VLC communication using ordinary LED's - experimental setup

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Rezumat. *Articolul prezintă modul de realizare și testare a unei platforme experimentale realizată dintr-un emițător optic ce transmite un fascicul luminos prin intermediul unui LED de putere, alb, fascicolul emis de acesta fiind captat de un receptor format dintr-o celulă fotovoltaică, al cărui semnal este amplificat la rândul său de un circuit operațional. S-a analizat modul de functionare a dispozitivului folosind programul Multisim, si a fost evaluată posibilitatea implementării ulterioare într-un sistem LiFi, ca parte a unei rețele de acces.*

Cuvinte cheie: *comunicație VLC, sisteme LiFi, rețele de acces.*

Abstract. *The article presents the way to realize and test an experimental platform made of an optical transmitter that transmits a light beam through a white power LED, the beam emitted by it being captured by a receiver made up of a photovoltaic cell whose signal is amplified by an operational circuit. We analyzed the way the device was running using the Multisim program, and evaluated the possibility of later deploying it into a LiFi system as part of an access network.*

Keywords: *VLC communication, LiFi systems, access networks*

INTRODUCTION

The paper reviews the current LiFi issue, with the presentation of standards and standardization attempts, specifying the need to study the LiFi networks architectures and how to interconnect with the existing networks. Here is an analysis of the opportunity to using Li-Fi technology, which is a two-way wireless technology similar to Wi-Fi technology. Communication is possible by implementing a transmitter and receiver in a device (transceiver), the purpose of which is to receive and emit light to another device operating according to the same standard.

Li-Fi systems can only work in places where artificial light sources are deployed. Compared to conventional Wi-Fi systems that can provide a decent coverage of Internet signal outside of buildings, Li-Fi systems are not able to provide this facility, depending on the existence of a lighting system or the installation of dedicated LiFi equipment (transceivers). LiFi features:

• Visible Light Communications (VLC) optical beams can be used;

• Working speed range: from 10 Mbit/s to a few Gbps per connection

• Cheap, ubiquitous components can be used, the technology is already mature;

• Components: LED sources, silicon photodiodes, technologies: digital signal processing.

LiFi systems offer lots of possible applications. The most common application is the need to wirelessly connect all devices located in a location (residential

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or office) to the Internet. Any living room or office, has a number of bulbs. If ordinary bulbs were replaced by the use of LEDs and a LiFi system, the whole room would benefit from Internet access via light. Due to this reason, LiFi technology has the potential to become very popular with local indoor networks.

In indoor (living and office) spaces, light from LiFi transmitters suffers multiple reflections that alter the channel impulse response, requiring proper design of modulation schemes and adapting working speeds of the LiFi system. Most indoor buildings have different reflection factors for visible light, a feature that should be taken into account when designing the system.

LiFi has a major potential because it can transform any conventional LED lighting system (residential / household or public) into an integral part of a Gbps network. Operates in the field of terrestrial wavelengths and avoids interference with radio spectrum requiring licensing. It is an emerging technology that will allow the use of rapid optical communications in areas where radio frequency clustering is high or in areas where radio waves are prohibited, such as hospitals, airport areas, medical recovery facilities and so on.

LiFi systems must also be analyzed through the security of the transit data. A unique feature of LiFi systems is the increased security of data transmitted by the use of visible light, access to data being possible only on devices located in the same room with the system and in the "cone" of the light beam of the transmitter optical.

Depending on the destination, it is possible to ensure a very low divergence of the optical beam, providing an extremely secure point-to-point connection. Unlike Wi-Fi systems, LiFi systems have a limited coverage range at the surface of the camera in which the light operates and the light does not have the property of wall and obstacle propagation as in the case of radio frequencies. This feature has contributed to raising interest in the implementation of LiFi systems in groups concerned with ensuring a high degree of security of transmission.

The experimental platform, shows the advantages and disadvantages of LiFi as well as the possible ways of interconnecting with the existing networks. The experimental platform provides design guidelines for the LiFi-based communications network. It also provides a working framework for LiFi's physical component specifications, functional organization and configuration, operational procedures and principles, and the format of data passing through the network.

The realization of the experimental platform in this article was required to present the characteristics of systems using LiFi technology for the transport of audio, video and data signals. LiFi systems must ensure video and audio transfer ensuring uninterrupted data flow. A LiFi-based digital system must be able to expand, insert, route, and route signals in a network so that the performance of the network is not affected (there are no streams of data flow).

