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Spis treści

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Spis treści

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Information transfer with adaptation to the parameters of the communication channel

***Abstract**. A variety of adaptation algorithms for the data transfer are proposed in order to select the optimal modes under difficult communication conditions. The performed calculations showed the efficiency of using the developed methods for adapting the information transfer device to the parameters of the communication channel. The results of the experimental verification of the work of adaptation algorithms showed the adequacy of theoretical studies with a deviation within 25%.*

Streszczeniue.** Zaproponowano różnorodne algorytmy adaptacyjne przesyłania danych w celu doboru optymalnych trybów w trudnych warunkach komunikacyjnych. Przeprowadzone obliczenia wykazały skuteczność wykorzystania opracowanych metod dostosowania urządzenia przekazującego informacje do parametrów kanału komunikacyjnego. Wyniki eksperymentalnej weryfikacji działania algorytmów adaptacyjnych wykazały adekwatność badań teoretycznych z odchyleniem w granicach 25%.* (Przekazywanie informacji z dostosowaniem do parametrów kanału komunikacyjnego***)

Keywords: adaptation methods, channel of communication, network interaction model, internetwork interaction model, arbitration, algorithm.

Słowa kluczowe: metody adaptacyjnwe, kanał komunikacyjny, soeć komunikacyjna

Introduction

Rapid and reliable transfer of large amount of information, in particular in the energy supply systems of agricultural consumers [1, 2, 3] is one of the most important technical tasks for the organizing of autonomous power supply using renewable energy sources, where the basic information already includes a component of the measurement error. Therefore, when transferring such information, it is necessary to minimize the impact of interference in the communication channel on the transferred information [4, 5]. Thus, the scope is limited to the modem method of transferring a known amount of information with the presence of interference, which is distributed mainly under normal law. The efficiency of information exchange is determined by the reliability and rate of data transfer [6, 7]. Mathematical models describing the process of information exchange in the field of application are generally characterized by partial approaches [8]. Reproduction of the holistic picture of the simulated phenomenon allows to achieve sufficient generalization of research results and to extend the latter to a number of similar phenomena [4, 9].

To increase the efficiency of the information exchange process within the management system of autonomous energy supply of agricultural enterprises it is advisable to use a single methodological framework and systematic approach at all stages of building the principles of information transfer, starting with the formation of a mathematical model and ending with their practical implementation. The use of generalizing methods of information transfer theory, in fact, at all levels of solving this problem is quite productive in this regard.

The construction of universal principles for the transmission of information with adaptation to the parameters of the communication channel is the subject of research, since there is a need to increase the reliability and speed of the process of transferring information by different communication lines.

Analyzing the ways to solve the problem

The development of information technology in all areas of activity has clearly defined the transition from technologies aimed only at digital data processing, to technologies that include the possibility of automatic receipt and input into the means of computer technology quantitatively determined information from the object of the material world with its further processing in accordance with the procedures specified by the operator or application program. Important elements of this technology are automatic measurements, as a result of which with the help of special technical means find experimentally the numerical values of physical quantities that characterize the object or phenomenon under study [10].

Functionally integrated set of computing devices and auxiliary devices, as well as communication channels (lines) designed to create signals of information in the form, convenient for direct perception by the operator or for automatic processing, transmission and use in automatic control systems is called a computer system (CS) [11]. Computer system (CS) that contain software-controlled computing tools are called management system (MS). Complexes of means for the creation of CS are called computational control systems (CCS) [7, 12, 13].

The transfer medium can be of different nature: electrical communication lines, telephone and radio channels, fiber-optic lines, etc. But currently information processing is carried out using electrical signals, therefore, it is necessary to provide for the presence of appropriate signal nature converters on both the transferring and receiving parts of the system [14, 15, 16]. The generalized structure of the multichannel information transfer system is shown in Fig. 1.

The sources of messages on the transfer side are the end devices of one or more computer systems. Using the appropriate message converters ai(t) are converted into signals Si(t), whose nature corresponds to the transfer medium. With the help of a shaper, a group signal is formed from channel signals V(t), which enters the communication line. It is affected by interference during transfer δ(t), and the input of the receiving part already receives a group signal, which is distributed to the respective channels. In accordance with the principle of inverse conversion, the channel signal is converted into a message [7, 17].

