Mathematical and Algorithmic Support of Detection Useful Radiosignals in Telecommunication Networks

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Abstract

The article is developed mathematical support of the component detection for useful stochastic-periodic radiosignals in telecommunication networks which based on the principles of the energy theory of stochastic signals applying the theory of periodically correlated random processes and component processing. On the basis of mathematical support is implemented algorithmic support for effective detection of useful stochastic-periodic radiosignals in telecommunication networks with interferences by calculating correlation components as quantitative indicators of detection.

Keywords
Mathematical and algorithmic support, detection, radiosignals, telecommunication network

1. Introduction

The problem of the process of efficient detection of useful radiosignals in telecommunication networks (computer networks, mobile networks, etc.) on the background of various types of interferences is the basic problem of radiosignal processing in the telecommunications industry. When solving the problems of processing radiosignals with interference, a number of works have a basic worth Tikhonov V.I., Akimova P.S., Kotelnikova V.A., Lezina Yu.S., Rabiner L., Gutkina L.S., Vinera N., Ageeva D.V., Sosulina Y.G., Levina B.R., Gould B., Oppenheim A. and other notable scientists of the technical direction.

In existence algorithms processing radiosignals with interferences in telecommunication networks for identify useful components used methods of maximum likelihood [1,2], filtration [3] and correlation [4], which are implemented on the basis of radiosignal models of the sum of white noise and useful radiosignal, stationary random process. These models are simplified in terms of their design because they take into account only stochasticity without taking into account periodicity (repeating), which is a structural characteristic of real radiosignals. The characteristic of the periodicity of radiosignals is due to the conditions of transmission of radiosignals in telecommunication networks.

Existing models and methods of detecting useful stochastic-periodic radiosignals in modern telecommunication networks, implemented on their basis, are characterized by a low level of authenticity of the results, when decisions are made regarding the fact of the absence or presence of radiosignals in telecommunication networks, which is distorted by various interferences.

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Therefore, the development of new mathematical support, in particular the mathematical model of radiosignals and the implementation of new effective mathematical methods and algorithms for detecting useful radiosignals in telecommunication networks in the presence of interferences on its basis is an actual problem.

2. Mathematical support

In the development of telecommunication networks (fig. 1), the transmission/reception channel is the basic link where the source of radio signals and blocks are coordinated.

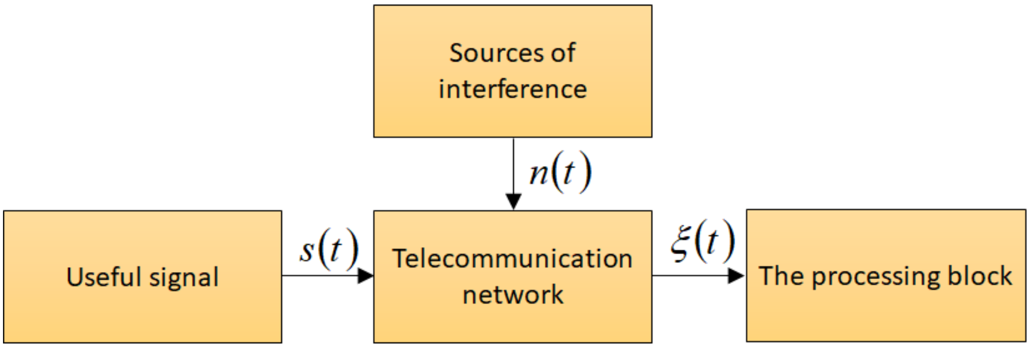


Figure 1: General model of radiosignals in a telecommunications network

The mathematical image of radiosignal network model of a real telecommunication network is directed for development of a mathematical apparatus of empirical radiosignals at the outputs/inputs of this telecommunication network and certain communication mechanisms of this network with the radiosignals of the network. For specify the indicators and characteristics of radiosignals in telecommunication networks, it is necessary to analyze the behavior of the values of real radiosignals, and on its basis to select the structure of the mathematical image of radiosignals.

Fig. 2 shows an amplitude-modulated radiosignal with the interferences in its structure.

