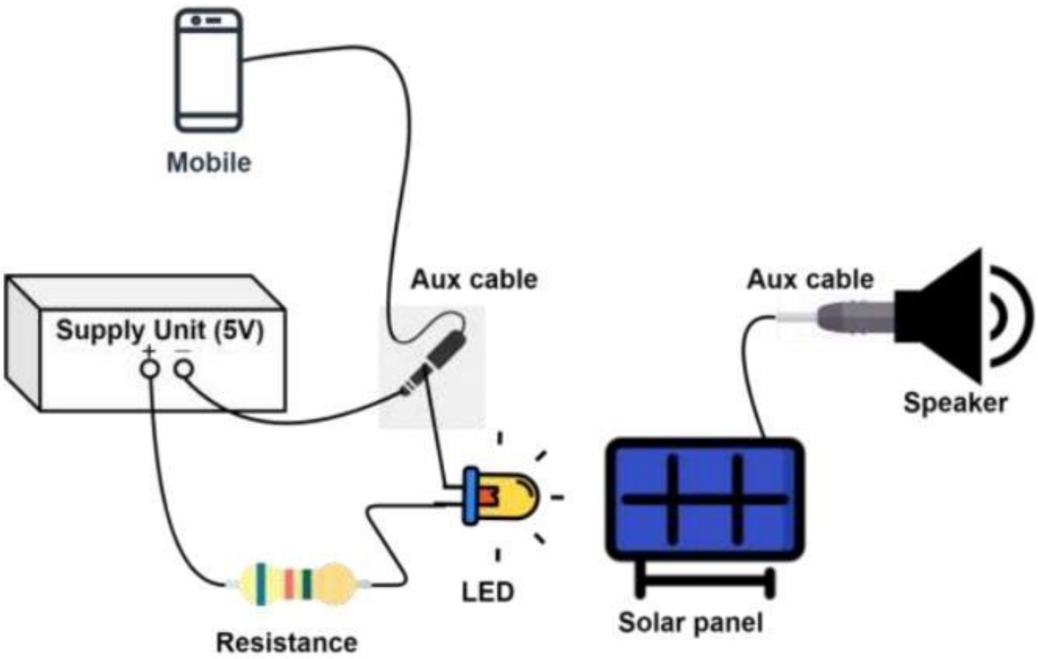


Figure 1

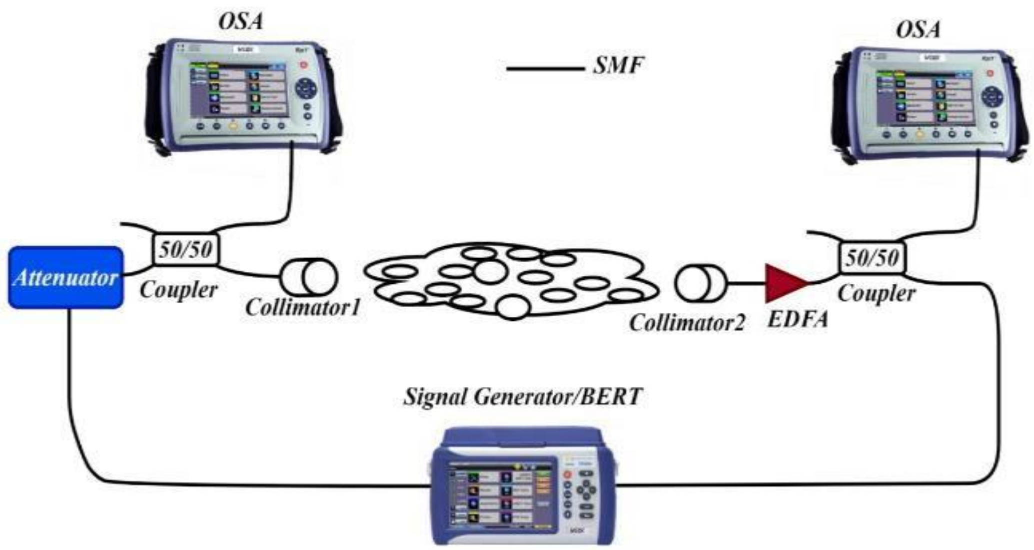
Procedure for this part of experiment is:

- First, we need to set up the transmitter. We do this by connecting the LED to a supply unit in series with an AUX cable connected to the audio source(mobile phone) in our case.
- The supplied potential at the AUX varies along with the amplitude of the audio signal from the mobile. This causes potential difference across the LED to vary accordingly thus changing its intensity with respect to the audio signal.
- For the receiver part, we used a solar panel. This was then connected to an AUX cable to a speaker. The AUX cable is used to transform the signal into a usable form

