Method, Algorithm and Computer Tool for Synphase Detection of Radio Signals in Telecommunication Networks with Noises

Liliia Khvostivska[a], Mykola Khvostivskyi[a], Iryna Dediv[a], Vasyl Yatskiv[b] and Yuri Palaniza[a]

[a] *Ternopil National Ivan Puluj Technical University, Rus'ka str. 56, Ternopil, 46001, Ukraine*
[b] *West Ukrainian National University, Lvivska str. 11, Ternopil, 46009, Ukraine*

Abstract

The article represents a model of radio signals as a periodically correlated stochastic process, which made it possible to implement a synphase method of effective detection of radio signals in telecommunication networks with noises.
Based on the synphase processing method, a method and algorithm for detecting radio signals in telecommunication networks with noises is implemented by calculating correlation components as quantitative indicators that reliably reflect the fact of the presence/absence of a useful radio signal component.
A computer (software) tool for synphase detection of radio signals in telecommunication networks with a graphical user interface is implemented in the Matlab environment.
The process of synphase detection of radio signals in telecommunication networks with noise of different power which confirmed the correct functioning of the developed method and algorithm of synphase detection of radio signals.

Keywords

Radio signal, periodically correlated stochastic process, synphase method, algorithm, computer tool, detection, noise, telecommunication network.

1. Introduction

The procedure of effective detection of the useful component of radio signals in telecommunication networks with interference is the main problem of radio signal preprocessing in the telecommunications industry. Basic developments in this direction are the works of V.A. Kotelnykov, V.I. Tikhonov and B.R. Levin and other scientists.

Known algorithms for processing radio signals for their detection of a useful component in telecommunication networks with interference are implemented using filtering methods [1-4], the core of which are mathematical models of types of random stationary process and the sum of useful signals and noise. The specified series of models are idealized through their constructive consideration of only stochastic components without combining them with a periodic component as the main feature of real radio signals with various types of modulation in telecommunication networks. In the works of L.V. Khvostivska, M.O. Khvostivskyi, V.L. Dunetc, I.Yu. Dediv and L.M. Koval [6, 7, 14] a model of the type of periodically correlated stochastic process (PCSP) is proposed to describe radio signals in networks with interference. The mentioned authors did not use the entire available arsenal of the PCSP model for the development of a software tool for processing radio signals, but limited themselves only to the component method for their detection.

Therefore, the use all PCSP arsenal for the development of a new method, algorithm and computer tool for processing radio signals for their detection in telecommunication networks with interference is actual problem.

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EMAIL: hvostivska@gmail.com (Liliia Khvostivska); hvostivskyy@tntu.edu.ua (Mykola Khvostivskyi); iradediv@gmail.com (Iryna Dediv); vy@wunu.edu.ua (Vasyl Yatskiv); palanizayb@tntu.edu.ua (Yuri Palaniza)
ORCID: 0000-0002-4997-8339 (Liliia Khvostivska); 0000-0002-2405-4930 (Mykola Khvostivskyi); 0000-0002-4913-139X (Iryna Dediv); 0000-0001-9778-6625 (Vasyl Yatskiv); 0000-0002-8710-953X (Yuri Palaniza)

2. Mathematical representation of the model of radio signals in telecommunication networks

In the development process, the telecommunications network is the most vulnerable link that is affected by disturbances of various power (Fig. 1).

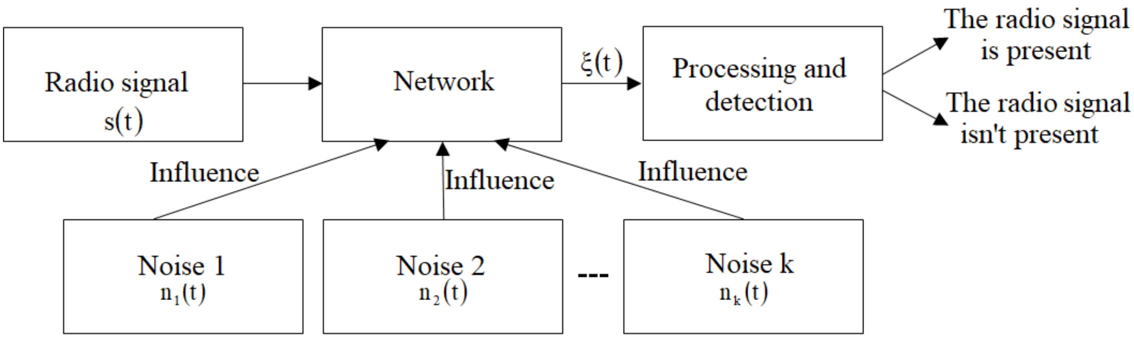


Figure 1: General presentation of the model of radio signals in the telecommunications network

