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STUDY OF COMMUNICATION LINE PARAMETERS WITH DIGITAL MODULATION METHODS

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Abstract. *In this article, data communication lines with digital modulation methods are considered and analyzed. The main properties and operating principles of binary and quadrature phase manipulation methods are presented. Simulation models of a communication line have been developed using the Matlab Simulink program. The results of the simulation model are also presented and the bit error rate (BER) parameter is analyzed.*

Keywords: *BPSK, QPSK, bit error rate, modulation, simulation model.*

I. INTRODUCTION

This article studies the properties and parameters of communication lines with various modulation methods. One of the changes that modern digital communication systems have brought to telecommunications is the need to measure the characteristics of the entire network from point to point. A measure of this performance is usually the error rate (BER-bit error rate), which quantifies the reliability of the entire radio system from “bits in” to “bits out”, including electronics, antennas, and the signal path between them [1].

When building data transmission networks, special attention is paid to the issues of ensuring the quality and speed of information transfer. The effectiveness of solving these issues largely depends on the choice of modulation method, among which binary phase shift keying (BPSK), quadrature phase shift keying (QPSK) and quadrature amplitude modulation (QAM) are widely used.

II. MAIN PART

With analog signals, FM and AM result in continuous changes in the frequency or amplitude of the carrier signal. When modulation techniques are used for digital communications, the changes applied to the carrier are limited according to the discrete information being transmitted.

Examples of common types of digital modulation are OOK (on/off keying), ASK (amplitude shift keying), and FSK (frequency shift keying). These schemes cause the carrier to assume one of two possible states depending on whether the scheme is to transmit a binary 1 or a binary 0; each discrete carrier state is called a symbol.

At first glance, BER is a simple ratio, its definition is simple:

$$BER = Errors/Total\ Bits. \qquad (1)$$

With a strong signal and an undisturbed signal path, this number is so small that it can be negligible. This becomes important when we want to maintain a sufficient signal-to-noise ratio in the presence of imperfect transmission through electronic circuits (amplifiers, filters, mixers, and digital-to-analog converters) and propagation medium (such as radio or fiber optics).

Any deep analysis of the processes that affect BER requires serious mathematical analysis. Noise is the main enemy of the performance of communication systems and transmission lines. The noise introduced by the circuit is described by a Gaussian probability density function, while the signal path is usually described by a Rayleigh probability density function. The Rayleigh, or decaying, signal path is not "noise" in the intuitive sense of the familiar hissing sound of "white noise", but a random process that is analyzed in the same way as Gaussian noise.The template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

Without going into too much detail, the mathematical representations of these functions allow you to analyze a system to help predict its performance. Further study of noise and statistical analysis of signals is highly recommended.

BER can also be defined in terms of Probability of Error (POE),

$$POE = \frac{1}{2}(1 - erf)\sqrt{E_b / N_o} \qquad (2)$$

where erf is the error function, Eb is the energy per bit, and No is the noise power spectral density (noise power in a 1 Hz bandwidth). The error function is different for each of the different modulation methods. What is important to note is that POE is proportional to Eb/No, which is a form of signal-to-noise ratio (SNR) [2].

The energy per bit, Eb, can be determined by dividing the carrier power by the bit rate. As a measure of energy, Eb has the unit of joules. No is in power (joules per second) per Hz (seconds), so Eb/No is a dimensionless quantity or just a numerical ratio.

Although the basic concept of measuring BER is simple - send a stream of data through the system and compare the output with the input, it is not trivial to implement. On an infinitely long time interval, we can assume that the transmission of data is a random process. However, we don't want to wait forever for a BER measurement. Therefore, a pseudo-random data sequence is used for this test. We call this "pseudo-random" because we cannot create a truly random signal using deterministic (mathematical) methods.

The next measurement problem is practical - we do not want to fully install our system to run the test. It would be too expensive and time consuming to build entire radios and set them up with transmission lines, towers and antennas just to test the bit error rate performance of a particular filter or demodulation scheme.

Our goal is to study this parameter in communication systems using digital modulation methods. BPSK and QPSK modulation techniques are digital modulation techniques where the data input is digital (represented in binary form) and the output is a modulated analog spectrum.

Quad-shift phase modulation is a form of phase shift keying modulation using 4 different phase values for transmission [3].

Quadrature Phase Shift Keying (QPSK) is based on representing each point of a binary signal with two bits using a complex carrier symbol, each of which is offset by 90 degrees from each other [3].

Thus, instead of a phase shift of 180 degrees, as provided in BPSK, QPSK modulation uses a phase shift of multiples of 90 degrees, that is, $\pi/2$.

