THE EFFECT OF INCREASING THE BANDWIDTH OF A TWO-CHANNEL RECEIVER ON NOISE-IMMUNITY

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This work discusses the effect of increasing the bandwidth of a two-channel receiver on the noise-immunity of the receiving system at low signal-to-noise ratios (S/N = 0....3). The dependency of the probability of false alarms on the signal-to-noise ratio at different ratios of the receiver bandwidth to the carrier frequency of the signal was given. It is notorious that the noise level increases with the increasing bandwidth of the receiving device, thereby reducing the sensitivity and noise-immunity of the receiving system when receiving pulse signals. In most practical cases, this problem is solved by increasing the signal-to-noise ratio at the input of the receiving device by increasing the power of the transmitter and using linear filtering on the receiving side. However, if we consider that the signal-to-noise ratio is low, the search for new methods to solve this problem is more relevant than ever. Differences in the structures of input processes were used as additional information features and identified using nonlinear converters. It should be emphasized that a phase switch was used as a nonlinear converter. The principle of its operational concept was to change the spectrum of the input process by switching the phase by 180 degrees when the envelope passes through zero. Our research proves that phase jumps in a mixture of signal and noise can be used as secondary information signs. Consequently, a conventional phase detector can be used in the second channel of the receiver. The viability of this idea has been tested in practice, so the main objective of this work was to investigate the possibility of using the above approaches to receiving short radio pulses in narrowband digital communication systems and the effect of increasing the bandwidth of a two-channel receiver on the noise immunity of the receiving system at low signal-to-noise ratios.

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Introduction

It is known that the noise level increases with increasing bandwidth of the receiving device, thereby reducing the sensitivity and noise immunity of the receiving system when receiving pulse signals [2].

It is almost impossible to get rid of external and internal noise, so that the urgent task is to find methods for processing a mixture of signal and noise to ensure optimal signal reception.

In most practical cases, this problem is solved by increasing the signal-to-noise ratio at the input of the receiving device by increasing the power of the transmitter and using linear filtering on the receiving side [3].

However, the studies which had started in the last century have convincingly shown the prospects of using nonlinear filters and nonlinear signal processing methods after a linear filter, i.e. when both signal and noise have passed the same linear cascades and their spectra are not distinguishable in appearance.

In the theory of linear filtering, as mentioned above, this problem is solved by increasing the power of the useful signal. Kotelnikov's theory also shows that for all types of signals, the reliability of receiving information does not depend on the type of signal, but depends on the ratio of signal power and noise at the input of the receiving system. Therefore, most receiving systems provide predetermined signal reception probabilities with large signal-to-noise ratios. (S/N>>3). With a small signal-to-noise ratio (0 < S/ N <3), the reliability of signal reception is not satisfactory.

In the works of KNITU-KAI scientists, the possibility of a significant increase in the sensitivity of the receiving device due to the use of structural differences in the mixture of signal and noise and just narrow-band noise was shown. Differences in the structures of input processes were used as additional information features and identified using nonlinear converters. [1]

The above converters were included in a separate receiving channel, where the decision on the presence or absence of a signal was made on the basis of secondary information signs. The final technical solution was the creation of a two-channel hybrid device, in which one channel decided on the presence of a signal in the classical way, and the second according to the refined theory of narrowband noise. Both solutions were analyzed in the summing solver device.

Based on the advantages of using a two-channel receiving device circuit, it was possible to reduce the probability of a false alarm by almost two times when receiving weak signals (0 <S/N<3) . It should be noted that a phase commutator was used as a nonlinear converter. The principle of its operation was to change the spectrum of the input process by commutation the phase by 180 degrees when the envelope passes through zero. In later studies, it was shown that phase jumps in a mixture of signal and noise can be used as secondary information signs [3].

A conventional phase detector can be used in the second channel of the receiver. The viability of this idea has been tested, and the results of the approbation were described in [2]. However, it should be noted that all of the above studies were conducted to solve the problem of receiving a single radio pulse against the background of the receiving device noises.

