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Experimental Study of the Quality of Led Driver Control Signal Broadcast Through Wireless Networks

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Abstract. The paper explores the quality of communication in wireless networks and the assessment of the quality of communication for the main parameters of indoor and outdoor use. The analysis of the influence of the surrounding radio waves of wireless communication networks was carried out on different types of medium. The propagation of radio waves in the room and in the open air was compared. In addition, there is some measurements of signal power passing through different obstacles.

1. Introduction

The current state of the electronics market allows us to use wireless modules to manage various devices of ubiquitous use. One of the main comforts that people use every day is light. Last year's technology gives us new types of light distribution by inventing LEDs. They become very popular in purpose of energy efficiency, long-live, economy. Also there is a LED driver which converts AC from network to acceptable DC. Due to this LED driver can supply microcontrollers with wireless modules, and use them to control condition of LED. However, positions of LED drivers in rooms always different, and control signal losses are imminent. The condition of wireless networks and control signals vary according to different types of rooms and environment.

There have been some experiments to solve the problem. Experiments were conducted on MSP laboratory facilities (two wireless modules: MSP-EXP430F6137R4 - baseboard with microcontroller CC430F6137 and a relay card MSP-EXP430F5137R4 with the microcontroller CC430F5137 on frequency 433 MHz). According to the theory of designing experiments [1-3] to ensure accuracy of measurement with an allowable error of ε = 0,5%, with a probability distribution β = 99% number of required measurements under equation (1):

$$n \geq \left(\frac{t_\beta}{\varepsilon_{\text{adm}}}\right)^2 \tag{1}$$

In accordance with the standard of distribution formulas for probability the distribution of 0.99 is equal to t_β = 2.58. Then the number of required measurements $n \geq 30$ is obtained. Therefore, in each experiment, 30 measurements must be performed. Based on the results obtained below: average mean M [X], dispersion D [X] and average quadratic σ (x) deviation

Modules (transmitter receiver) are located at the height of 1.15 meters. Experiments were made in identical conditions. Experimental conditions: 1) distribution of a radio signal within direct visibility;

2) distribution of a radio signal in free space; 3) distribution of a radio signal indoors with stationary obstacles; 4) distribution of a radio signal with different types of obstacles.

2. 1st Experimental Study

To carry out the experiment, the position of the transmitter has been established, the receiver moved along a straight line, moving away from the first. The experiment is repeated 30 times in 1-2 minutes.

As a result of data processing the following results which are presented in table 1 are received.

Table 1 - Distribution of a radio signal within direct visibility

distance, м	M[X]	D[X]	σ(x)
1	-51,7	0,0648	0,2545
2	-62,8	0,00658	0,0811
4	-65,2	0,0063759	0,0798
6	-65,9	0,00239	0,0488
8	-69,9	0,0265	0,1627
10	-75,5	0,00808	0,0898
14	-80,4	0,081087	0,2847
18	-81,1	0,000799	0,0282
22	-82,7	0,0489	0,2211
26	-83,6	0,1062	0,3258
30	-83,9	0,06204	0,2490
34	-84,9	0,12015	0,3466
40	-85,5	0,04774	0,2184
50	-90.3	0,00631	0,0794
60	-102,1	0,0516	0,2271
74	-103,3	0,0029	0,0538

From table 1 it can be seen that the signal monotonously weakens according to the theory [6-7]. It is caused not only geometrical parameters of the building, but also low power of the transmitter and strong weakening of a signal through obstacles. Existence in the building of walls, partitions, furniture, people and other objects creates a difficult environment of distribution of radio waves. The main effects observed at distribution of radio waves in rooms are the multipath caused by repeated reflections of radio waves from walls and other objects, diffraction on numerous sharp edges of the objects located in the room and dispersion of radio waves. These effects create the difficult interferential structure of the electromagnetic field which is strongly changing when moving people and other objects [10].

3. 2nd Experimental Study

Experiment was made on the street. Results of experiment are presented in table 2. From table 2 it is visible that with increase in distance between the receiver and the transmitter the signal fades [8]. At distribution of a radio signal in free space there are problems connected with influence on a signal of various parameters, such as distance, multibeam distribution, reflection and others [10]. Signal level on reception will be defined not only the bearing signal frequency, but also distance. Besides an obvious tendency of attenuation of a signal, fast fluctuations of power level which depend on distance are observed. At distribution of a signal in free space, the accepted power is inversely proportional to a distance square to the transferring antenna [9]. The phenomena of dying down of a signal are observed. At some values of distance of a signal from antennas, they pass different ways, come in an antiphase to the reception antenna that can reduce power. At some other values of distance the entering signals develop that increases signal level. The schedule of dependence of power of a signal from distance within direct visibility is represented in figure 1.

