Determination of the Eb / N0 Ratio and Calculation of the Probability of an Error in the Digital Communication Channel of the IP-Video Surveillance System

Mher V. Markosyan
Yerevan Telecommunication Research Institute, Republic of Armenia, Yerevan

Rafail T. Safin
Russian-Armenian (Slavonic) University Republic of Armenia, Yerevan

Vladimir V. Artyukhin
Almaty University of Power Engineering and Telecommunication Republic of Kazakhstan, Almaty

Elena G. Satimova
Almaty University of Power Engineering and Telecommunication Republic of Kazakhstan, Almaty

ABSTRACT

Due to the transition from analog to digital format, it possible to use IP-protocol for video surveillance systems. In addition, wireless access, color systems with higher resolution, biometrics, intelligent sensors, software for performing video analytics are becoming increasingly widespread.

The paper considers only the calculation of the error probability (BER - Bit Error Rate) depending on the realized value of S / N .

Keywords

Signal noise ratio(S/N), Digital video channel, Quality of channel, protocol of data exchange, wireless LANs

1. INTRODUCTION

New opportunities expand the scope of application of video surveillance systems - in industry and transport, in telecommunications and financial institutions, in healthcare and education, in retail trade, gambling (casino). Video surveillance is used in government monitoring and national security systems and systems designed to protect the public. At the same time, the requirements for the main characteristics of the video system remain the same [1]. And if the light sensitivity and resolution of the video camera can be determined in a traditional way using a designed stand [2], there are certain difficulties with the signal-to-noise ratio, however.

Wireless video systems, as well as wired ones, consist of cameras and video recorders. And it is not correct to classify cameras and recorders separately. The main parameter, which determines the functional characteristics of the wireless video surveillance system, is the protocol for transmitting information over the communication channel. In this case, a large number of parameters affect the quality of the video. The quality of the video affects almost everything: the number of users connected to the network, the number of connected cameras, network equipment, etc.

For the experiment, a wireless IP video camera D-Link DCS-7000L was chosen. When using a radio channel in the 2.4 GHz band for wireless networks, 13 channels are available with 5 MHz intervals between them. For signal transmission, 802.11b / g / n wireless devices use 20 MHz channels. A 802.11b / g / n standard wireless device uses one of 13 channels from the 20 MHz band within the 2.4 GHz frequency, however in fact it uses 5 overlapping channels. For example, if the access point uses channel 6, it interferes significantly with channels 5 and 7, and interferes with channels 4 and 8. When the data is transmitted by the device, the wireless signal deviates from the center frequency of the channel by +/- 11 MHz. In some cases, the radio frequency energy deviates up to 30 MHz from the central channel. To avoid interference between channels, it is necessary that their bands are spaced apart by 25 MHz. Thus, there are only 3 non-overlapping channels on the 20 MHz band: 1, 6, and 11 [3].

Wireless access points operating in the 2.4 GHz band within one covered service area should avoid overlapping of channels to ensure the quality of the wireless network (Figure 1).

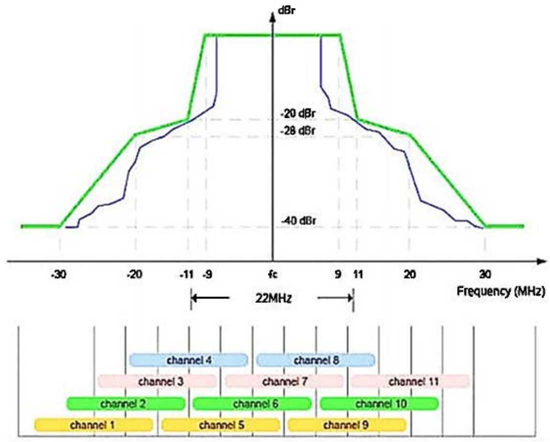

Figure 1 - Bandwidth of the IEEE 802.11ac channel

One of the main points is the compatibility of 802.1a / b / g / n 802.11a / with 802.11ac wireless devices.

Most 802. 11ac wireless LANs use 40 MHz channels only in the 5 GHz band. In networks using the frequency band 5 GHz (802.11ac), there are no problems of crossing channels. 802.11ac standard devices can use a channel width of 20 or 40 MHz. When using 40 MHz bandwidth (802.11ac devices), there is a double increase in bandwidth compared to the channel bandwidth of 20 MHz (802.11b / g / n devices).

In the 5 GHz band, 19 non-overlapping channels are available which are more suitable for use in 802.11ac devices, and they provide the highest possible data rate. The signals are distributed without overlapping channels with a bandwidth of 40 MHz.

However, when using 40 MHz band by 802.11ac devices, existing 802.11b / g / n access points can interfere with their operation, which will lead to a decrease in the performance of the entire network segment [3].

2. DIGITAL VIDEO CHANEL AND CALCULATION OF S/R

The purpose of any communication channel is the transmission of information. In this case, broadband communication channels are considered for transmitting both video and audio signals. From the communication theory it is known that there are two main reasons for the decrease in the reliability of the transmission. The first is a reduction in the signal-to-noise ratio (S / N-Signal to Noise, or SNR-Signal Noise Ratio). The second reason is signal distortion. The signal can be an information signal, a video pulse or a modulated carrier.