The main objective of this work was to investigate the possibility of using the above approaches to receiving short radio pulses in narrowband digital communication systems. Recall that a narrowband signal is called narrowband if the width of its spectrum is significantly less than the average frequency [4]:

$$\Delta f \ll f_{cp} \quad (1)$$

However, the literature does not indicate how many times the carrier oscillation should exceed the bandwidth of the receiving device. Therefore, to begin the research, it was necessary to find out where the boundary between narrowband processes and broadband signals is located. As a criterion for the transition from narrowband processes to broadband, we used the fact of the presence of leap phase by 180 degrees during the transition of the envelope through 0, which is characteristic of narrowband noise, but is not observed in broadband processes [5-8].

To this end, we created a mathematical model in which we changed the bandwidth of the receiving device by changing the parameters of the master generator without changing the frequency of the carrier oscillation. (Fig. 1).

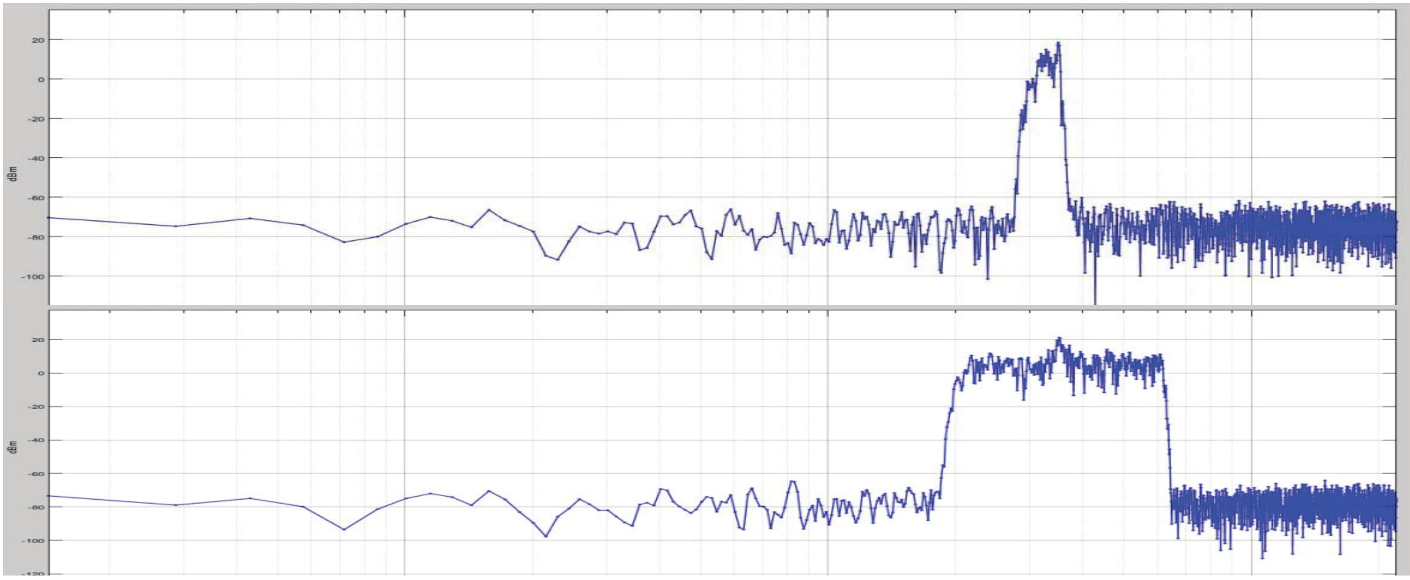

Figure 1. Changes in the filter bandwidth at a constant frequency of the carrier oscillation

The first graph corresponds to a narrow-band system with a large difference between the bandwidth and the frequency of the carrier oscillation. The second graph corresponds to a narrow-band system with the most extended bandwidth, in which the process at the filter output meets the criteria of a narrow-band process.

In the future, we will test the two-channel receiving system in two operating modes. The first is when the system is narrow-band, and the second area is when working in an area that has been defined as the boundary between narrow-band receiving systems and broadband.

