Creation of LED network of data transmission based on Visible Light Communication technology

A.Baklanov*, O. Baklanova*, K.Eleusizova*, V.Sayun**, E.Grigoryev**
* D.Serikbayev East Kazakhstan State Technical University/ Faculty of Information Technology and Energy, Ust-Kamenogorsk, Kazakhstan
** Tomsk State University of Control Systems and Radioelectronics/ Faculty of Electronic Engineering, Russia
ABaklanov@ektu.kz, svm@ie.tusur.ru

Abstract—**One way to improve the characteristics of data transmission in wireless networks is to transition to the optical wavelength range. This became possible with the appearance of white LEDs used for lighting. Since 2011, the new technology Visible Light Communication (VLC) is rapidly developing - a technology that allows the light source, in addition to lighting, to transmit information using the same light signal. This technology can use LEDs at speeds up to 500 Mbps. In the article, the amplitude-frequency characteristics of light-emitting diodes of visible light, the principle of their action and technical characteristics necessary for constructing networks using VLC technology are studied.**

I. Introduction

Currently Wi-Fi is the most widely used data communications technology, and using it helps setting up local computer networks and allows connecting and transmitting data to mobile devices. However, the technology has limitations on data transfer rate related to electromagnetic radiation wave length, and, based on medial research, emission intensity near a router assuming a large amount of users may have harmful effects on human health. One way to improve data transfer characteristics in wireless networks may be the conversion to optical wavelength range. This was made possible by the appearance of white LEDs used for lighting. Since 2011 a new technology of VLC (visible light communication) has been rapidly progressing, the technology allowing a light source to not only illuminate a room, but also transfer information using the exact same light signal [1]. VLC uses visible light in optical spectrum (about 400-800 THz). This technology may utilize fluorescent lamps for signaling at about 10 Kbit/s or LEDs for signaling at about 500 Mbit/s. This project proposes developing and creating a prototype of a new generation data transfer wireless network Li-Fi (Light Fidelity or Light-based Wi-Fi) based on an LED system used for illuminating a room.

Since 2011 Harald Haas, optical wireless data transmission specialist and a Professor at the University of Edinburgh (Edinburgh, the United Kingdom), was seriously advancing the new technology of wireless data transmission through blinking light-emitting diode [2,3]. At that time the majority of university professors decided that the idea was definitely interesting, but hardly implementable. Four years later Haas has created the first router that works according to his conception.

The technology was called Li-Fi. The new router showed amazing capabilities. It surpassed Wi-Fi in speed 100 times. The new router achieved record data transmission at 224 Gb/s in the laboratory conditions. The test was performed by the Estonian company Velmenni in the laboratory. Haas provided his first router with a solar cell battery to make the network access offline. Currently the router has stable data transfer rate at 10 Gb/s through barely noticeable blinking LED [4].

In order to deliver the first serial systems to the European market the Li-Fi inventor Harald Haas consolidated his purecompany with Lucibel company to collectively develop and effectively advance the innovation closer to an average consumer in order to make Li-Fi the main way to access the network for users.

The core of technology works according to the following scheme. Three color channels of the miniature LED. lamp (red, green, and blue) transmit data in parallel up to 3.5Gb/s. As the result we can obtain 10Gb/s. Turning on or off the light occurs at breakneck speed that creates enormous aggregation of binary data.

This is called digital modulation with orthogonal frequency-division multiplexing (OFDM), and it allows transmitting millions of light beams with different intensity per second.

Professor Haas demonstrates it with shower head example that spouts strictly in parallel, the light in Li-Fi system working much in the same way.

Meanwhile Chinese and German researches took an interest in researching this topic. As far back as in 2011 the Germans could achieve data transmitting with record rate 800Mb/s at 1.8m distance, and the Chinese connected 4 computers to the internet at 150 Mb/s speed rate.

Professor Haas accentuated that the light waves technology is more reliable in terms of security than Wi-Fi. It is known that it is easy to hack into the Wi-Fi network from outside and intercept the files, since the radio waves pass through the walls beyond premises.

In the meantime the Li-Fi traffic can theoretically be captured only if you are in the same room, where the transmitter and receiver are located, since the light can’t pass through the walls. Thus a reliable barrier is set up for the intruders, they won’t be able to hack or intercept anything either from a street or even from the next room.

But first and foremost the advantage of Li-Fi is in the high speed rate and low power consumption (the standard routers' efficiency reaches 5% in the best case).