The mathematical representation of the model of radio signals is aimed at describing real signals, taking into account all the features of the influence of various types of interference on the network itself. In this case, the connection between the input and output signal is represented mathematically in the form of an expression:

$$\xi(t) = s(t) + \sum_{k=1}^{K} n_k(t), \quad t \in \mathrm{R}\,. \tag{1}$$

where $n_k(t)$ - k-th additive interference affecting the network, in particular, the incoming radio signal $s(t)$ throughout the observation time.

The experimental implementation of a radio signal, in particular, on the example of an amplitude-modulated signal, is shown in Fig. 2.

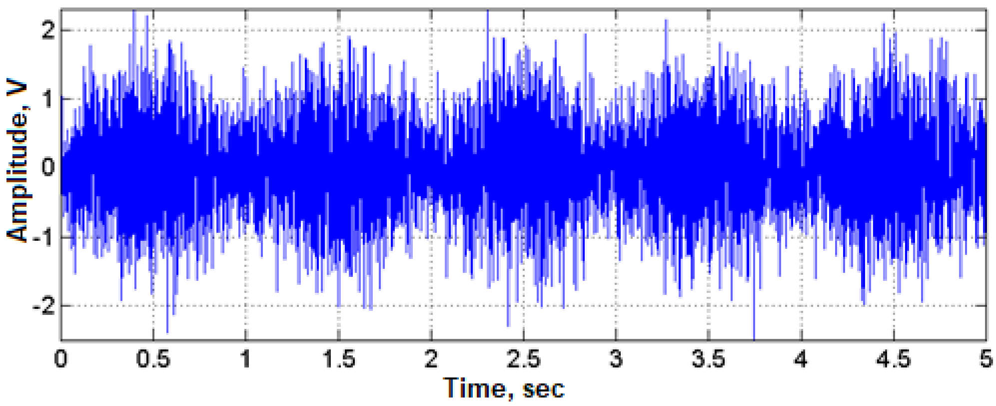


Figure 2: Amplitude-modulated radio signal with noises

All modulated radio signals in the process of their transmission are characterized by indicators of stochasticity and periodicity, which are through the influence of interference and the harmonic component in the modulation of radio signals.

Therefore, when implementing the method of processing radio signals in networks with noises, it is necessary to adequately present their model, which is a determining factor in the effectiveness of methods and means of detecting signals, in particular, their useful component.

These requirements are satisfied by a model of the type of periodically correlated stochastic process, which has a powerful arsenal for processing radio signals and is suitable for their detection in telecommunication networks with noises. Such evidence is substantiated in the work of Khvostivska L.V. and L.M. Koval [6].

Radio signals in telecommunication networks with interference are represented as PCSP in the form of an expression [5, 6]:

$$\xi(t) = \sum_{k \in Z} \xi_k(t) e^{ik\frac{2\pi}{T}t}, \ t \in \mathrm{R} \tag{2}$$

where $\xi_k(t)$ - the stochastic component of the radio signal in telecommunication networks with noises; $e^{ik\frac{2\pi}{T}t}$ - periodic component of the radio signal in telecommunication networks with a period indicator.

The mathematical presentation of the model of a radio signal in telecommunication networks with noises through PCSP according to the energy theory of stochastic signals [8] enables the implementation of methods and computer tools for the detection of useful radio signals based on synphase processing as a method of calculating the indicator of reliable detection, namely correlation components $B_k(u)$.

3. Method and algorithm of synphase detection of radio signals

Synphase processing of the radio signal provides the process of estimating the correlation components taking into account covariance statistics $\hat{b}(t,u)$ [5, 6, 8, 9]:

$$\hat{B}_k(u) = \frac{1}{T}\int_0^T \hat{b}(t,u) \exp\left(-ik\frac{2\pi}{T}t\right)dt, \tag{3}$$

where

$$\hat{b}_{\xi}(t,u) = \sum_{k=0}^{N-1} \overset{0}{\xi}(t+u+kT)\overset{0}{\xi}(t+kT), \tag{4}$$

where T – radio signal period (calculated according to the methodology given in the work [10]);

N – the total number of repetitions of the radio signal;

u – time shift.