2. Radio pulse model in Matlab/Simulink

The model of a radio pulse with digital amplitude manipulation performed in the Matlab/Simulink visual modeling system is shown in Figure 2. The elements of this model are: a pseudorandom binary code generator, a Bernoulli Binary block, a carrier frequency generator, a Sin Wave block, a signal multiplier, a block.

Also Figure 2 shows a simulation model of a radio pulse channel with digital amplitude manipulation and broadband noise in Simulink. It includes the following elements: 1) an amplitude-manipulated signal source, which corresponds to the generator shown in Fig. 2; 2) a broadband white noise source (Band-Limited White Noise); 3) A useful signal adder with noise (simulates a radio signal transmission channel with broadband noise); 4) A input band-pass filter that allocates the frequency band of the useful signal in which the primary filtering of channel interference occurs); 5) block Model (two-channel receiver). The first element is a classic optimal receiver consisting of a linear filter matched with the parameters of the input useful signal and an amplitude detector, the second channel uses the same optimal filter and a phase detector that records the presence of a useful signal by the presence of phase jumps of 180 degrees.

In addition, the model has a control single-channel receiver assembled according to the classical scheme. The solver calculates the probability of false alarms of a two-channel receiver and a receiver assembled according to the classical scheme.

This scheme was implemented in the form of a mathematical model using a software package (Simulink MATLAB).

3. Investigation of the passage of a radio pulse in a channel with broadband interference through a phase detector

The results of simulation modeling of the constructed channel model of a radio communication system with digital amplitude manipulation and broadband interference are presented (see Fig. 3). As is known in a real communication channel, the noise level is approximately constant, while the level of the useful signal is determined by the power of the transmitter and the distance from the transmitter to the receiving point. The results of simulation modeling of the constructed channel model of a radio communication system with digital amplitude manipulation and broadband interference are presented (see Fig. 3).

It can be seen from the diagrams presented, at low signal-to-noise ratios, the signal mixture practically does not differ from narrowband noise. As our research has shown, the effect of indistinguishability manifests itself faster in systems with extended bandwidth. However, in a channel with a phase detector, the phase jump points are clearly visible, which may indirectly indicate the presence or absence of a signal at the input of the receiving device.