The coding rules for BPSK and QPSK modulation are defined by the IEEE 802.16-2004 standard [4].

QPSK modulation can be represented mathematically as follows:

$$\begin{aligned} S(t) &= A\cos\left(2\pi f_c t + \pi/4\right);\ \textit{for bits}\ "11" \\ S(t) &= A\cos\left(2\pi f_c t + 3\pi/4\right);\ \textit{for bits}\ "01" \\ S(t) &= A\cos\left(2\pi f_c t - 3\pi/4\right);\ \textit{for bits}\ "00" \\ S(t) &= A\cos\left(2\pi f_c t - \pi/4\right);\ \textit{for bits}\ "11" \end{aligned} \tag{3}$$

where fc is the carrier frequency, S(t) is the complex signal.

To study the parameters of a modern data transmission network, various software for simulation and simulation is widely used today. One of the main tools is the Matlab Simulink library, which is highly extended.

The developed model shows the implementation of a QPSK transmitter and receiver in the Matlab Simulink simulation environment. The receiver solves practical problems in radio communications such as carrier frequency and phase offset by synchronizing drift and frame synchronization. The receiver demodulates the received symbols and outputs a simple message and simulation to the Diagnostic Viewer.

Another difficulty is that the demodulation of PSK signals is more difficult than that of FSK signals. Frequency is "absolute" in the sense that changes in frequency can always be interpreted by analyzing signal changes over time. Phase, however, is relative in the sense that it does not have a universal reference point - the transmitter generates phase changes with respect to one point in time, while the receiver can interpret phase changes with respect to another point in time.

The practical manifestation of this is that if there are differences between the phases (or frequencies) of the oscillators used for modulation and demodulation, the PSK becomes unreliable. And we have to assume that there will be phase differences (unless the receiver includes a carrier recovery circuit).

Differential QPSK (DQPSK, differential QPSK) is a variant that is compatible with non-coherent receivers (i.e., receivers that do not synchronize the demodulation generator with the modulation generator). Differential QPSK encodes data by creating a certain phase offset from the previous symbol so that the demodulation circuit analyzes the phase of the symbol using a reference point that is common to both the receiver and the transmitter.

To implement the modeling process based on the QPSK method, you need to assemble the circuit shown in Fig.1.

The scheme consists of the following Simulink library elements Random Integer element that generates uniform random integers in the range [0, M-1], where M is specified by the Set size parameter, a QPSK modulator and demodulator that are connected by an AWGN channel element that adds white Gaussian noise to the input signal. Also used are oscilloscopes that are used to analyze the signal at different stages.

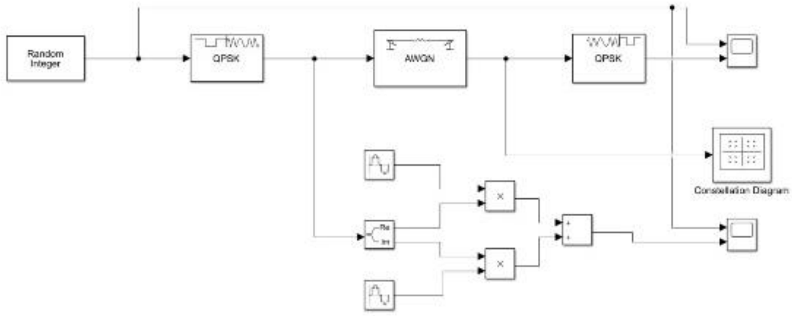

Figure. 1. Scheme assembled to analyze the QPSK modulation process.

On Fig.2. represented by a fixed point in the I/Q plane. This diagram can be use to perform qualitative and quantitative analysis of single carrier modulated signals.

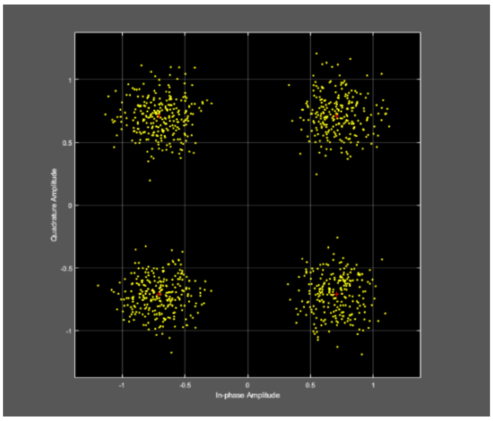

Figure 2. Results demonstrated using the Constellation Diagram element.

In the next part of the work, the modeling of a communication line with the binary phase shift keying method (Fig. 3) is considered. The block diagram consists of a random number generator to create a data stream, a BPSK modulator and a demodulator, an element for calculating errors after passing through a communication line with white noise.

