# METHOD OF DETECTING RADIO SIGNALS WITH PHASE MODULATION IN A MIXTURE WITH NOISE

***Vasyl Dunets[1], Anatoly Martsenyuk[2], Kateryna Kamchatna-Stepanova[3], BohdanAndreichuk[4]***

*[1] Ternopil National Ivan Puluj Technical University, Rus'ka str. 56, 46001, Ternopil, Ukraine; vasyadunets@gmail.com*
*[2] Ternopil National Ivan Puluj Technical University, Rus'ka str. 56, 46001, Ternopil, Ukraine; oljynka23@gmail.com*
*[3]National Technical University "Kharkiv Politechnic Institute", 2 Kirpichova str., Kharkiv, Ukraine, 61002; katerina.ks@i.ua*
*[4]Ternopil Ivan Puluj National Technical University, 56 Ruska str., Ternopil, Ukraine, 46001*

**Abstract:** Using Matlab software, a process of computer simulation of the phase modulation and demodulation process with different values of carrier frequency and phase deviation over the test signal in the form of an additive mixture of two deterministic sinusoidal signals under the influence of white Gaussian noise of various power. A justified method of detecting radio signals in a mixture with noise allows to expand the capabilities of radio systems, and the developed computer simulation model of radio signal is suitable for testing data processing algorithms to monitor and evaluate the signal-to-noise ratio in radio systems.

**Keywords:** radio signals, phase modulation, radio systems, matlab.

## 1. Introduction

Improving the efficiency of electronic devices and systems for various purposes, including information transmission and processing systems, still remains one of the main challenges facing modern radio systems. Today, a significant part of the frequency range suitable for radio systems is overlapped, and some parts of this range are heavily congested and poorly protected from the effects of various internal and external noise. Therefore, the task is to increase the efficiency of systems and their noise immunity, working in well-developed parts of the spectrum.

One of the options for solving this problem is the use of single-band signals for data transmission, which allow rational use of the frequency resource [1], but the disadvantage of this method is the low potential noise immunity. When using signals with continuous single-band phase modulation for information transmission, there is a problem of asymmetry of the spectrum of signals with continuous two-band phase modulation. In the works of Volkov A.A. [2] proposed a new method of signal generation with continuous single-band phase modulation and proposed different schemes for receiving such a signal and evaluated the noise immunity.

Despite the above work on the study of message transmission using single-band signals with phase modulation was not performed. Therefore, solving a scientific problem related to the reception and transmission of signals with single-band phase modulation, and their detection in a mixture with noise is an urgent scientific problem [3].

## 2. Algorithm for experimental research of test radio signals

When conducting an experimental study using computer simulation using Matlab software, the sequence of operations on which the experimental program will work was established [4]. Therefore, we will establish a sequential link, and present it in the form of a block diagram, which is shown in Figure 1.