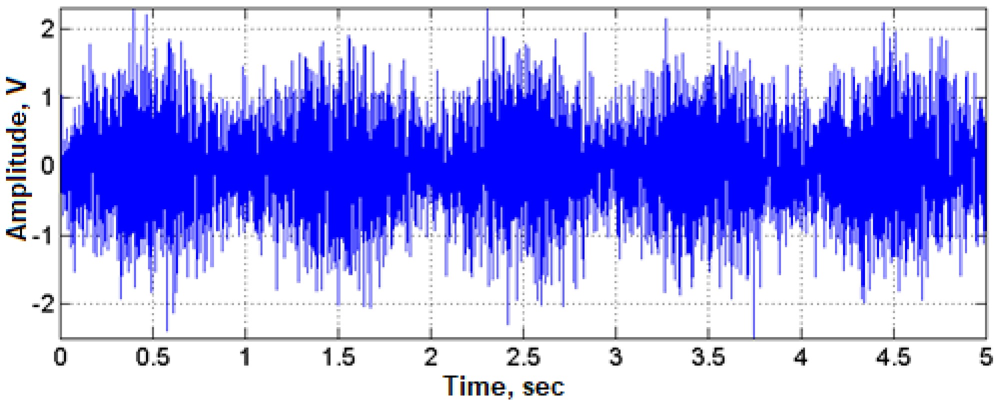


Figure 2: The amplitude-modulated radiosignal with background interferences

Amplitude-modulated radiosignals in the telecommunications network are characterized by periodicity by the modulation method and stochasticity by the influence of interference of various natural and artificial origins.

Therefore, the mathematical image of the model should provide a constructive combination of periodicity and stochasticity. These needs are agreeing a mathematical image as a periodically correlated random process (PCRP), which organizes the process of ensuring the specified combination and has methods of processing radiosignals of the network for effective detection of the useful component in these radiosignals in telecommunication networks with interferences.

Because of the fact that the value of the power of radiosignals is limited and characterized by a certain ending within one modulation period of time, it is possible to confirm that the radiosignal belongs to the class known from the energy theory of stochastic signals (ETSS) as class π^T [5]. ETSS indicates an adequate mathematical representation of the model of radiosignals by the PCRP representation from the class π^T in which, in the most general form, the stochasticity of radiosignal values is combined with the indication of periodicity, which is interpreted as the periodicity of statistics.

The radiosignals represent as the PCRP belong to the class π^T and represented in expression [5]:

$$\xi(t) = \sum_{k \in Z} \xi_k(t) e^{ik\Lambda t}, \quad t \in \mathrm{R} \tag{1}$$

where $\xi_k(t)$ - stochastic component of the radiosignal in the network, Λ - periodic component $\Lambda = 2\pi/T$.

The selected representation of the mathematical image of the radiosignal by the PCRP model from the ETSS theory provides the development of means of detecting useful components in telecommunication networks with interferences based on in-phase or component processing by the calculation of numerical indicators of statistics as the correlation components.

The statistics of the correlation components in the component processing of the radiosignal are calculated according to the expression:

$$\hat{B}_k(u) = \frac{1}{T} \int_0^T \overset{0}{\xi}(t+u) \overset{0}{\xi}(t) \exp\left(-ik \frac{2\pi}{T} t\right) dt, \tag{2}$$

where $\overset{0}{\xi}(t)$ - centered implementation of the radiosignal relative to the average.

3. Algorithmic support

Fig. 3 shows a general algorithm for researching the process of detecting useful radiosignals in interferences transmitted through telecommunication networks.

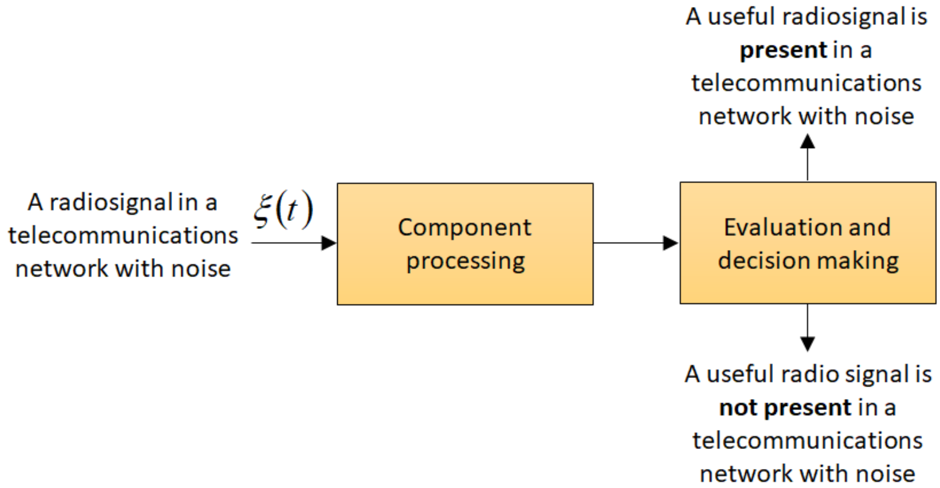


Figure 3: Generalized algorithm of empirical analysis of radiosignal detection process

The structure is based on procedures:

- Component processing of radiosignals in the network according to expression (2) for calculating correlation components as indicators of detection of useful radiosignals in telecommunication networks with interferences.
- The process of assessment components and making a decision based on their look, structure, shape and values which regard to the presence/absence of useful radiosignals in the network on the background of interferences.