Figure 3 shows the structural sequence of the research process of detecting useful radio signals in telecommunication networks with noises.

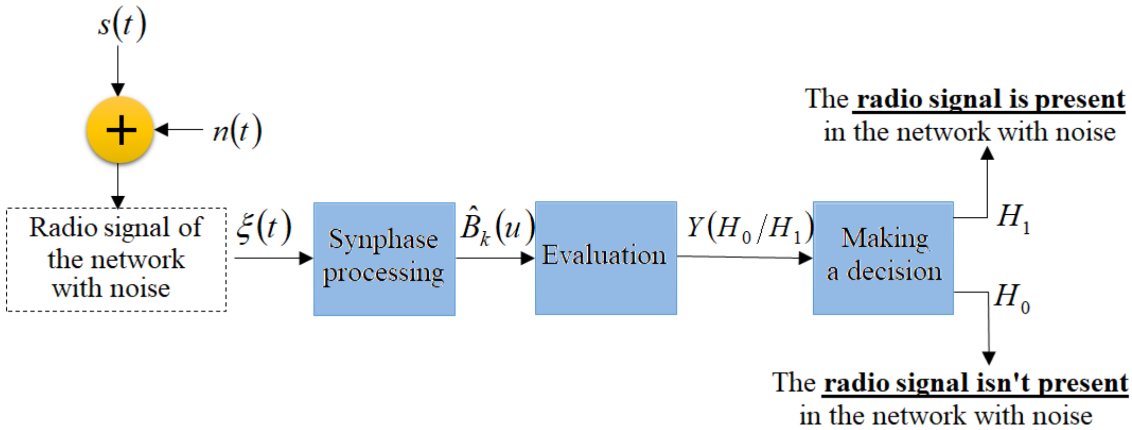


Figure 3: Structural sequence of radio signal detection

The structural elements of the sequence are as follows:

- Synphase processing of radio signals in telecommunication networks with noises according to expression (3), which calculates the detection rate in the form of correlation components $\hat{B}_k(u)$.

- Evaluation of the calculated correlation components according to the form and values of which will ensure the process of detecting radio signals.
- Making a decision based on the form and indicators of the estimated correlation components regarding the presence/absence of useful radio signals in telecommunication networks with noises.

The algorithm for synphase radio signal processing in telecommunication networks with noises is shown in Fig. 4.