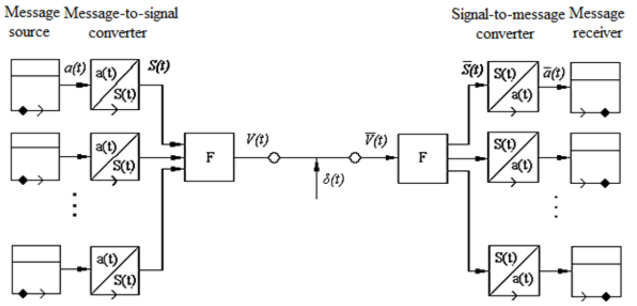

Fig. 1. Generalized structure of a multichannel information transfer system

Creating an CS requires combining different elements, blocks and devices into a single structure. To organize the process of interactions, you need to prepare the data in advance, as well as perform some additional operations. It is clear, for example, that the preparation of data and the operations of their input into the computer, transfer to the end user or from computer to computer differ qualitatively [18, 19]. To solve this problem, ISO has developed a reference model of IOS (interaction of open systems) [20].

Model of network and internetwork interaction defines a hierarchy of 7 levels of interaction of network components [21, 22]: applied, representative, session, transport, network, channel or data link level, physical.

When considering these 7 levels, it should be noted that the main thing is that it is possible in the framework of such a review to establish uniform general rules and regulations, with the help of which it is necessary to make different devices, to develop programs so that different elements of integrated equipment, manufactured by different manufacturers, work together, join.

To distinguish services, each layer adds its own protocol control information to the data in the form of a header and a so-called ending. And the headers appear at all stages, the ending – the control sequence of bits, which is used to check the correctness of the message, adds only the second level. The physical level doesn't add a title.

It is clear that in addition to the general standard it is necessary to have standards for each level, so today there are up to 20 standards for one level. Nevertheless, the IOS reference model facilitates further development.

Development and research of methods of adaptation of devices to the parameters of the communication channel

Consider the implementation of adaptive information transfer between computer devices and control systems using various methods of adaptation, which allow to increase the speed and reliability of the information transfer process under certain conditions of transfer.

Method of adaptation by arbitration in the transfer (Fig. 2.). The task of adaptation to arbitration in the transfer is solved by the fact that the transferring side first measures the level of interference in the communication channel, then the number of times that need to be repeated is determined, and then in the accumulation mode is the transfer of information with repetition and arbitration [8-9].

If during the transmission time the signal level is constant and equal to U_c, and the signal is affected by additive hindrance U_ξ then the sequence of deductions can be represented as:

$$\begin{cases} U_1 = U_c + U_{\xi 1} \\ U_2 = U_c + U_{\xi 2}\,, \\ U_m = U_c + U_{\xi m} \end{cases} \quad (1)$$

where $U_{\xi m}$ – voltage value at the moment of the m-th deduction.

The signal will pass through the communication channel:

$$U = \sum_{i=1}^{m}(U_c + U_{\xi i}) = m \cdot U_c + \sum_{i=1}^{m} U_{\xi i}. \quad (2)$$

The ratio of the signal and hindrance will be determined by the relation [10]:

$$\left(\frac{P_c}{P_\xi}\right) = \frac{(m \cdot U_c)^2}{D\left(\sum_{i=1}^{m} U_{\xi i}\right)}, \quad (3)$$

where $D\left(\sum_{i=1}^{m} U_{\xi i}\right)$ – hindrance dispersion in a communication channel.