A notable feature is the propriety of these systems to accept a variety of signal formats and to easily interconnect (with the interface) with today's communications networks. Signal formats for video transmissions should include video encoding at different levels of digitization accuracy, video compression, high definition video, and high-speed data (internet). Understanding the issues of optical emission and reception, optical beam propagation, optical detection as well as multiplexing issues and the correct choice of modulation schemes is important for the practical implementation of a LiFi-based transmission system.

All systems using LiFi share a number of elements that form the base blocks from which such a system is built. These include: transmitters, receivers, signal regenerators, repeaters, encoders, decoders,

switches, modulators, amplifiers, A / D and D / A converters, splitters:

- the signals are inserted / extracted from a network;

- the system is used to distribute the signal;

- the system switches to make a redundant circuit;

- the circuit can be connected to different types of data interfaces for network control.

The process of designing a LiFi system involves defining specific requirements and selecting a suitable implementation platform. The main design criteria for a LiFi interconnected system with communication systems are:

1. Scalability:

a) Types of light sources (LED or LASER) and their number.

b) Possibility to use / develop different software tools (optional); this must be supported by a properly chosen hardware.

c) Possibility to connect to other communication media (use of media-signal converters).

2. Utility:

a) Easy to modify, mainly by using modular hardware and reconfigurable software;

b) Simple and efficient connection (with good efficiency - without significant loss of signal power / quality) with different types of equipment and networks.

c) Equipment is bidirectional (uplink-downlink) capable of duplex communication.

3. Low costs

a) Design, implementation and adjustment (alignment) of transmitter / receiver optics. This is the most difficult thing to achieve and implement in practice;

b) Choosing components or hardware modules with the lowest price / performance ratio;

LiFi has some advantages compared to traditional RF (Radio Frequency) and Infrared (IR) communications technologies, with the main advantage being the availability of 400 THz available for secure and radio-independent wireless communications. The IR bandwidth is approximately equal to that of VLC, but the bandwidth for RF communications is only 300 GHz, being strictly limited and regulated. Also, the use of high RF frequencies will reduce the distance between the transmitter and the receiver, which will affect the using appropriate of the respective frequencies in certain applications. Compared to IR and RF technologies that require their own base stations to increase energy consumption, another VLC advantage is low power consumption and low deployment costs for VLC lighting.

The main difference between RF/IR and VLC technologies resides in propagation through environmental hurdles. While RF technology is not limited from this point of view, VLC and IR can be used to establish high-speed and high-security connections only in well-defined areas and without obstacles as possible. Also, RF communications may be influenced by electromagnetic interference, while the proper operation of VLC and IR communications will depend on the ambient light of the area where the respective systems are implemented. Table 1 shows up a LiFi-WiFi comparison.

From the point of view of the impact on the health of the human body, RF presents more risks than IR and VLC. Following several studies, the World Health Organization (WHO) International Agency for Research on Cancer (IARC) has demonstrated the harmful potential associated with the intensive use of RF technology that may cause cancer. The thermal effect of RF frequencies on the human body is also a

well-known factor, but causes of occurrence and potential risks could not be determined with certainty.

LiFi technology has only one known health risk, called BLH (Blue Light Hazard), which can be determined by light sources emitting high intensity blue light. If the light levels and color temperatures used are normal, the possibility of BLH is null. As far as IR technology is concerned, skin and eyes can absorb invisible radiation from the emission sources, which will determine the effect of heating the body.

Table 1. **LiFi-WiFi comparison**

Features	LiFi	WiFi
Designation	Light fidelity	Wireless fidelity
Operation	LiFi transmits data using existing LED bulbs	WIFI transmits data using radio technology using routers.
Interferences	There is only interference from similar devices	Phenomena of interference from neighboring routers
Technology	Devices working on the IrDa standard.	Devices using WLAN standards 802.11 a/b/g/n/ac/ad
Applications	Use in hospitals, schools, military units,	Ubiquitous WiFi technologies, routers, hotspots, etc.
Advantages	Lack of interference, lack of licensing (currently)	Interference in congested urban environments
Security	High Security	Security dictated by the encoding systems used
Working speeds	Gbps order	WLAN provides approximately 300mbps. Can be obtained 1-2Gbps using WiGig/Giga-IR
Working frecquencies	Terrahertz order	2.4GHz, 4.9GHz şi 5GHz
Working distances	Meters, tens of meters, depending on the optical power used.	Ten of meters (WLAN 802.11 b/11g). varies depending on the emission power and type of antenna used.
System components	Optical transceivers	Need to use routers and radio transmitters.

