ISSN 2712-0562
Original Research
Sustainable Engineering and Innovation
Vol. 5, No. 1, June 2023, pp.85-98
https://doi.org/10.37868/sei.v5i1.id192

Li-Fi technology-based long-range FSO data transmit system evaluation

Omar Faruq[1*], Kazi Rubaiyat Shahriar Rahmana[2], Nusrat Jahanb[3], Sakib Rokoni[4], Mosa Rabeya[5]
[1] School of Communication and Information Engineering, Chongqing University of Posts and Telecommunications, P.R. China
[1,2,3] Computer Science and Technology, Saic Institution of Management and Technology, Bangladesh
[1,2,4,5] Computer Science and Engineering, Daffodil International University, Bangladesh

*Corresponding author E-mail: smomarfaruq99@gmail.com

Received Jan. 17, 2023
Revised Mar. 29, 2023
Accepted Apr. 19, 2023

Abstract

Visible light is used by a technology known as Light Fidelity to establish wireless internet connections very quickly. This article offers line-of-sight communication between the transmitter and receiver using LED technology. Li-Fi technology is a method that transmits data using LED light, which is faster and more efficient than Wi-Fi. Since it is practically ubiquitous, light can be used for communication as well. A cutting-edge technology called optical communication includes a subset called Li-Fi. By sending out visible light, the Li-Fi device enables wireless intranet communication. An in-depth study and analysis of Li-Fi, a novel technology that transmits data at high speeds over a wide spectrum by using light as a medium of transmission.

Keywords: Data transmission, Light Fidelity, Optical communication, Wireless network, Wireless communications

1. Introduction

In audio communications, frequencies ranging from 20 to 20000 Hz are utilized. An "audio transmission system" is a mechanism that routes and processes audio signals. The audio signal was sent through sensors and processed for a single output channel. Although microphones send and interpret audio signals, the light in this article acts as a transmitter, transferring data. Li-Fi means "Light Fidelity". The term Li-Fi was coined by Harald Hass, a German scientist. This is the internet's next generation, in which data is sent using light as a channel. Li-Fi is a state-of-the-art wireless light-based communication system. Li-Fi is a novel and efficient wireless communication technology that transmits data using light [1]. It's the same light we have in our homes and businesses, but with a few modifications, it can transmit data to all of our internet-connected gadgets. Visible light communication (VLC) and Li-Fi (Light Fidelity) technologies are used to convey audio data. Li-Fi is a one-of-a-kind means of quickly and effectively transferring data over short distances. The Li-Fi operational premise is to send data in a standardized manner by utilizing the AM of the sunlight source. This technology can carry data at speeds of more than 10 GB/s, and its functional bandwidth ranges from 400 THz to 800 THz. Laser light waves move in unison, meaning their characteristic peaks are all coordinated or in phase. This explains how laser beams can be incredibly narrow and concentrated in such a small space. Because laser light is focused and does not spread out as much as a spotlight, laser beams can travel incredibly long distances. During the 2011 Tide Global Talk, Professor Herald Hood introduced the concept of wireless data transmission from any light source, which led to the creation of the term "Li-Fi." He is a pure Li-Fi co-founder and chair of mobile communications at the College of Edinburgh. Data is transmitted over the visible light portion of the electromagnetic spectrum using General Sound VLC, a technology that has been around since the 1880s. From January 2010 to January 2012, funding was provided for the A-Lite project at the Edinburgh Institute of Digital Communication [2]. To drive this technology, Haas expanded this market in 2011 with TAD Global Talk, which has benefited the market company. Puru Li-Fi is the parent company of a market-ready OEM company for Li-Fi system products to integrate with the current PVLC, a LED (lighting) system.

In October 2011, businesses and industry associations established the Li-Fi Consortium to significantly enhance optical communications networks and get around radio spectrum restrictions. Li-Fi, which was created by the IEEE 802.15.7 RATA Standard Committee, is not the same as the Universal Database VLC devices sold by some businesses. In 2012, VLC technology was shown to utilize Li-Fi. In August 2013, single-color LEDs flashed data rates of over 1.6 GB/s. According to a press release from September 2013, neither the VLC system nor general Li-Fi had to meet any line-of-sight requirements. In October 2013, firms in China stated that they were developing Li-Fi development kits. The Li-Fi wireless network Beam Custard was unveiled in April 2014 by the Russian business Steincomm. While future speeds of up to 5 GB/s are anticipated, the current module transmits data at a rate of 1.25 GB/s. Sisoft achieved a new record in 2014 by transporting data at 10 GB/s throughout the light spectrum given by LED lights. The latest integrated Li-Fi system's CMOS optical receiver employs less sensitive glacier photodiodes. IEEE transitioned to Gig-Mode in July 2015, which improves energy consumption as a photon beam charges ions diode and boosts receiver sensitivity.

This procedure may also be carried out with computational sensitivity, in which the receivers detect a faint signal from a long distance. Li-Fi is not a brand-new technological breakthrough; infrared light has been used in remote controls since the nineteenth century. The discovery was made in 2011, when the first gigabit-class semiconductor, Li-Fi, was developed. Fraunhofer IPMS and Ibisentelcom support this new development. Li-Fi has a one-of-a-kind chance to broadcast radio frequency (RF) technologies. One Wi-Fi building is excellent for widespread wireless coverage, both technologies can be viewed as complementary because one is ideal for high-density wireless data coverage with minimal liability, and the other is perfect for that [3]. Bandwidth, distance, data quality, Security, dependability, availability of power, transmission, power production, influence on the environment, device-to-device communication, interference, device accounting, market preparedness, and comparison of each transmitter and receiver technology. Li-Fi technology will therefore be superior in the future, as we can infer from this data. Our project's main goals have been presented. To develop and construct a long-range data transmitter structure based on Li-Fi technology. Must put the entire system into action in order to assess its actual impact and validate our efforts to investigate the performance of the system for future reference and upgrade.

2. Literature review

This section is based on a review of the literature. Here is a look at the literature of the past year, including our efforts. Perhaps by reading it we can overcome the weaknesses of the previous project and improve its effectiveness. We can overcome the weaknesses of the previous project and make it more effective by reading it. The development of Li-Fi technology aims to increase data throughput, power usage, and performance. Li-Fi is a bidirectional network solution that provides a user experience very similar to Wi-Fi. Over time, connectivity requirements will increase dramatically [4]. We need a network with higher spectral capacity to meet these demands. With Li-Fi, we can use a spectrum that is 100,000 times larger than that of radio frequencies. Li-Fi is now capable of delivering unparalleled data and capacity. It is a type of optical radio technology that includes infrared, ultraviolet, and visible light transmission [3]. Li-Fi is distinguished by the fact that the identical light energy utilized for lighting might also be used for connectivity [4]. Li-Fi technology is simple but effective. Photons are emitted from a LED bulb when a continuous current flow is applied to it. It appears to be light. With semiconductor technology, LED bulbs allow for very rapid changes in current and light that may be detected by a photodetector. High-speed information may be sent using this technology via an LED light. Remote controllers, for example, are examples of low-cost optoelectronic gadgets, Li-Fi uses direct modulation techniques. LED light bulbs can also transmit very high data rates due to their high intensity [5]. The requirement to transfer bandwidth with certain other users is reduced by high bandwidth density, which improves the user experience. Li-Fi has a data density that is a thousand times greater than that of Wi-Fi. As a result, more data per square meter is provided [6]. Li-Fi communication technology can function even in direct sunlight since modified light rays may be recognized. Because the system detects quick variations in light intensity rather than the gradual fluctuating levels created by interruptions induced by sunlight, and because light waves in Li-Fi are substantially modulated, the sun just provides a continuous light that the receiver can simply filter out. Connecting to local network settings, integrated Li-Fi wireless technology for new "smart luminous" technology, including Li-Fi short range and for communities worldwide, is used.