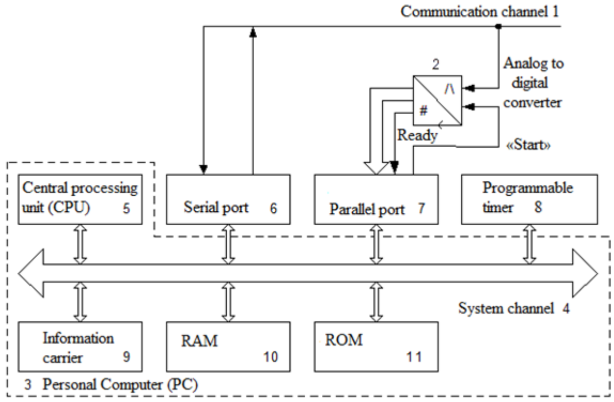

Fig. 2. Scheme of implementation of the method of transferring information with adaptation to arbitration

Taking into account the fact that the values of the hindrance level are not correlated, variance of the sum of deductions $U_{\xi i}$ is equal to the sum of the variances of deductions:

$$D\left(\sum_{i=1}^{m} U_{\xi i}\right) = \sum_{i=1}^{m} D(U_{\xi i}). \quad (4)$$

Assuming that the hindrance is a stationary random process, we can get:

$$D\left(\sum_{i=1}^{m} U_{\xi i}\right) = m \cdot D(\xi_i). \quad (5)$$

Then the ratio of signal power and hindrance in the communication channel can be represented as:

$$\left(\frac{P_c}{P_\xi}\right)_2 = \frac{(m \cdot U_c)^2}{m \cdot D(U_\xi)} = m \cdot \frac{U_c^2}{D(U_\xi)} = m \cdot \left(\frac{P_c}{P_\xi}\right)_1. \quad (6)$$

That is, under the above conditions, retransmission of the same information *m* times can be considered as an increase in the signal-to-noise ratio by *m* times [19].

The signal volume *V* can be written as:

$$\begin{aligned} V &= 3{,}5 \cdot log_2\left(\frac{P_c}{P_\xi}\right) = 3{,}5 \cdot N \cdot log_2\left(\frac{P_c}{P_\xi} \cdot \frac{1}{m} \cdot m\right) = \\ &= 3{,}5 \cdot N \cdot log_2\left(\frac{P_c}{m \cdot P_\xi} \cdot m\right) = \\ &= 3{,}5 \cdot N \cdot \left(log_2 m + log_2\left(\frac{P_c}{P_\xi}\right)\right) = \\ &= 3{,}5 \cdot N \cdot log_2 m + 3{,}5 \cdot N \cdot log_2\left(\frac{P_c}{P_\xi}\right). \end{aligned} \quad (7)$$

Or, if we move from power to amplitude:

$$\begin{aligned} V &= 3{,}5 \cdot N \cdot log_2\left(\frac{U_c}{U_\xi}\right)^2 = 7 \cdot N \times log_2\left(\frac{U_c}{U_\xi} \cdot \frac{1}{m} \cdot m\right) = \\ &= 7 \cdot N \cdot log_2\left(\frac{U_c}{m \cdot U_\xi} m\right) = 7 \cdot N \times \left(log_2 m + log_2\left(\frac{U_c}{U_\xi}\right)\right) = \\ &= 7 \cdot N \cdot log_2 m + 7 \cdot N \cdot log_2\left(\frac{U_c}{U_\xi}\right). \end{aligned} \quad (8)$$

In practice, expressions (7) and (8) can be interpreted as follows: if the hindrance level has increased by m times, then the information, transferred to the communication channel, needs to be repeated $log_2 m$ times or transfer $(log_2 m+1)$ times. In this case, the influence of random hindrances decreases in $log_2 m$ times that is, the probability of signal distortion decreases and, accordingly, in $log_2 m$ times the probability of transferring information over a communication channel increases.

For m-multiple transfer, to improve efficiency, it is advisable to implement the arbitration mode, when the information is transmitted an odd number of times and the correct one is determined by the majority of repetitions [11, 16]. The registration of voltage values must be carried out under conditions close to the real transfer mode (taking into account the speed) in order to avoid dynamic error. The measurement period of the hindrance voltage must be determined from the ratio:

(9) $$T_{bum} = \tau_{in} = \frac{1}{k \cdot v},$$

where τ_{in} – the duration of the transfer of one information pulse.