EXPERIMENTAL SETUP

Light sources (LED / LASER) and receivers (PIN photodiodes and photovoltaic cells) are manufactured at low cost in large quantities, representing combinations of semiconductor components that are widely used in fiber optic and FSO technology. This paper compare the characteristics of sources and receivers optimized for high bit rate digital transmissions for FO and FSO transmissions, and extracting / highlighting features that make them suitable for use in LiFi / VLC communications.

In this regard, an experimental platform made up of an optical transmitter that transmits a light beam through a white power LED, the beam emitted by it is captured by the receiver consisting of a photovoltaic cell whose signal is amplified at turn of an operational circuit. The block diagram can be seen in figure 1.

Two identical systems will be built for duplex communication. The practical realization of the device can be seen in Figures 2 and 3, respectively.

Figure 2 and 3 represents an overview of the experimental device (laboratory model), used to demonstrate the operating principle of the LiFi system.

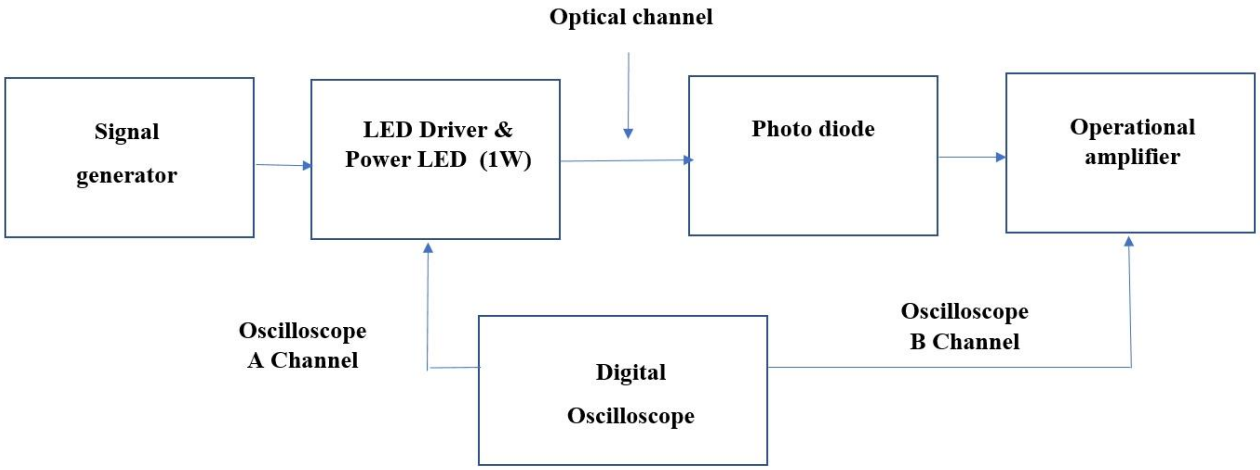


Fig. 1. Block diagram of experimental platform.



Fig. 2. Experimental platform. Overview.

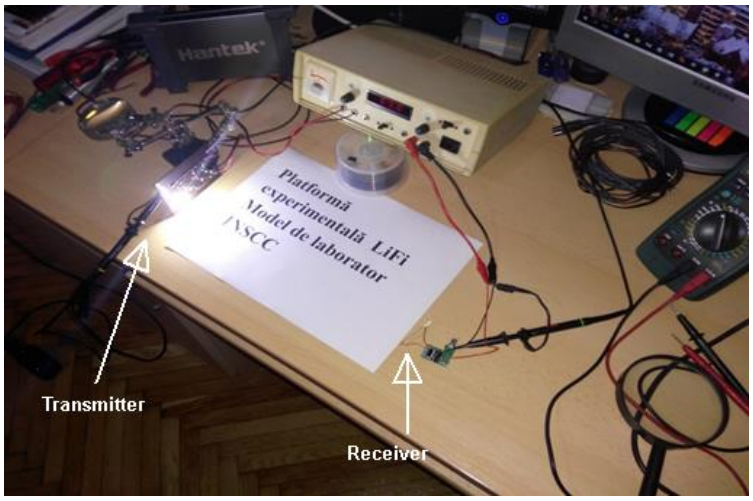


Fig. 3. Experimental Platform - Layout of components.