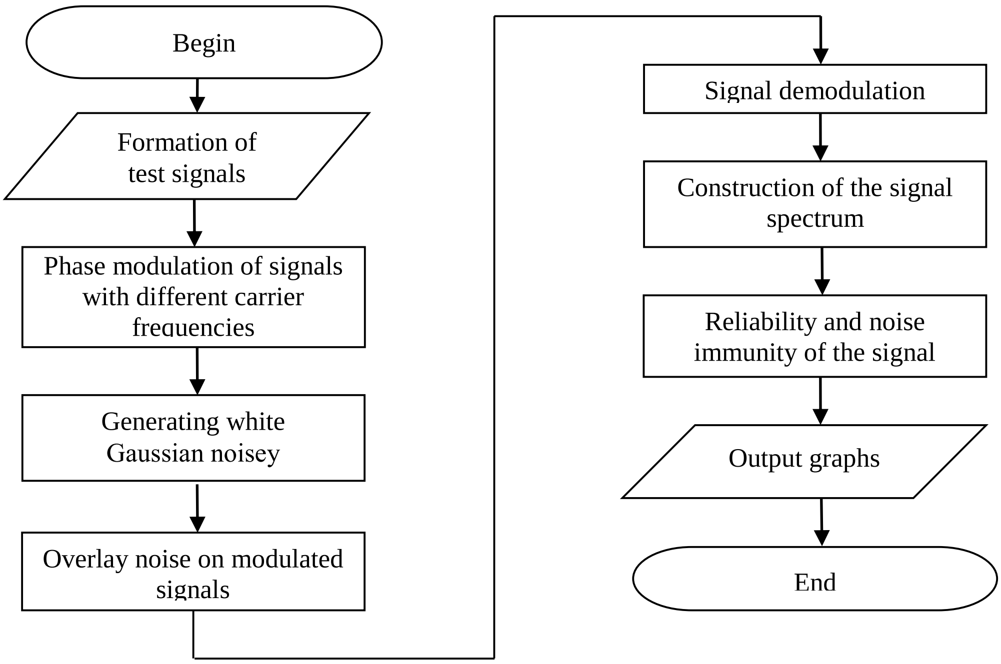


Fig. 1. Algorithm of the experiment

**3. Generation of a test signal with phase modulation**

We will conduct the experimental study according to the block diagram shown in Figure 1. Using the graphical interface Matlab we will display a test signal on the graph, the result of which is shown in Figure 2.

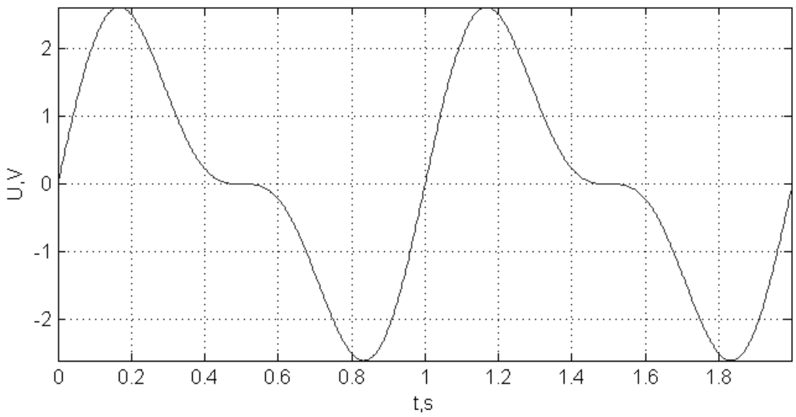


Fig. 2. Test signal with sampling rate parameters 400Hz

When transmitting a signal over a distance, it is necessary to convert the test signal (Figure 2) into one that would have a fixed frequency component by which it would be possible to distinguish the signal from others in the radio channel. Therefore, it is necessary to modulate the signal in the form of a simple oscillation, which is described by the following equation [5]:

$$\xi(i\Delta t) = s(i\Delta t) + n(i\Delta t), \qquad (1)$$

where $s(i\Delta t)$ - discrete useful signal, $n(i\Delta t)$ - noise, $\Delta t$ - sampling step ( $\Delta t = \frac{1}{2f}$, $f$ – signal frequency from the conditions of Kotelnikov theorem).

Accordingly, we set the values of the carrier frequencies *Fc* (5, 10, 15, 20, Hz) and determine the sampling frequency Fs in the input signal, and accordingly substitute into a given function. Figures 3.1 - 3.4 show graphs of the displayed simulated test signals using phase modulation.

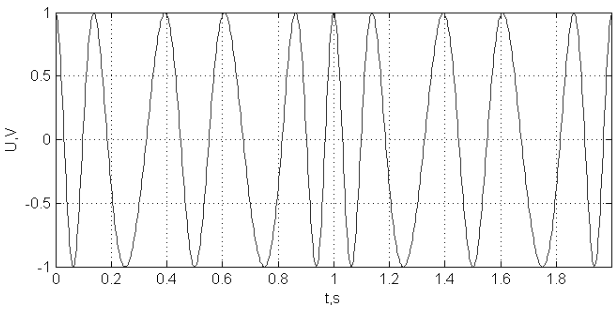


Fig. 3.1. Phase modulation with a carrier of 5 Hz, and the deviation of π/4 radians

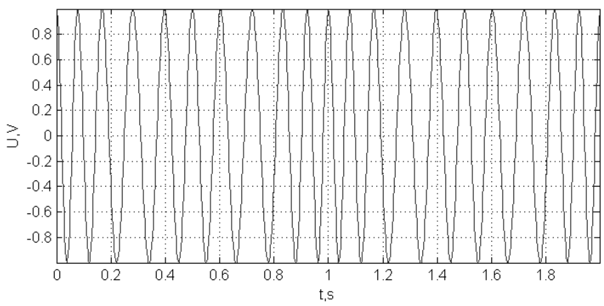


Fig. 3.2. Phase modulation with a carrier of 10 Hz, and the deviation of π/4 radians