The simplest type of PSK is called binary phase shift keying (BPSK), where "binary" refers to the use of two phase shifts (one for logic one and one for logic zero).

We can intuitively recognize that the system will be more reliable if the separation between these two phases is large - of course, it will be difficult for the receiver to distinguish between a symbol with a phase shift of 90° and a symbol with a phase shift of 91°. We have a 360° phase range to work with, so the maximum difference between the phases of a logic one and logic zero is 180°. But we know that switching a sine wave 180° is the same as inverting it; thus, we can think of BPSK as simply inverting the carrier signal in response to one logical state and leaving it in its original state in response to another logical state.

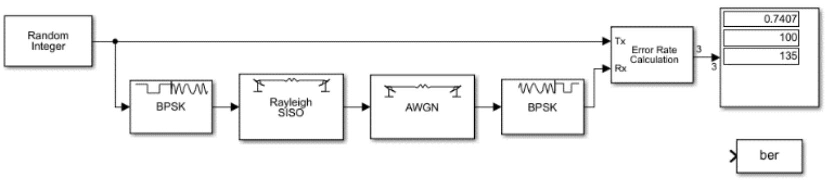

Figure 3. Communication line model with BPSK modulation method.

Using the bertool component, you can analyze the error rate parameter depending on the change in the parameters of network elements. The results demonstration in plot (Fig. 4).

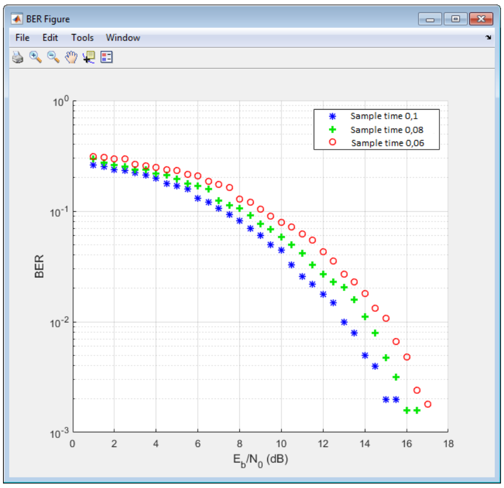

Figure 4. Dependence of error rate and signal-to-noise ratio.

Dependences of the error rate on the signal-to-noise ratio are modeled (Fig. 4), which presents the results for three special cases where the sampling time parameter is changed, with which you can change the intensity of the appearance of random bits in the Random integer element. It can be seen from the graph that with an increase in the intensity of the occurrence of bits, in order to keep the BER parameter unchanged, it is necessary to increase the signal-to-noise ratio.

III. CONCLUSION

Phase shift keying is a digital modulation in which data is transmitted by changing the phase of the carrier signal. Modulation occurs by changing the sine and cosine input signals at the exact time. It is widely used for wireless LANs, RFID and Bluetooth communications. The use of BPSK and QPSK modulation allows you to increase the data rate by several times.

The BER parameter allows you to analyze the entire network with modulation elements, with noise, etc.

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ИЗУЧЕНИЕ ПАРАМЕТРОВ ЛИНИИ СВЯЗИ С ЦИФРОВЫМИ МЕТОДАМИ МОДУЛЯЦИИ

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Аннотация. *В данной статье рассмотрены и проанализированы линии связи передачи данных с методами цифровой модуляции. Приведены основные свойства и принципы работы бинарных и квадратурных методов фазовых манипуляций. Разработаны имитационные модели линии связи, при использовании программы Matlab Simulink. Также представлены результаты работы имитационной модели и проанализирован параметр частоты возникновения ошибок (BER).*

Ключевые слова: *BPSK, QPSK, частота возникновения ошибок, модуляция, имитационная модель.*

RAQAMLI MODULYATSIYA USULLARIDAN FOYDALANILADIGAN ALOQA LINIYALARINING PARAMETRLARINI O‘RGANISH

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Annotatsiya. *Ushbu maqolada raqamli modulyatsiya usullari asosida ishlovchi ma'lumotlar uzatish liniyalari ko'rib chiqilgan va tahlil qilingan. Ikkilik va kvadrat fazali manipulyatsiya usullarining asosiy xususiyatlari va ishlash tamoyillari o’rganilgan va natijalari keltirilgan. Matlab Simulink dasturi yordamida aloqa liniyasining simulyatsiya modellari ishlab chiqilgan. Simulyatsiya modelining natijalari ham taqdim etilgan va xatolik paydo bo’lish chastotasi (BER) parametri tahlil qilingan.*

Kalit so‘zlar: *BPSK, QPSK, modulyatsiya, imitatsion model.*