Visible Light Communication (VLC) technology transfers data from people's minds at the speed of light. Li-Fi is being utilized to provide low-cost, long-lasting, secure, and high-quality work. VLC does not offer a health risk, but it may harm the human body because it employs microwaves and sustainable and environmentally green technology. However, along with EPP, VLC, and simple wireless plug-and-play technology come the system's benefits and applications. LEDs are more practical than the present fluorescent pipes, and VLC systems work at light speed in direct sunlight. It is not eliminated by Wi-Fi or other RF interference with system users, electromagnetic interference for visible light, or free, uncontrolled, and outdated THz. VLC is safe for the human body since it uses ecologically friendly green technology, such as microwaves, which pose no health hazards. The hybrid system is made up of many components. They layer structures: the structure of a complex system, a channel model, and modulated schemes. The MAC and PHY layers are separated in the framework. The Li-Fi VLC was created to construct the PLC. We attempted to complete this project by reading the aforementioned material, and we were able to complete it successfully by avoiding the faults of the previous year's project.

3. Research method

We detailed our study process, project block diagram, circuit diagram, the project functioning concept, and the final project view in this area. This review relied on specific criteria and settings to construct its connected articles, from the beginning stages of the search procedure to the final stages of the production of this work. A critical component of every inquiry is the usage of proper keywords to discover possible research areas. The phrase "Li-Fi" is one of the most common search phrases for previous research on Li-Fi technology. This phrase has appeared in all Li-Fi studies, including Haas' work and other relevant articles [7].

As a result, it is concluded that this keyword is sufficient and acceptable to cover crucial areas in this evaluation. The papers considered for the study were all written in English. Review studies, which offer a literature review and are also valuable sources of knowledge, or journal research papers, which present original research, are employed. All work in this review has been produced within the ten-year time frame since 2011 when Li-Fi was first made public. Li-Fi offers a wide range of applications. As a result, including them, all in a single document will be tough. Instead, focusing on a few areas of Li-Fi research and emphasizing them will provide fascinating findings.

As a result, the closing paragraph in this section will concentrate on the methods of inclusion and exclusion utilized in this study [8]. All of the research involved Li-Fi-related simulation studies. We picked this study because we wanted to provide simulation-based studies on Li-Fi. Only a few countries and industries have adopted LiFi as a communication system, and it is still not widely used worldwide. Presenting all relevant numerical simulations would therefore encourage researchers and developers to test with Li-Fi before it is legally implemented. Due to methodological limitations, all OWC papers that do not contain Li-Fi-based systems as part of their communication and equipment analyses have been eliminated [7]. The procedure for this project is as follows: (a) develop an idea for the design and construction of a long-range data transmission system based on Li-Fi technology, (b) design a block diagram and schematic to determine which components we need to build, (c) assemble all the components and program the microcontroller to control the entire system, and (d) assemble all the components on a printed circuit board and solder them. Finally, put all the components on the board and test the system.

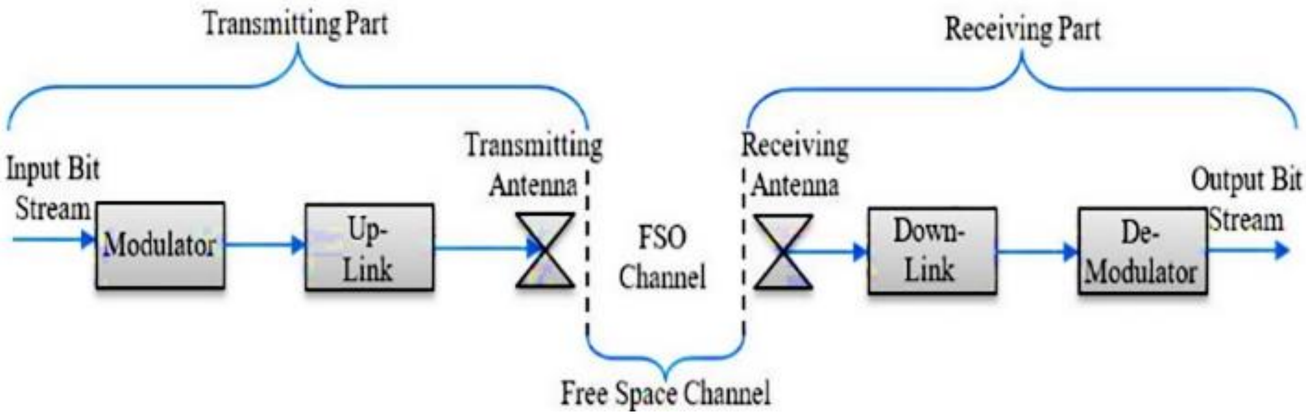

Figure 1. FSO structure

In our project, we developed a long-range data transmission system based on Li-Fi technology [9]. The current from the AC source enters the DC output circuit through an adaptor. This circuit included an audio amplifier, a lithium-ion battery, a laser light, a tiny solar panel, and a speaker. Li-Fi is a free-space wireless communication system that uses light to convey data and location between devices. The laser light, DC power supply, and Li-Fi audio amplifier are all connected to a 3.5mm port, which will be connected to the audio source on the transmitter side. We have a solar panel, a lithium-ion battery-powered audio amplifier, and a speaker on the receiving side. At the connection of the 3.5mm port to the audio source on the transmitter side, the laser or LED will illuminate, but there is no variation in the intensity of light at the time of audio source is turned off.