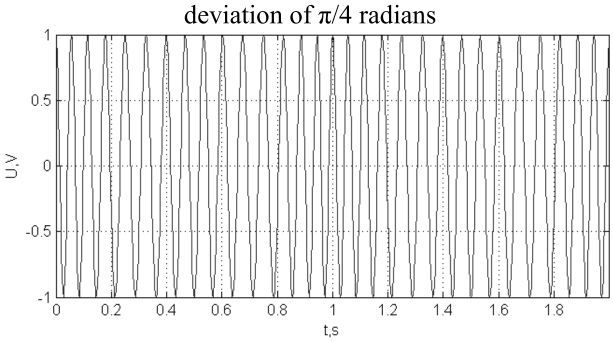


Fig. 3.3. Phase modulation with a carrier of 15 Hz, and the deviation of π/4 radians

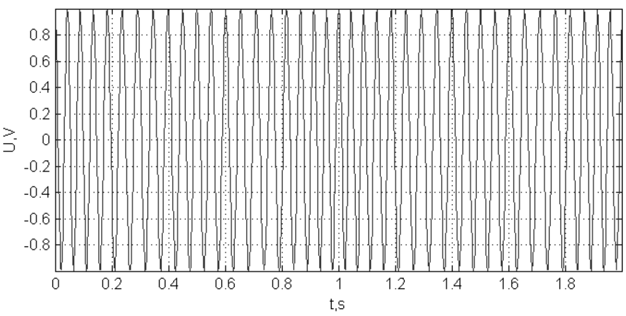


Fig. 3.4. Phase modulation with a carrier of 20 Hz, and the deviation of π/4 radians

In order to determine how noise-tolerant the phase-modulated communication channel is at different carrier frequencies, we simulate the simulated signal with white Gaussian noise with a standard deviation of 0.2 V., as shown in Figures 4.1-4.4.