The given procedures (fig. 3) and the structure (fig. 4) provide the procedures for the development of the algorithmic consistency for the implementation of detecting useful radiosignals in telecommunication networks with interferences on bases of ETSS and the mathematical representation of such radiosignals as PCRP.

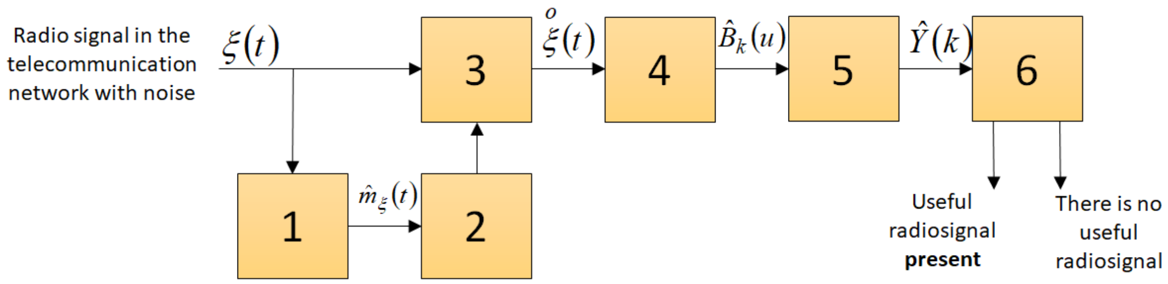


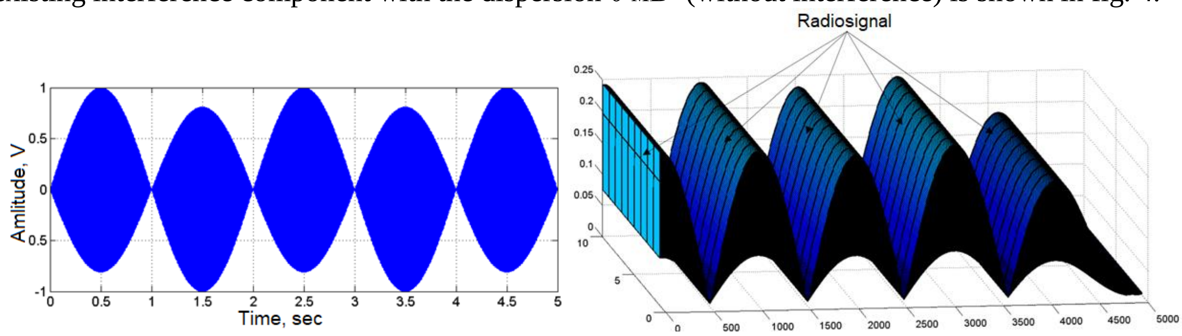
Figure 3: Algorithmic progression of detection radiosignals in networks with interference

In fig. 3 sign operations: 1 – calculation of the average statistics of the radiosignal $m_\xi(t)$;

2 – modeling of a consistency of average radiosignal statistics [$m_\xi(t)\ \ m_\xi(t)\ \ m_\xi(t)\ \ldots\ m_\xi(t)$] by their periodic arrangement; 3 – a procedure for centering a radiosignal relative to a set of consistency average statistics $\xi(t)$; 4 – the procedure for calculating radiosignal components $B_k(u)$; 5 – the procedure for evaluating radiosignal components $B_k(u)$ as indicators of their detection in a network with interferences $\hat{Y}(k)$; 6 – procedure for making decisions about the presence of a useful radiosignal.

4. Results of detection of useful radiosignals

The result of calculating the correlation components of the radio signal of the network with the existing interference component with the dispersion 0 мВ^2 (without interference) is shown in fig. 4.