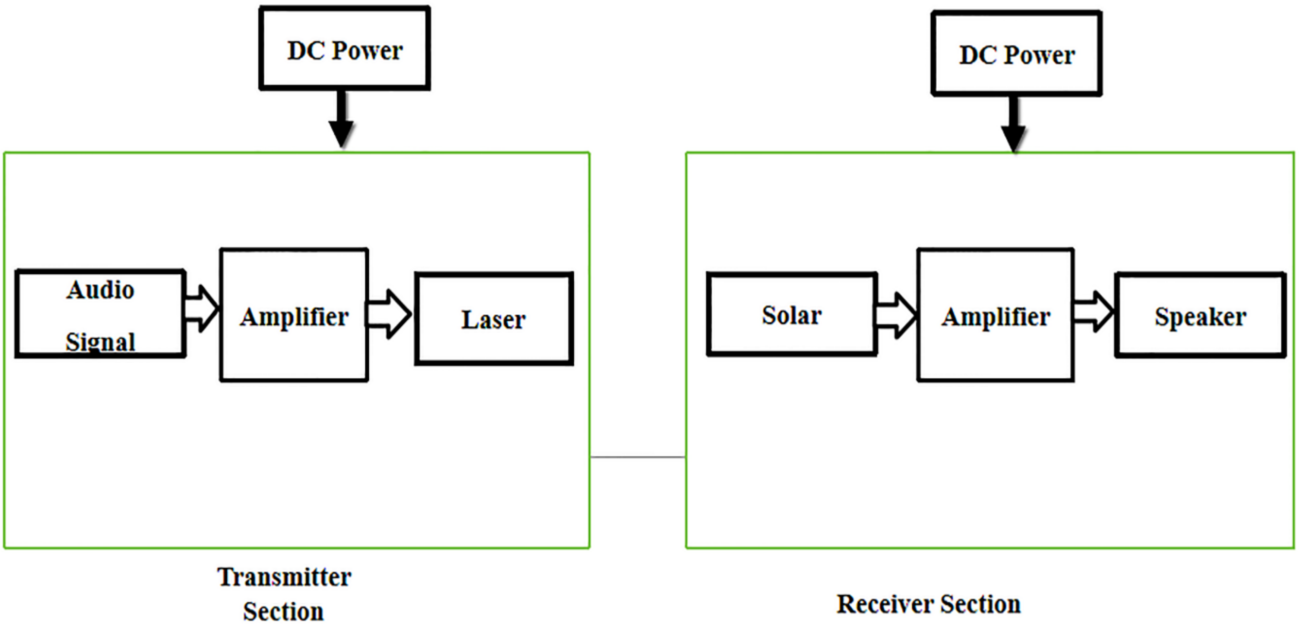

Figure 2. Block diagram of Li-Fi technology-based long-range data transmit system

When researchers perform the sound, you'll also notice that light intensity varies regularly. When the volume is increased, the intensities of LEDs and lasers vary more quickly. The photovoltaic system is so sensitive that even small variations in the intensity result in a variation in voltage at the panel's output. As a result, when light from the LEDs falls on the panel, voltages fluctuate depending on the intensity of the light. The photovoltaic voltages are instead sent into the amp Li-Fier (it is a speaker), which amplifies the signal and audio output through the speaker attached to the amp Li-Fier [10]. As long as the solar cell is in contact with the LEDs, the output will be produced.

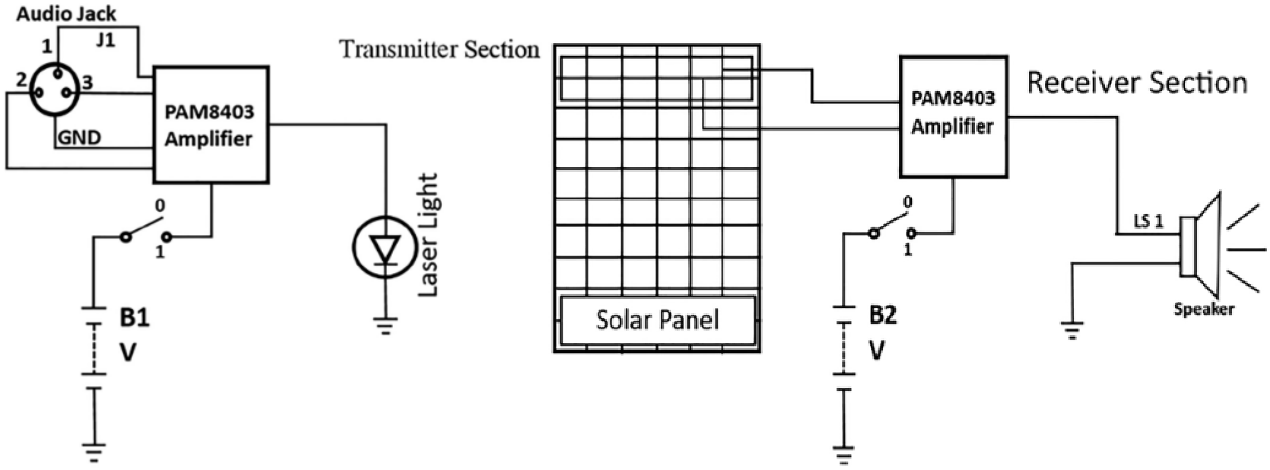

Figure 3. Circuit diagram of Li-Fi technology-based long-range data transmit system

4. Experimental setup, results, and discussion

This project focused on two areas: hardware and software. The most apparent component of any information system is the hardware. An audio amplifier, a lithium-ion battery, a laser light, mini-solve software, and a speaker comprise the hardware. "Software" refers to the entire collection of procedures, techniques, and programs necessary for a computer system to function. The program aids in the design of circuits. For schematic capture, we utilize Proteus software. The hardware and software are described in depth below. Proteus 8.9 is the software. The hardware components are the PAM8403 Audio Amplifier Li-Fi Module, Mini Photovoltaic Panel, Communication Module, Laser Light, Adapter DC Power Supply, and Speaker [11].

Audio amplifier module (PAM8403): An electrical amplifier known as an audio power amp (or power amp) boosts weak electronic signals, such as those from a radio reception or a musical instrument pickup, to a volume that can drive loudspeakers or headphones. Many different types of audio equipment, Sound reinforcement, broadcasting, and domestic sound systems, as well as audio instrument amps and Li-Fiers such as guitar amps, are all examples of products that fall into this category, containing audio power amplifiers and Li-Fiers. It is the last electrical stage before the signal is routed to the loudspeakers in a conventional multichannel audio chain. PAM8403 Li-Fier Stereo Audio Amp Module: The PAM8403 is an amplified Li-Fi board that can drive two 3W + 3W LEDs and is powered by a typical 5V input. Anyone looking for a Class-D stereo audio amp with lithium-ion batteries that fits on a small board should definitely consider this option. With this amplifier, users can output high-quality audio from stereo input [12]. It also has a unique function because it is able to drive speakers straight from its output. As seen in the project prototype photographs below.