Definitely there are future prospects for the technology. The visible light waves have very wide frequency band, it is 4 times wider than the radio waves. There is no risk that the networks become overloaded, it won't lose either speed rate or the network performance like with Wi-Fi [5].

The LEDs are widespread. The infrastructure is almost here, and in addition the LEDs can fulfill dual roles - data transmitter and source of light at the same time. But there is still a question, how correct will the work of the system be in the illuminated room or in the bright sunlight condition.

Yet the Developers have high hopes for VLC - for visible light data transmission that is how this technology is called in scientific terms [6].

The high speed rate of Li-Fi already allows to successfully transmit video streams in HD quality, while keeping up high power performance of the system [7]. Another advantage over Wi-Fi is the accuracy and stability with the internet connection inside the buildings. The weak and intermittent signal area problem is solved due to the equalized LED transmitters distribution [8].

II. Really model of electronic devices

The structural scheme of data transmission using an LED lighting device is shown in Fig. 1.

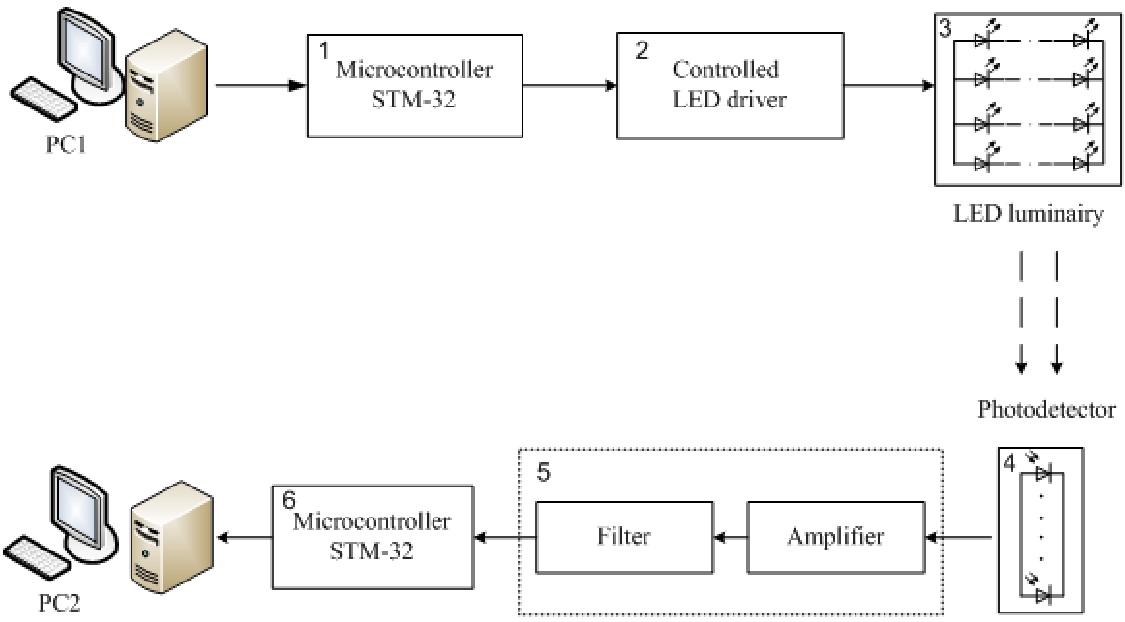

Figure 1. Structural scheme of data transmission system on VLC technology

The transmitting unit of the system consists of three parts. Block (1) - preparing data in a specific format. We use the microcontroller STM 32, which allows to match the signal coming from the personal computer (PC) with the lighting control system.

Block (2) - lighting control. This can be a standard driver, built on the basis of the MAX16800 or LM3404HV, which supports the dimming mode. You can use the control scheme shown in Figure 2.

Block (3) - LED luminary. It consists of 4 LED strips, each of which includes 8 Nichia LEDs connected in series with 1W power.

The receiving unit also consists of three parts. Photodetector (4) based on the photodiode array. Further, a signal amplifier with a high-pass and low-pass filter and a matching device (5). We also use the STM32 microcontroller (6).