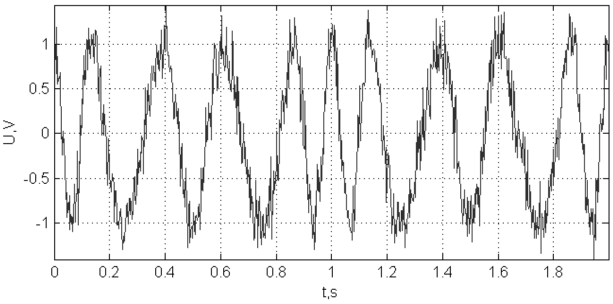

Fig. 4.1. A mixture of modulated signal (5 Hz) and noise

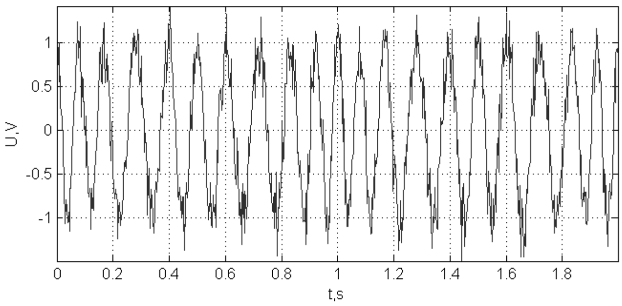

Fig. 4.2. A mixture of modulated signal (10 Hz) and noise

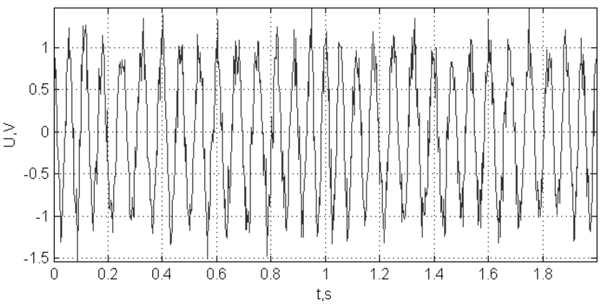

Fig. 4.3. A mixture of modulated signal (15 Hz) and noise

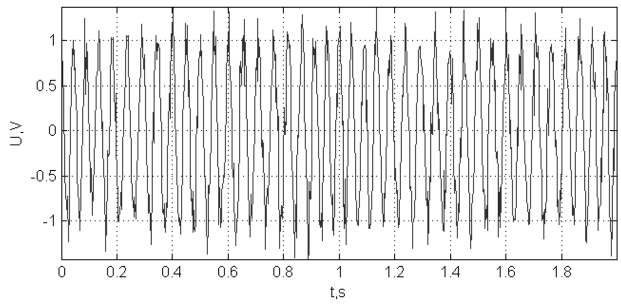

Fig. 4.4. A mixture of modulated signal (20 Hz) and noise

To determine how much this modulation is noise-tolerant for different carriers, we will carry out the demodulation process, the result of which is shown in Figures 5.1 - 5.4

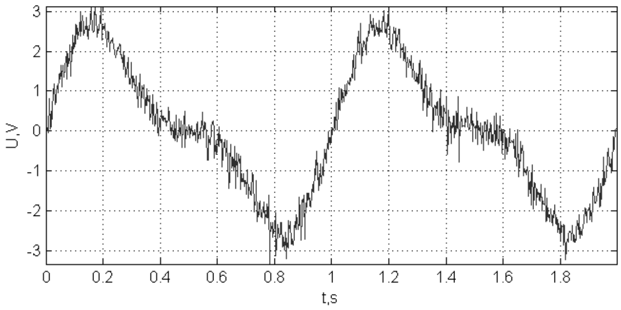

Fig. 5.1. Implementation of the demodulated signal (5 Hz)

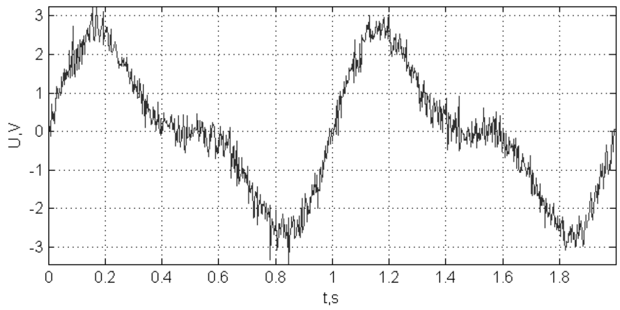

Fig. 4.2. Implementation of the demodulated signal (10 Hz)

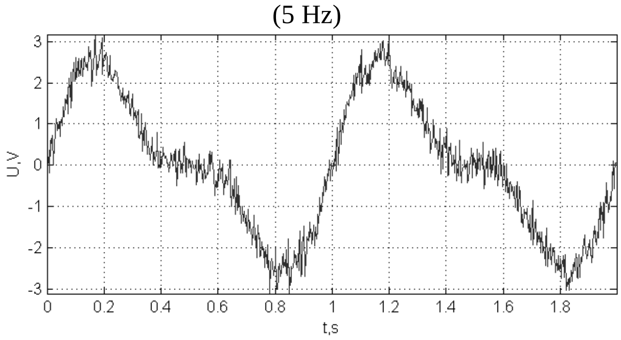

Fig. 4.3. Implementation of the demodulated signal (15 Hz)

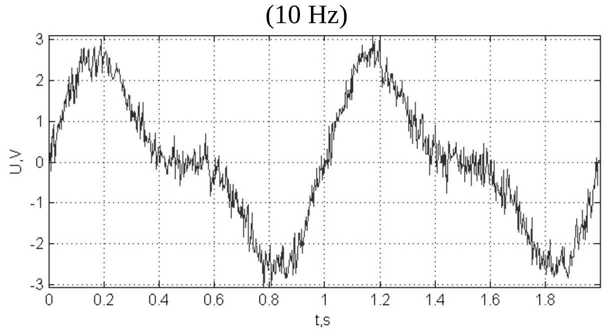

Fig. 4.4. Implementation of the demodulated signal (20 Hz)

Figures 4.1 - 4.4 show that the amplitude modulation procedure is not noise protected at different carrier oscillation frequencies, which is reflected in the presence of noise in the demodulated signals.