Adaptation method for noise-protected coding conditions (Fig. 3). The first step is to test the communication channel. In this case, a test sequence of ones and zeros is sent to the receiving part to determine the probability of distortion of elementary binary signals. Signals are converted according to the rules of modulation [23, 24]. From the receiving part comes a message about the number of distorted units and zeros, based on which it is possible to calculate the probability of errors in the communication channel for units p_1 and zeros p_0 to be transferred, by formulas:

(10) $$p_0 = \frac{N_{0.c}}{N_{0.\Sigma}},$$

(11) $$p_1 = \frac{N_{1.c}}{N_{1.\Sigma}},$$

where $N_{0.c}$ and $N_{1..c}$ – respectively, the number of zeros and test reference units that were distorted by interference during transf by the communication channel;

$N_{0.\Sigma}$ and $N_{1..\Sigma}$ – respectively the number of zeros and units in the test link.

The error in the amount of information transferred over a communication channel is equal to that part of this information that is missing in the received signal, in other words, the uncertainty about the transferred signal that occurs when the received signal is known [10, 25]. In fact, this will be determined by the averaged entropy:

(12) $$H_{\xi} = -\sum_i p_i \cdot log_2\, p_i.$$

Taking into account the principles of data formation in microprocessor systems, they can be considered uncorrelated. Based on formula (12), the entropies for H_1 units and H_0 zeros will be:

(13) $$H_1 = -(p_1 \cdot log_2\, p_1 + (1 - p_1) \cdot log_2(1 - p_1)),$$

(14) $$H_0 = -(p_0 \cdot log_2\, p_0 + (1 - p_0) \cdot log_2(1 - p_0)).$$

The calculated entropies will show the proportion of signals that can be distorted during the transfer of information. To simplify, it is advisable to choose largest of them, getting the result with a margin:

(15) $$H_{\xi} = max(H_0, H_1).$$

The number of elementary signals that can be distorted by interference during transfer over a communication channel is:

(16) $$\xi_{\Sigma} = n \cdot 8 \cdot H_{\xi},$$

where n – size of the file to be transferred.

The number of errors to be corrected in each link is:

(17) $$\xi_p = \frac{\xi_{\Sigma}}{n \cdot 8} \cdot m,$$

where m – the number of information bits in each link.

Thus, at the first stage, the number of information bits in each link that can be disfigured is determined. To implement the encoding algorithm, this parameter must be rounded up to an integer:

(18) $$s = int(\xi_p) + 1.$$

At the second stage, an algorithm is selected and information is encoded in accordance with the selected algorithm. If it is necessary to correct two errors, then the transfer must be done in nibbles (four information and nine control bits) [27]. If you need to correct one error, you can transfer information in nibbles (four information and three control bits) or bytes (eight information and four control bits). The type of coding algorithm (Hamming, cyclic, etc.) [12] is of no fundamental importance. But taking into account the fact that serial interfaces carry out the transfer of only eight binary bits (if there are fewer digits, they are padded with zeros), for a reduce the time to wait for the channel to transfer information after a noise-protected coding it is necessary to repackage the data, supplementing the insufficient number of digits up to eight from the next byte [14].

At the third stage, service messages are first transmitted according to the coding algorithm (type and number of bugs which are correction) voting method [21]. In this case, the same link is transferred several times, and on the receiving side, after receipt bit by bit, the most probable one is selected. After that, the transfer of basic information comes into play.

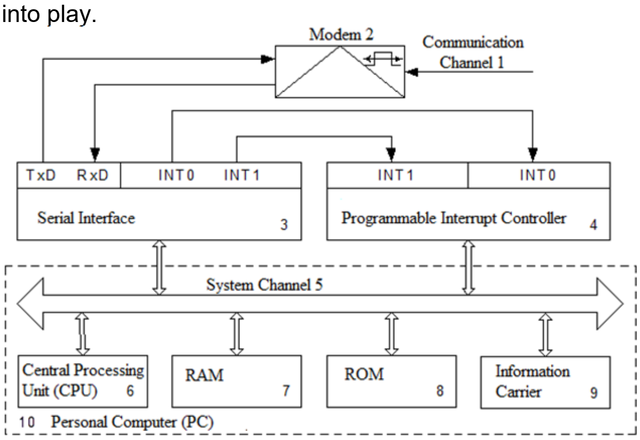

Fig. 3. Scheme of implementation of the method of coding and transferring discrete information for the conditions of noise-protected coding

Through the introduction a set of operations related to channel testing (the first stage), it is possible to determine the optimal noise-proof coding mode, and due to the introduction of the second stage associated with the preparation of data and their compaction, there is no need to occupy a transfer channel to perform operations not directly related to the transfer process.