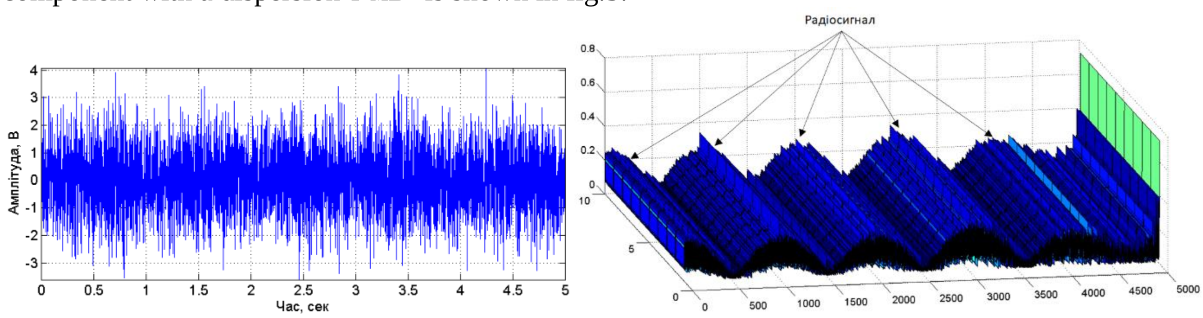


(a) (b)

Figure 4: The result of detection of a network radiosignal with an interference component with a dispersion 0 mV^2 (abscissa axis – shift, ordinate axis – component number, applied axis power (mV^2)): a) radiosignal; b) components as a result of detection

On fig. 4, it can be seen that the components of the useful radio signal (fig. 4, a) are clearly localized according to the correlation components as a detection indicator (fig. 4, b).

The result of calculating the radiosignal components of the network with an existing interference component with a dispersion 1 мВ^2 is shown in fig.5.



(a) (b)

Figure 5: The result of detecting a network radio signal with an interference component with a dispersion 1 mV^2 (abscissa axis – displacement, ordinate axis – component number, applied axis – power (mV^2)): a) radiosignal; b) components as a result of detection

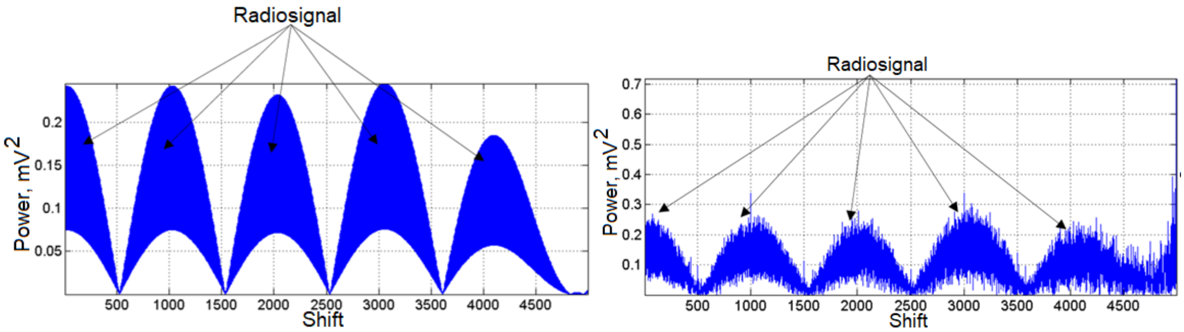
Fig. 5, b shows that the components of the radiosignal are clearly localized, unlike radiosignal implementation, where the signal is not noticeable (fig. 5, a) in the background of interference. Correlation components quantitatively establish the fact of the presence or absence of radiosignals in the background of various types of interferences.

As a criterion for a more adequate and more detailed assessment of indicators of radiosignal components (fig. 4-5, a), used the procedure for calculating their averaging by radiosignal components according to the expression (the idea of Khvostivskyy M.O.):

$$M_k\left\{\hat{B}_k(u)\right\} = \frac{1}{N_k}\sum_{k=1}^{N_k}\hat{B}_k(u), \quad u=\overline{1,N_u}, \; k=\overline{1,N_k} \,. \tag{3}$$

where u – time shift; N_u – total number of shifts; N_k – total number k-th component.

The result of the averaged components of the radiosignal of the network with interference and with the level of dispersion 0-1 мВ^2 is shown in fig. 6.



a) b)

Figure 6: Averaged components of the radio signal of the network with interference with a dispersion level of 0 mV^2 (a) and 1 mV^2 (b)

The averaged components (fig. 6) provide a more detailed comparison procedure when compared with non-averaged components (fig. 4-5, a), which guarantees the effective detection of radiosignals in telecommunication networks with interferences.

According to the results of processing radiosignals, in particular their averaged components of the radiosignal with interference, it was established that the developed mathematical and algorithmic support is provides the process of detecting and tracking the presence of useful radiosignals in telecommunication networks with the given distortions. Such facts indicate the effectiveness of the radiosignal detection procedure which based on the developed mathematical and algorithmic support.

5. References

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