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Method of detecting random signals based on determining the deviations of the main parameters of radio signals

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ABSTRACT
The article proposes a new method of detecting signals of secret means of obtaining information. The novelty of the method is the combination of two methods: the method of determining the deviations of the amplitude and the method of determining the phases of random signals from the signals of devices legally operating in a given radio range. The signals of the means of secretly obtaining information can be detected by determining the variance of the amplitudes and phases of the signals.

To detect the signals of the means of covert receipt of information, it is proposed in the first stage to determine the deviation of the amplitude of the signals from the signals of legally operating devices, in the second stage to determine the phase deviation of the signals. Thus, for two parameters of the deviation of the amplitude and phase, it is possible with high probability to detect signals from the means of covert receipt of information. By measuring the signal parameters of legally operating devices, and using these parameters as a comparison parameter, the detection time of random signals is reduced. Because the parameters of known signals are excluded from the additional analysis.

In order to confirm the proposed method, modeling of the first and second methods. The received graphic materials. Graphic materials fully confirm the reliability of the proposed method.

Key words: comparison, method, signal detection, deviation, amplitude, phase.

1. INTRODUCTION

A typical problem today is the issue of information security. It so happened that information has become the most valuable resource in the modern world. Under its influence, our lives change every minute. Every day important problems are solved, new solutions and ideas are found. The struggle for information resources has become very fierce. Information often becomes a factor in large-scale conflicts, tragedies, and political manipulation. Therefore, there is a growing need to ensure the confidentiality, integrity and reliability of the data processed for the sake of a peaceful and stable quiet life. The cost of information is often hundreds or thousands of times higher than the cost of the computer system in which it is stored.

Therefore, the issue of information security is more relevant today than ever before. The leakage of information from the technical channel means the uncontrolled spread of information from the information carrier, which is protected through the physical environment to the technical means that intercepts the information. Technical means that receive and transmit information are means of covert receipt of information. Guaranteed detection and reliable recognition of the signals of these tools is a very important task. The problem is that it is difficult to distinguish a legal device operating for its intended purpose from a device for secretly obtaining information, which makes the development of methods for detecting means of obtaining secret information very relevant.

1.1 Literature analysis and problem statement

A significant number of publications are devoted to the issues of information protection, search and localization of radio bugs. Thus, in [1] the issues of searching for radio bugs with the help of search engines and auxiliary devices are considered. However, for the detection of radio bugs signals, mainly only the principles laid down in the software package are used and the issue of signal allocation for further recognition and identification is not considered.

In [2,3] describes the methods of searching for radio bugs using search equipment (manual methods) and search systems (semi-automatic methods). Using a device for measuring the distance to the radio bookmark, but these methods also do not reflect the radio bookmark signal itself based more on the practical experience of the specialist and the acoustic features of the equipment.

However, in [4,11] mathematical modeling is considered as a mathematical model of specific parameters (some parameters are probabilistic). Questions of interrelation of input parameters at modeling of processes, depth of their interrelation of model are not considered. These interrelationship and interaction factors can significantly distort the simulation results and call into question the adequacy of the model and the results obtained.

In [5,6] methods of detection of signals of means of secret reception of information and their generalization are resulted. Entry to the database with sequential spectral and other methods of analysis. However, the issue of signal analysis in order to separate real and complex radio signals is not raised. As a result, significant mathematical and technical resources are used. Which increases the search time for dangerous signals.

In [7,12] the methods of spectral analysis based on the use of any model to describe the signal are considered, when using them an assumption is made about the behavior of the signal outside the observation interval. The task of spectral analysis or evaluation in this case is to find the parameters of the model used, which is selected on the basis of available a priori information about the process under study. This is a method of spectral analysis that uses part of the classical Proni method. It is proposed to determine not only static parameters, but also the rate of change of these parameters. The rate of change of parameters allows you to more accurately determine the signal of the means of receiving information. But such a method is very complex and time-consuming, which may not make it possible to identify in a timely manner the means of covert information that work in pulse mode.

In [8,9] the calculation of the main parameters of random signals by the method based on the mathematical model of differential transformations within the framework of correlation theory is investigated. But there are no clearly defined parameters for determining the signals of covert means of obtaining information.