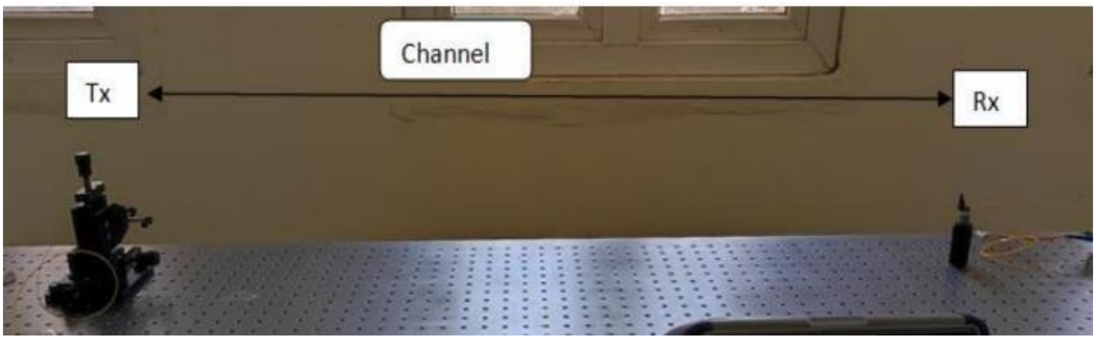
for the speaker. The solar panel produces a voltage that varies with respect to the intensity of the light illuminating the panel surface.

- Task 1: We compared the sound quality of the received signal when the setup was kept inside a dark box and outside.
- Task 2: Next we varied the distance between the LED and the solar panel and compared the sound quality as the distance was varied. The distance we taken for experiment is at 10 cm , 20 cm , 30 cm.
- Task 3: We change the number of LED arrays as 2 , 4 , 8 one by one and observe the sound quality.
- Task 4: A pen laser was used instead of LED. The sound quality was compared between the two sources.
- Task 5: Next, the light from the LED was blocked and the sound received was observed.
- Task 6: Three LEDs were placed linearly separated by 15cm between each and the solar panel was moved from one end to another. The resulting variation in sound quality was observed.

BER Analysis Experiment : FSO (free space optical) communication is a technique that transmits data by propagating light in free space, allowing optical connectivity. FSO is a line of sight technology where data, voice, and video communication are achieved.



System model of end to end FSO communication



The channel can be atmosphere, space, or vacuum, whose characteristics determine the transmission and reception of optical signals for designing reliable and efficient communication systems. Using FSO technology, data is transmitted by propagating light through atmospheric or space communication channels, allowing optical connectivity.

The equipment required are:

- Optical Power Meter
- Optical Attenuator
- EDFA(Erbium- doped fiber amplifier)
- BERT(BERT – VeEx VEPAL TX300)
- Collimator
- Patch Cords (LC-LC Patch cord ,LC-FC Patch cord ,SC-Patch cord)
- IPA
- Cutter (CT50)
- Receiver with PIN Detector

Procedure for this part of experiment is:

- Strip off the outermost layer of the optical fiber carefully using fiber strippers.
- Remove any protective coatings or jackets to expose the bare fiber.
- Use a precision cleaver to cleave the fiber end. A cleaver ensures a clean and flat break in the fiber, providing a proper surface for fusion splicing.
- Use a fiber microscope to inspect the cleaved end of the fiber. Ensure it is clean and free from any contaminants.
- Turn on the fusion splicer and allow it to initialize.
- Clean the fusion splicer's V-grooves and electrodes using appropriate cleaning tools.
- Carefully place the prepared fiber into the fusion splicer's fiber holders, ensuring proper alignment.
- Initiate the fusion splicing process. The splicer aligns and fuses the optical fibers, creating a low-loss joint.
- The fusion splicer may have an automatic or manual mode for initiating the fusion process.
- After fusion splicing, inspect the quality of the splice using the splicer's microscope or a separate fiber inspection tool.
- Ensure the splice is smooth and has minimal loss.
- Then , we configure the Bit error rate tester (BERT).
- Connect all devices, including the FSO transmitter and receiver, optical power meter, optical attenuator, EDFA, and collimators.
- Align the transmitter and receiver collimators carefully.
- Use the attenuator to adjust the power level.
- Comparing BER values under different conditions.

Test Results:

The signal noise ratio is calculated using formula:

$$SNR = \frac{(Signal + Noise) - (Noise)}{Noise}$$

Using 2 LED arrays and outside dark box:

Distance(cm)	Signal + Noise (Volt)	Noise(Volt)	Signal Noise Ratio
10 cm	15.6 V	14.6 V	0.068
20 cm	15.2 V	15.1 V	0.006
30 cm	16.3 V	15.6 V	0.044

Using 2 LED arrays and With dark box:

Distance(cm)	Signal + Noise (Volt)	Noise(Volt)	Signal Noise Ratio
10 cm	2.6 V	1.2 V	1.16
20 cm	3.5 V	1.26 V	1.77
30 cm	6.4V	2.3 V	1.57

Using 4 LED arrays and outside dark box:

Distance(cm)	Signal + Noise (Volt)	Noise(Volt)	Signal Noise Ratio
10 cm	15.6 V	13.3V	0.1729
20 cm	15.4 V	15.2V	0.013
30 cm	16.5 V	15.9 V	0.037

Using 4 LED arrays and with dark box:

Distance(cm)	Signal + Noise (Volt)	Noise(Volt)	Signal Noise Ratio
10 cm	7V	2.6V	1.69
20 cm	4.2V	1.4V	2
30 cm	2.4V	1.2V	1