**4. Evaluation of noise immunity and reliability of the communication channel with phase modulation**

The main parameter of noise immunity during modulation is the signal-to-noise ratio [6].

The signal-to-noise ratio (SNR) is calculated as an expression $q = 10\log\left(\frac{E_{ÑÈÃÍÀËÓ}}{Å_{ÂÈÕ.ØÓÌÓ}}\right)$.

where $E_{ÑÈÃÍÀËÓ}$ - signal energy.

Accordingly, in order to determine the energy of the signal, it is necessary to find its frequency components (frequency response), and summing the sum of the squares of its harmonics we obtain the energy:

$$E = \left|A_n{}^2\right|, \tag{2}$$

where $A_n$ - amplitude $n$ - harmonics.

Using a discrete Fourier transform, we obtain a graph of the spectrum of the input signal shown in Figure 5.

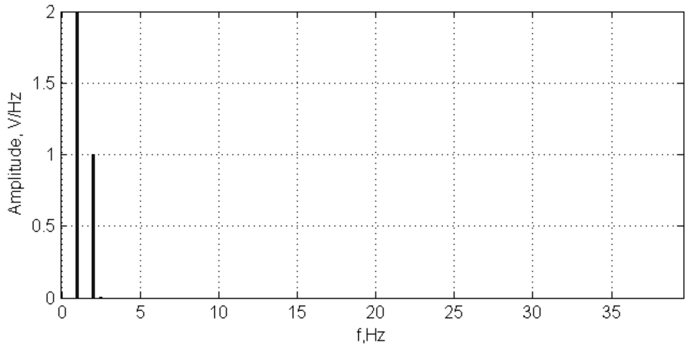


Fig. 5. The spectrum of the input test signal

Given that the test signal is the sum of two sinusoidal signals with frequencies of 1 Hz and 2 Hz, so in the constructed spectrum (Figure 5) such harmonic peaks are reflected at these frequencies.

Let's build graphs for simulated and de-simulated signals, Figures are shown in Figures 6.1-6.4, respectively simulated signals, in Figures 7.1-7.4 - demodulated signals.

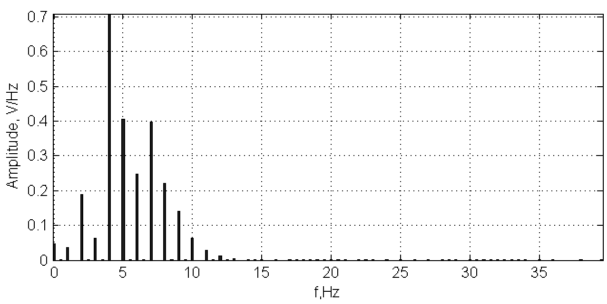


Fig. 6.1. Spectrum of phase-simulated signal (5 Hz)

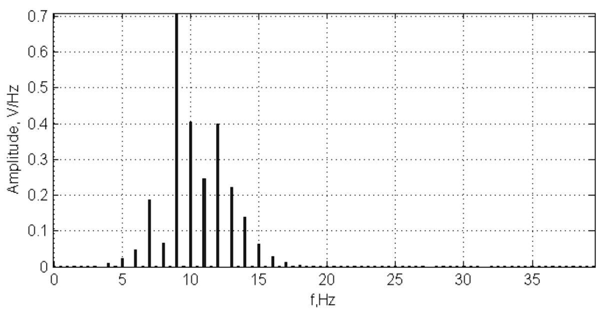


Fig. 6.2. Spectrum of phase-simulated signal (10 Hz)

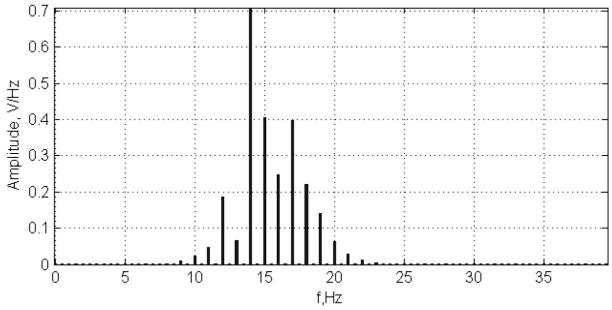


Fig. 6.3. Spectrum of phase-simulated signal (15 Hz)