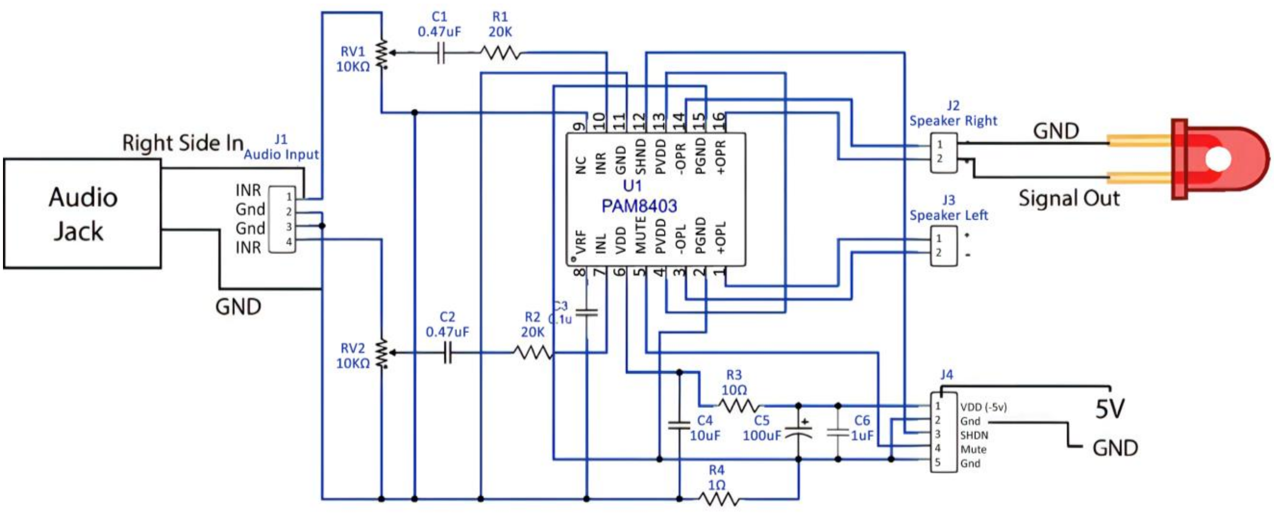

Figure 4. Li-Fi transmitter circuit diagram

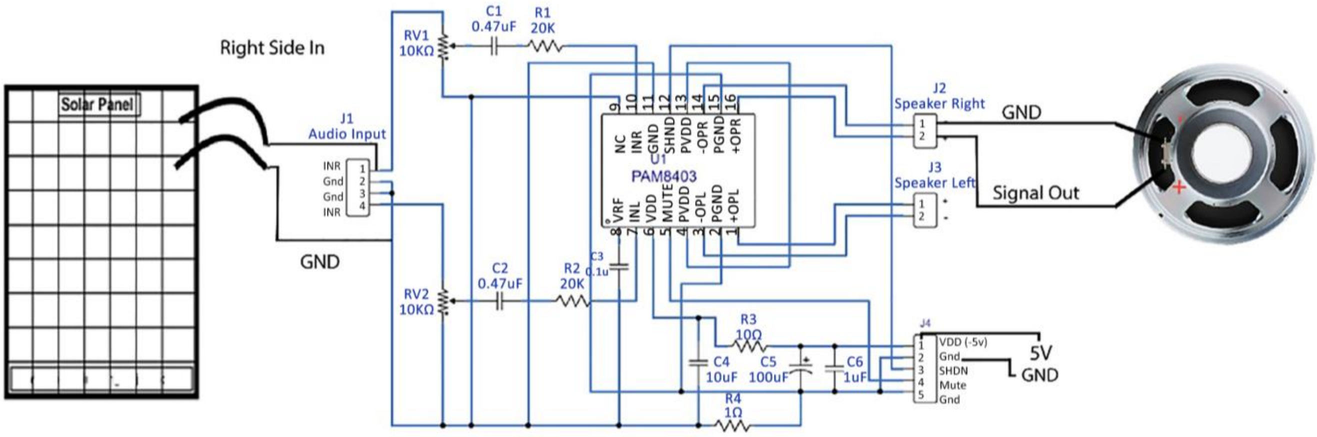

Figure 5. Li-Fi receiver circuit diagram

The PAM8403 Amp Li-Fier Board has the following features. The voltage of operation of amp is power supply voltages range from 2.5-5V DC. With a four-channel load at 5 volts DC, dual-channel stereo with a high maximum output (3 W + 3 W) at 10% THD Maximum Gain: 24 dB Architecture without Filters Low EMI and low quiescent current Temperature range: -30 to +80°C Short-circuit protection, thermal shutdown, and up to 90% low capacity PAM8403 is the primary power amp Li-Fi IC, as seen in the figure below. Aside from IC, the module is made up of a few other components, such as capacitors and resistors. The amp board is a dual-channel Li-Fi amp board with a total output power of 6W (3W + 3W). At Left Channel Input Audio Jack is ‘ └’. At Ground Channel Input Audio Jack is ‘⊤’, at Right Channel Input ‘ʀ’ Audio Jack, the power supply is 5V. L± indicated Left Channel Positive and Negative Output and R± indicated Right Channel Positive and Negative Output. The PAM8403 includes built-in short circuit protection, which is crucial for a trouble-free operation because each big Li-Fi system requires it [13, 14].

Since PAM8403 Amp Li-Fier IC does not require a heat sink, it is an excellent choice for bespoke speaker applications. It can also drive 4 or 8 speakers directly. You must use a good speaker with a maximum output power of 3 W. Since this is a Li-Fi board with a stereo amplifier, the input section includes two inputs, L and R, separated by a common ground. It will generate 3W + 3W audio output from any form of audio input that requires amplifying with lithium-ion batteries. At 5V DC input and 4 Ohms load output, this amplified Li-Fi module has a peak gain of 24 dB and a THD of 10%. Without a heatsink, it works smoothly, which frees up space on board. Regardless of the heatsink, it might also provide thermal protection, which is an important function for a low-wattage Li-Fier module. LCD monitors and TV projector speaker output Notebook laptops' lithium-ion batteries improve speaker output. Portable speakers, portable DVD players, and game machines can all be used. Any wireless amplified project with a compact footprint and 5V output.

A solar panel is made up of many electrically connected photovoltaic modules that are mounted on structural support [15]. Solar cells that have been pre-packaged and linked together form a photovoltaic module. The solar panel can be utilized in commercial and domestic applications as a part of a bigger solar power delivery and generation system. Each module is rated for its DC output power under conventional test settings, which generally varies from 100 to 320 watts under International Electro-Technical Commission specifications (IEC). The size of a module is dictated by its efficiency for a given maximum power: a 230-Watt module with an efficiency of 8% requires twice as much area as a 230-Watt module with an efficiency of 16%. Due to a single solar panel's capacity limitations, the majority of systems use multiple solar panels [16]. A photovoltaic system is made up of a panel or array of solar cells, a transformer, and, on rare occasions, a battery, a solar tracker, and communication cables. Photovoltaic solar modules only generate power when the sun shines. They do not store energy; hence, to assure the flow of power when the sun is not shining, a portion of the electricity produced must be stored. The most apparent answer is to employ batteries, which store electrical power naturally.