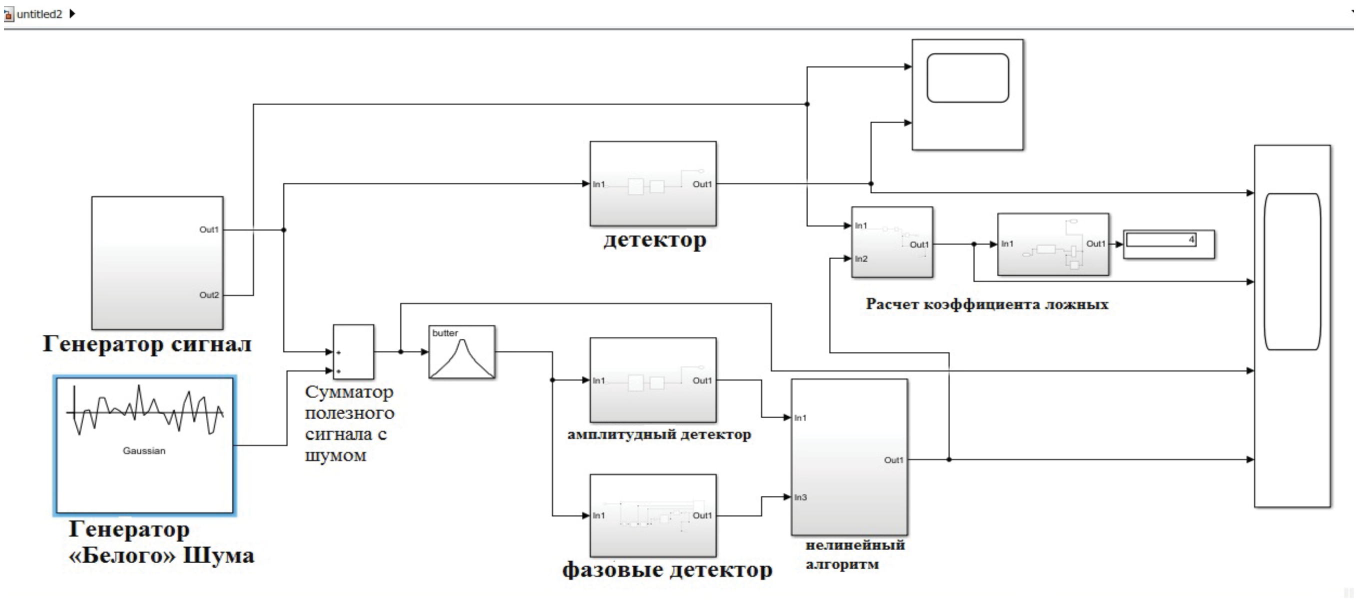

Figure 2. The model of an experimental setup for studying the noise immunity of a two-channel receiver compared to single-channel receiver