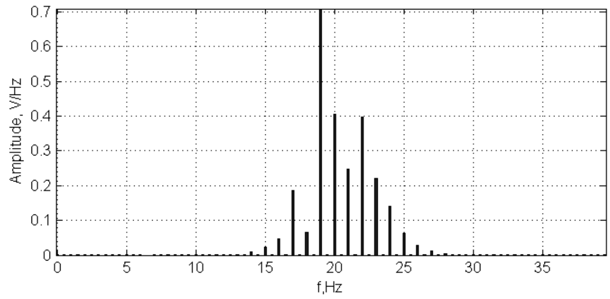


Fig. 6.4. Spectrum of phase-simulated signal (20 Hz)

In fig. 6.1 there is a selection of the main spectral components that correspond to the significant spectrum of the phase-simulated signal 5, 10, 15, and 20 Hz.

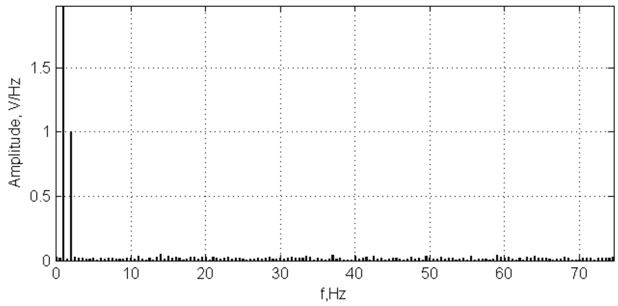


Fig.7.1. The spectrum of the demodulated signal (5 Hz)

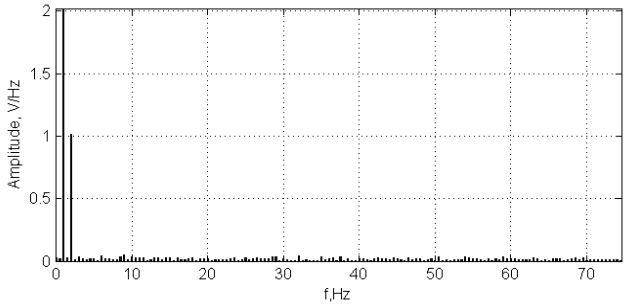


Fig. 7.2. The spectrum of the demodulated signal (10 Hz)

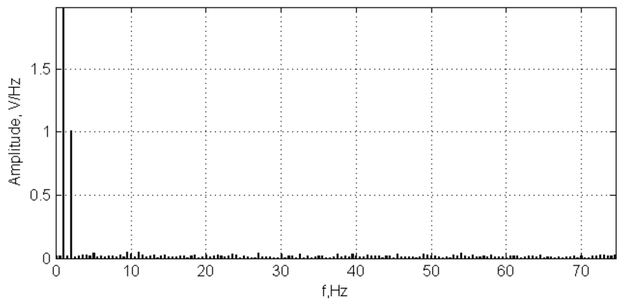


Fig. 7.3. The spectrum of the demodulated signal (15 Hz)

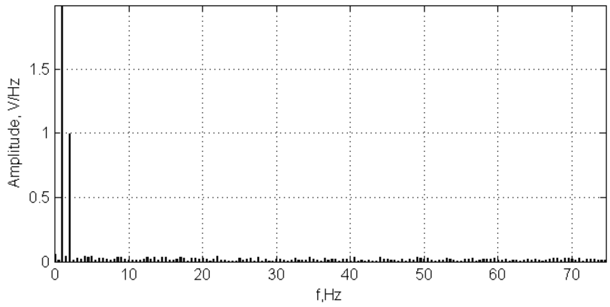


Fig. 7.4. The spectrum of the demodulated signal (20 Hz)

According to the results of the constructed spectra of demodulated signals (Fig. 7.1-7.4) we can say that the noise of the white noise type makes a significant contribution to the spectral structure of the output signal and is evenly distributed over the entire frequency domain.

Determine the signal energy according to formula 3:

Accordingly, in order to determine the energy of the signal, it is necessary to find its frequency components (frequency response), and summing the sum of the squares of its harmonics we obtain the energy:

$$E = \left| A_n^{\ 2} \right|, \tag{3}$$

where $A_n$ - amplitude $n$ - harmonica.

