Development of a light control system using an optical aerial information transmission system

D D Savin¹, V V Davydov¹,² and V Yu Rud³,⁴

¹ Peter the Great Saint Petersburg Polytechnic University, 29 Politechnicheskaya str., Saint Petersburg, Russia, 195251
² All-Russian Research Institute of Phytopathology, 5 Institutsky Ave., P. B. Vyazemy, Moscow region, Russia, 143050
³ FTI A. F. Ioffe, 26 Politechnicheskaya str., Saint Petersburg, Russia, 194021

sav.in.dd@edu.spbstu.ru

Abstract. The inefficiency of the use of electric energy for indoor lighting is shown. The necessity of modernization of lighting control systems in the workplace area is justified. The method of automatic control and adjustment of illumination of workplaces and zones where it is necessary is offered. A control system has been developed, which is integrated into the air optical information transmission system (Internet). The simulation of the system operation is carried out, its parameters are calculated. The main characteristics of the fiber-optic communication line with the connected device were measured. The efficiency of the developed device was evaluated.

1. Introduction
The development of scientific and technological progress, the increase in the population and the demand for consumption requires more and more electric energy [1-10]. The increase in the volume of electricity production has an extremely adverse effect on the ecological state of the planet [11-19]. In addition, natural sources of fuel and raw materials for electricity production are being depleted more and more rapidly [4-8, 10-12, 20-23]. Alternative energy sources cannot fully compensate for the growing energy consumption [24-27].

It should also be noted that during the processing of raw materials, a large amount of impurities is released into the atmosphere [9, 11, 28-32]. These pollutants lead to a deterioration in the quality of natural light sources (smog is present in the atmosphere) [32-34]. It is necessary to compensate for the loss of light by increasing the intensity of artificial lighting, that is, to spend more electricity. Therefore, solving the problems of efficient use of the generated electricity is a very urgent task for humanity, which affects several areas.

One of the ways to reduce electricity consumption is to reduce its lighting costs, especially in office and educational premises with windows. This problem is still very relevant, despite the large number of its technical solutions. The main disadvantage of these systems is that they are aimed at controlling the illumination from artificial lighting in some points of the room with automatic adjustment of the power of lighting devices. It is due to the lack of natural light metering in these systems that leads to an unjustified consumption of electrical energy.
2. Automatic light control system with optical communication channel

Nowadays, information is transmitted in various systems (including lighting control systems) using Wi-Fi. This leads to some difficulties: with a large number of users, there is a large congestion of the airspace and an increase in the amount of electromagnetic interference [35-40]. An effective solution to this problem was an optical channel using fiber-optic communication lines (FOCL). Optical systems have greater information transfer capabilities than Wi-Fi, at least by an order of magnitude [36-40]. In addition, various electromagnetic interference and congestion of the air space do not affect the transmitted information [35-40].

Figure 1 shows a block diagram of the automatic lighting control system of workplaces integrated into the optical air information transmission system (Internet).

![Figure 1. Diagram of an automatic illumination monitoring system using an optical aerial information transmission system.](image)

The information from the light sensors is sent to the information processing unit developed by us, which is located in the same building as the computer connection system. In this block, data packets are formed based on the received data. In this case, the channel switching device selects the least loaded channel and receives a time interval during which information about the light level at control points in the workplace will be transmitted over the optical Internet. This creates several features when operating an aerial optical information transmission system. One of them is associated with an additional displacement of the operating point of the electro-optical modulator when switching from one channel to another, since additional temperature stabilization is not provided in such systems.

After the receiving and transmitting module, the light data packets are transmitted over the optical channel to the server, where they are processed. Based on the information received, the server sends commands to the lighting control system to increase or decrease the voltage on a particular lamp.

In addition, to increase the efficiency of the system (in terms of time), the issue of additional charging of the optical communication system batteries from the energy of solar cells located in a number of zones of work desks and lighting devices powered by light was considered.