Table 2 - Distribution of a radio signal in open space

distance, м	M[X]	D[X]	σ(x)
1	-57,4	0,0169	0,13
2	-59,7	0,00032	0,0178
4	-68	0,0516	0,2271
6	-70,6	0,00068	0,0260
8	-75,4	0,011632	0,1078
10	-79,7	0,00648	0,0804
14	-81,9	0,00658	0,0811
18	-77,9	0,00759	0,0871
22	-85	0,0023	0,0479
26	-85,5	0,00265	0,0514
30	-88,2	0,004498	0,0670
34	-92,06	0,00151	0,0388
40	-94,03	0,0022	0,0469
50	-96,69	0,00297	0,0544
60	-104,9	0,0036	0,06
70	-105	0,0064	0,08
80	-106	0,006	0,077

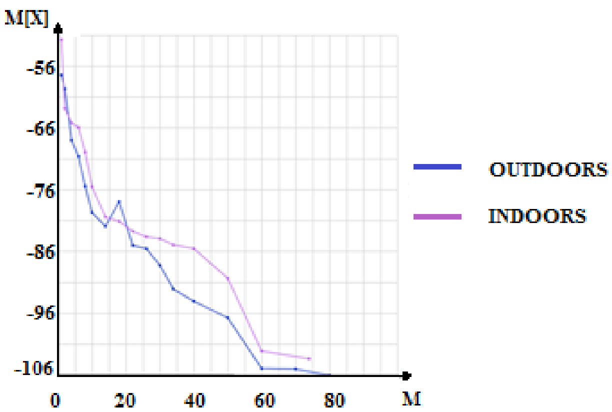

Figure 1 - The schedule of dependence of power of a signal from distance within direct visibility

At distribution of a signal indoors it meets on the way barriers of an artificial origin as furniture, walls, and various stands. At distribution out of the room obstacles of a natural origin meet these are mountains, trees, a lawn, asphalt. Thus, any more or less broad object can create an obstacle. Depending on the sizes of a barrier several options are possible: a signal, the obstacle will be possible, simple to bend around, or behind the found object the so-called parietal zone with very low level of a signal is formed, or the signal will be absent at all. By results of experiment it is visible that distribution of a signal out of the room worse than indoors. It is explained by negative or destructive multibeam distribution [9]. There is a decrease in force of a signal that is reduction of amplitude. When multiple radio signals arrive to the receiver at the same time and are not in a phase with a basic signal, decrease in level of a signal will be result. It is assumed that the phenomenon of the influencing other signals became much more powerful. Indoors at distribution of a radio signal the special gain, that is increase in force of a signal, increase in amplitude compared with distribution of a signal out of the room for MSP430RF4 payment is swept up. It is also positive or constructive multibeam distribution of a signal. When multiple radio signals arrive to the receiver at the same time and are in a phase or with a small in relation to a basic signal, increase in force of a signal (increase in amplitude) will be result. The small difference in phases ranging from 0 degrees to 120 degrees will cause a signal level gain [10].

4. 3rd Experimental Study

Indoors, in a zone of the complicated visibility of a condition of distribution of radio waves are more diverse. Concrete walls (M350 brands) with thickness of 10-15 cm [4] between offices are stationary obstacles (figure 2). Rigid obstacles (part of a design of the building) also influence opportunities of distribution of a radio signal.

Results of experiment are presented in table 3.

Table 3 – Signal passing through concrete obstacles

distance, m	4	6	10	12	20
M[X]	-63,4	-64,1	-75,1	-75,5	-98,2
D[X]	0,0346	0,0085	0,0079	0,0202	0,0042
σ(x)	0,186	0,0921	0,088	0,1421	0,0648

The schedule of dependence of power of a signal from distance taking into account obstacles 1 is represented in figure 2.

From table 3 it is visible that attenuation of a signal happens to increase in distance of the receiver from the transmitter.

In the analysis of results of experiment it is necessary to take into account reflection of a signal on walls at normal falling of a radio wave and "focusing" of a wave stream owing to refraction [4]. When falling a radio wave on an interface of two environments with various indices of refraction the part of a wave is reflected back. Coefficients of reflection of S_{11} and passing of S_{21} are determined by power by formulas are represented in equation (2):

$$S_{11} = \left(\frac{n_2 - n_1}{n_2 + n_1}\right),\ S_{21} = \frac{4n_2n_1}{(n_2+n_1)^2} \quad (2)$$

where n_1, n_2 – indices of refraction of environments [5]. When calculating it is possible to take $n_1 = 1$ (air), $n_2 = 1{,}9 – 2$ (wall), then from a wall about 10% of a signal are reflected. Not accounting of this effect leads to overestimate of value of weakening of Q approximately on 0,5 dB.