From the above graphs (Figures 7.1-7.4) it is seen that the spectral components are changed, ie there is a noise contribution to the total signal energy, which is equal to the energy difference of the input and demodelled, ie the modulus of the energy difference of the demodulated and input signal.

Let us plot the dependence of the signal-to-noise ratio on the carrier frequency which is shown in Figure 8.

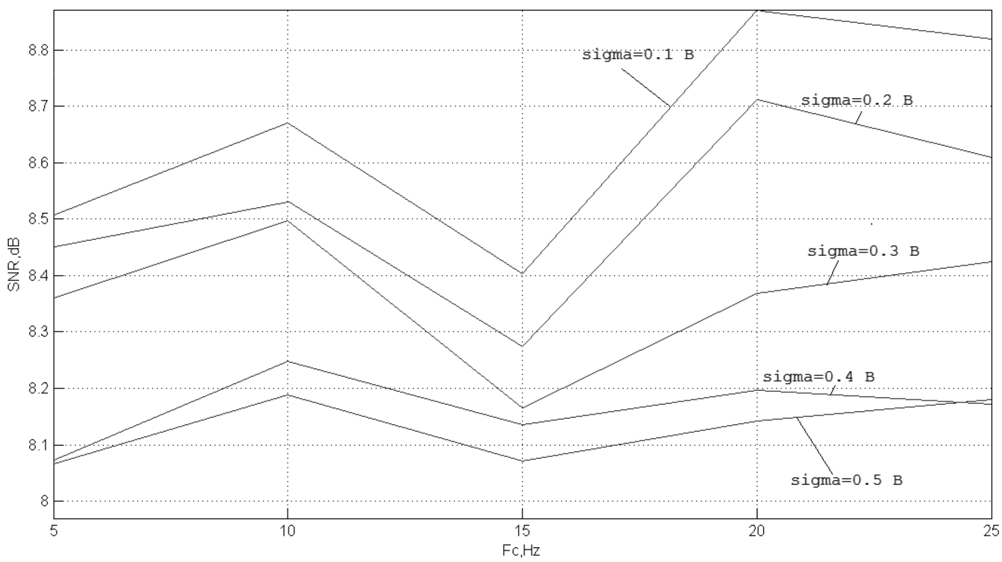


Fig. 8. The dependence of the signal-to-noise ratio on the carrier frequency at different standard deviations of BGS

Figure 8 shows that the value of the signal-to-noise ratio of the demodulated signal increases with increasing energy of the input noise and retains its structure at different carrier frequencies.

The indicator of radio communication data, in addition to the signal-to-noise ratio, is the deviation of the original from the original, so we build the dependence of the SNR on the standard deviation of different carriers.

The standard deviation is calculated by the following formula:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}\left(x_i - M\{x\}\right)^2}{N-1}}, \tag{4}$$

where N - number of samples; $M\{x\}$ - mathematical expectation of the difference between the output and the input signal.

Using formula 4, we construct the dependence of SNR on the standard deviation for different carriers, which is shown in Figure 9.

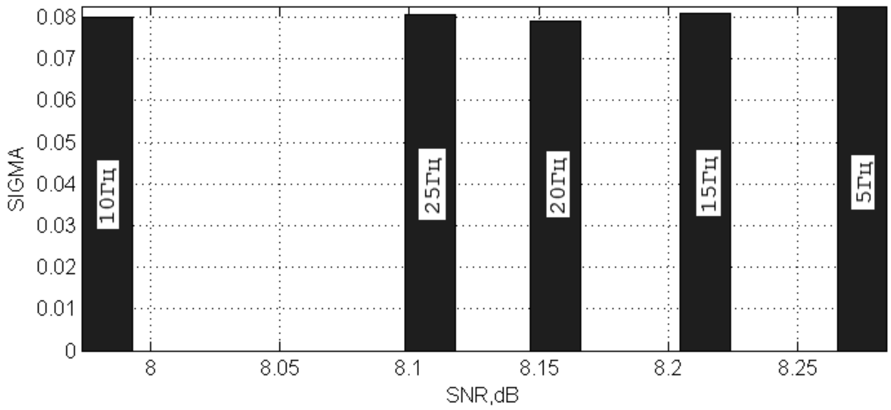


Fig. 9. SNR values at the standard deviation of the output signal from the input at carrier frequencies (5,10,15,20,25 Hz)

According to the values of Figure 9, it was found that at all frequencies used in the experiment, the standard deviation of the noise of the demodulated signal at different frequencies of the carrier oscillation remains almost the same. These results confirm the homogeneity of the noise immunity at different frequencies.