Using 8 LED arrays and outside dark box:

Distance(cm)	Signal + Noise (Volt)	Noise(Volt)	Signal Noise Ratio
10 cm	16.4 V	14.8 V	0.108
20 cm	15.6V	15.1 V	0.033
30 cm	15.8V	15.1 V	0.046

Using 8 LED arrays and with dark box:

Distance(cm)	Signal + Noise (Volt)	Noise(Volt)	Signal Noise Ratio
10 cm	10.9 V	3.7 V	1.94
20 cm	5.8 V	1.9 V	2.05
30 cm	3.1 V	1.44 V	1.15

- Observation 1: In an open environment, we noted a slight degradation in sound quality due to the presence of background noise. However, when placed within a dark enclosure, the audio clarity significantly improved.
- Observation 2: Varying the distance between the LED and solar panel revealed an inverse relationship between distance and sound loudness. As the distance increased, the loudness of the sound decreased.
- Observation 3: The quality of sound in Li-Fi communication is directly impacted by the quantity of LED arrays. Increasing the number of arrays positively influences signal strength and, consequently, enhances audio transmission quality.
- Observation 4: Laser, as a focused light source, demonstrated superior signal transmission capabilities over larger distances compared to LEDs. Despite its advantages, using lasers limits the coverage area, requiring the receiver to remain stationary.
- Observation 5: Blocking light from the LED resulted in noise on the speaker, attributed to sunlight and background noise in open conditions. However, in a dark enclosure, no audio was received.
- Observation 6: Moving the solar panel across different positions revealed maximum sound intensity when directly above the LED (minimal distance). Conversely, placing the panel between two LEDs resulted in minimum sound loudness due to reduced light reception at that point. At the end we observe it is minimum because light reception is very less at that point.

Discussion:

- Li-Fi transmit data using light signals from LED or lasers which are received by photodetector.
- As seen in the experiment the analog signal from the mobile phone is converted into transmitter light signals using 1 AUX cable connected to a LED based with asupply voltage. This is the transmitter part of the set up.
- A solar panel is used as a receiver which is then converted back to analog signals using an AUX cable and output is through a speaker.
- The outcome observed in Task 1 aligns with theoretical expectations, where keeping the setup open introduces interference from sunlight and ambient light sources, potentially affecting the LED signal. In contrast, the absence of other noise sources in the dark box enhances signal clarity.
- The findings in Task 2 can be rationalized by recognizing that the loudness of the sound is directly correlated with the intensity of light reaching the solar panel. This intensity demonstrates an inverse relationship with distance, with the maximum sound reception occurring when the LED is in close proximity to the solar panel.
- An inherent limitation of employing lasers is the confined coverage area. Unlike a single LED light source that can illuminate an entire room, a laser requires a fixed receiver position due to its directional nature. This restricts the receiver's mobility and adaptability compared to the versatility offered by an LED.

- The results obtained in Task 5 are explicable by acknowledging that the loudness of the sound is contingent on both the distance between the panel and the light source and the extent of light exposure received by the solar panel.
- The significance of strategically placing the LED and solar panel to minimize external interference and maximize signal strength was evident in the experiment. This emphasizes the critical role of precise system deployment in achieving optimal Li-Fi performance.
- The optical power meter, optical attenuator, and EDFA play crucial roles in maintaining signal quality. The experiment showed that adjusting the attenuation using the optical attenuator allowed control over the signal power, influencing the Bit Error Rate.
- The observed Bit Error Rate at different link lengths indicates the impact of fiber length on signal integrity. Longer link lengths might introduce more attenuation and dispersion, affecting the overall performance of the optical wireless communication system.
- The observed inconsistencies in the results were attributed to the fact that the mobile device playing music introduced variations in sound timing. This variation in timing contributed to fluctuations in the perceived sound quality during the experiment.

Conclusions:

In this experiment , we conclude that the Li-Fi is a very convenient and efficient mode of data transmission due to its simplicity and good results. In Li-Fi the quality of sound received is inversely dependent on the amount(intensity) of light received by the solar panel(receiver). Various light sources can be used for Li-Fi transmission. From the experiment, we were able to conclude that LEDs are better for situations where the receiver is moving and Laser is better for situations where the receiver is placed far and is fixed in position. In the experiment, we observe how the variation in distance, number of LED arrays, with noise , without noise affect the sound quality.

The experiment underscored the impact of link length on signal integrity. Varied link lengths resulted in observable changes in the Bit Error Rate, emphasizing the importance of considering fiber length in designing reliable optical wireless communication systems.

References:

- Lab Manual For Experiment #10.
- Principles of communication systems – S.Haykin.
- Communication system Notes.
- https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8455097

Appendices:

These are some of the measuring equipment screenshots and outputs :

AUX CABLE SPECIFICATION:

Optical Power Meter : Optical Attenuator:

BERT:

APC 1550 nm Collimator

Cutter CT-50:

LC-LC Patch cord LC-FC Patch cord SC-Patch cord

EDFA(Erbium-doped fiber amplifier):