3. System results and discussion

The conducted simulation of the operation of the lighting control system showed that the Internet speed does not decrease significantly. The additional energy required for the stable operation of the system is not more than 5% of the electrical energy consumed for the operation of the optical communication channel.
Also, the main parameters of the optical communication channel were analyzed, since when connecting a lighting control system in a room, the main problem is the deterioration of these parameters.

One of the important parameters that characterize the operation of fiber-optic communication systems (FOCL), which include an air optical communication channel, is the amplitude-frequency response (AFC). Figure 2 shows the frequency response of a fiber-optic network in the frequency range from 3 to 7 GHz, which operates over the aerial optical channel of the Internet.

![Figure 2](image)

**Figure 2.** The amplitude-frequency response of an air optical channel with a connected light control device at T=294.2 K.

![Figure 3](image)

**Figure 3.** Dependence of the tangential sensitivity of the receiving path on the frequency of the transmitted signal at T=293.7 K.

The obtained result shows that the unevenness of the frequency response of a fiber-optic communication system in the frequency range (3-7 GHz) is about 4-5 dB. This allows you to realize a stable signal transmission with a large amount of information after connecting the lighting control device developed by us.

Another important characteristic of the operation of a fiber-optic cable with an air optical channel is the tangential sensitivity G of the receiving path, which is placed on the users’ table. Figure 3 shows the dependence of the tangential sensitivity G of the receiving path on the frequency of the transmitted signal.

When the lighting control system is connected to the path, the G value has not changed significantly and is about 78 dBm. Therefore, it is not necessary to include additional low-noise amplifiers in the receiving path circuit after connecting the lighting control system developed by us. That is, the main equipment does not need to be reworked.

Let’s define the dynamic range of our system. Figure 4 shows the experimental dependence of the power of the $P_{out}$ output signal on the power of the $P_{in}$ input signal.

![Figure 4](image)

**Figure 4.** Dynamic characteristic of a fiber optic cable with an air optical channel with a connected light control system at T=294.2 K.
The analysis of the obtained results shows that after connecting the lighting control system, the dynamic range of stable operation of the fiber-optic cable with an air optical channel was about 112 dBm. This value of the linearity of the characteristic allows reliable transmission of large amounts of information and corresponds to the values in the classical backbone fiber-optic lines.

4. Conclusion
The simulation of the developed light control system and the calculation of its parameters showed that this system does not introduce significant distortions in the transmitted information over the optical channel for Internet users. For different seasons of the year, preliminary estimates have shown that the use of this system allows you to reduce the electricity consumption for indoor lighting from 10 to 20 