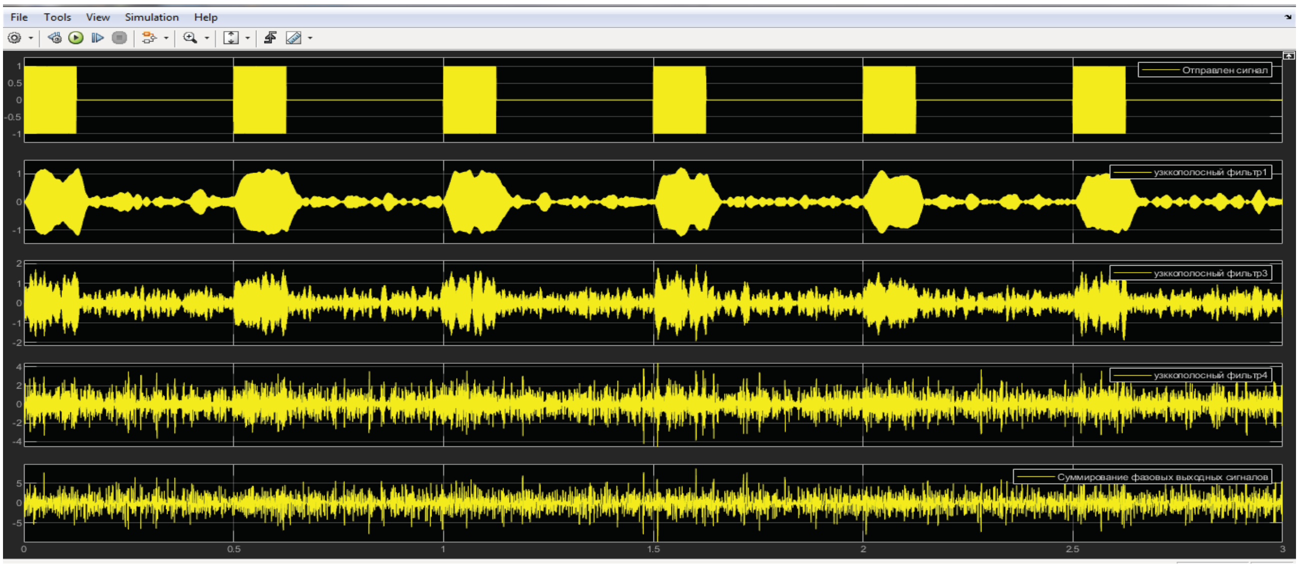

Figure 3. Radio pulse model with digital amplitude manipulation

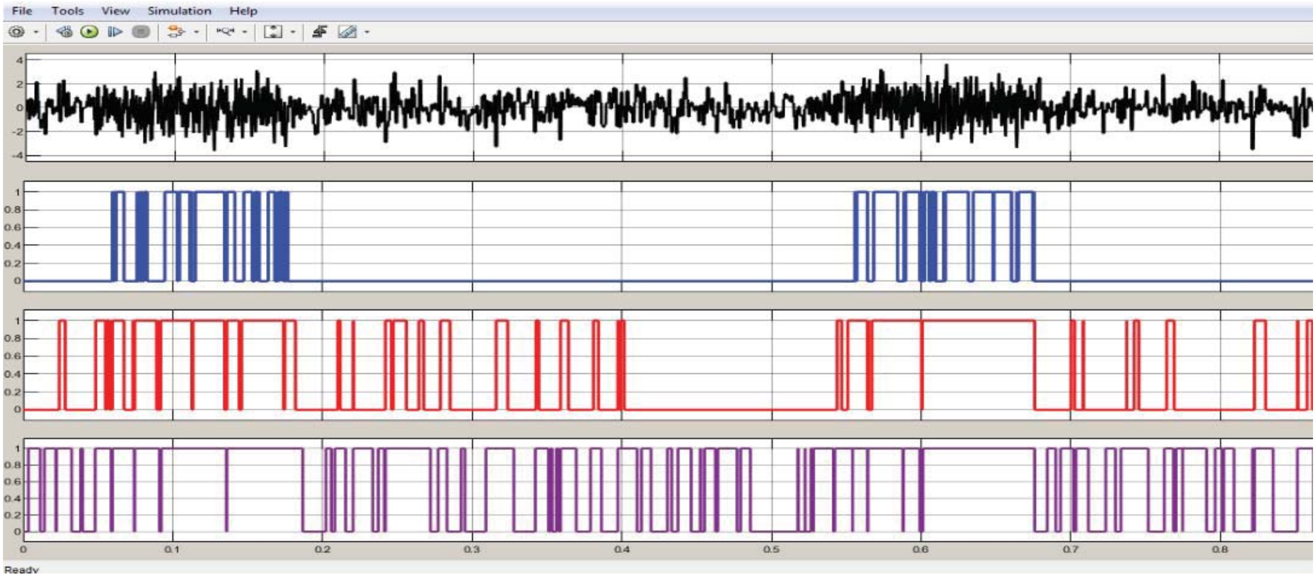

Figure 4. Results of signal reception, with different ratios of the receiver bandwidth to the frequency of the carrier oscillation using an amplitude detector

The output signals at the output of receiver with an amplitude detector are shown in Figure 4. The first graph shows the input process. In the second column, the results of the decision of the decisive.

The devices with a relatively narrow filter bandwidth. Pulses shaded with a solid tone correspond to the correct decision about the presence of a signal. Unpainted pulses correspond to erroneous decision-making about the presence of a signal (false alarm). The third graph corresponds to the results of the decision-making of the solver with the widest possible bandwidth. The second graph corresponds to the average bandwidth value between a narrowband receiving system and a broadband receiving system.

As can be seen from the graphs presented, the probability of a false alarm in a classical receiver increases with increasing bandwidth and to the region of small signal-to-noise ratios (S/N <3) turns out to be unacceptably large. Consider the operation of a two-channel receiving device, in which a phase detector is used in the second channel instead of an amplitude detector.

The decision on the presence or absence of a signal in this case is made based on the number of phase jumps by 180 degrees. In the case of a narrow-band process with a large bandwidth-to-carrier frequency ratio, we have a pronounced reaction of the phase detector to the presence of a useful signal in a mixture of signal and noise (Fig.5).