Experimental studies of communication channels and developed adaptation algorithms

An experimental check of the transfer system operation was carried out using the public telephone network.

The objective of the experiment was to determine the number of errors in the transfer of symbols by day without the use of interference codes and adaptation algorithms [18]. The tests were conducted at 10 am. The test sequence consisted of 50,000 bytes of zeros and ones. The research results are presented in Fig. 4 and Fig. 5.

The test results showed:

- there is a certain relationship between the number of errors (congestion of telephone lines) and the days of the week;
- the number of conversions of zeros to one is approximately 2-3 times greater than the conversion of one to zero;
- the number of errors in the worst case reaches two per byte of the test sequence [28].

During the day, testing was carried out every two hours in compliance with the experimental conditions. The error distribution graph is shown in Fig. 6.

The results show:

- the number of recorded errors varies per day from almost zero to thirty;

- there is a certain relationship between the number of errors (congestion of telephone lines) and the time of day;

- the number of distortions of zeros and ones corresponds to the results of the previous experiment;

- the maximum number of errors, and, accordingly, the congestion of the lines is observed during the period 8 am to 12 am and 2 pm to 8 pm;

- the repeatability of testing within five working days showed a divergence of results by 20%.

When transferring information depending on the time of day [25], it is necessary to change the algorithm, using one or another developed method of adaptation: in the period of 8 pm to 8 am and 12 am to 2 pm it is enough to apply the adaptation method with arbitration, combining it with the method of taking into account marginal interference, and in the period of the greatest loading it is necessary to use noise-protected coding taking into account marginal interference.

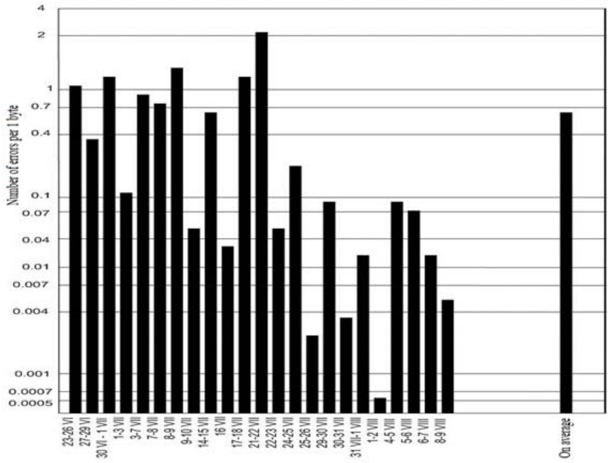

Fig. 4. Distribution of errors per 1 byte of the test sequence by day

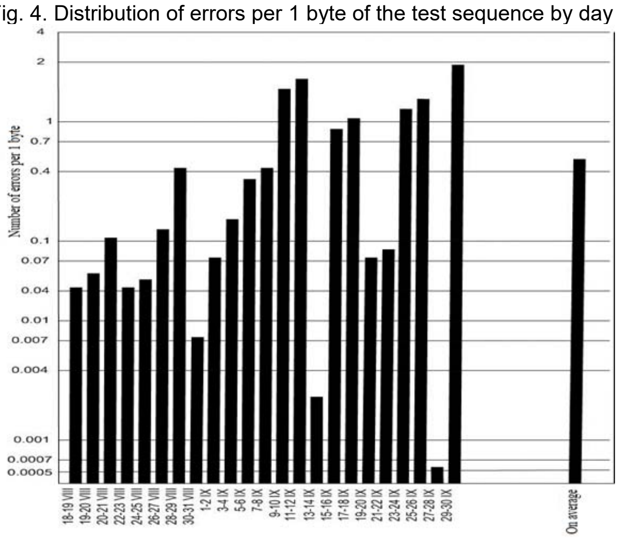

Fig. 5. Distribution of errors per 1 byte of the test sequence by day

The results show that the probability of occurrence of two or more errors in the transfer of information of a nibble is approximately 1%, and a byte does not exceed 10%.