Fig. 4. Experimental platform. Optical transmitter view.

RESULTS

The National Instruments - Multisim 14 program, which has a component database that allows simulation of the circuits, was used to analyze the behavior of the transmitter of the experimental model. The Multisim simulator interface can be seen in Figure 5, detailing the schema of the transmitter and the measuring devices.

For viewing real-time waveforms, a Hantek 6022BE 20 MHz bandwidth digital oscilloscope with PC-USB connection and monitor display was used.

This type of oscilloscope has the advantage that the waveforms, taken from the transmitter power LED and the receiver's operational circuit output, can be compared directly in the same window of the program and easily exported to a graphic file, which can then be viewed and processed.

The waveforms obtained at the output of the transmitter (the waveform 1 on the oscilloscope screen), the power LED and the output of the receiver (the output of the operational circuit - the waveform 2 on the oscilloscope screen) can be seen in figure 6. The rectangular input signal has a frequency of 1 MHz, it is also supplied by an oscilloscope (fixed frequency rectangular signal generator) and, as seen, undergoes changes in the passage through the optical channel.

This signal is obtained, as can be seen in figure 6, by placing the photovoltaic cell at a distance of approximately 30cm from the LED source. At 1m distance between the transmitter and the receiver, the signal obtained is much smaller in amplitude (almost an order of magnitude) and the signal fronts are heavily distorted.

CONCLUSIONS

This experimental model demonstrates that, using common, inexpensive components, a simplex data transmission can be achieved via LiFi between a transmitter and a receiver. The platform shows up the transmission of signals between the transmitter and the receiver, at a low working frequency, for the purpose of analyzing the signals exchange, simplex transmission between the emitter and the receiver.

The realization of the experimental platform facilitates the presentation of the characteristics of systems that use LiFi technology to transport audio, video and data signals. LiFi systems must ensure video and audio transfer providing seamless data flow. A digital system operating with LIFI technology must be able to expand, insert, reroute and switch signals on a network in such a way that network performance is not affected (there is no dropped should congestion of data flow).