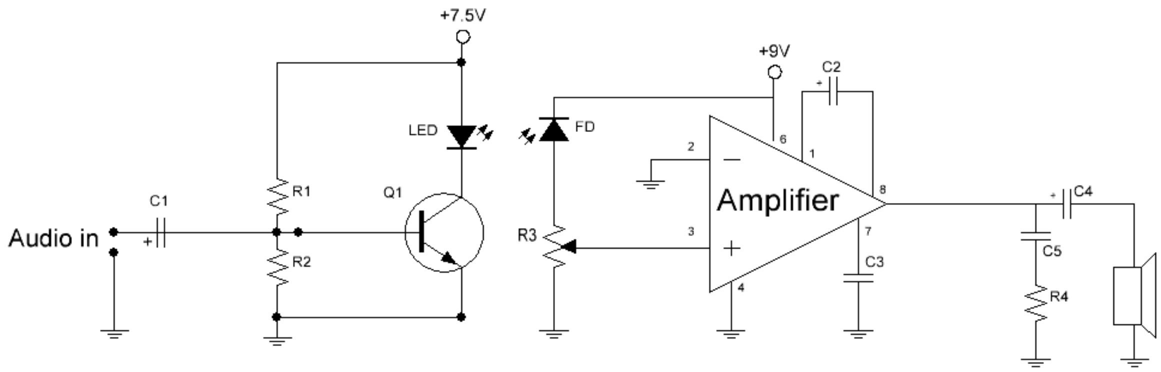

Figure 2. Schematic scheme of the device for transmitting sound with a white LED

To demonstrate the work and test this scheme we created model, a circuit diagram of which is shown in Fig.2.

In this circuit, to control LED, we used an amplifier assembled on transistor Q1, providing the necessary current for the LED. We worked with transistor BC337 (originally with transistors 2N2222A, 2N4401).

For the transistor BC337, the nominal values of the circuit elements: C1 = 2.2μF, R1 = 4.7kΩ, R2 = 1kΩ. The LED was used with a nominal value of 1W produced by Nichia NCSL219B.

The authors have sufficiently well studied the lighting characteristics of this LED. LED was used in the design of luminaires and installation of LED systems for office lighting [9].

The investigation of the frequency characteristics of this LED showed (Fig. 3) that for a signal frequency of 250 kHz the signal does not change in amplitude. Further, a decrease from the original signal to a level of 3dB at a frequency of 3.4 MHz is observed. This means that data transfer using LED in lighting systems will be limited to a speed of 3.2 Mbit/s.

The photodiode BPW34S was used in the receiving path. The amplifier is assembled on the LM386 chip. The nominal elements of this amplifier: C2 = 10μF, C3 = 0.1μF, C4 = 250μF, C2 = 0,05μF, R3 = 10kΩ, R4 = 10kΩ.

For normal operation of the described scheme, it is necessary to conduct studies in the room without daylight, in order to remove the power supplies of the lighting devices. Also, in bright sunlight, data transmission was not possible.

If the input and output of this circuit are connected to microcontrollers, as shown in Fig.1, then real-time audio is transmitted from PC1 to PC2.

Microcontroller STM32F4 Discovery used to organize the transfer of sound. The USB input was used for the transmission channel. A signal from which it was converted using a 24-bit DAC and entered the input of the LED control circuit. An input-output port was used for the receiving channel. The signal to the port came from the amplifier after the low-pass filter C4. Then the signal was digitized and transmitted via USB to a personal computer.

Structural scheme of the STM32F4 Discovery card is shown in Fig. 4.

