Modelling of Noise Influence on the Characteristics of Multiphase Signals on the Example of the Signal Based on the Generalized Frank Code

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Abstract — **This paper is devoted to the problem of noises influence on the complex multiphase signals that could be used as probing signals in the radar systems.**

Keywords — **Complex multiphase signals, optimal processing, generalized Frank code, signal-to-noise ratio**

I. INTRODUCTION

In radio electronic systems signals that are used to receive and transmit the information meet the condition of narrow band

$$\frac{\Delta w}{w} << 1 \qquad (1)$$

Considering these signals as infinite sum of harmonic components according to the central limit theorem of probability theory the law of distribution of instantaneous values is described by Gaussian distribution law.

This allow using the model of such signals in the form of analytical signal

$$\overset{\bullet}{Z}(t) = |Z(t)| e^{jj(t)} e^{jw_0(t)} \qquad (2)$$

where $|Z(t)|$ – module of the analytical signal;

$j(t)$ - the law of angle change (phase).

Then,

$$S_0(t) = |Z(t)| e^{jj(t)} \qquad (3)$$

where $S_0(t)$ – complex envelope amplitude, which takes into account all changes in the signal and allows one to determine the spectrum of the signal.

Thus, substituting in (3) instead of $j(t)$ the law of the phase changes according to code sequence or another law of phase changes we get a model for the phase modulated signal.

II. MODELS OF THE NOISE AND SIGNAL'S MIXTURE WITH NOISE

Obviously, the analytical signal and complex envelope signal are the random function, but the laws of their distribution will be different. Complex envelope will vary by Rayleigh distribution law and argument (phase) by uniform distribution law. So the noise signal shall consist of two parts: complex envelope (complex amplitude) of the noise ($Z_N(t)$) and phase component ($j_N(t)$).

To analyze the influence of the noise on the properties of complex multiphase signal we will form mixture of signal and noise:

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$$S_{SN}(t) = |Z(t) + Z_N(t)| e^{j(j(t)+j_N(t))} \qquad (4)$$

One of the main parameters of such a mixture is the signal-to-noise ratio. It is determined by the ratio of signal power to noise power or square of the ratio of their amplitudes. Assuming that the amplitude of "pure" signal does not change and is equal to 1, signal-to-noise ratio will be determined as:

$$q^2 = \frac{1}{\frac{4-p}{2} b^2} \qquad (5)$$

where b^2 – scale coefficient of the Rayleigh distribution law of random values.

The loses of the signal-to-noise ratio on the output of the filter, agreed with discrete wideband phase modulated signal [1], can be induced by the incomplete agreement of the probing signal with the discrete filter owing to:

- Inaccuracy of the phase setting in the elemental signals.
- Inaccuracy of the reference frequency.
- Inaccuracy of the phase shifters (if such are used).
- Additive noises on the input of the filter.

The biggest interest is to find the dependencies between the signal-to-noise ratio on the filter input and the value of the central ambiguity peak of the ambiguity function on the filter output.

In this article the influence of noise on complex multiphase signal based on the generalized Frank code with the number of quantization levels of the phase N = 11 is investigated. Method of forming of such code is well known and described in many publications and papers [2]. Characteristics of the signal are also known and studied [3, 5], particularly in the writings of the authors [4, 7].