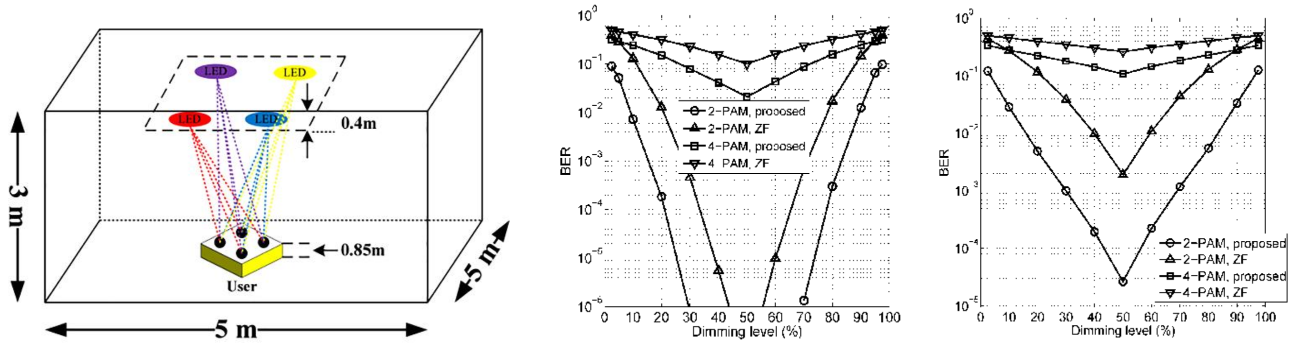

Figure 6. FSO operation

Batteries are series-connected sets of rechargeable batteries (devices that convert electrical energy from chemical energy). Batteries are made up of two electrodes submerged in an electrolyte solution, which when connected by a circuit generate an electric current. The current is generated by reversible chemical reactions within the cell between the two electrodes and the electrolyte. Supplementary or extra batteries are rechargeable batteries. Electric energy is stored as chemical energy in the cells while the battery is charged. When the battery is drained, the chemical energy contained in it is released and transformed into electrical energy [17 – 20]. A robust outer poly frame encloses and safeguards high-quality, specially designed solar modules and polycrystalline solar cells. The highest output power is 0.66 W, the highest operating voltage is 6 V, and the highest charging current is 110 mA. The minimum output power is 0.55 W, the operating voltage is 5.5 V, and the charging current is 100 mA.

The installation of or integration of small epoxy solar panels into a product is simple. There are no frameworks or specific adjustments required for construction. Installation requires only a minimal amount of room. Comparable amorphous thin-film solar cells only produce half as much electricity as these ones. They don't need any additional frames or modifications and are ready to use right away. Simply solder or crimp the copper tape to make connections. Trays are made of thin, incredibly strong, and weather-resistant substrates, or they can be custom-designed, injection-molded trays that are laser-cut, wrapped in UV and weather-resistant materials, and made for the good or service in question.

Possibilities include making your own solar-powered models or toys as well as small crafts, science experiments, electrical applications, charging small DC batteries, and electrical applications [21]. Laser light waves travel together, with their peaks in alignment, or phase. This explains why laser beams can be focused in such a small space and are so brilliantly focused and narrow. Due to the laser light's continued concentration and lack of dispersion relative to a flashlight, laser beams can cover very long distances. A laser is a device that produces light by amplifying it optically through the electromagnetic radiation that is stimulated to emit.

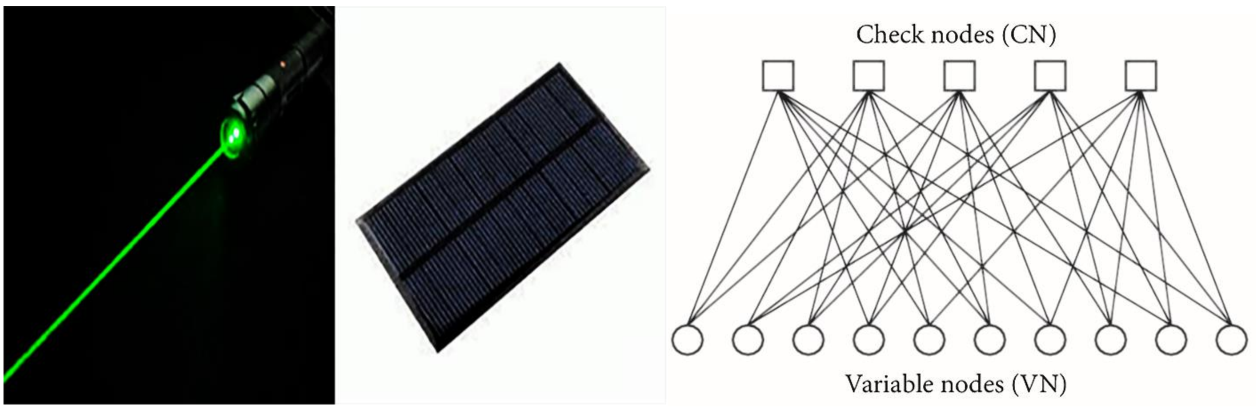

Figure 7. Laser light operations

"Laser" is an abbreviation for "light amp Li-Fiction via stimulated emission of radiation." Based on the theoretical work of Charles Hard and Arthur Leonard Schawlow, the first laser was created in 1960 at Hughes

Research Labs by Theodore H. Maiman [22, 23]. The coherent light that a laser emits sets it apart from other light sources. Lasers can be concentrated in a small space thanks to spatial coherence, making it possible to use them for processes like lithography and laser cutting. Additionally, spatial coherence enables a laser beam to collimate, which enables the use of lidar and laser pointers over long distances.

The only way to create light with an extremely narrow spectrum is by using lasers, which have the maximum degree of spatial synchronization. Alternately, femtosecond-long, wide-spectrum ultrashort light pulses may be made via temporal coherence. Electroacoustic transducers, also known as loudspeakers, are devices that convert electrical audio streams into the desired sound. A loudspeaker system, also known as a "box" or "speaker," is made up of one or more of these speaker drivers, an enclosure, and electrical connections, which may or may not include a crossover. An analogy with the driver of a loudspeaker can be made between a linear motor and a diaphragm that converts the motion of the motor into the motion of air or sound. The acoustic equivalent of the original, unamplified electronic signal is achieved by electronically amplifying an audio signal, usually through a microphone, recording device, or radio broadcast, to a power level that drives the motor. Proteus is a proprietary software toolset used primarily for electrical design automation. Electronics designers and engineers use the program primarily to develop schematics and electronic prints for PCB production. The original version of what is now referred to as Proteus Design Suite, PC-B, was developed in 1988 for DOS by the company's CEO John Jameson. Support for schematic capture was added in 1990, and Windows environments were adopted at the same time. Proteus originally included multipathing simulation in 1996 SPICE, followed by microcontroller simulation in 1998. Shape-based auto routing was introduced in 2002, and 3D visualization of printed circuit boards was added in 2006. 2011 saw the creation of a specific IDE for simulations, and 2015 saw the addition of MCAD import and export. 2017 saw the introduction of support for high-speed design.

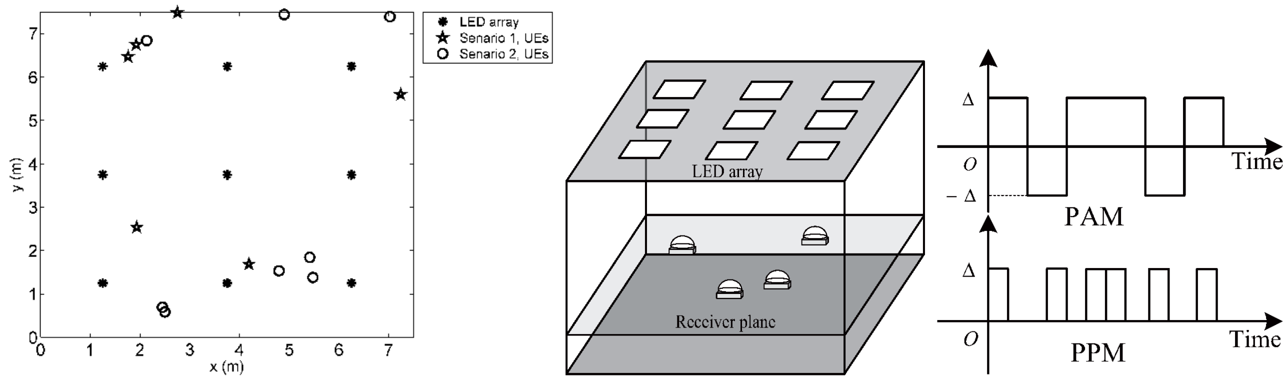

Figure 8. Proteus software interface

Deployment of Li-Fi technology of the practical in wireless access networks necessitates of calculating techniques for determining the key operational characteristics: Identifying sites where Li-Fi systems can be most efficiently utilized. The development of architectural suggestions for the system, its parts, and the sequence in which they interact. Compiling a collection of operational indicators for telecommunications systems. A new model development that mirrors the system with customer service procedure. Define a mathematical apparatus for finding the primary key indicators of telecommunications system operations. This work investigates the approach of evaluating the waste of energy of LED in light pathways within actual wireless access organization situations in a normal office space.