In terms of analog signals, the concepts of intermodulation distortions are used (for example, well-known STB, CSO and channel distortion). In digital communication systems, for the most part, the concept of intersymbol interference is used. The paper considers only the calculation of the error probability (BER - Bit Error Rate) depending on the realized value of S / N [4].

An important characteristic of the performance of digital communication systems is the signal to noise ratio. The signal-to-noise ratio for digital communication systems is the ratio of the signal energy per bit to the noise power density per 1 hertz. Consider a signal containing binary digital data transmitted at a certain rate - R bit / s. Recall that 1 W = 1 J / s, and calculate the specific energy of one bit of the signal: Eb = STb (where S is the signal power or the output power of the transmitter of the video camera; Tb is the transmission time of one bit). The data transfer rate R can be expressed in the form. Considering that the thermal noise present in the 1 Hz bandwidth for any device or conductor is:

$$N_0 = kT(\text{Вт/Гц}), \qquad (1)$$

where N_0 is the noise power density in watts per 1 Hz band; k is Boltzmann's constant, , $k = 1{,}383 \times 10^{-23}\, J/K$;

T is the temperature in Kelvin (absolute temperature), then, consequently,

$$\frac{E_b}{N_0} = \frac{S/R}{N_0} = \frac{S}{kTR}\ . \qquad (2)$$

The E_b/N_0-ratio is of great practical importance, since the rate of error bits occurrence is a (decreasing) function of the given ratio. At a known value of E_b/N_0, which is necessary to obtain the desired error level, all other parameters in the above equation can be selected. It should be noted that in order to maintain the required value of E_b/N_0, when the data rate R is increased, it is necessary to increase the power of the transmitted signal with respect to noise. Quite often, the noise power level is sufficient to change the value of one of the data bits. If you increase the data transfer rate by half, the bits will be "packed" twice as densely, and the same external signal will result in the loss of two bits of information. Consequently, with constant signal and noise power, an increase in the data transfer rate entails an increase in the level of error occurrence.

Among the power ratio indicators, the carrier-to-noise ratio (C/N) is also widely used, which shows how many times the power C of the received modulated high-frequency (RF) carrier at the output of the receive filter with a band greater than the noise power N generated by the joint action of all sources of noise in this tract. The C / N ratio is a convenient parameter for energy calculations at the receiver input.

For example, using a QAM system with the following parameters: symbolic speed: = 6.875 MHz, spectrum rounding factor: a = 0.15, receiver band noise (IRD) W = 8 MHz; The constellation size is M = 64, the carrier power is -25 dBmW (83.75 dBμV). The required ratio is C / N = 23 dB. Conversion formulas from dBm to dBμV:

$$U_{(\text{dBμV})} = 108{,}75 + D_{(\text{dBμV})}. \qquad (3)$$

For convenience, we will give numerical values in both frames.

1) Energy per bit of information

$$E_b = C - 10lg[\log_2 M\ \cdot\ f_S\ ] = 101{,}15 \text{ dBμV } (7{,}6 \text{ dBμV}).$$

2) Noise power:

$$N\ =\ C\ -\ C/N\ = -48{,}00 \text{ дБмВт } (60{,}75 \text{ dBμV}).$$

3) Noise Spectrum Density:

$$N_0\ =\ N -\ 10lg\ (W)\ = -118{,}03 \text{ дБмВт } (-9{,}28 \text{ dBμV}).$$

4) Normalized ratio Eb / No:

$$E_b/N_0\ =\ E_b\ -\ N_0\ =\ 16{,}88\ dB.$$

The probability of an error in the reception of digital signals is a very important parameter, which is used to evaluate the possibility of its transmission over a particular communication channel. We should note that the error probability (Bit Error Probability - BEP) and the bit error rate (BER) are somewhat different concepts. Nevertheless, their numerical values are very close, and when talking about BEP (P_B), they always mean BER, since it is a physical quantity recorded by measuring devices. Similarly, we will do the same in this case [5].

The probability of error in the general case is equal to the sum of the probabilities of all the possibilities of its appearance. We, as before, will consider the impact of only the main source of error - Additive White Gaussian Noise (AWGN).

For a rectangular set, a Gaussian channel, and reception by means of matched filters, the probability of a bit error occurrence when modulating M-QAM, where M = 2k and k is an even number, and $L = \sqrt{M}$, the expression can be written in the calculated form:

$$P_b \approx \frac{2(1-L^{-1})}{\log_2 L} \cdot Q\left[\sqrt{\left(\frac{3\log_2 L}{L^2-1}\right)\frac{2E_b}{N_0}}\right]\ . \qquad (4)$$

For BPSK, QPSK:

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)\ . \qquad (5)$$

Here, as before - the number of level samples and Q (x) is a Gaussian error integral and is often used in describing the probability with a Gaussian distribution density. This function is defined as follows:

$$Q(x) \approx \frac{1}{\sqrt{2\pi}}\int_x^\infty exp\left(-\frac{u^2}{2}\right)du. \qquad (6)$$

The Gaussian error integral can be determined in several ways. Moreover, all definitions are equally suitable for describing the error probability for Gaussian noise. Q (x) is not directly calculated analytically and is usually given in the form of reference tables. This circumstance to a certain extent inhibits the development of computer methods for calculating digital communication channels. Nevertheless, under certain restrictions, the function Q (x) is approximated by simpler expressions. The most successful approximation for x> 3 is a rather simple function, suitable for further calculations:

$$Q(x) \approx \frac{1}{x\sqrt{2\pi}} exp\left(-\frac{x^2}{2}\right). \quad (7)$$

The calculations were carried out in the Delphi 7 program (Figures 2-5).