III. CHARACTERISTICS OF THE SIGNAL AND ITS MIXTURE WITH THE NOISE

Figure 1 shows the comparison of the "clean" signal spectrum (fig.1a) and the mixture of the signal with one of the realizations of the noise (fig.1b) with the signal-to-noise ratio of 0.0233 which means that the noise has almost 43 times more power than the signal.
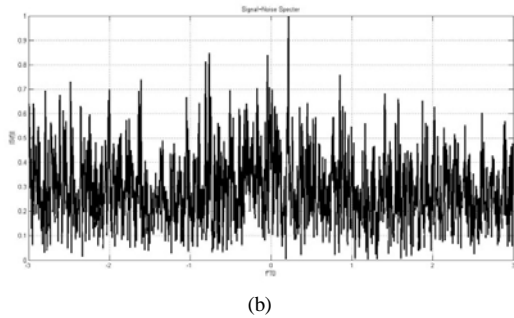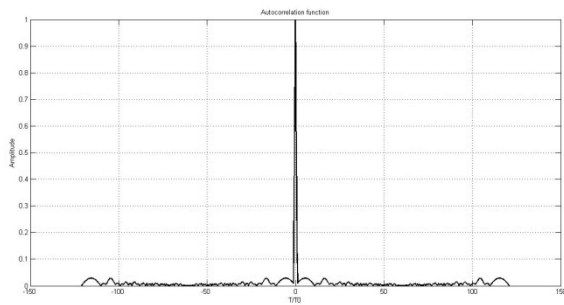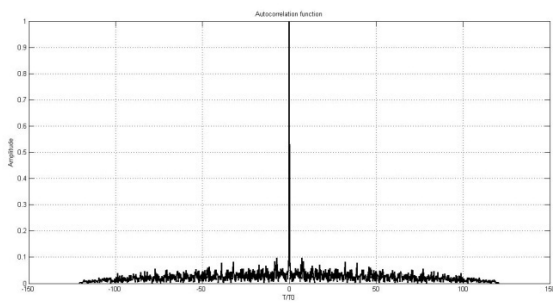

(a)

(b)
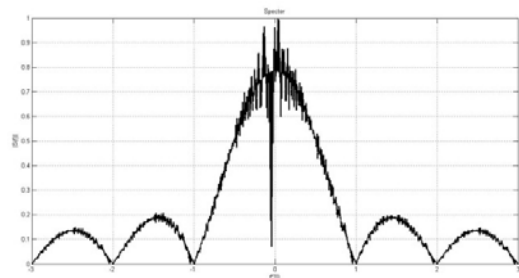
Figure 1. Spectrums of the signal (a)and the mixture of the signal with one of the noise realizations (b)

As can be seen with such signal-to-noise ratio the spectrum of the mixture approaches the uniform distribution. Detection or selection of the signal from the mixture by means of filters becomes almost impossible. Therefore, in such cases the correlation method of processing should be used [6].

Figure 2 shows the autocorrelation function of the "clean" signal based on the generalized Frank code (fig.2a). The autocorrelation function of the mixture of the signal with one of the realizations of the noise (fig.2b) and cross-correlation function between the "clean" signal and the mixture of the signal with one of the realizations of the noise (fig.2c).

As can be seen from the fig.2c noise has quite a significant influence on the level of side lobes of the correlation function. However, their value remains well below the level of the main correlation peak, which allows using only the main correlation peak in further signal processing.

(a)

(b)

(c)

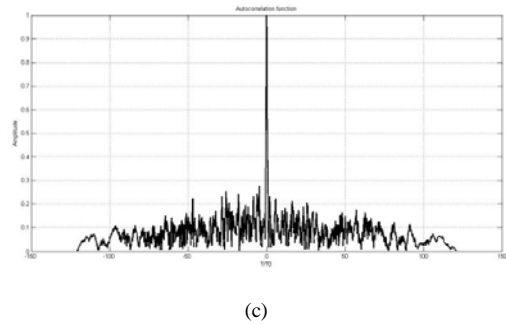Figure 2. Spectrums of the signal (a)and the mixture of the signal with one of the noise realizations (b)

Figure 3.

As known from previous research [4, 8], the signals on the basis of the generalized code Frank are a little sensitive to the Doppler shift of frequency. Therefore, it is important to know their ambiguity and side lobes distribution diagrams on a plane of time-Doppler frequency shift under the influence of noise on such signal.

IV. CONCLUSIONS AND FUTURE INVESTIGAIONS

The conducted investigations show that using the complex multiphase signals and correlation methods of their processing allows to decrease the level of the side lobes and guarantee better probability parameters such as the probability of correct detection. Using the signal based on the generalized Frank codes as the probing signal of the radar system will make it more protected from the influence of noises and obtain better detection characteristics in comparison with other signals such as linear frequency modulated and based on Barker codes.

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