We construct graphs of dependence separately for each component (Fig. 10), by generating input noise of influence on the modulated signal of different power.

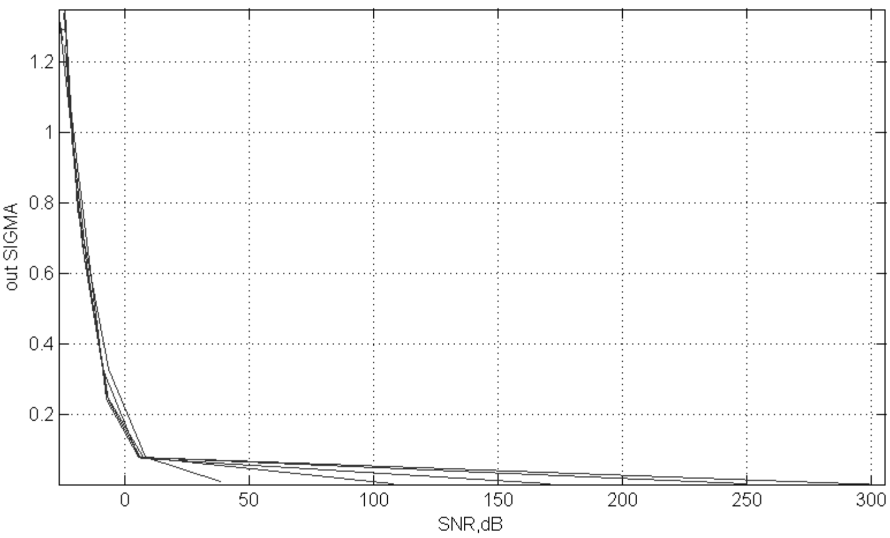


Fig. 10. Dependence of SNR at the standard deviation of the output signal from the input for carrier frequencies (5,10,15,20,25 Hz).

According to Figure 10, it is found that as the signal-to-noise ratio of the input signal increases, the standard deviation of the noise of the output signal at different frequencies attenuates exponentially. The detection curves of the phase-modulated test signal against the background of noise are shown in Figure 11.

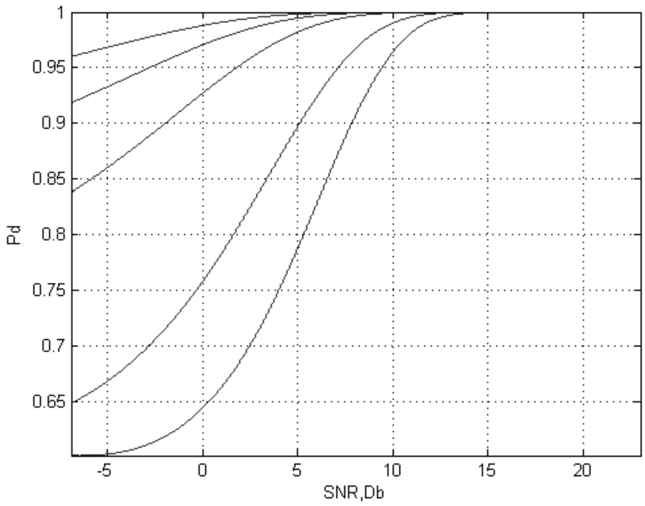


Fig. 11. Test signal detection curves

Considering the detection curves of the phase-modulated test signal against the background of noise (Figure 11), we see that the given probabilities do not depend on the waveform and is determined only by the peak signal-to-noise ratio.

## 5. Conclusions

From the study it is established that the proposed method of detecting a phase-modulated test signal in a mixture with noise at optimal reception with given probabilities and does not depend on the waveform and is determined only by the peak signal-to-noise ratio, ie signal-to-noise ratio. This method allows to expand the capabilities of radio systems, and the developed computer simulation model of the radio signal is suitable for testing data processing algorithms to monitor and evaluate the signal-to-noise ratio in radio systems.

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