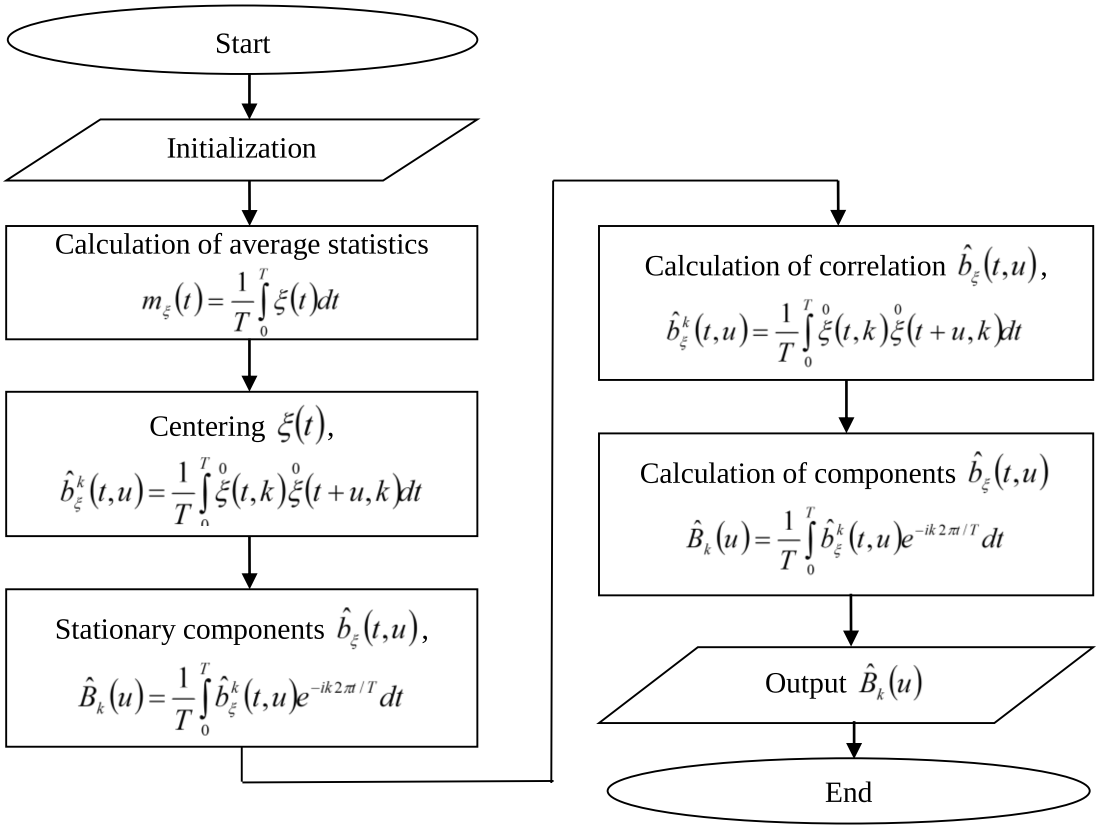


Figure 4: Algorithm of synphase radio signal processing as the core of a detection tool

The developed algorithm created prerequisites for the implementation of a computer tool for synphase processing as the basis of the method of synphase detection of radio signals in telecommunication networks with noises. The developed algorithm is also of practical importance for cyber-physical systems [12, 13].

4. Results of detection of radio signals

The result of synphase detection of radio signals in telecommunication networks with noises in the form of calculated correlation components with the interference power level (dispersion level 0 V^2) is shown in the form of a 3D implementation in Fig. 5.

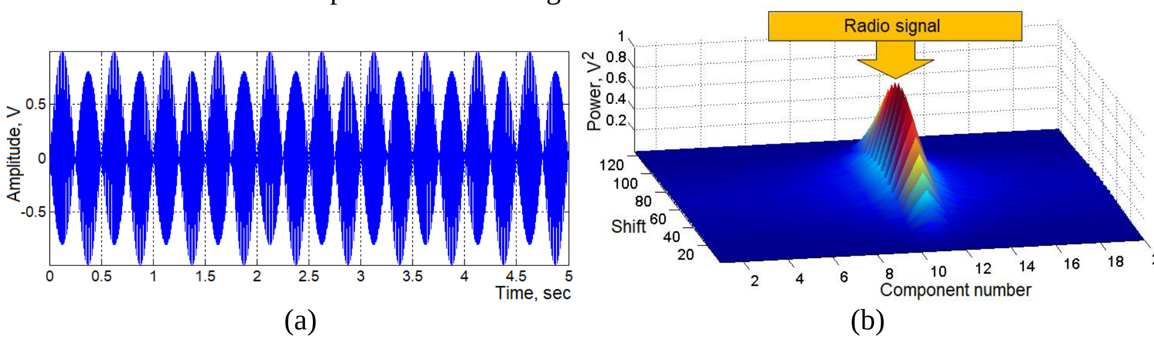
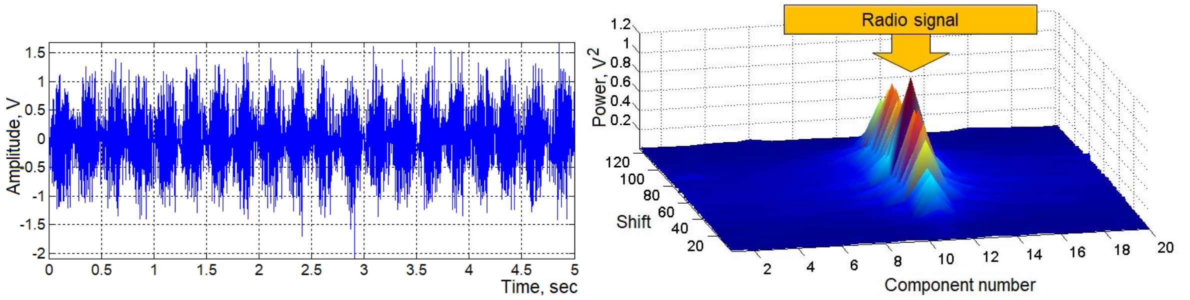


Figure 5: The result of synphase detection of a radio signal at noise's dispersion level of 0 V^2: a) radio signal; b) components as a detection indicator

Fig. 4 shows that the radio signal (Fig. 5, a) is clearly localized according to correlation components as a detection indicator (Fig. 5, b).