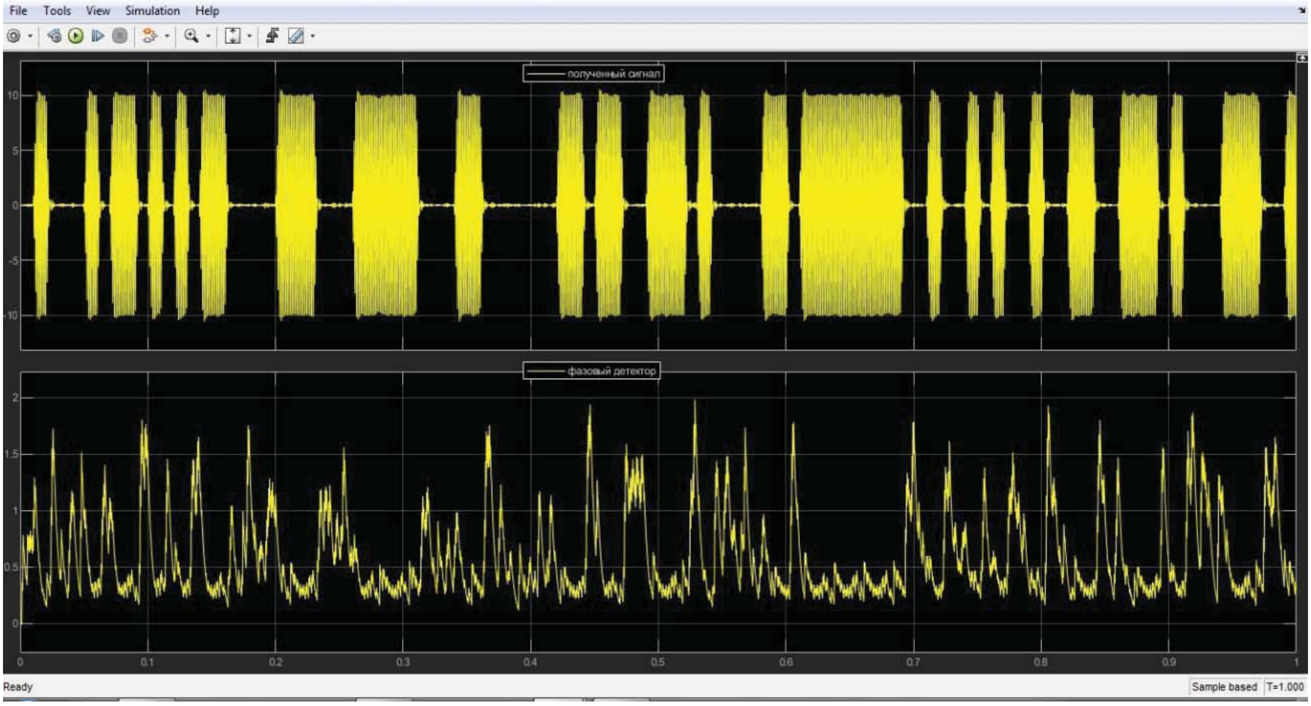

Figure 5. The passage of a mixture of signal and noise through the phase detector
(1 is the signal at the output of the useful signal generator, 2 is the signal at the output of the phase detector)