When transferring code combinations with a length of 3 bytes, the probability of packet errors is close to 50%. Thus, depending on the day of the week and time of day, it is expedient to transmit information in nibbles or bytes using the proposed adaptation methods [24].

The probability of error-free transfer of information at different amplitudes (Fig. 8.): bipolar amplitude 12 V; bipolar amplitude 5 V; unipolar amplitude 12 V; unipolar amplitude 5 V.

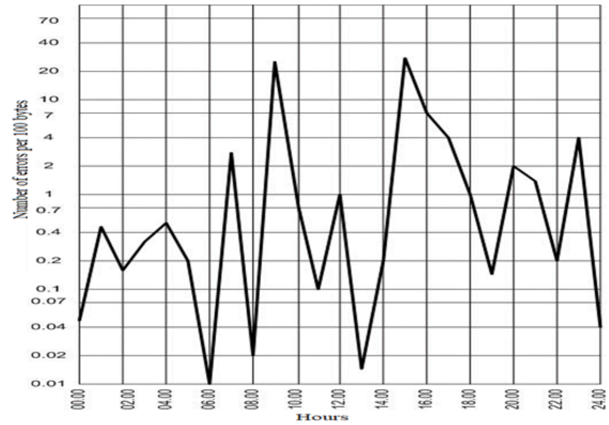

Fig. 6. The dependence of the occurrence of errors on the time of day

Probability of errors package character depending on the length of the code combination is shown in Fig. 7.

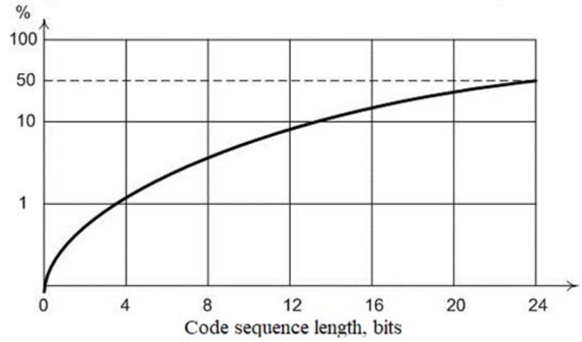

Fig. 7. Probability of occurrence of two or more errors

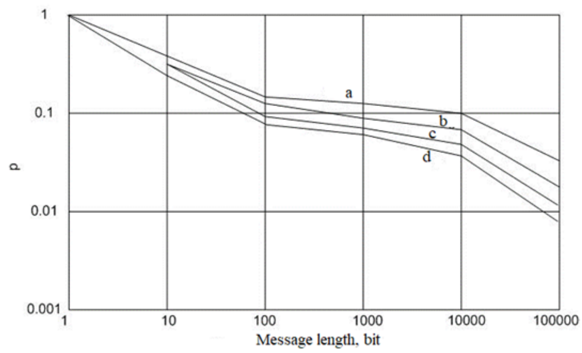

Fig. 8. Probability of error-free transfer of information depending on the mode and amplitude of transfer: a – bipolar mode, 12 V; b – bipolar mode, 5 V; c – unipolar mode, 12 V; d – unipolar mode, 5 V.

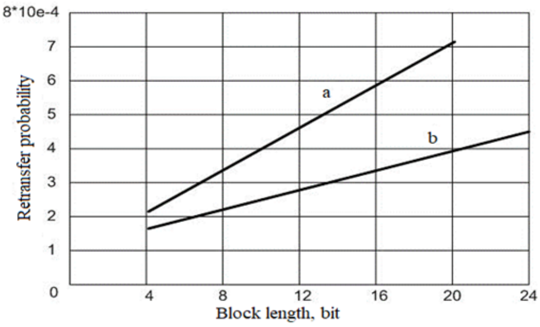

Fig. 9. Testing the Adaptation Method with Transfer Arbitration: a - three-fold transfer; b - five-fold transfer

The results confirm that information transmission must be carried out in a bipolar mode, correcting the signal amplitude depending on external conditions.

