INTERACTION AND EFFICIENCY OF DIGITAL SIGNAL TRANSMISSION SYSTEMS

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Abstract
The effectiveness of the use of the digital communication system spectrum (frequency band), two modulation types – phase modulated (PM) and quadratic AMLP, the potential interference of the types of modulation signals, the most used types of modulation in digital television systems based on the use of one or more carrier frequencies are considered. For the types of modulation used in digital communication systems, methods for determining real (real) spectral efficiency are presented, the dependence of the probability of error in coherent reception on the signal/interference ratio is analyzed.

Keywords: Digital communication, modulation, digital TV, signal, frequency, range, amplitude-phase, error reception.

Introduction

When choosing the type of modulation in any communication system, including in digital communication systems, the following two opposing requirements should be considered. The first is to effectively use the range of allocated frequencies, and the second is to provide a demand-level interference. It is known that under the same conditions, the quality of signal transmission depends on the width of its spectrum, but increasing the number of subscribers in the allocated frequency range requires increased electromagnetic flexibility and the speed of signal transmission corresponding to the polosa unit contributes to the effective use of the allocated frequency range.

Main part

The efficiency of using the digital communication system spectrum (frequency band) is determined as follows [1]:

$$\gamma = R_b / \Delta F_{ak} , \qquad (1)$$

in this case – R_b the speed of information transfer bit/s;

ΔF_{ak} – communication channel signal transfer frequency band.

Spectral efficiency is measured (evaluated) by the number of bits that can be transferred per second through the 1 Hz band of the communication channel, that is, by bit/sec.

In Real conditions, the frequency band ΔF_{ak} allocated for the communication channel is not fully used for various reasons, therefore, a communication system with high indicators in terms of technical indicators will not be effective at the level of demand on the indicator of the use of the band (spectrum) of these frequencies [1]. In addition, in order to clarify the criterion of efficient use of the spectrum in the communication system, it is necessary to consider it with the band ΔF_N, which is determined based on the Nyquist criterion, and the coefficient α, which evaluates the shape of the spectrum wrapper, because the α coefficient is the frequency band (signal spectrum) that is actually used, ΔF_Φ is based on the Nyquist criterion indicates how wide the required bandwidth is from ΔF_N:

$$\Delta F_\Phi = \Delta F_N(1+\alpha). \qquad (2)$$

For the types of modulation used in digital communication systems, the real (real) spectral efficiency η is determined by the following expression:

$$\eta = \frac{R_b}{\Delta F_\Phi} = \frac{R_b}{\Delta F_N(1+\alpha)}. \qquad (3)$$

Only in the only ideal case, when the frequency band allocated to the communication channel is fully used, the efficiency indicators η and γ values coincide, that is, η=γ is [1].
It is also desirable to include the criterion of the highest potential of effective use of the spectrum corresponding to $\Delta F_{ak} = \Delta F_\Phi$ and $\alpha = 0$ values of each used modulation method.
We determine the potential efficiency of using the frequency spectrum as follows:

$$\gamma_0 = \frac{R_b}{\Delta F_N}. \qquad (4)$$

We can find out:

$$\eta = \frac{\gamma_0}{(1+\alpha)} \quad \text{or} \quad \gamma_0 = \eta(1+\alpha) \qquad (5)$$

from this expression.
When using a multi-position (state) digital modulation type, the information transfer rate is found using the following expression [2]:

$$R_b = \log_2(M)\, R_s, \qquad (6)$$

In this case M is the number of elementary symbols in signals that are formed as a result of digital modulation;
R_s - the speed of transmission of digital signal flow symbols.
The highest (maximum) speed of transmission of signals through a band of frequencies allocated on the basis of the "Nyquist" criterion is determined by the following expression:

$$R_s = \Delta F_{ak}/(1+\alpha). \qquad (7)$$

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As a result, the effectiveness of the use of frequency bands with ΔF_{ak} $\Delta F_{ak} = \Delta F_{\Phi}$

$$\eta = \log_2(M)\,/(1+\alpha). \qquad (8)$$

will be.

At the same time as enlarging the modulation carriageway number $\log_2(M)$ it will be necessary to reduce the slopes as a result of passing a change in the front and rear fronts of elementary signal pulses through a filter of low frequencies with a Gaussian frequency characteristic. As a result, the change slope of this signal spectrum scroll becomes larger [3]. But the use of small values of α requires the use of complex digital filters to process it, and the signal instantaneous values that are given to the input of the decision-making device on the receiving side will have random shifts (djitter effect) over time. In addition, the sensitivity to additional nonlinear disturbances in the communication channel tract increases, and as a result, the degree of opacity of the radio received signal "eye" decreases. Therefore, the minimum value of α must be equal to 0.3 in radio reception devices intended for mass use. Typically, in communication systems, the maximum interference is 0.4 the value of α to ensure stability...It is necessary to ensure that it is in the range of 0.6. In digital television systems, values of α 0.15; 0.25; 0.35 are used [5].

The transmission spectral efficiency for OFDM modulation is determined as follows [2]:

$$\eta = 2/(1+\alpha/L), \qquad (9)$$

in this case, the number of data flows transmitted in parallel in the L – OFDM system (not the number of orthogonal carriers) [2].

In terrestrial digital television, spectral efficiency can change over a very large range at the time of perceived modulation and the speed of codes. This case (Table 1) is given for several types of modulation for a case where the channel band is 8 MHz wide.

Phase modulation interference of signal transmission systems

The most commonly used types of modulation in digital television systems based on the use of one or more carrier frequencies are: 16-QAM and 64-QAM types of quadrature phase differential modulation (QFDM), (QPSK) and quadratic amplitude-phase modulations (QAPM).

