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# Visible Light Communication

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**Abstract:** ***Visible light Communication (VLC) creates technology revolution in network sector. In this technology, visible light is used to transmit or receive data. In this paper, OOK [ON-OFF keying] modulation is used to send and receive data's using LED lights and the audio signal is transmitted through 1W LED and received by solar cell and the played in loudspeaker. It does not require front end and receiver end antenna and any light emitting devices with faster switching rates can be converted into internet modem with small integrated chip. It has very wide range of applications apart from the internet such as traffic management and places where RF radio waves are restricted.***

**Keywords:** LI-FI, WI-FI, RF, VLC, LED, OOK

## 1. Introduction

Visible Light Communication [VLC] is a data communications method which uses visible light between 400-800 Tetra Hz [Wavelength=780–375 nm]. VLC is a subset of optical wireless communications technologies. This technology uses fluorescent lamps or Light Emitting Diodes [LED] to transmit signals.

Photosensitive components are used to receive the signals. Although in some cases a cell phone camera or a digital camera can also be used (since the camera is an array of photo sensitive components arranged in a definite pattern). Such sensors may provide high input efficiency since a large number of photosensitive components receive the signal.VLCdoes not require a separate system to operate, module can be added to any illumination device.

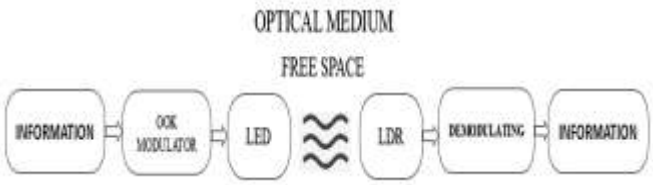
This paper explores a new approach for Visible Light Communication where the LED's are the transmitter, visible light is the medium for communicating and a photodiode is a receiver. The advancement of this prototype leads to Li-Fi [Light-Fidelity] which is a bi-directional, high-speed and fully networked wireless communication technology similar to Wi-Fi.

In this paper, Li-Fi is applied and tested through:
1) Data Transmission.
2) Audio Transmission.

## 2. Data Transmission

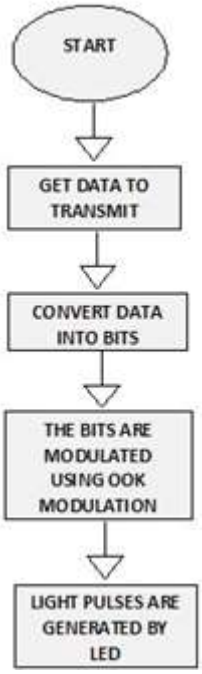
The outline of the operation of VLC systems is shown below:

**a) VLC Process block Diagram**



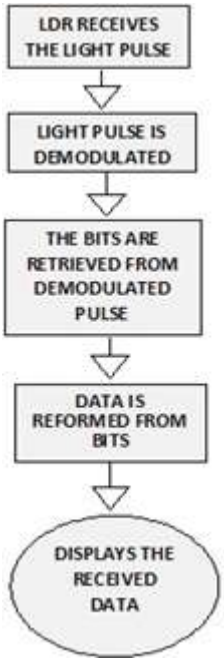

The block diagram (a) shows the process involving in data transmission using visible light or in other words process involved in Li-Fi.

**b) Transmission Process Block Diagram:**




The block diagram (b) shows the process of the transmission section. The data is first obtained from the user and it is converted into bits (assumption) by micro controller (in this paper Arduino is used), then OOK modulation technique is applied and light pulses are generated from light source.

**c) Receiver Process Block Diagram**




The above block diagram (c) shows the process of receiver section. The light pulse is obtained from light source is sensed bye the photosensitive elements (LDR is used in this paper).The sensed pulsed is demodulated and the bits are identified. The transmitted data is framed from the received bits.

**Overview:**
1) Transmitter.
2) Receiver.
3) Characteristics.
4) Drawbacks.
5) Conclusion.

## 3. Li-Fi Transmitter

**Transmitter Module Contains:**
1) Power Supply
2) LED
3) Arduino

The function of Transmitter is to convert Electrical signals into optical pulses. The VLC transmitter is different from conventional communication transmitter in viewpoint that it must act as a transmitter and as an illumination device simultaneously. For each character, 7 bits are assigned uniquely. Each character is identified by 7-bit combination. The LED have high flickering rate hence they can be set to switch off and on at very low time delay for few milliseconds such that it cannot be detected by human eyes.