Experimental verification of the algorithm, which implements the adaptation method with transfer arbitration, identified an error in the case when a bitwise verification gives a result different from the link [17]. Testing was carried out when a quadruple transfer was necessary. To maintain the efficiency of the algorithm, 3- and 5-fold transfer of words of different lengths was performed.

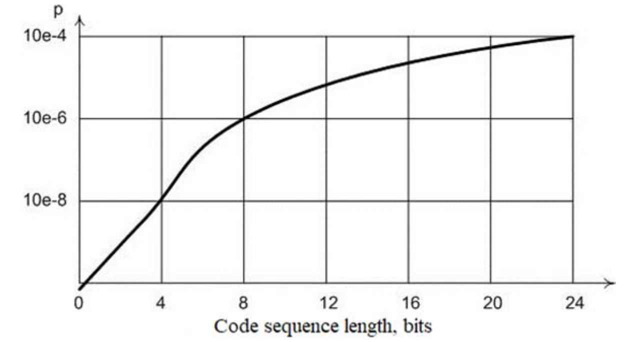

Fig. 10. Probability of an irreparable error depending on the length of the informational message

The results are presented in Fig. 9 and show good agreement with theoretical calculations. In case of ambiguity in making a decision, it is necessary to round the number of gears up [28]. The results of testing the algorithm, built according to the adaptation method for the conditions of noise-protected coding, confirmed its effectiveness when correcting one error when the length of the informational message isn't more than one byte which is confirmed by Fig. 10.

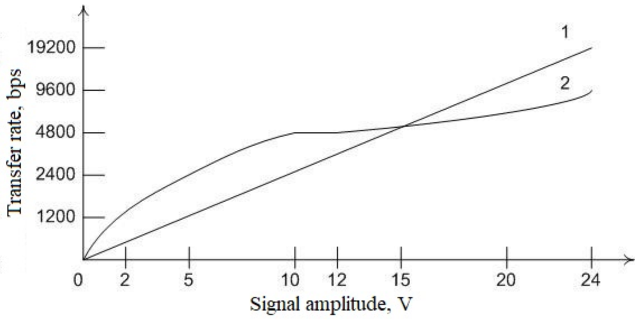

Fig. 11. Theoretical and operational characteristics of a device that implements the adaptation method, taking into account limiting interference: 1 – Theoretical; 2 – Operational

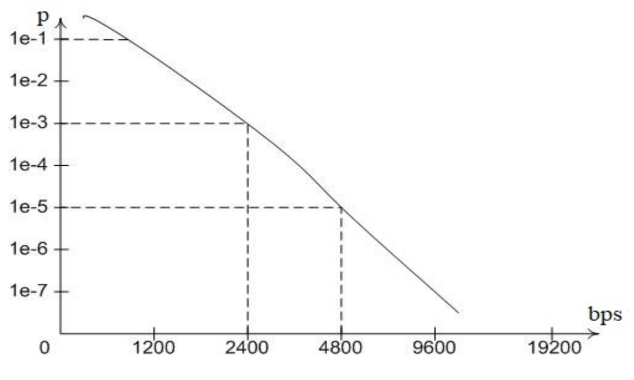

Fig. 12. Probability of error-free transfer

For the equipment used in the testing process, the theoretical and operational characteristics presented in Fig. 11.

Experimental studies have shown that for the calculated limiting rate of 2400 bps, the probability of error-free transfer differs from the specified one by no more than 25%. If the calculated limit is exceeded, the probability of an error-free transfer drops rapidly.

Conclusions

The performed calculations showed the effectiveness of using the developed methods for adapting the information transfer device to the parameters of the communication channel.

Experimental studies of communication channels confirmed the need to implement these algorithms and showed the limits of their use.

The results of experimental verification of the work of adaptation algorithms showed the adequacy of theoretical studies with a deviation within 25%.

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