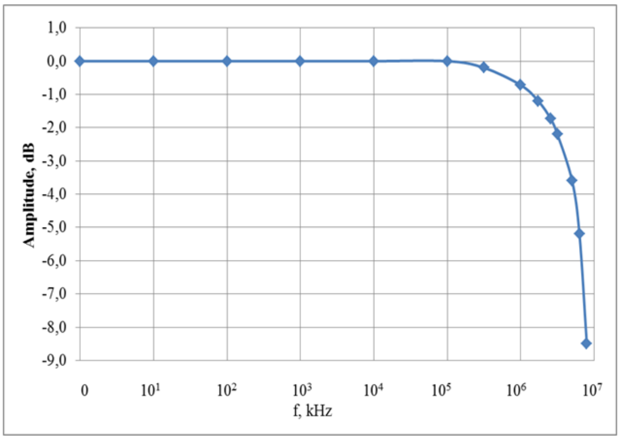

Figure 3. Amplitude-frequency characteristic of a white LED

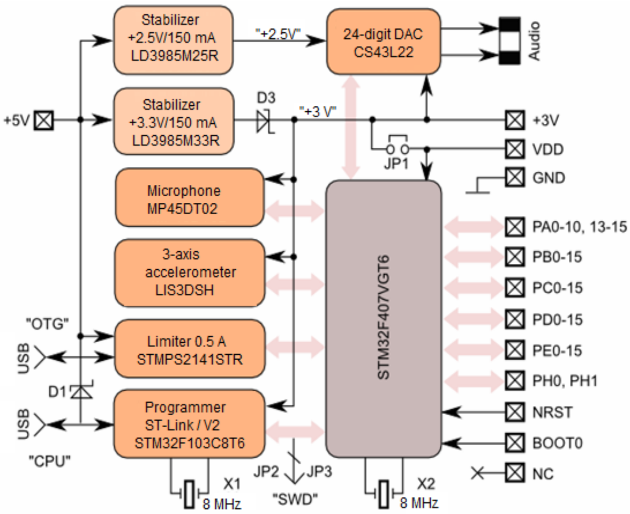

Figure 4. Structural scheme STM32F4 Discovery

The choice of this board for the experiment was due to the fact that this assembly has all the necessary components for working with sound – Analog I / O port, 24-bit DAC connected to the audio connector, USB port for data exchange with the computer. In addition, this board has a low cost (less than $ 10). The appearance of the STM32F4 Discovery card is shown in Fig. 5.

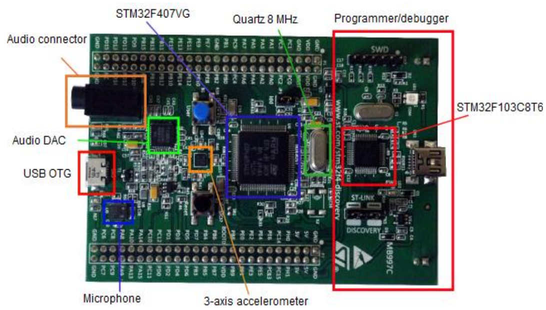

Figure 5. The appearance of the STM32F4 Discovery board

The microcontroller control program is standard. An example is the implementation carried out in [10, 11]. Distortions were almost absent when playing audio using microcontrollers in real time. However, detailed studies of the frequency characteristics of the transceiver-based communication channel based on white light, set forth in this work, were not carried out.

The appearance of the device assembled according to the structural scheme is shown in Fig. 6. In addition, headphones were used to control the sound quality, and a notebook was used to analyze the frequency characteristics of the LEDs, to program the microcontroller and to monitor the operation of the entire circuit.

The optimization of the placement of luminaries in the room plays an important role for the stable transmission of data using LED lighting devices. The decision of the task of choosing lighting devices and the optimization of their placement for uniform illumination of the room while performing the required level of illumination of the working surface of a particular room were published authors in [12, 13].

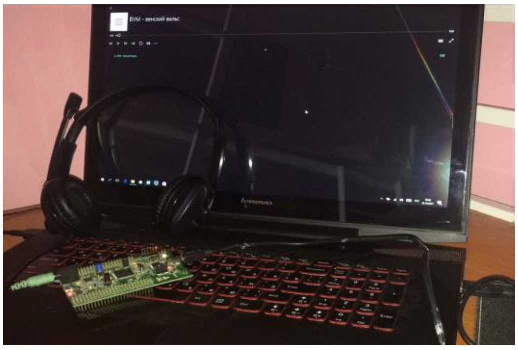

Figure 6. The appearance of the device

Calculations were carried out in DIALux and Statistica programs, simulation of the distribution of illumination was carried out in the MATLab program.

An example of the optimal placement of LED lamps for a particular office space is shown in Fig. 7. Optimal arrangement of lamps is not accidental. LED luminaires 1, 2, 8 and 9 have the highest luminous flux (3120 lm) and are used as basic lighting devices. LED lamps 3, 4, 6, 7 have the smallest light flux (1980 lm) and are used to illuminate unreached "dark" areas of the room. The value of the light flux of the LED luminaire 5 (2390 lm) is the average between the values of other luminaires and is the central lighting device.

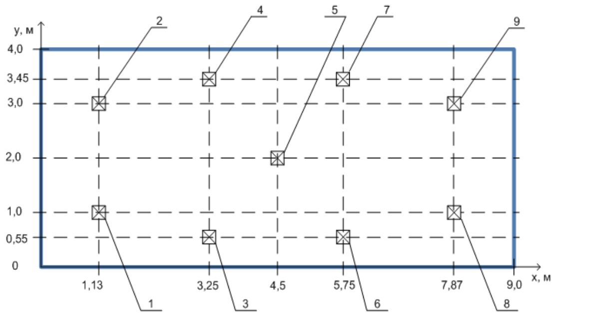

Figure 7.- The placement of LED lamps

After determining the location of the fixtures, a room illumination map was drawn up at the level of the working plane and a model of the distribution of illumination on the working plane was constructed (Fig. 8). It can be seen that the oscillation of the light intensity on the working surface does not exceed 10%, which allows to say about uniform illumination of the room.