The level of noises dispersion is increased by 0.3 V^2, and the result of the calculated components of the radio signal at this level of noises is shown in Fig. 6.

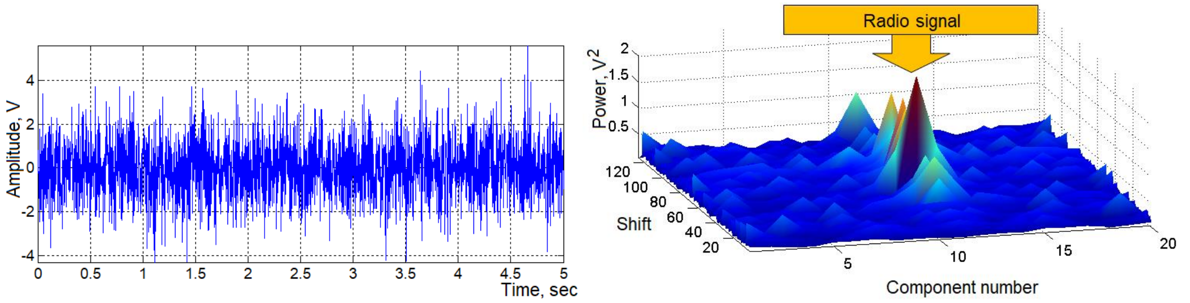


(a) (b)

Figure 6: The result of synphase detection of a radio signal at noise's dispersion level of 0.3 V^2: a) radio signal; b) components as a detection indicator

In this case, the radio signal is clearly localized (Fig. 6), as in the case without noises in Fig. 5.

The level of harmful dispersion was increased to 1.2 V^2, which exceeds the level of the most useful radio signal, and the components shown in Fig. 7 were calculated. The result of the localization of the radio signal component is identical to the above results, that is, the detection is obvious without any difficulty.



(a) (b)

Figure 7: The result of synphase detection of a radio signal at noise's dispersion level of 1.2 V^2: a) radio signal; b) components as a detection indicator

From the calculated detection indicators in Fig. 5-7, it can be seen that the radio signal in telecommunication networks with noises is clearly localized, which ensures the process of its reliable and effective detection without any difficulty.

Therefore, the correlation components ensure the formation of logical and justified conclusions regarding the presence or absence of a useful radio signal (Fig. 5-7).

For a more detailed evaluation of the calculated correlation components $\widehat{B}_k(u)$, their averaged evaluation by components was used, as suggested by M.O. Khvostivskyi [11] according to the expression:

$$M_k\left\{\hat{B}_k(u)\right\} = \frac{1}{N_k}\sum_{k=1}^{N_k}\hat{B}_k(u), \quad u=\overline{1,N_u}\,,\; k=\overline{1,N_k}\,. \tag{5}$$

where u –shift value; N_u – total number of components k; N_k – shift length.

The result of averaging radio signal components $\widehat{B}_k(u)$ according to expression (5) at different levels of noises dispersion is shown in Fig. 8.

