OCCURRENCE CHANNEL OF LEAKAGE OF THE ACOUSTIC DUE TO THE MODULATION OF THE VISIBLE LIGHT

Shvyrev B.A. PhD. (Phys.-Math.)[1], Assoc. Prof. Vlasenko A.V. PhD. (Engineering)[1], Makaryan A.S. PhD. (Engineering)1, PhD student Timonov D.A.[1]
Kuban State University of Technology, Krasnodar, the Russian Federation [1]
bor2275@yandex.ru, alex_vlasenko@list.ru, msanya@yandex.ru, dmitrii-timonov@bk.ru

Abstract: *The development of microelectronics forms new channels of confidential information leakage. The transmission of acoustic information by digitally modulating the light output of LEDs has now become physically realizable. Theoretical calculations showed a high potential sensitivity of MEMS microphones. The combined use of digital MEMS microphones and LED room lighting controllers allows you to transmit a digital data stream of 40 800 Bits / s over 100 meters with minimal signal-to-noise ratios. Conducted research reveals a new information leakage channel and describes its characteristics, which will make it possible to develop administrative and technical countermeasures.*

Keywords: ACOUSTIC LEAK CHANNEL, LED, MODULATION OF THE VISIBLE LIGHT, DSP, MEMS.

1. Introduction

Visible light produced by LEDs has great potential as a medium of transmission of acoustic information by means of modulation of visible light. The very nature of visible light reveals a number of important properties such as a huge unregulated frequency band, the absence of radio interference, the possibility of using high frequencies of carrier waves, a small attenuation of visible light with distance, so on a clear day the attenuation of the optical signal in the atmosphere is only a few decibels per kilometer. The main problem in ensuring the transmission of information through the optical channel is a strong background illumination and noise of the photodetector.

2. Identification of information leakage channel

2.1. Determination of the leakage channel of acoustic information

The acoustic channel of information leakage by means of the modulation of visible light (AKUMS) is understood as the acquisition of acoustic information using the equipment that receives the modulated optical signal in the visible range. The modulation of visible light is generated by a microcontroller that controls a non-coherent LED visible light source. It is possible to use various types of modulation, such as analog amplitude modulation of light intensity, and digital modulation types in terms of the duration and intensity of transmitted light pulses.

The technological transition in the creation of lighting in rooms from incandescent lamps to high-tech low-inertia LED illuminators containing controllers creates the prerequisites for the formation of a new information leakage channel.

2.2. AKUMS structure

The generalized leakage channel of acoustic information through the modulation of visible light has the form shown in Fig.1.

The considered AKUMS channel consists of a transmitter of a signal in the visible range, located in the room, or a special technical means (CTS) and a reconnaissance receiver remote at a distance R from the transmitter in an optical medium.

Acoustic confidential information is transmitted through a microphone to a digital signal processing unit (DSP). The output signal is a digital data stream with different coding. The digital signal is modulated by the LED controller according to the intensity and duration of the light pulses. Visible modulated light from the LED propagates in the optical medium both directly in the forward direction to the receiver, and by means of scattered re-radiation. The receiving part of the AKUMS equipment consists of an optical system of lenses and a photodetector. Photodiode as an embodiment of the photodetector under the influence of the incident light flux with varying intensity generates an electrical photocurrent of digital data. The encoder and digital-to-analog converter of the DSP unit generates from the received digital coded sequence a reconstructed acoustic signal with confidential information.

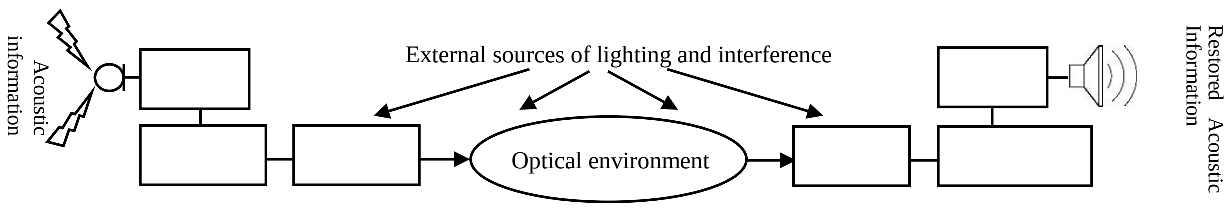

Fig.1. *Block diagram of the acoustic channel information leakage through the modulation of visible light*

3. Acoustic Information Leak Channel Characteristics

The main characteristics of the JTS significantly affect the possibility of unauthorized information: the signal-to-noise ratio at the transmitter microphone, the parameters of the digital processing of the acoustic signal (the amount of information), the type of digital modulation, the solid angle and the luminous flux of the radiation power.