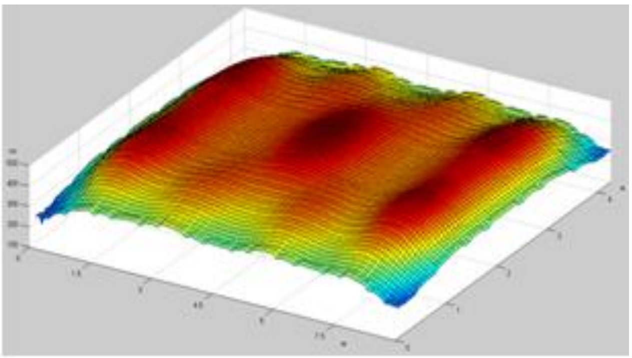

Figure 8. 3D model of the distribution of illumination on the working plane of the room

This arrangement allows for a stable reception of the signal at any point in the room.

CONCLUSION

The work demonstrates the transfer of data (sound) from one computer to another using VLC technology, while the implementation of the transfer is carried out using a simple scheme and a common element base.

To increase the data transfer rate, it is necessary to use the modulation of each color of the white LED. In this case, the hardware that supports higher frequencies is required as the transmitting receiving network. So for high frequencies of the order of 100 MHz the sensitivity of the LED falls by 12-13 dB. This circumstance indicates that for data transmission it is necessary to use more powerful LEDs or several LEDs in parallel.

ACKNOWLEDGEMENT

The study has been conducted with the financial support of the Science Committee of RK MES in the framework of the program target financing for the 2017-2019 biennium by the program 0006/PTF-17 “Production of titanium products for further use in medicine”.

REFERENCES

[1] Kumar N., Terra D., Lourenço N., Alves L.N., and Aguiar R.L. Visible light communication for intelligent transportation in road safety applications // in Proc. 7th Int. Wireless Commun. Mobile Comput. Conf. 2011. – pp. 1513 – 1518.

[2] Ravi Prakash, Prachi Agarwal. The New Era of Transmission and Communication Technology: Li-Fi (Light Fidelity) LED & TED Based Approach // International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), Vol. 3, Issue 2, February 2014.

[3] https://www.ted.com/talks/harald_haas_wireless_data_from_every_light_bulb/transcript

[4] https://www.ted.com/talks/harald_haas_a_breakthrough_new_kind_of_wireless_internet/transcript

[5] Jitender Singh, Vikash. A New Era in Wireless Technology using Light-Fidelity // International Journal of Recent Development in Engineering and Technology, Volume 2, Issue 6, June 2014.

[6] Karthika R., Balakrishnan S. Wireless Communication using Li-Fi Technology // SSRG International Journal of Electronics and Communication Engineering (SSRG-IJECE), volume 2, Issue 3, March 2015.

[7] Dinesh Khandal, Sakshi Jain. Li-Fi (Light Fidelity): The Future Technology in Wireless Communication // International Journal of Information & Computation Technology, Vol.4, N 16, 2014.

[8] Shubham Chatterjee, Shalabh Agarwal, Asoke Nath. Scope and Challenges in Light Fidelity(LiFi) // Technology in Wireless Data Communication International Journal of Innovative Research in Advanced Engineering (IJIRAE), Issue 6, Volume 2, June 2015.

[9] Grigoryeva S., Baklanov A., Gyorok Gy. Control of LED Lighting Equipment with Robustness Elements // Acta Polytechnica Hungarica. – Budapest.2016. – v.13, № 5. – pp.105–119.

[10] Playing sound on STM32-Discovery with Speex. http://we.easyelectronics.ru/STM32/vosproizvedenie-zvuka-na-stm32-discovery-pri-pomoschi-speex.html

[11] Playing sound on STM32F4 Discovery. http://microtechnics.ru/vosproizvedenie-zvuka.html

[12] Grigoryeva S., Grigoryev E. Optimization of the placement of LED lighting for the organization of uniform illumination of office premises // Student: science, profession, life/ OSGUP. - Omsk, 2015. - pp.86-90.

Grigoryeva S., Baklanov A., Kvasov A. Modeling and experimental study of the placement of LED lighting fixtures for office space // Vestnik EKSTU. - 2015. - No. 3 (69). - pp.114-121.