Table-1. Spectral efficiency of various digital modulation signals.

Code speed	Modulation spectral efficiency, bit / (sec·Hz)		
	QPSK	16-QAM	64-QAM
1/2	0,62	1,24	1,87
2/3	0,83	1,66	2,49
3/4	0,93	1,87	2,80
5/6	1,04	2,07	3,11
7/8	1,09	2,18	3,27

In this type, modulated signals are also used in digital mobile communication systems. Therefore, let's briefly consider the interference nature of these types of modulation and modulated signals similar to it [2].

We will first consider two types of modulation – phase modulated (FM) and quadratic amplitude modulation (low) signals. Based on the re – encoding of most digital signal flows and modulations based on Phase Shift-simple phase modulation is obtained. Let's consider the potential interference tolerance of the main types of FM.

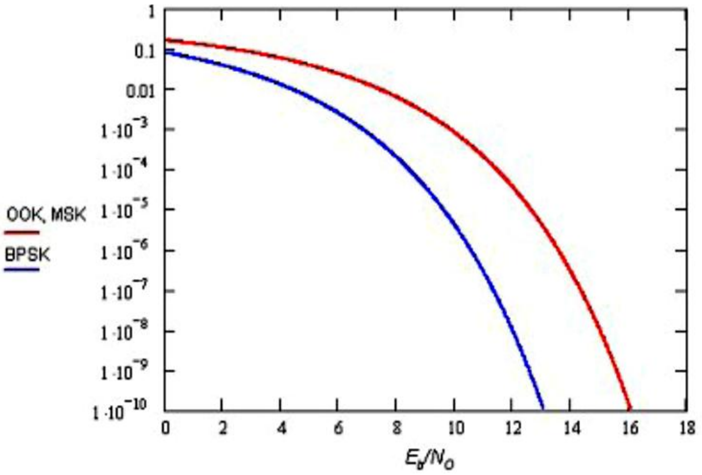

Figure 1. For 2-FM and 4-FM signals, the dependence of [2]

The probability of an error in the coherent reception of elementary signal bits in the detector of 2-FM and 4-FM signals of dependence graphs to is shown in Figure 2.

From this $P_x = F(E_b / N_0)$ link graph, it is seen that when using coherent detection, it will be necessary to increase the S/N ratio to 3 dB when receiving a 4-FM signal so that the E_b / N_0 ratio in the radio channel is maintained as the interference resistance in 2-FM when using 4-FM [2].

When using relative phase modulation (NFM), the probability of error reception of a one-bit elementary signal is 2 times greater than that of a system based on the transmission of simple phase change.

Quadratic amplitude modulation

Multi-m-State (position) quadratic amplitude modulation when using the M-QAM signal, the probability of receiving an error of one bit symbol is calculated through the following expression [2]:

$$P_э = \frac{1}{\log_2(M)}\left\{1 - \left[1 - \left(1 - \frac{1}{\sqrt{M}}\right)\left[1 - erf\left(\sqrt{\frac{3\log_2(M)E_b}{2(M-1)N_0}}\right)\right]\right]\right\} \qquad (10)$$

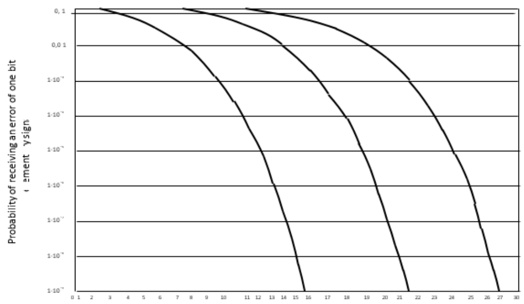

Figure 2. 4-(1), 16-(2), and the dependence of P_x on E_b / N_0 for 64-QAM (3) signals

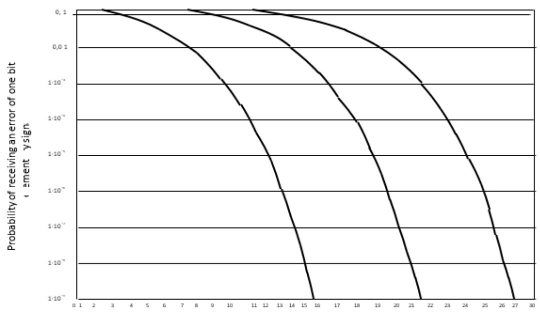

Figure 3. 4-(1), 16-(2), and the dependence of P_x on S/N for 64-QAM (3) signals

Graphs of the dependence of the potential interference values of 16-QAM and 64-QAM digital modulated signals on E_b / N_0 are shown in Figure 2. This picture also shows graphs of the potential interference resistance of the 4-FM signal for comparison [3].

In most cases, it is considered convenient to use the S/N ratio instead of E_b / N_0. When moving from the ratio E_b / N_0 to the ratio S/N, it will be necessary to carry out the following calculations:

$$\frac{S}{N} = E_s / N_0 = E_b / N_0 \log_2(M).(12)$$

By placing (2) in (1), it is possible to draw a graph of the dependence of P_x on S/N (fig.3)

CONCLUSION

In conclusion, it can be said that in communication systems based on the use of interference encoding, it will be necessary to take into account a decrease in the energy corresponding to the elementary signal due to the introduction of additional checking symbols to transmit the flow of the group signal. When using relative phase modulation (NFM), the probability of error reception of a one-bit elementary signal is 2 times greater than that of a system based on the transmission of simple phase change. Multi-m-State (position) li quadratic amplitude modulation is calculated by the probability of receiving an error of one bit symbol when using the M-QAM signal.

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