The main characteristics of the optical environment have a significant impact on the ability to transmit information: the distance between the CTS and the intelligence receiver, the light power of the illumination, the scattering, absorption and reflection coefficients, the optical density of the propagation medium, the noise power.

The main characteristics of the reconnaissance receiver affecting the possibility of obtaining information at a distance R: angular and numerical apertures, as well as the values of the relative aperture, f-number, geometric aperture of the optical system; sensitivity, geometric size, spectral and frequency response of the photodetector.

3.1. The sensitivity of the digital transmitter microphone

The threshold for hearing a person is $2x10^{-5}$ N / m² or 20 μPa for a 1 kHz sine wave. This is the minimum sound level or a very quiet sound that a person can still hear.Уровень звукового давления в децибелах Lzv определяется по формуле

$Lzv = 20lg(P/P_0)$, where $P_0 = 2 \cdot 10^{-5}$ Pa.

Not loud speech man ranges from 45 to 55 dB.

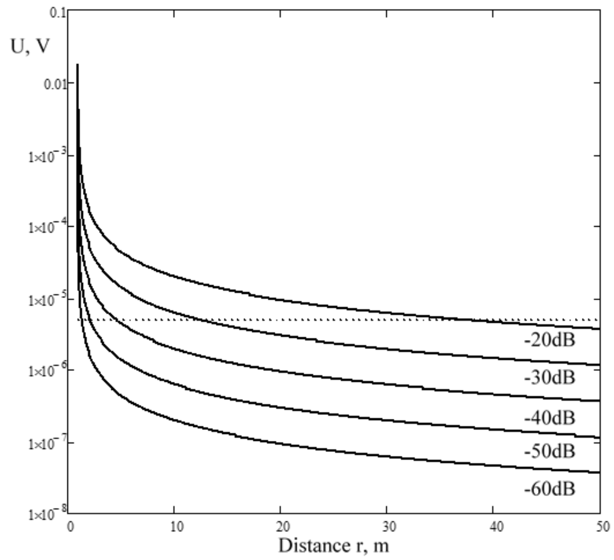

Fig. 2. The dependence of the voltage generated by the sound pressure on the microphone on the distance r from the speaker with the level Lzv = 50 dB. The dotted line corresponds to a level of 5 μV.

Microphones have diverse parameters, but to analyze the leakage channel, consider the sensitivity of the Lm microphone. Lm shows the magnitude of the induced potential difference when exposed to a sound pressure of 1 Pa. Lm is the ratio of the voltage E developed at the nominal load resistance at a sound pressure of 1 Pa to the voltage corresponding to 1 mW of power, expressed in decibels.

$Lm = 20lg(E/1000)$.

As it is known with increasing distance, the sound pressure level drops and the 6dB rule is valid for free space without scattering and absorption. According to which the pressure level decreases by 6 dB each time the distance is doubled. In reality, the environment is affected by the propagation medium, medium temperature, etc. For practical calculations use the following relationship:

$L_p = L_w - lg(r) - 11, dB.$

Where L_w is the sound pressure level at the source, L_p is the sound pressure level at distance r from the source (distance r is measured in meters).

Taking into account the considered dependencies, the voltage induced on the microphone with regard to the distance is determined by the expression:

$$U = \frac{2}{r} 10^{[0,05(Lzv+Lm-11)-5]}$$

Clause 5.3.2 outlines the requirements for microphone amplifiers when measuring the parameters of microphones. So the microphone amplifier should have the following parameters: “the voltage of its own noise and background, brought to the input, should not exceed 5 μV”. We assume that the voltage value of 5 μV determines the lower threshold recorded. In accordance with this threshold, we find the dependence of the potential difference created by the microphone on the distance for microphones with different sensitivity values.

For the formation of a leak channel, other parameters of the microphone are not very informative, since the greatest threat is the leakage of confidential negotiations carried out in a quiet voice. From the graph it is clear that the sensitivity of the microphone is the defining characteristic of the source of information. Maximum sensitivity is determined by the largest negative number. Classic analog microphones provide sensitivity from -40 to -65 dB. MEMS digital microphones are characterized by high sensitivity from -18 to -35 dB. Microphones with Lm = 22 dB are quite common. The dependences presented in Fig. 2 show the good theoretical results of MEMS microphones in free space along the axis. And identifies the potential threat of an acoustic leakage channel.