Multipath Light Signal Li-Fi Network: The following scheme represents the model of the Li-Fi network. Receiving and transmitting modules are critical components of such a system. Figure 2 depicts these components in further detail. An approximation of the components and their functional purpose is provided. Model of dynamic routing laser signal interaction across transceivers taking into account. A no-view line and a LOS comprise a VLC channel (NLOS). Depicts the geometry of VLC dispersion inside a single room. Each receiver is considered to have a photodetector. The straight line path between both the transceivers is known as LOS, and the appropriate Euclidean distance is indicated by the fact that each receiver has a photodetector. The line segment channel in between the transceiver is denoted by LOS, and the relevant Euclidean distance is denoted by d_{iu}. The direction of emission and attenuation linked with the LOS path is denoted by d_{iu}, $\varphi_{i,u}$, and $\psi_{i,u}$ respectively. Many different types of LEDs with modulation bandwidths varying from many tens of MHz to around 150 MHz or even too many scores were used to broadcast data. A detector or photovoltaic grid is frequently used to detect a signal on the receiver side [24]. Depicts many sorts of models of a light-emitting diode's intensity of radiation and their related values of the Lambert radiation parameter m. Consider the following situation to acquire precise indications for the operation of the Li-Fi network: let's have a system where user 1 sends data to user 2. The signal is sent from user #1's transmission module to the reception module on the ceiling, Signal is picked up with a cluster of LED lights mounted on the ceiling. Photons are transformed into electric current once they have been collected by the photodetector. The optical energy is converted into electric current, which then enters the microprocessor, which controls the LED panel. The signal was transferred from the microcontroller to the data by the second user. The power of the intermediate transmitter is defined as the ratio of the received data to the value of the transmission data, which is determined by the structural features of a particular bulb. This is critical to remember. When transmitting information from a set of LED bulbs on the ceiling to user 2's receiver, the previously outlined processes apply. Table 1 includes the data required to execute the computations [25 – 28].

Table 1. Data required to execute the computations

Parameter	Symbolic designation	Value
Height between ceiling and user (photodetector)	h	2m
Photodetector area	A_{pd}	$1sm^2$
The optical filter coefficient	g_f	1
Refractive index	n	1,5
Half-intensity radiation angle	$\Phi_{1/2}$	60^o; 1,047rad
Photodetector field view	ψ_{max}	90^o; 1,571rad
Optical transmitter power	P_{opt}	3 Watt
Coefficient of conversion of optical energy into electric	k	3
Receiver responsivity	R_{pd}	0,53 A/W
Coefficient of Reflection from the wall	p_ω	0,8

To calculate how much energy is emitted during the transfer of a light signal to the receiver from the transmitter, use the following mathematical equation:

$$H_{PLiFi} = H_{LOS} + H_{NLOS} \tag{1}$$

The LOS channel, according to [13], may be computed as follows:

$$H_{LOS}^{i,u} = \frac{(m+1)Apd}{2\pi d_{i,u}^2} cos^m(\phi_{i,u}) g_f g_c(\psi_{i,u}) cos(\psi_{i,u}) \tag{2}$$

Where, $m = \frac{-ln\,(2)}{ln(cos\,\phi_{1/2})}$ Lambertian discharge mechanism is represented by

$\phi_{1/2}$ represents the emission direction with 1⁄2 the strength of the principal optical axis.

A_{pd} - physical region of Parkinson's disease;

g_f – gain of optical filter's.

$g_c\left(\psi_{i,u}\right)$ is an abbreviation for laser concentration gains, which is described as follows:

$$g_c\left(\psi_{i,u}\right) = \begin{cases} \frac{n^2}{\sin^2(\psi_{max})}, \psi_{i,u} < \psi_{max} \\ 0, \psi_{i,u} > \psi_{max} \end{cases} \quad (3)$$

where *n* stands for the refractive index and ψ_{max} is the semiangle of the PD's field of vision (FOV).

Let L_{iu} define the relative separation between sender (i) as well as the received (u) as varying from 1m to 2m in 0.5 m increments, and the angle ϑ_{iw} as varying from 40 o to 75 o, or from 0.669 rad to 1,309 rad. We can determine the angles $\psi_{i,u}$ and $\phi_{i,u}$: using Pythagoras' theorem and some trigonometric adjustments.

$$\phi_{iu} = \Psi_{iu} = arctg\left(\frac{L_{iu}}{h}\right) = \begin{matrix} 0.464 \\ 0.644 \\ 0.785 \end{matrix} \quad (4)$$

The MathCad application was used to do the computations. The following are the Hlos results:

$$Hlos = \frac{(m+1)A_{pd}cos\,(\phi_{iu})^m g_f g_c cos\,(\Psi_{iu})}{2\pi\left(\frac{L_{iu}}{sin(\phi_{iu})}\right)^2} = \begin{matrix} 4.686 \times 10^{-5} \\ 3.749 \times 10^{-5} \\ 2.929 \times 10^{-5} \end{matrix} \quad (5)$$

Based on the dataset obtained, the result of HLOS at the fastest route is 4,686*10-5 between the light and the photodetector, and 2,929*10^{-5} at the largest distance (according to the input data). For the purpose of simplicity, only the reflection of the first order is considered in the NLOS route. First-order reflection is divided into two parts: Distances are indicated by $d_{i,w}$ and $d_{w,u}$. The ranges of beam and incident are $\varphi_{i,w}$ and $\theta_{i,w}$ for the original section, and $\theta_{w,u}$ *i* $\psi_{w,u}$. for such a second section. Because the route allocation throughout the room is quite small, delays among these diverse paths may be ignored. In other terms, information from various pathways is believed to arrive at the receiver at the same time. The following method is used to determine the NLOS of a Li-Fi channel:

$$\begin{gathered} H_{NLOS}(x) \\ = \int_{min\theta iw}^{max\theta iw} \frac{(m+1)Apd}{2\pi\left(\mathrm{diw}\,(\vartheta iw) + \frac{x}{\cos\,(\vartheta wu(\vartheta iw))}\right)^2} * \\ * p_w \cos^m\left(\phi_{i,w}(\vartheta iw)\right) g_f g_c \cos\left(\psi_{w,u}(\vartheta iw)\right) \\ \cos\,(\vartheta iw)\cos\,(\vartheta wu(\vartheta iw))d\vartheta iw \end{gathered} \quad (6)$$

where A_w signifies a modest wall reflection zone; ρ_w– reflection from the wall.