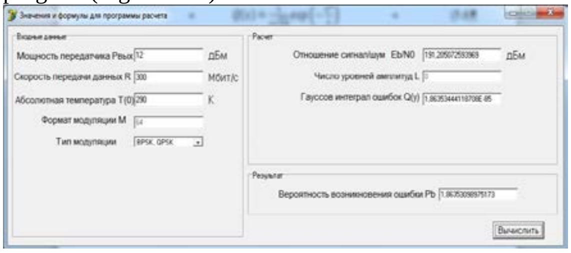

Figure 2 - Calculation of the error probability for BPSK, QPSK on Delphi 7

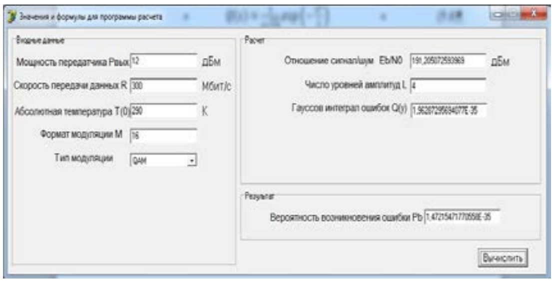

Figure 3 - Calculation of error probability for 16QAM on Delphi 7

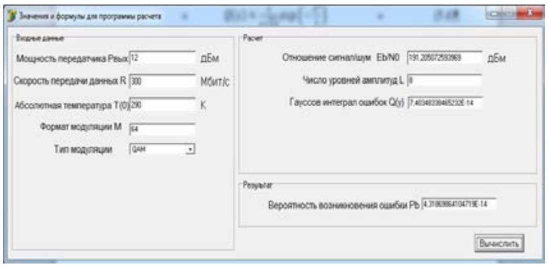

Figure 4 - Calculation of error probability for 64QAM on Delphi 7

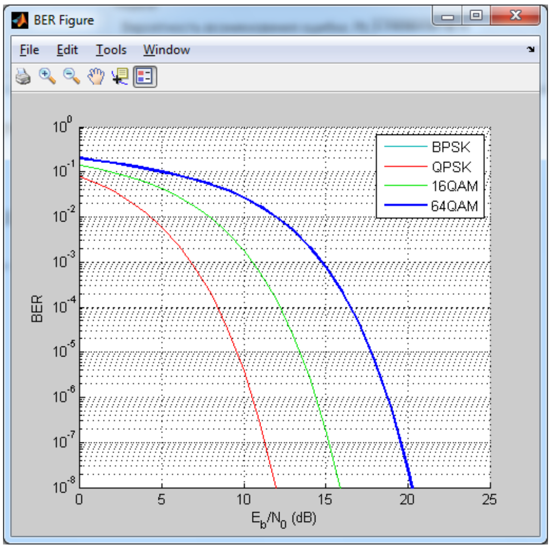

Figure 5 - Graph of curves for the probability of error (BER) from E_b/N_0

Thus, according to the characteristics of the selected video camera, the Eb/N0 ratio was calculated and the probability of an error in the digital communication channel was calculated under the influence of the main source of erroneous bits - additive white Gaussian noise. With BPSK and QPSK modulation, the error probability is 1.86, for 16QAM - 1.47, for 64QAM - 4.32. On the basis of the calculation done, it can be concluded that the smaller the required ratio Eb / N0, the less effective the detection process for a given error probability.

3. ACKNOWLEDGEMENT

The authors would like to thank various sponsors for supporting their research.

REFERENCES

[1] ГОСТ Р 51558-2000. «Системы охранные телевизионные. Общие технические требования и методы испытаний». 2001.

[2] В.В. Артюхин, Инструментальное определение качественных характеристик видеокамер в системах охранного телевидения. Материалы 6-ой научно-практической конференции. «Актуальные возможности науки – 2010». Praha. «Education and Science». с.43-46. 2010.

[3] В Вишневский., А. Ляхов, С. Портной, И. Шахнович, Широкополосные беспроводные сети передачи информации. М. Эко-Трендз, 2013.

[4] Б. Скляр, Цифровая связь. Теоретические основы и практическое применение. Издательский дом «Вильямс». 2010 год.

[5] В.Г. Олифер, Н.А. Олифер, Компьютерные сети. Принципы, технологии, протоколы: Учебник для вузов. 3-е изд. Спб. Питер, 2011.