3.2. Digital processing options in the acoustic leak channel

The parameters of digital processing of an acoustic signal determine the amount of information for transmitting a streaming audio signal from a room for processing confidential information. Consider the minimum requirements for converting voice information. In international and domestic standards, the bandwidth is specified from *fmin* = 300 Hz to *fmax* = 3400 Hz of the standard telephone channel, which determines the maximum frequency of the transmitted acoustic signal via AKUMS. The upper frequency determines the required number of samples of a discrete signal. Another voice parameter is dynamic range. The dynamic range of the ADC is determined by the expression:

$DR_A = 20log\left(\frac{A_{max}}{A_{min}}\right),$

where A_{min}, A_{max} is the minimum and maximum value of the harmonic signal, $A_{max} = Q \cdot 2^{(q-1)}$, $A_{min} = Q/2$, Q is the quantization step, q is the number of digits. The number of digits and dynamic range can be represented as

$DR_A = 20log\left(\frac{Q \cdot 2^{(q-1)}}{Q/2}\right) = 6.02q.$

The dynamic range of the voice (main tone) is 25 - 35 dB, chorus 30-45 dB, etc. . Thus, for a speech path with a dynamic range of 35 dB, q = 6 is required.

Calculate the capacity of the speech path with the upper frequency of 3400 Hz and a dynamic range of 35 dB for the presentation, which requires a six-digit code $3400 * 2 * 6 = 40800$ bps or 5.1 Kb / s. The considered values correspond to the minimum requirements for a digital speech path, an increase in the frequency and dynamic range will inevitably lead to an increase in the amount of information.

The digitized speech signal is converted to a digital modulation type by controlling the LED controller. Light incoherent sweat from the LED is a sequence of pulses of different amplitudes and durations propagated in an optical medium. In the process of propagation, the information luminous flux fades and dissipates. Let us find an estimate of the limiting values of the transmission distance of messages.

In [7], the authors note the feasibility of a data transfer rate of 11 Mbit / s in a laboratory experiment at a distance of 3 meters. When using bright LEDs, a blue filter and binary amplitude modulation, a data rate of 280 Mb / s was obtained at a distance of 23 cm. The experiments did not use optical lens systems and were studied with the aim of obtaining the highest data rate. Based on the results of the experiments described and on the relation between bandwidth and signal-to-noise ratio, we describe the bandwidth of the information leakage channel as a function of distance:

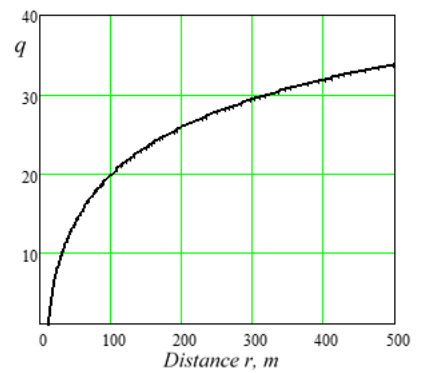

Fig.3. Influence of signal-to-noise ratio and transmission range for transmission of 40800 bit/s streaming information

$$C(r) = \Delta f \log\left(1 + 10^{q/10}/r^2\right),$$

где C – пропускная способность, Δf – полоса пропускания, q – отношение сигнал/шум в дБ в непосредственной близости от источника данных.

4. Conclusion

The development of microelectronics forms new channels of confidential information leakage. The transmission of acoustic information by digitally modulating the light output of LEDs has now become physically realizable. Theoretical calculations showed a high potential sensitivity of MEMS microphones. The combined use of digital MEMS microphones and LED room lighting controllers allows you to transmit a digital data stream of 40 800 Bits / s over 100 meters with minimal signal-to-noise ratios. Conducted research reveals a new information leakage channel and describes its characteristics, which will make it possible to develop administrative and technical countermeasures.

5. Literature

1. Ananiev V.A. Balueva L.N. Murashko V.P. "Ventilation and air conditioning systems" theory and practice ed. Euroclimate, 2008.

2. GOST R 53576-2009 (IEC 60268-4: 2004) Microphones. Methods of measurement of electroacoustic parameters.

3. Acoustics: A Handbook / A. P. Efimov, A.V. Nikonov, M.A. Sapozhkov, V.I. Shorov; Ed. M.A. Sapozhkova. - 2nd ed., Pererab. and add. - M .: Radio and communication, 1989. - 336 p.

4. Alexander Radzishevsky. Basics of analog and digital sound. From - to the house “Williams”, M, St. Petersburg, Kiev, 2006, - 281.

5. Julian Dunn. Measurement Techniques for Digital Audio. Audio Precision, 2004, - 203.

6. AES17-1998. Revision of AES17-1991. AES Standard Method for Digital Audio Equipment.

7. Visible light communication: applications, architecture, standardization and re-search challenges. Latif Ullah Khan. Digital Communications and Networks 3 (2017) p78–88.