In [10,13] analyzes the complexity of modern radio monitoring in the interests of ensuring the detection of radio signals of covert information. The problem is that modern embedded devices with the transmission of information over the radio channel increasingly use the same standards for the transmission of information as legally located in the premises of the device. Therefore, the old methods of radio monitoring are not able to identify embedded devices operating under the guise of legally operating devices. New devices and techniques need to be developed to search for covert means of obtaining information operating in the frequency bands permitted by the State.

The above factors allow us to conclude that at the present stage of development of society, the process of finding dangerous signals goes qualitatively to another level. The problem of distinguishing a legal device working for its intended purpose from the device used for covert retrieval of information is difficult, this allows to make the development of methods for detecting means of covert retrieval of information very relevant.

1.2 Aim of the article

In the process of information protection, the task of identifying critical threats to information leakage arises. The means of secret obtaining information is one of the most critical threats to information leakage. Reliable detection of covert means of obtaining information is a very difficult task. Therefore, the issue of developing new methods and techniques for detecting means of covert information is very relevant.

The purpose of this study is to develop a new method of detecting signals of means of covert information.

2. THE MAIN SECTION

When searching for means of secretly obtaining information, a method of estimating the parameters of a random signal is proposed, when changes in the parameters of radio monitoring signals can be neglected. More precisely, it is possible to neglect constant or legal signals operating in this frequency range[13-15,19]. These signals should be ignored in the first approximation. Therefore, the task is to estimate the fluctuating parameter applied to the reception of a fully known signal against the background of white noise. The task of detecting a fluctuating signal against the background of signals legally operating in a given frequency range.

Let the input of the receiving device at time $0 \le t \le T$ receives the additive mixture:

$$x(t) = A_0 S_0(t\ , l_0(t)) + b(t)\ , \qquad (1)$$

where $S(t\ , l_0(t)) = A_0 S_0(t\ , l_0(t))$ - useful signal

$b(t)$ - white noise signal.

With optimal signal reception, the receiving device must build the logarithm of the plausibility function of the fluctuating parameter. The exact solution of the problem of constructing the plausibility function of a fluctuating parameter, in general, is quite difficult and requires a lotof a priori data[16,17,20]. From a fundamental point of view, a posteriori probability density can be found in two cases:

1) Parameter $l_0(t)$ is a Markov process;
2) Parameter $l_0(t)$ is a normal random process.

To obtain an approximate expression of the posteriori probability density with optimal signal reception against a background of white noise, it is possible to take into account that over time, equal to the correlation of the fluctuation parameter $l_0(t)$, the value of the estimated parameter remains unchanged.

In real conditions, the final integration time is determined by the time constant of the device for comparing the fluctuation signals with the constant legal signals of a given frequency range and the time constant of the smoothing filters located after the discriminators. Then we get:

$$V_s(l,T)=\int_0^T W(T-t)x(t)s(l,t)dt\ , \quad (2)$$

where $W(T-t)$ is a weighting factor of the characteristics of the device for comparing fluctuation signals with constant legal signals of a given frequency range and time constant of smoothing filters.

The presence of a weighting factor in expression (2) can be interpreted as follows. As the estimate is formed at a given point in time due to fluctuations in the estimating parameter, the information about its value, which was known in the expression preceding time $T=t$, gradually loses its weight.

In expression (2) it is assumed that the more interesting value of the parameter is measured in $T=t$. However, in some cases it is advisable to determine the estimate at the second time, for example in $T\ge t_1$. This position is typical for non-rectangular signals, when by time $T=t$, the signal value drops to a minimum or to 0.

$$W(T-t)=e^{-\beta(T-t)},\quad 0\le t\le T\ , \quad (3)$$

or

$$W(T-t)=e^{-[\beta(T-t)]^2},\quad 0\le t\le T\ , \quad (4)$$

where parameter β is calculated inversely proportional to the correlation time of the fluctuation of the estimating parameter.