Let us do the computation, substituting the gap between both the wall and also the photodetector for the parameter x:

$$\begin{aligned} Hnlos\,(0) &= 4.074 \times 10^{-10} \\ Hnlos\,(2) &= 1.91 \times 10^{-13} \\ Hnlos\,(6) &= 2.205 \times 10^{-14} \\ Hnglos\,(9) &= 9.863 \times 10^{-15} \end{aligned} \quad (7)$$

As we can see from the calculations above, in the best case, $H_{NLOS}(0)$ equals 4,074*10^{-10}, this is 5 orders of scale less than the best route value (H_{LOS}). As a result, we shall disregard the H_{NLOS} value throughout the remainder of this study.

Thereafter: $H_{Li\text{-}Fi} = H_{LOS} + H_{NLOS} = H_{LOS}$, Which means that: $H_{Li\text{-}Fi} = H_{LOS}$

The photons are received in a light sensor now at the received signal and transformed into an electrical charge, the value of which could be quantified as shown in:

$$I_{elec} = \frac{R_{pd} H_{Li-Fi}^{i,u} P_{opt}}{k} \tag{8}$$

Where: R_{pd} – detector responsivity;

P_{opt} – transfer optical signal per Li-Fi access point,

κ – is a transformation factor from optoelectronics to power production; the P_{opt}/κ factor is equal to the strength of the signal.

The findings of calculations done using MatLab software with the input data supplied in Table 1 are displayed in the received signal power and the value of the electric current in the photodetector. The received signal has an optimum output of 0.043079 watts and a lowest value of 0.00011096 watts. It must be noted that its light sensor may receive signals ranging from 4-6 Watt to 500-3 Watt, therefore the values received are within the allowable range. The maximum electric current value is 0.06847 A, while the smallest value is 0.00017643 A. We continuously monitor our work once it is completed. It performs as expected. Our project yields faultless results, and every piece of equipment works perfectly. We tested it to see how well it worked, and we got great results on that project.

Finally, we effectively completed our project and made sure everything was running as planned. First, we start our system and test it under different settings. When the laser light hits the solar panel, the audio can be transmitted. We created this technique to transport audio using laser light. Our major goal was to employ the wireless transmission method. Although we had some difficulties creating this system, we were able to finish it in a wonderful manner thanks to the dedication and great assistance of the supervisor, sir. Because of its precision, our project has several advantages. Some of the benefits are listed below: Unlike Wi-Fi, Unlike Wi-Fi, which operates on the radio frequency spectrum, Li-Fi operates on the visible wavelength spectrum, which is still underutilized. Li-Fi addresses the problem of radio frequency signal interference due to the vast range of the light wave frequency spectrum. Low use and maintenance expenses are required for Li-Fi. Light waves, since they are impenetrable, give greater privacy, security, and monitoring than Wi-Fi. User-friendliness: The entire system requires very little energy. Audio transmission in a wireless system; audio transmission in a Li-Fi system The project is small, inexpensive, and simple to use. This project has several possible applications in today's modern and practical world, some of which are listed below: Relief from RF Spectrum Mobile Connectivity, Smart Lighting, Hazardous Environments, and RF Avoidance.

5. Conclusions

This article takes an in-depth look at the audio transmission system that uses Li-Fi technology. The notion of Li-Fi is now causing quite a stir all over the world. This system is routinely used with this infrastructure and requires no substantial modifications. Visible light communication may be a fast-evolving technique in the field of wireless technology. Li-Fi is a wireless data transfer system that is both fast and inexpensive. The growing need for larger bandwidth, faster and safer data transfer, audio transfer, and environmentally and demonstrably human-friendly technologies predicts the beginnings of a massive wireless revolution. This new technology is typically touted as ecologically benign and safe. It can also be used in potentially hazardous situations, such as in thermal and nuclear power plants, without causing electromagnetic interference. As a consequence, Li-Fi may effectively replace Wi-Fi. We are considering adding numerous features to our project in the future to get better outcomes. Some of the actions that we are considering are as follows: We are considering adding more functions in the future, such as data transmission and video distribution methods. Adding a noise termination circuit at the receiver end may help minimize output noise in the future.

Author contribution

Successful in this study, we investigated various transmission and reception techniques while transmitting and receiving data via FSOC using light technology. We have shown that our technique can distinguish the best results from others. The contribution to the paper is as follows: Omar Faruq[1]: study conception, physical project supervision, design, analysis and interpretation of results, draft preparation; Kazi Rubaiyat Shahriar Rahmana[2], Nusrat Jahan[3]: data analysis, data collection, coding, operation, and draft preparation; Sakib Rokoni[4], Mosa Rabeya[5]: physical project making, calculation, operation, and draft preparation. All authors approved the final version of the manuscript.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

Funding information

The author(s) did not receive any funding for the project making, research, writing, or publication of this work.

Acknowledgements

We are very happy to work together. We wish we will do work in the future for related research. Specially thanks to our colleagues and teammates.

Software application code availability: We are not able to reveal our unique code. However, we have used OptySim, MatLab, and C to create our code, schematics, and simulations.

References

[1] Gupta, S., Sarkar, M., Kaur, H., Agrebi, M., Roy, A. (2022). An Efficient Data Transferring Through Li-Fi Technology: A Smart Home Appliance. In: Kumar, R., Sharma, R., Pattnaik, P.K. (eds) Multimedia Technologies in the Internet of Things Environment, Volume 3. Studies in Big Data, vol 108. Springer, Singapore. https://doi.org/10.1007/978-981-19-0924-5_4

[2] J. C. R. BIRSAN, F. Moldoveanu, A. Moldoveanu, M. -I. Dascalu and A. MORAR, "Key Technologies for Indoor Positioning Systems," 2019 18th RoEduNet Conference: Networking in Education and Research (RoEduNet), 2019, pp. 1-7, doi: 10.1109/ROEDUNET.2019.8909406.

[3] V. Karthik, B. K, A. S, A. S and A. S, "High Speed Transmission of Data or Video Over Visible Light Using Li-Fi," 2022 International Conference on Advanced Computing Technologies and Applications (ICACTA), Coimbatore, India, 2022, pp. 1-6. doi: 10.1109/ICACTA54488.2022.9753036

[4] G Madhuri et al (2020_, IOP Conference Series: Materials Science and Engineering, Volume 872, Second International Conference on Materials Science and Manufacturing Technology 9-10 April 2020, IOP Conf. Ser.: Mater. Sci. Eng. 872 012010.doi: 10.1088/1757-899X/872/1/012010

[5] D. Samudika, L. Jayasinghe, K. E. Gunathilaka, Y. Rumesh, R. Weerasuriya and D. Dias, "Stereo audio streaming via Visible Light," 2016 Moratuwa Engineering Research Conference (MERCon), 2016, pp. 132-136, doi: 10.1109/MERCon.2016.7480128.