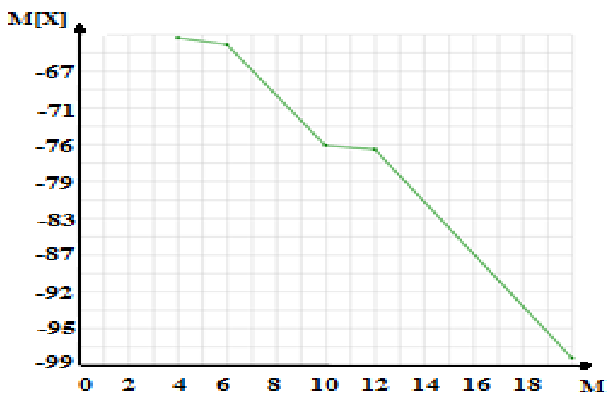

Figure 2 – The schedule of dependence of power of a signal from distance taking into account obstacles 1

The second factor – "focusing" of a radio wave owing to a refraction, leads to understating of size of absorption as it is explained on figure 5. The spherical radio wave extending from O1 point upon transition from the environment with index of refraction of n1 on Wednesday with an indicator of n2 and again on Wednesday with an indicator of n1 "nestles" from an axis O1O2. Narrowing of a radiowave passing through an obstacle is represented in figure 3.

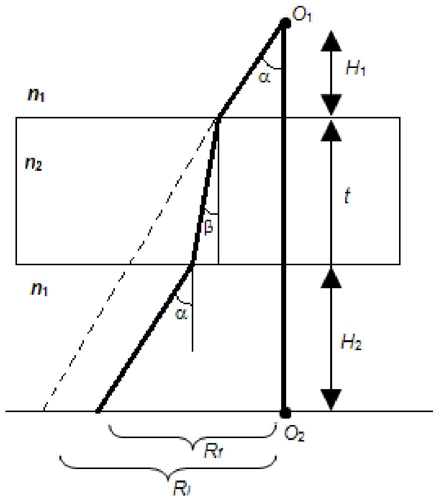

Figure 3 - Narrowing of a radiowave passing through an obstacle

Let the receiver settle down in O_2 point. If the wall wasn't, then cone radius bare with a corner from the top in O_1 point at distance (H_1+t+H_2) would make R_i. In the presence of a wall about the radius of a cone will make R_f. Thus, as a first approximation, energy of the transmitter in this cone in the first case is distributed on the square, and in the second case – on the square. Then relative strengthening of a signal in the receiver (in the absence of absorption in a wall) will be calculated by the equation (3):

$$M = \left(\frac{R_i}{R_f}\right)^2 = \frac{(H_1+t+H_2)\cdot tg\alpha}{H_1\cdot tg\alpha+t\cdot tg\beta+H_2\cdot tg\alpha} = \frac{H_1+H_2+t}{H_1+H_2+t\cdot tg\beta/tg\alpha} \quad (3)$$

where $\frac{\sin\alpha}{\sin\beta} = \frac{n_2}{n_1}$.

Along an axis O_1O_2 ($\alpha = 0$) strengthening will be calculated by the equation (4):

$$M \approx \frac{H_1+H_2+t}{H_1+H_2+t/n_2} \quad (4)$$

Strengthening owing to a refraction as much as possible if the receiver and the transmitter are driven into the corner (H_1 = by H_2 = 0), (3 dB). With increase in distance of the receiver and transmitter up to a wall this effect quickly decreases.

Taking into account the considered factors, results of measurements of absorption of Q in provisions 1-5 have made:

- Q" 0,7 ± 1 dB; (situation 1 and 2);
- A concrete wall with thickness of 10 cm of Q" 12,1 ±1 dB. (situation 1 and 3, L = 6 m);
- Q" 0,4 ± 1 dB; (situation 3 and 4);
- A concrete wall with thickness of 10 cm of Q" 22,7 ± 1 dB. (situation 3 and 5, L = 10 m)

Thus, experiments established that if the receiver and the transmitter are installed at distance of several centimeters from a wall (on different sides) the concrete wall brings least of all easing – about 0,7 dB taking into account a refraction. Weakening of a signal is influenced by increase in distance of the receiver from the transmitter [11].