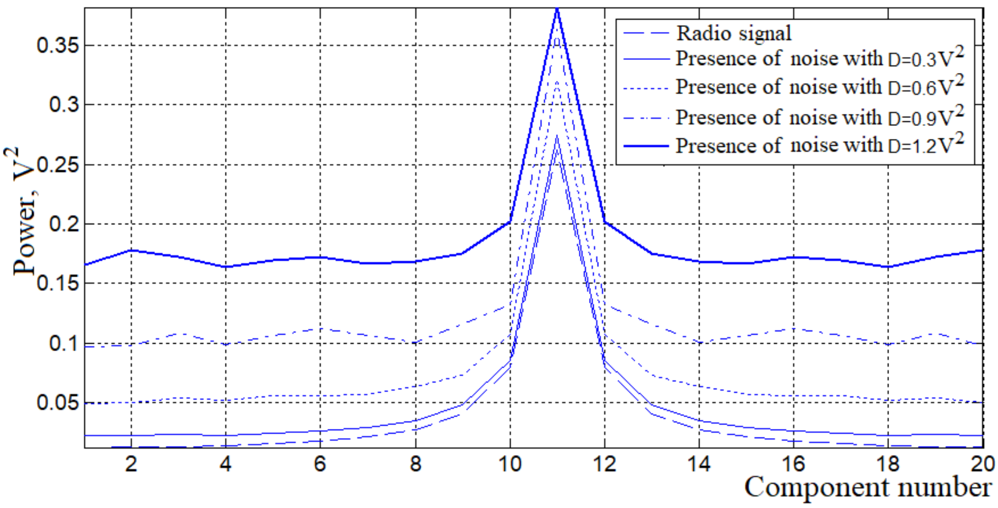


Figure 8: Average components of the network radio signal with noises component with a level of dispersion $\{0;0{,}3;0{,}6;0{,}9;1{,}2\}$ V²

The estimated components through their averaging (Fig. 8) make it possible to compare the detection results in more detail than in the case of non-averaged components (Fig. 5-7), which ensures the process of effective and reliable detection of radio signals in telecommunication networks with noises.

4. A computer tool for detecting radio signals

Using MATLAB GUIDE, a computer tool with a graphic interface was developed to detect useful radio signals in a telecommunication network with noises (Fig. 9).

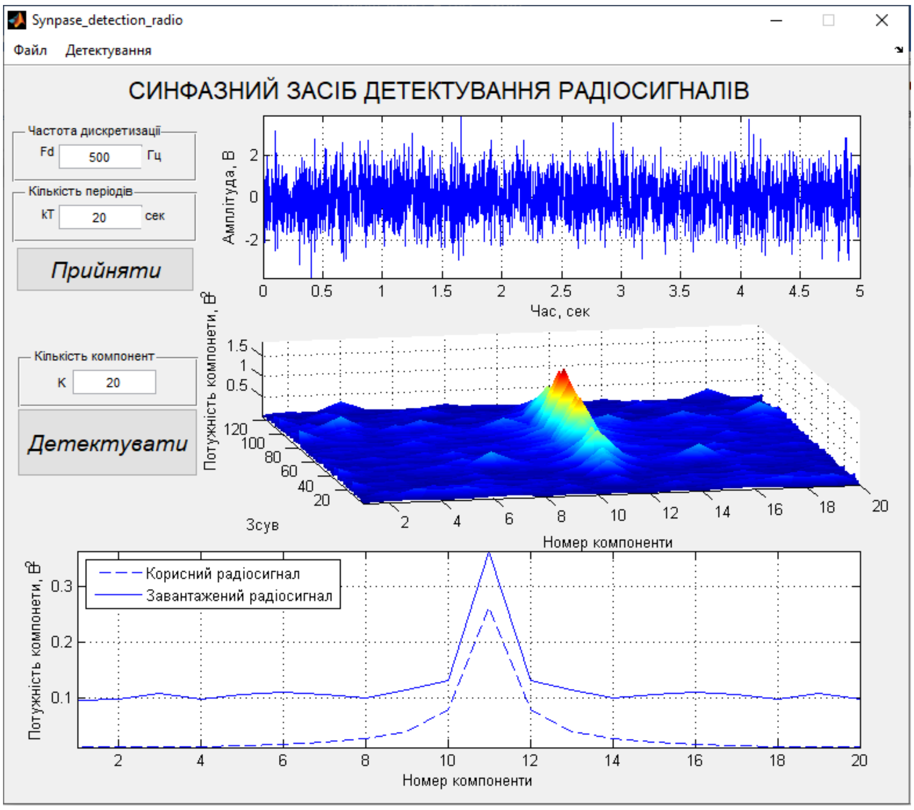


Figure 9: The result of the work of the computer tool for synphase radio signal detection (interference dispersion level 0.9 V²)

The implemented computer tool provides a procedure for automating the synphase detection of a useful radio signal in telecommunication networks with noises of different power.

5. Conclusions

The results of processing radio signals as a periodically correlated stochastic processes in telecommunication networks with noises in the form of averaged correlation components state that the developed synphase method, algorithm and computer tool organize the process of tracking and synphase detection of the presence of a useful radio signal component against the background of noises of different power. This fact indicates the effectiveness of the process of detecting useful radio signals as periodically correlated stochastic processes when using the synphase method.

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