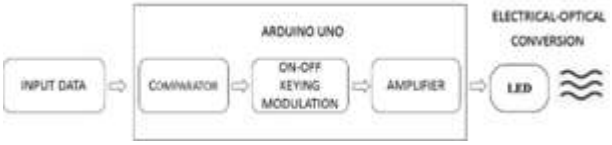
The concept of VLC is similar to the IR communication. Every kind of light source can theoretically be used as transmitting device for VLC. However, some are better suited than others. For instance, incandescent lights quickly break down when switched on and off frequently. Thus are they are not recommended as VLC transmitters. More promising alternatives are fluorescent lights and LEDs. VLC transmitters are usually also used for providing illumination of the rooms in which they are used. This makes fluorescent lights a particularly popular choice because they can flicker descent enough to transmit a meaningful amount of data and are already widely used for illumination purposes. Nowadays LED's are replacing fluorescent lamps since they are highly powered efficient and has a longer lifetime. This is the major advantage for VLC communication because LED's have higher flicker rate than fluorescent lights thus the rate of data transmission is increased greatly.

The development of LEDs has made the solid state lighting an emerging field. LEDs have surpassed the incandescent light sources in terms of reliability, power requirements and luminous efficiency. The efficiency of LEDs is much greater than the incandescent lamps efficiency. LEDs and Lasers are used as transmission sources for VLC. The LED's can be used as both communication and illumination device. The white light based emitting LED's is one of the attractive candidates for being used as the VLC source.

There are different possible spectra in which white light is produced by the LEDs. The Tetra-chromatic [Combination of Cyan-Red-Green-Blue], dichromatic [combination of Blue-Yellow] and trichromatic [Combination of Red-Green-Blue] modes used for generation of white light. The most commonly used methods for generation of white light using LEDs is trichromatic (such as red, green and blue).For more efficiency monolithic trichromatic led is used since they have high data transfer speed compared to other LED types.

The input data [character] to be sent from the personal computer is first converted into corresponding binary code in which 1's in the binary code represents LED-ON and similarly, 0's represents LED-OFF. The character is represented in binary form by the micro controller unit in the Arduino module. Because of the high on-off speed characteristic of LED, human eyes cannot identify the faster flickering of light such that both illumination and information passing can be realized simultaneously. The generated optical signals carrying information is then delivered to the receiver.

**Block Diagram:**




In this experiment, the 7 Bits are assigned to each character [A-Z] in Arduino. The program for transmission is compiled and uploaded in the Arduino. The Arduino controls the light is transmitter end and sends the compiled information. The 7-bit assumption for each character is as follows:

| *Character* | *Binary Representation* |
|---|---|
| A | 011 0001 |
| B | 011 0010 |
| C | 011 0011 |
| D | 011 0100 |
| E | 011 0101 |
| F | 011 0110 |
| G | 011 0111 |
| H | 011 1000 |
| I | 011 1001 |
| J | 011 1010 |
| K | 011 1011 |

| | |
|---|---|
| L | 011 1100 |
| M | 011 1101 |
| N | 011 1110 |
| O | 011 1111 |
| P | 100 0000 |
| Q | 100 0001 |
| R | 100 0010 |
| S | 100 0011 |
| T | 100 0100 |
| U | 100 0101 |
| V | 100 0110 |
| W | 100 0111 |
| X | 100 1000 |
| Y | 100 1001 |
| Z | 100 1010 |

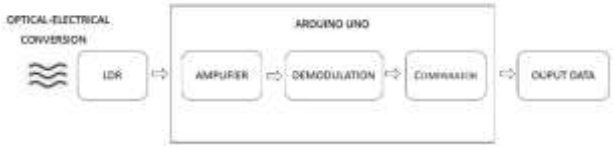
In Binary representation, logic 1 represents LED ON and logic 0 represents LED OFF. This modulating technique is known an OOK [On-Off keying]. In OOK, the LED is not turned completely off in the off state, but the reduction in the level of intensity is performed. The main advantage of using OOK is its easy implementation. Many other modulating techniques can also be used for data transmission. Each modulating technique has its own characteristics. Some of the modulating techniques are PWM, M-PAM, M-PPM etc.