If the requirement is met: the observation time is much longer than the correlation time of the fluctuations of the estimating parameter, then the lower limit of integration can be extended from 0 to $-\infty$. Then expression (2) will take the form:

$$V_s(l,T)=\int_{\infty}^T W(T-t)x(t)s(l,t)dt \quad (5)$$

If the weight parameter depends on the modulus of the time difference $|t_1-t_2|$, and t_1 and $T-t_1$ is much longer than the correlation time of the fluctuations of theestimating parameter, then expression (2) will take the form:

$$V_s(l,T)=\int_{\infty}^T W(|t-t_1|)x(t)s(l,t)dt \quad (6)$$

To calculate the static characteristics of the estimate - variance, we present the output signal in the form, signal and noise:

$$V_s(l,T)=S(l,T)+N(l,T)\ , \quad (7)$$

where

$$S(l,T)=\int_0^T W(T-t)s(l_0,t)s(l,t)dt \quad (8)$$

$$N(l,T)=\int_0^T W(T-t)n(t)s(l,t)dt \quad (9)$$

To find the characteristics of the evaluation of the maximum output signal of the device, taking into account that the integration of the weight function $W(T-t)$ does not change the integrity of the signal function of expression (8) at point $l=l_0$, it is possible to use expressions for random evaluation of the parameter and variance:

Expression for random parameter estimation:

$$\Delta l=\left[\frac{\frac{d}{dt}N(t)}{\frac{d^2S(l)}{d^2l}}\right]_{l=l_0}\ , \quad (10)$$

Expression for estimation variance:

$$D(l)=<\Delta l^2>=\left[\frac{\frac{d^2}{dl_1dl_2}<N(t_1)N(t_2)}{\left|\frac{d^2S(l)}{d^2l}\right|^2}\right]_{l_0} \quad (11)$$

The variance of the estimate of the fluctuating parameter of the signal is determined by the expression:

$$D(l)=\left[\frac{N_0}{2}\times\frac{\int_0^T W^2(T-t)\frac{d^2}{dl_1dl_2}S(t,l_1)S(t,l_2)dt}{\left|\int_0^T W(T-t)S(t,l_1)\frac{d^2S(t,l)}{d^2l}dt\right|^2}\right]_{l_0=l_1=l_2=l} \quad (12)$$

For the parameters encoded in the phase of the radio signal, up to the fast-oscillating terms, the equality is true:

$$\left[\frac{d^2}{dl_1dl_2}S(t,l_1)S(t,l_2)dt\right]_{l_0}=\left[\frac{d^2}{d^2l}S(t,l_1)S(t,l_2)\frac{dl}{dl_1}\frac{dl}{dl_2}\right]_{l_0}= \quad .(13)$$
$$=-S(t,l_0)\frac{d^2}{d^2l}S(t,l_0)$$

Then expression (12) can be represented as:

$$D(l)=-\frac{N_0}{2}\times\frac{\int_0^T W^2(T-t)S(t,l_0)\frac{d^2}{d^2l}S(t,l\ )dt}{\left[\int_0^T W(T-t)S(t,l_0)\frac{d^2S(t,l)}{d^2l}dt\right]_{l_0}}\ . \quad (14)$$

Expression (14) is an expression for detection - any random deviation from the parameters of signals that legally operate in a given frequency range. That is, it is an expression, the implementation of which in the automated software complex for searching for covert means of obtaining information will detect signals of means of covert retrieval of information.

The block diagram of the meter of deviation of a random signal is shown in Figure 1.

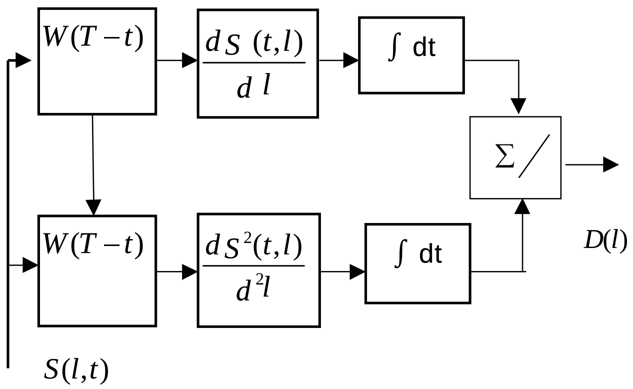

Figure. 1: Block diagram of the meter of deviation of a random signal from «signals of devices legally operating in this radio range».