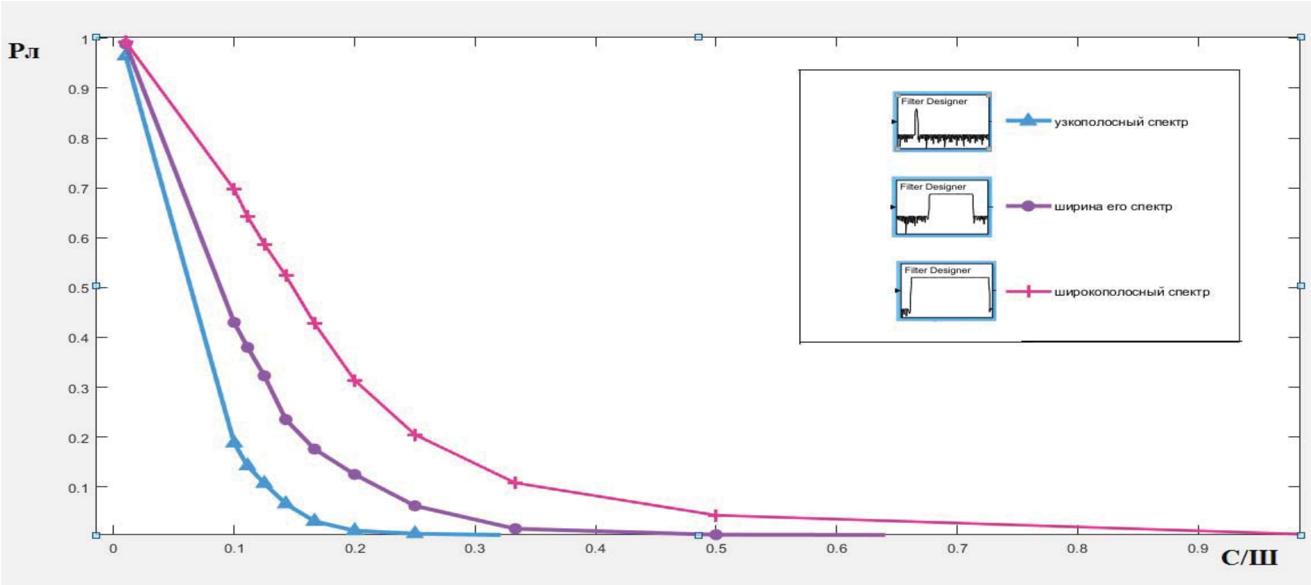

Figure 6. Results of the signal receiver, various indicators of the throughput through the phase detector

In case of the filter bandwidth changes and the ratio of the bandwidth to the frequency of the carrier oscillation, the signal at the output of the phase detector decreases. When switching to the area of broadband receiving systems, as can be seen from the ones shown in (Figure 6), the phase jumps completely disappear. That is, when working in the broadband range, the use of phase jumps as an additional information feature is not advisable.

In order to calculate the value of false positives for various values of the signal-to-noise ratio when changing, a part was added to the main circuit (Fig.2), which designed to calculate false positives of the solver. The results of the study are presented in the following figure (7). Also included a comparison of several frequency ranges depending on the probability of a false alarm of a two-channel receiver and the degree of response of the receiving system to it.