## 4. Li-Fi Receiver

*RECEIVER MODULE CONTAINS:*

1. Photodiode
2. Arduino
3. PC

*BLOCK DIAGRAM:*




The light from Transmitter is picked up by an array of or single photosensitive filament on the receiver side. In the VLC receiver, the light is detected using a photosensitive device and then converted to photo current. The parameter specification of the VLC will be different from that of the infrared communication because of the different wavelengths. When subjected to light energy, a Photoconductive light sensor will change its physical property. Photo Resistor [LDR] is most commonly used photosensitive device. Photo resistor is a semiconductor device that uses light energy to control the flow of electrons and therefore the flow of current in them.

A Light Dependent Resistor is a semiconductor device that changes its electrical resistance depending on the presence of light. A Light Dependent Resistor changes its electrical resistance from a high value of several thousand Ohms in the dark to only a few hundreds of Ohms when the light is incident on it by creating electron–Hole pairs in the material. LDR is most preferred because they have low rise time and moderate fall time. Faster rise time and fall time is essential for faster transmission of data. The signal produced by the transmitter is received completely by the receiver. The surrounding illuminating light increases the base luminance but does not alter the variations produced by the transmitter. Adopting the base luminance of environment the variation produced can be fully received by the receiver even after reflection.

The most common type of photoconductive cell is a Light Dependent Resistor or LDR. Silicon Photodiode, Phototransistor, avalanche photodiode, PIN diode and camera [array of light sensitive elements] can also be used as receiver.

The coding technique [OOK MODULATION] used in the transmitter section is interrupted and the corresponding decoding technique is used. The decoding is done by the microcontroller [in this paper Arduino is used] in the receiver end. The binary representation of each character is stored in the receiver end too. In receiver end, they are used for matching the obtained signal via LDR from LED with the actual binary representation. For example, the 7-bit code for character A is assumed to be [011 0001] in transmitter section is saved in receiver end such that it can compare the obtained signal word with the actual word.

Delay time for the receiver should be matched to the delay time of the transmitter.The synchronized process should take place such that information sent by the transmitter is received fully in receiver end, a small delay between transmitter and receiver end would possess an error.

The variations in LDR due to light emitted by the LED in the transmitter end is continuously observed by the Arduino. The received variation is amplified and compared with the binary representation of the character which is predefined in the transmitter. Thus the character is displayed as output in the computer via Arduino serial monitor.

**Audio Transmission**

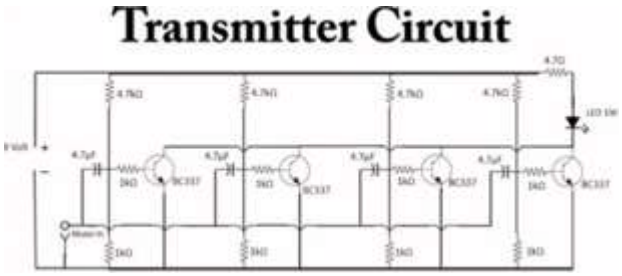
The audio transmission is similar to data transmission but in audio transmission since audio signal itself is an analog signal it can be transmitted either directly or after modulation for better output.


The above block diagram shows the process involved in audio transmission

Thus in audio transmission it consists of two sections transmitter section and receiver section:

**Audio Transmitter**

It consists of three stages:
1) Audio in.
2) Pre Amplifier.
3) Led.




**Audio In:**
The input to transmitter circuit is through 3.5mm jack pin connected to computer (or mobile).The audio signal is given to the base of the transistor. The capacitance connected serially increases the analog signal stability and blocks DC signal.

**Pre Amplifier:**
The audio signal is amplified before transmission to compensate the loss that occur during transmission and to ensure the audio signal is power enough to ignite the LED. In this paper, BC337 is used in common emitter voltage divider configuration, since it has high current gain.