[6] G. S. Spagnolo, L. Cozzella, F. Leccese, S. Sangiovanni, L. Podestà and E. Piuzzi, "Optical Wireless Communication and Li-Fi: a New Infrastructure for Wireless Communication in Saving Energy Era," 2020

IEEE International Workshop on Metrology for Industry 4.0 & IoT, 2020, pp. 674-678, doi: 10.1109/MetroInd4.0IoT48571.2020.9138180.

[7] O. FARUQ, N. Narayan, A. S. M. Parvez, N. Nizamuddulla, S. Rana, “Performance Evaluation and Design of a Hybrid FSO/RF Communication Antenna: Atmospheric Link and Attenuation Turbulence.” IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), 17(3), (2022): pp. 01-09. doi: 10.9790/1676-1703010109

[8] S. Chergui and S. Abdesselam, "Design and realization of a visible light communication system for Li-Fi application," 2020 1st International Conference on Communications, Control Systems and Signal Processing (CCSSP), El Oued, Algeria, 2020, pp. 30-35. doi: 10.1109/CCSSP49278.2020.9151780

[9] R. Sharma, Dilip Sharma, New Trends and Applications in Internet of Things (IoT) and Big Data Analytics, XIV, 271, https://doi.org/10.1007/978-3-030-99329-0

[10] S. S, R. B, P. L, S. S, S. M and V. V, "Audio Transmission using Visible Light Communication and Li-Fi Technology," 2021 6th International Conference on Inventive Computation Technologies (ICICT), Coimbatore, India, 2021, pp. 19-24. doi: 10.1109/ICICT50816.2021.9358638

[11] M. Aman, G. Qiao and M. Muzzammil, "Design and Analysis of Li-fi Underwater Wireless Communication System," 2021 OES China Ocean Acoustics (COA), Harbin, China, 2021, pp. 1100-1103. doi: 10.1109/COA50123.2021.9519887

[12] R. Mahendran, "Integrated LiFi (Light Fidelity) for smart communication through illumination," 2016 International Conference on Advanced Communication Control and Computing Technologies (ICACCCT), 2016, pp. 53-56, doi: 10.1109/ICACCCT.2016.7831599.

[13] D. Giustiniano, N. O. Tippenhauer and S. Mangold, "Low-complexity Visible Light Networking with LED-to-LED communication," 2012 IFIP Wireless Days, 2012, pp. 1-8, doi: 10.1109/WD.2012.6402861.

[14] Y. -L. Gao, Z. -Y. Wu, Z. -K. Wang and J. Wang, "A 1.34-Gb/s Real-Time Li-Fi Transceiver With DFT-Spread-Based PAPR Mitigation," in IEEE Photonics Technology Letters, vol. 30, no. 16, pp. 1447-1450, 15 Aug.15, 2018. doi: 10.1109/LPT.2018.2852662

[15] B. G. Guzmán, C. Chen, V. P. G. Jiménez, H. Haas and L. Hanzo, "Reflection-Based Relaying Techniques in Visible Light Communications: Will it Work?," in IEEE Access, vol. 8, pp. 80922-80935, 2020. doi: 10.1109/ACCESS.2020.2990660

[16] S. Razzaq, N. Mubeen and F. Qamar, "Design and Analysis of Light Fidelity Network for Indoor Wireless Connectivity," in IEEE Access, vol. 9, pp. 145699-145709, 2021. doi: 10.1109/ACCESS.2021.3119361

[17] R. Jiang, Q. Wang, H. Haas and Z. Wang, "Joint User Association and Power Allocation for Cell-Free Visible Light Communication Networks," in IEEE Journal on Selected Areas in Communications, vol. 36, no. 1, pp. 136-148, Jan. 2018. doi: 10.1109/JSAC.2017.2774400

[18] X. Wu, M. D. Soltani, L. Zhou, M. Safari and H. Haas, "Hybrid LiFi and WiFi Networks: A Survey," in IEEE Communications Surveys & Tutorials, vol. 23, no. 2, pp. 1398-1420, Secondquarter 2021. doi: 10.1109/COMST.2021.3058296

[19] H. Abumarshoud, M. D. Soltani, M. Safari and H. Haas, "Realistic Secrecy Performance Analysis for LiFi Systems," in IEEE Access, vol. 9, pp. 120675-120688, 2021. doi: 10.1109/ACCESS.2021.3108727

[20] M. Dehghani Soltani, X. Wu, M. Safari and H. Haas, "Bidirectional User Throughput Maximization Based on Feedback Reduction in LiFi Networks," in IEEE Transactions on Communications, vol. 66, no. 7, pp. 3172-3186, July 2018. doi: 10.1109/TCOMM.2018.2809435

[21] Y. Wang, N. Chi, Y. Wang, L. Tao and J. Shi, "Network Architecture of a High-Speed Visible Light Communication Local Area Network," in IEEE Photonics Technology Letters, vol. 27, no. 2, pp. 197-200, 15 Jan.15, 2015. doi: 10.1109/LPT.2014.2364955

[22] W. Niu et al., "Phosphor-Free Golden Light LED Array for 5.4-Gbps Visible Light Communication Using MIMO Tomlinson-Harashima Precoding," in Journal of Lightwave Technology, vol. 40, no. 15, pp. 5031-5040, 1 Aug.1, 2022. doi: 10.1109/JLT.2022.3172867

[23] H. Liu, P. Zhu, Y. Chen and M. Huang, "Power Allocation for Downlink Hybrid Power Line and Visible Light Communication System," in IEEE Access, vol. 8, pp. 24145-24152, 2020. doi: 10.1109/ACCESS.2020.2970097

[24] P. H. Pathak, X. Feng, P. Hu and P. Mohapatra, "Visible Light Communication, Networking, and Sensing: A Survey, Potential and Challenges," in IEEE Communications Surveys & Tutorials, vol. 17, no. 4, pp. 2047-2077, Fourthquarter 2015. doi: 10.1109/COMST.2015.2476474

[25] W. Niu et al., "Neural-Network-Based Nonlinear Tomlinson-Harashima Precoding for Bandwidth-Limited Underwater Visible Light Communication," in Journal of Lightwave Technology, vol. 40, no. 8, pp. 2296-2306, 15 April15, 2022. doi: 10.1109/JLT.2021.3138998

[26] H. Ma, L. Lampe and S. Hranilovic, "Hybrid visible light and power line communication for indoor multiuser downlink," in Journal of Optical Communications and Networking, vol. 9, no. 8, pp. 635-647, Aug. 2017. doi: 10.1364/JOCN.9.000635

[27] A. Sevincer, A. Bhattarai, M. Bilgi, M. Yuksel and N. Pala, "LIGHTNETs: Smart LIGHTing and Mobile Optical Wireless NETworks — A Survey," in IEEE Communications Surveys & Tutorials, vol. 15, no. 4, pp. 1620-1641, Fourth Quarter 2013. doi: 10.1109/SURV.2013.032713.00150

[28] Y. Wang, J. Yu and N. Chi, "Symmetrical full-duplex integrated passive optical network and optical wireless communication transmission system," in Journal of Optical Communications and Networking, vol. 7, no. 7, pp. 628-633, July 2015. doi: 10.1364/JOCN.7.000628