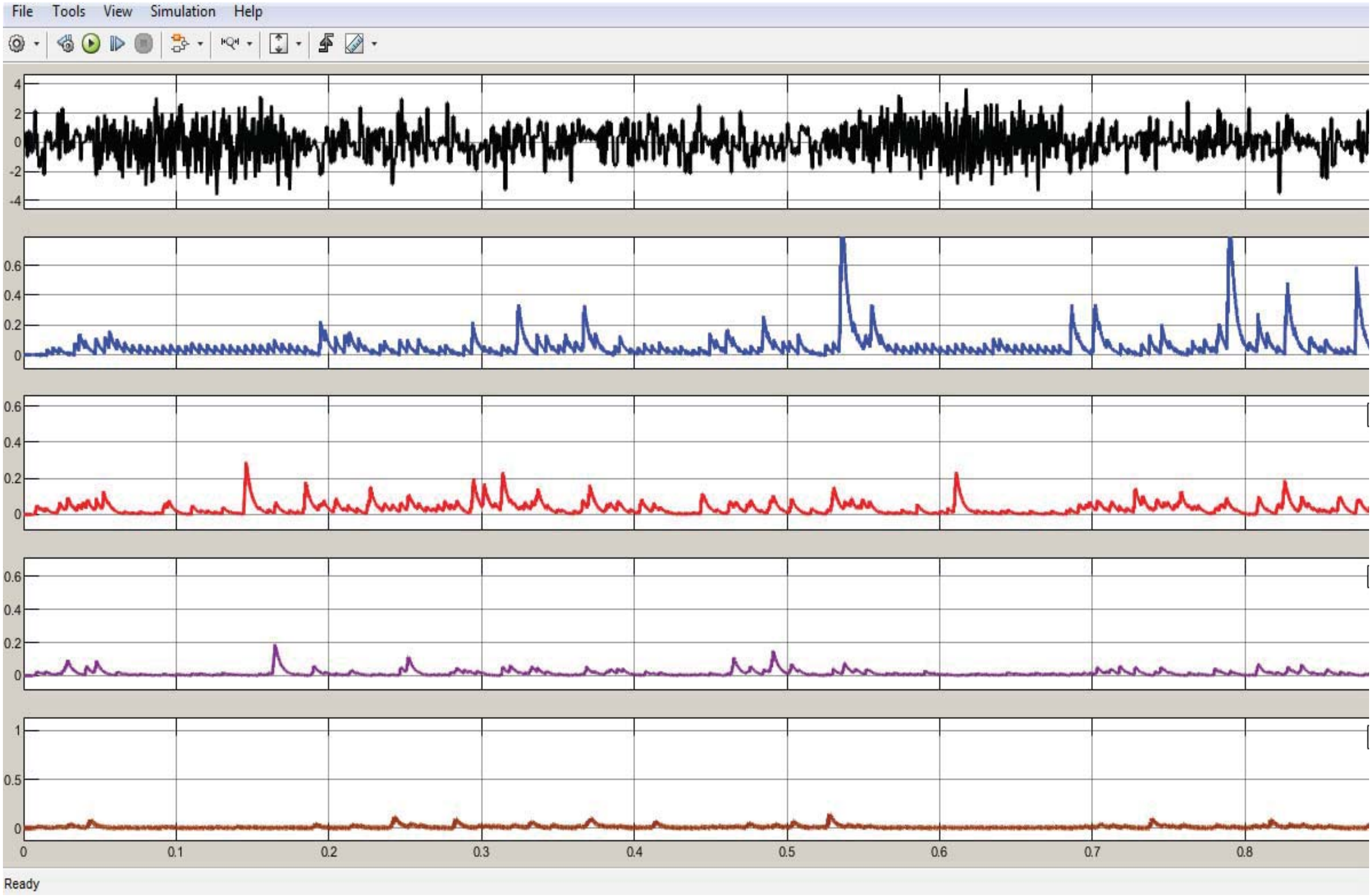

Figure 7. Dependences of the false alarm probability on the signal-to-noise ratio at different bandwidth-to-frequency ratios of the carrier oscillation

As shown from the presented diagrams of the operation of a two-channel receiver in the area of small signal-to-noise ratios (S / N <3), the greatest efficiency can be achieved with a large difference between the bandwidth and the frequency of the carrier oscillation. For broadband systems, a receiver with an additional channel based on a phase detector is not effective and its use is not advisable.

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ВЛИЯНИЕ УВЕЛИЧЕНИЯ ПОЛОСЫ ПРОПУСКАНИЯ ДВУХКАНАЛЬНОГО ПРИЕМНИКА НА ПОМЕХОЗАЩИЩЕННОСТЬ

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Аннотация

В статье рассмотрено влияние увеличение полосы пропускания двухканального приемника на помехоустойчивость приемной системы при малых отношениях сигнал/шум (С/Ш=0….3). Приведены зависимости вероятности ложных тревог от отношения сигнал/шум при различных отношениях полосы пропускания приемника к несущей частоте сигнала. Известно, что уровень шума увеличивается с увеличением полосы пропускания приемного устройства, тем самым снижая чувствительность и помехоустойчивость приемной системы при приеме импульсных сигналов. В большинстве практических случаев эта проблема решается за счет увеличения отношения сигнал/шум на входе приемного устройства за счет повышения мощности передатчика и использованием линейной фильтрации на приемной стороне. Но когда отношение сигнал/шум низкое, актуален поиск новых методов для решения данной проблемы. Различия в структурах входных процессов были использованы как дополнительные информационные признаки и выявлены при помощи использования нелинейных преобразователей. В качестве нелинейного преобразователя был использован коммутатор фазы. Принцип его работы заключался в изменение спектра входного процесса за счет коммутации фазы на 180 градусов при переходе огибающей через нуль. Это доказывает, что перескоки фазы в смеси сигнала и шума могут быть использованы в качестве вторичных информационных признаков. Следовательно, во втором канале приемника можно использовать обычный фазовый детектор. Жизнеспособность данной идеи была опробована, поэтому основной задачей данной работы являлось исследование возможности использования выше рассмотренных подходов к приему коротких радиоимпульсов в узкополосных цифровых системах связи и влияние увеличения полосы пропускания двухканального приемника на помехоустойчивость приемной системы при малых отношениях сигнал/шум.

Ключевые слова: *фазовый детектор, помехоустойчивость, радиоимпульс, узкополосный шум, широкополосный шум.*

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