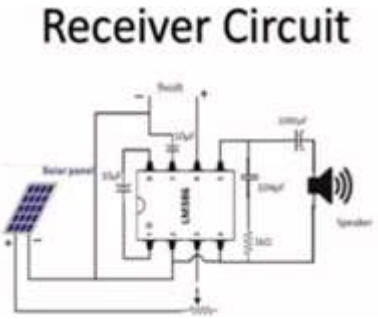
**LED:**
The 1W LED is used as a transmitter. The audio signal is given to one of the terminals of LED. The LED produces variation in light due to audio signal. This light is emitted in open space to be received by photocell.

**Audio Receiver**

This section also contain three stages:
1) Photocell.
2) Audio amplifier
3) Audio out.

**Photocell:**
The photocell is used to receive the analog signal emitted by the LED. In this paper, solar cell is used which generates electric pulse according to the light incident on the solar cell.

**Audio Amplifier:**
The audio amplifier, amplifies the low power audio input signal to the high power audio signal. In this paper, LM 386 audio amplifier is bypassed with capacitor to produce gain of 200. The audio out signal is power enough to given to the Loudspeaker.




**Audio Out:**
The amplified audio signal is given to the loudspeaker which plays the transmitted audio signal.

**Characteristics of Li-Fi**

| *Property* | *VLC* | *RF* |
|---|---|---|
| Visibility | Yes | No |
| Frequency | 400THZ-790THZ | 20KHZ-300GHZ |
| Security | More | Less compared to VLC |
| Power Consumption | Relative low | Medium |
| Coverage Distance | Short | Medium |
| Harmful For Human Body | No | Yes |

**Frequency:**
Visible light has more frequency than radio waves and spectrum for visible light is not limited. Visible light frequencies lie between Ultraviolet and Infrared waves frequency. Since Visible light is divided into four ranges:

- Near Ultraviolet [3 PHz].
- Far Infrared [3 THz].
- Mid Infrared [30 THz].
- Near Infrared [300 THz].

**a)** ***Speed*****:** The speed of the Visible light communication can be obtained up to 100 times the speed of the Wi-Fi. In laboratory condition the speed of Li-Fi can be obtained up to 224Gbps by using suitable modulating techniques.

b) ***Power:*** They do not require external power as it has power for the LED light it just alters the light emitting frequency to transmit data. Illumination lights are used in this technology thus external power is not required.

c) ***Antenna:*** Antenna front end is not required in this technology which reduces the power consumption greatly. Since existing illumination LED's are used transmitter is not required. Similarly the receiver is photo sensitive elements. There is no restriction in the angle of projection, they can be projected $360^0$.Such that more receivers can be benefitted from the single transmitter.

d) ***Security:*** VLC uses visible light for communication and so, in this case, it's easy to determine who can receive the message and it's impossible to tap the communication without breaking the link.

**e)** ***Human Safety:*** VLC doesn't affect the human body in any situations. Thus, the transmission power can be kept high if needed.

f) ***Bandwidth****:* VLC has a bandwidth range from 430 THz to 750 THz and this range is larger than the bandwidth in the RF Communications from3 kHz to 300 GHz.

g) ***Unlicensed Spectrum:***No company owns property rights for visible light and thus no royalty fees have to be paid nor does expensive patent-license have to be purchased in order to use visible light for communication purposes.

## 5. Li-Fi Drawbacks

- Although there are a large number of advantages to the use of a VLC system, there are also a number of drawbacks. Of these drawbacks, the most obvious fact is that it will only work in places where there are electronic lights. Conventional Wi-Fi can function a decent distance from a house, allowing internet access while outside. A VLC system would not be able to achieve this due to the need for a lighting system. It will generally work best in confined spaces where it is easy to ensure the whole room is being covered in the light.

- Another disadvantage to VLC systems is the issue of blocking the light required to receive the signal. It would be very easy to unintentionally block the receiver of the system. This would cause the signal to be interrupted, potentially by things like a person walking through a room. While this disadvantage could be overcome by using multiple light sources, it would still be very easy to inadvertently interrupt the connection by blocking the light sources.
- Another potential problem would be seen mostly with outdoor systems, such as a traffic light system previously described. There could be a number of issues with the system functioning well depending on the weather outside. On cloudy days, it may work while on sunny days it most likely would not. On days when it is raining, snowing, or foggy the signal might be prevented from being transmitted well enough that it could be used. Even indoor systems with many windows might experience this issue.