References
[1] Davydov V V, Dudkin V I and Karseev A Yu 2014 Optical Memory & Neural Networks (Information Optics) 23(4) 259 – 264
[2] Davydov V V, Dudkin V I and Karseev A Yu 2014 Optical Memory & Neural Networks (Information Optics) 23(3) 170 – 176
[3] Davydov V V, Dudkin V I and Karseev A Yu 2013 Optical Memory & Neural Networks (Information Optics) 22(2) 215 – 218
[4] Nikitina M, Grebenikova N and Batov Y 2019 IOP Conference Series: Earth and Environmental Science 390(1) 012024
[5] Gryznova E and Batov Y 2019 E3S Web of Conferences 140 09001
[6] Gryznova E, Grebenikova N, Ivanov D and Bykov V 2019 IOP Conference Series: Earth and Environmental Science 390(1) 012044
[7] Davydov R V, Mazing M S, Yushkova V V and Stirmanov A V 2019 Journal of Physics: Conference Series 1410(1) 012067
[8] Davydov R V, Antonov V I, Yushkova V V and Smirnov K J 2019 Journal of Physics: Conference Series 1400(6) 066037
[9] Van S, Cherenmisin A, Chusov A, Switala F and Davydov R 2019 IOP Conference Series: Earth and Environmental Science 390(1) 012011
[10] Davydov V V 1999 Russian Physics Journal 42(9) 822–825
[11] Fadeenko I, Fadeenko V, Reznik V, Moroz A, Popovskiy N and Nikolaev D 2019 IOP Conference Series: Earth and Environmental Science 390(1) 012022
[12] Myazin N S 2018 Journal Physics: Conference Series 1124(1) 031004
[13] Davydov R, Antonov V, Makeev S, and Batov Y 2019 E3S Web of Conferences 140 02001
[14] Davydov R, Antonov V and Moroz A 2019 International Conference on Electrical Engineering and Photonics EExPolytech-2019 (Saint-Petersburg), vol. 8906791 (IEEE), p. 295-297
[15] D’yachenko S V and Zhernovoi A I 2016 Technical Physics 61(12) 1835–1837
[16] Davydov V V and Kiyukhin A V 2020 Atomic Energy 127(5) 274–279
[17] Myazin N S 2018 Journal Physics: Conference Series 1135(1) 012061
[18] Davydov R V and Antonov V I 2018 Journal of Physics: Conference Series 1124(8) 081037
[19] Davydov R V and Antonov V I 2018 Journal of Physics: Conference Series 1135(1) 012087
[20] Myazin N, Neronov Y, Dudkin V and Yushkova V 2018 MATEC Web of Conferences 245 11013
[21] Rukin E V, Myazin N S and Dudkin V I 2019 Journal of Physics: Conference Series 1368(4) 042011
[22] Myazin N S, Yushkova V V and Taranda N I 2019 Journal of Physics: Conference Series 1410(1) 012130
[23] Gizatullin B, Gafurov M, Vakhin A, Mattea C and Stapf S 2019 Energy and Fuels 33(11) 10923–10932
[24] Neronov Y I 2021 Biomedical Engineering 54(5) 333–336
[25] Myazin N S and Yushkova V V 2019 *Environmental Research, Engineering and Management* 75(2) 28–35

[26] Myazin N, Neronov Y, Dudkin V and Petrov A 2019 *IOP Conference Series: Materials Science and Engineering* 497(1) 012111

[27] Smirnov K J and Batov Y V 2019 *Journal of Physics: Conference Series* 1368(2) 022073

[28] Grevtseva A S, Smirnov K J, Greshnevikov K V and Glinushkin A P 2019 *Journal of Physics: Conference Series* 1368(2) 022072

[29] Grevtseva A S, Smirnov K J, Davydov V V and Rud V Yu 2018 *Journal of Physics: Conference Series* 1135(1) 012056

[30] Kozlova E S and Kotlyar V V 2014 *Computer Optics* 38(1) 132-138

[31] Kuzmin M S and Rogov S A 2019 *Computer Optics* 43(3) 391-396

[32] Smirnov K J, Glagolev S F, Rodygina N S and Ivanova N V 2018 *Journal of Physics: Conference Series* 1038(1) 012012

[33] Smirnov K J, Glagolev S F and Tushavin G V 2018 *Journal of Physics: Conference Series* 1124(1) 022014

[34] Smirnov K J, Medzakovskiy V I, Vysocky M G and Glagolev S F 2017 *Journal of Physics: Conference Series* 917(6) 062019

[35] Myazin N S, Dudkin V I, Grebenikova N M, Rud’ V Y and Podstrigaev A S 2019 *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 11660 LNCS 744–756

[36] Fadeenko V B, Kuts V A and Vasiliev D A 2018 *Journal Physics: Conference Series* 1135(1) 012053

[37] Davydov R V, Saveliev I V, Lenets V A and Tarasenko M Yu 2017 *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 10531 LNCS 177-183

[38] Moroz A V and Davydov R V 2019 *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 11660 LNCS 710 – 718

[39] Moroz A V 2019 *Journal of Physics: Conference Series* 1410(1) 012212

[40] Moroz A V, Davydov V V, Malanin K Y, Krasnov A A and Rud V Yu 2019 *Journal of Physics: Conference Series* 1400(4) 044009