5. 4th Experimental Study

Experiment was made at the laboratory stand. The imitating reduced model of carrying out experiment with different types an obstacle is offered. For carrying out experiment position of the transmitter and receiver has been recorded. Wave guide length 1,5 m. Measurements repeated 30 times in 1-2 minutes, considering 4 types of materials on the way of distribution of a radio signal (figure 6). It were a foil (with thickness of 10 microns), gypsum cardboard (with thickness of 10 mm), chipboards (with thickness of 8 mm) and ceramics (with thickness of 5 mm).

Table 4 – Radio signal distribution through different types of obstacles

№ experiment	1	2	3	4	5
M[X]	-46,79	-49,02	-49,72	-50,46	-52,89
D[X]	0,10201	0,00698	0,01922	0,00032	0,0803
σ(x)	0,319	0,0835	0,1386	0,0178	0,2833

When passing through objects of a radio wave are weakened or absorbed by material. When passing through materials of a radio wave lose part of the energy due to absorption [11]. Force of easing depends from

− thickness,
− structures/properties of material,
− material density.

From table 4 it is visible that availability of gypsum cardboard and chipboard approximately equally influence distribution of a radio signal in a wave guide. And the obstacle in the form of ceramics was sharply worsened by a signal on 6,1 dBm.

Schedule of dependence of power of a signal from a type of an obstacle is represented in the figure 4.

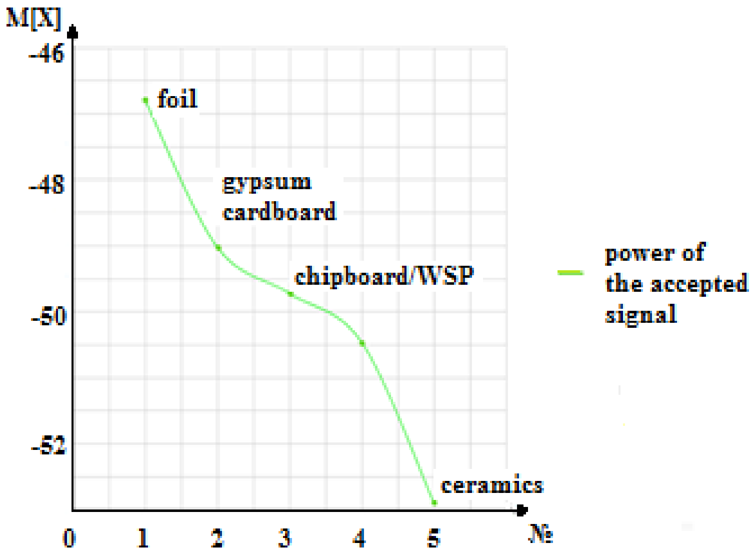

Figure 4 – Schedule of dependence of power of a signal from a type of an obstacle

Important parameter for a signal is power. The power accepted at a certain distance from the transferring antenna can be expressed through the power measured at any standard distance i.e. through basic power [11]. Considering the basic power of a signal without obstacles, we find the relative size of reduction of power of the accepted signal, which is represented in table 5.

Table 5 – Relative size of reduction of power of the accepted signal

Type of obstacles	foil	gypsum cardboard	WSP	ceramics
Power difference (-basic power) [dBm]	-2,23	-2,93	-3,67	-6,1
Thickness [mm]	0,01	10	8	5
Relative size [W/m]	59,8	0,0509	0,043	0,0245

6. Conclusions

By results of the made experiments dependence of power of the accepted signal from distance between the receiver and the transmitter inner outer space of the room in the conditions of direct visibility was received. At distance of 10 m reduction of power of a signal by 4,2 dBm, on 20 meters 3,2 dBm, on 30 meters 4,3 dBm, on 60 meters about 3 dBm is noticed. As a result of experiment it was revealed that by wireless transfer of text and numerical data between MSP430RF4 TI payments the radio signal extends indoors better, than out of the room.

It was revealed that attenuation of a signal happens to increase in distance of the receiver from the transmitter. In information transfer between MSP430RF4 payments concrete walls exert not considerable impact as at situation 1 and 2 weakening of a signal makes 0,7 dBm on attenuation of a radio signal, and at provisions 3 and 4 weakening of a signal makes 0,4 dBm. At the maximum distance recommended by firm the producer – 100 meters, the radio signal has sharply weakened on-98 dBm, that is at this distance transfer of a text or numerical package of information is impossible.

Recommendations: research of the MSP 430 microcontroller shows that they are recommended for transfer of control signal at distance no more than 90 meters in rooms that can be used for controlling LED driver, in case location of transmitter and receiver located in different rooms an there are many obstacles between them recommended distance no more than 10 meter.

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