***Remedies:***

- LED lights are commonly used for illumination hence more LED lights can be converted as Li-Fi modem and it is economical.
- By using suitable modulating technique rate of transmission and range can be increased in near future.
- Once variations created in visible spectrum remains for longer range, only its base luminous is reduced to various factor but the variations are still present. Such that suitable technique can be used to retain the variations even after great loss during transmission.

## 6. Li-Fi Application

***Smart Lighting:*** Smart lighting with VLC technology provides better infrastructure for illuminationcontrol, and communication. Since communication between LED's is possible, additional wirings are greatly reduced and thus the power consumption is greatly reduced. They can be designed to function in many ways, Example: If VLC technique is used in BURJ KHALIFA [Tallest building currently] it can either illuminate the whole building in particular pattern or it can transmit the message over a great distance and communication between its neighbour is also possible.

***Mobile Connectivity:*** By pointing a visible light from Li-Fi modem to another device you can create a very high-speed data link with inherent security. This overcomes the problems of having to pair or connect and provides a much higher data rate than Bluetooth or Wi-Fi.

***Hazardous Environments*:** Communicating in areas where there is a risk of explosions can be a problem (e.g. in mines, Petro-chemical plants, oil rigs, Nuclear plant etc.). VLC is inherently safe and provides safe communication and automation.

***Vehicle & Transportation:*** Traffic signage, traffic lights, and street lamps are adopting the LED technology so there are massive applications opportunities here. VLC can be used for vehicular communication due to the presence of the vehicle lights and the existing traffic light infrastructure. The high priority applications indicated by the Vehicle Safety Communications Project include cooperative forward collision warning, pre-crash sensing, emergency electronic brake lights, lane change warning, and stop sign movement assistant, left turn assistant, traffic signal violation warning and curve speed warning. All of the high priority applications require reliable reachability with extremely low latency. Due to the extremely low allowable latency in the vehicle safety communication, a high-speed visible light communication system like Li-Fi can be used, an outdoor VLC system using Controller Area Network (CAN) was proposed and the back lights and headlights were used in the proposed system for communication.

***Defense & Security:*** The ability to send data quickly and in a secure way is the key to many applications. The fact that the visible light cannot be detected on the other side of a wall had great security advantages.

***Hospitals & Healthcare:*** There are advantages for using VLC in hospitals and in healthcare. Mobile phones and Wi-Fi's are undesirable in certain parts of hospitals, especially around MRI scanners and in operating theatres.

***Wireless Fidelity Spectrum Relief:*** Wi-Fi has got faster over but cannot keep up with demand for wireless data. VLC can provide data rates greatly in excess of current Wi-Fi and this can be done at low cost since the RF components and antenna system have been eliminated.

***Aviation:*** Radio is undesirable in passenger compartments of aircraft. LEDs are already used for illumination and can also be used instead of wires to provide media services to passengers. This reduces the aircraft construction costs and its weight.

***Underwater Communications:*** RF does not work underwater but visible light can support high-speed data transmission over short distances in this environment. This could enable divers and underwater vehicles to talk to each other.

## 7. Conclusion

Though, this technology is still in its infancy, with further studies and development its far-reaching applications will only get better. The VLC technology is all about using LED light bulbs meant for illumination to also send data simultaneously. It is best suited as an alternative option for data transfer where radio transmission networks are not desired or not possible. In future, we can transmit an image, audio and even a high definition video using an LED light bulbs.

The features of high bandwidth, non-interference with the radio waves in electromagnetic sensitive areas and non-hazardous to health has made visible light communication an attractive technique for future communication. Li-Fi is 100 times faster than its analogous Wi-Fi, which uses radio frequency for communication. The optical wireless communication system is a very good replacement for the regular communication systems. Visible Light Communication is a rapidly growing segment of the field of communication.

In this experimentation of transferring a character through LED and receiving the data in LDR is successful. The characters are sent from A-Z continuously from the LED and these characters are received by the LDR and the obtained character is displayed in the computer through Arduino serial monitor. This simple prototype ensures data transmission using light is promising and has wide applications in future.

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