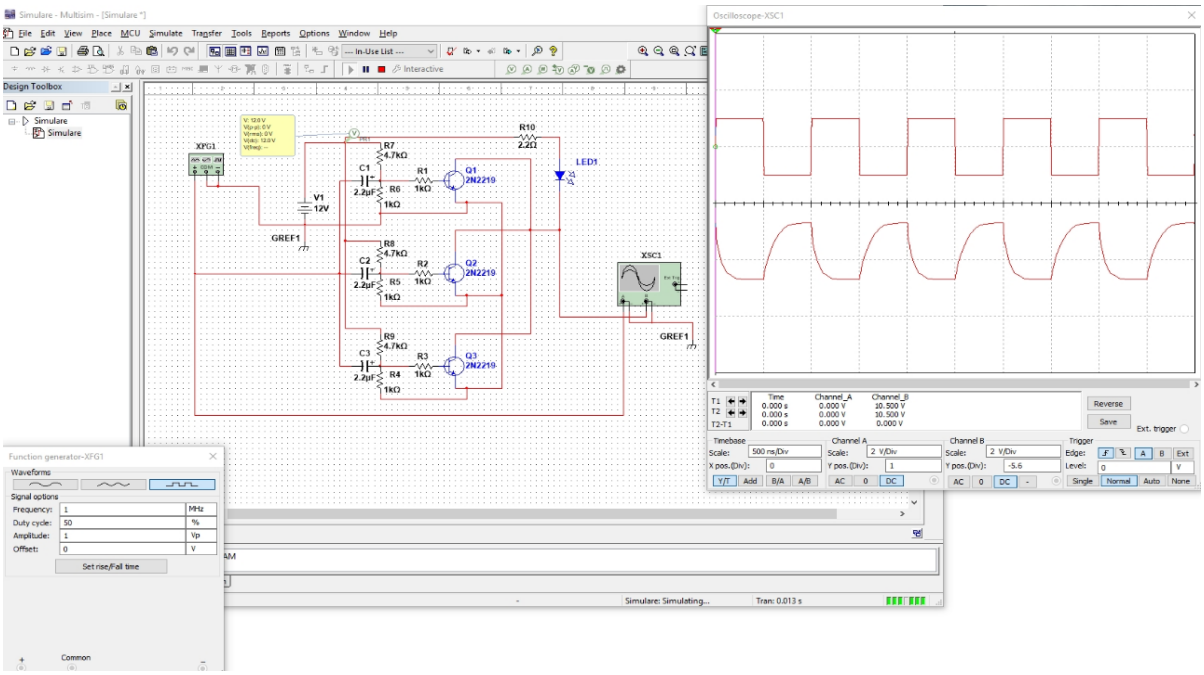


Fig. 5 Simulation of the experimental model transmitter with NI – Multisim program

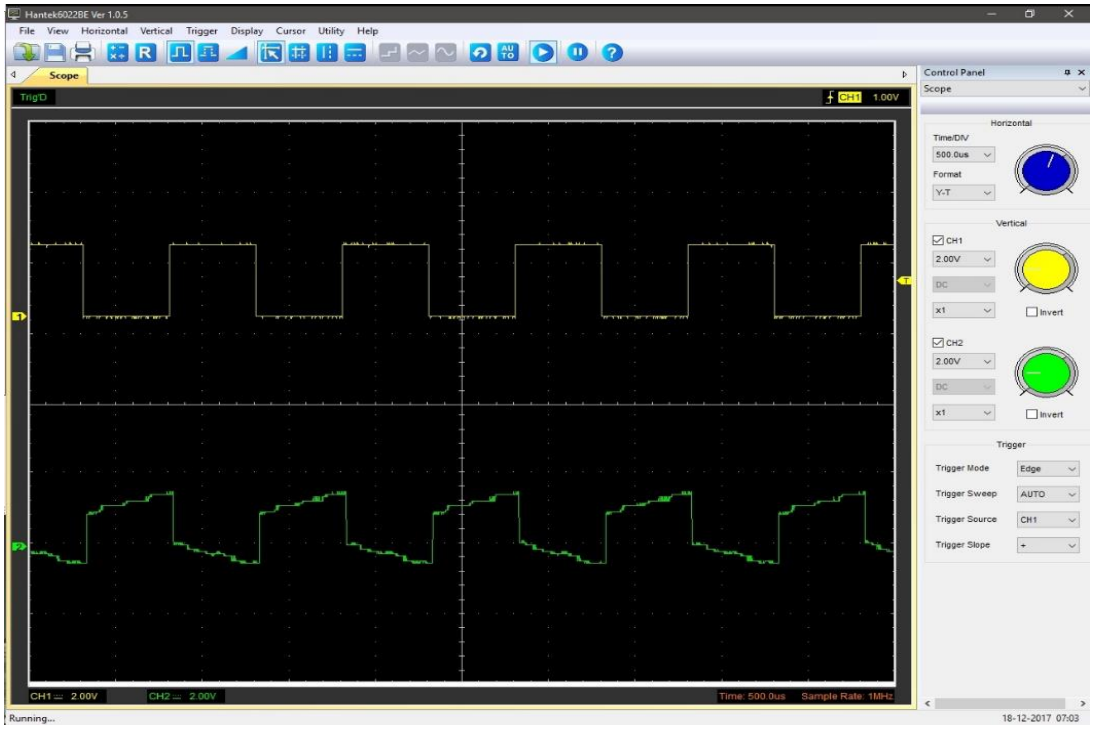


Fig. 6. The waveforms obtained at the output of the transmitter (channel 1) and at the receiver output (channel 2).

In a future paper, the experimental platform will be used for transmitting audio, video and data signals, indicating the using limits of this technology. Maximum transfer rates will be analyzed in different

scenarios of propagation and disposal of optical emitters/receptors

The main characteristic is the property of these systems to accept a variety of signal formats and to connect easily (at interface level) with current communications networks. The signal formats for video transmissions must include video encoding at different levels of digitization accuracy, video compression, high-definition video, and high-speed data (Internet). Understanding aspects of emission and optical reception, the propagation of optical beam, optical detection, and the problems related to multiplexing and the corectă choice of modulation schemes is important for the practical implementation of a transmission system that uses LiFi.

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