We will perform mathematical modeling of the process of detecting random signals. To do this, take a signal that will mimic a random signal, define the signals «signals of devices legally operating in this radio range». Let's make a comparison with these signals and determine the value of the deviation from the «signals of devices legally operating in this radio range». The obtained graphic materials are shown in Figure 2.

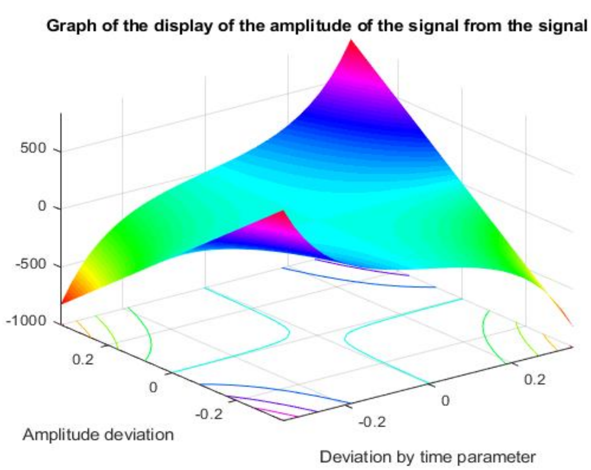

Figure 2: The schedule of definition of a random signal, by a method of comparisonwith known «signals of thedevices legally working in this radio range».

The graphical results obtained as a result of mathematical modeling prove the possibility of detecting the deviation of the amplitude of the random signal, which simulates the signal of the means of unauthorized receipt of information, from «signals of devices legally operating in this radio range». That is, it is possible to detect signals of the means of covert receipt of information by the proposed method.

In order to more accurately detect the signals of the means of covert receipt of information and to exclude erroneous decision-making on the detected signal, it is necessary to analyze a larger number of signal parameters. Therefore, further improvement of the method is proposed through additional analysis of such a parameter as the signal phase.

To determine the deviations of the phase characteristics. We will consider the signal in the form:

$$S(t,\varphi_0) = A_0 U_0(t)\cos[\omega_0 t + \psi_0(t) - \varphi_0], \quad 0 < t < T, \quad (15)$$

where

$U_0(t)$ - law of amplitude modulation

$\psi_0(t)$ - law of phase modulation

A_0 - signal amplitude

φ_0 - the initial phase of the signal.

The useful signal at the output of the receiver when receiving against the background of «signals of devices legally operating in this radio range», has the form:

$$S(\varphi - \varphi_0) \approx \cos(\varphi - \varphi_0)\frac{A_0^2}{2}\int_0^T U_0(t)F(t)dt = \\ = Q_0\cos(\varphi - \varphi_0) \quad (16)$$

Then the variance of the phase estimate taking into account the second approximation will look like:

$$D(\varphi) = \frac{1}{Q_0}\left(1 + \frac{1}{Q_0}\right), \quad (17)$$

Where Q_0 is the signal / «signal ratio of devices legally operating in this radio range». Double the ratio of the signal energy to the power of the «signals of devices legally operating in this radio range» per unit of effective frequency band of its energy spectrum, taking into account the frequency characteristics of the signal and «signals of devices legally operating in this radio range».

If for example we take a weighted signal in the form of white noise with a spectral density of N_0, then:

$$Q_0 = \frac{E_0}{N_0} = \frac{A_0^2}{N_0}\int_0^T U_0^2(t)dt. \quad (18)$$

From this example we can see that the signal function, and then the variance of thephase estimate does not depend on the type of amplitude and phase modulation of the received signal.Normalized signal function:

$$G_{N0}(\varphi - \varphi_0) = \frac{1}{Q_0}S(\varphi - \varphi_0), \quad (19)$$

Varies according to the harmonic law with period 2π, i.e. in the choice of phase estimation there is an ambiguity of definition, a multiple of 2π radians.

Consider the solution of the plausibility equation in order to obtain an estimate of the signal phase:

$$\left(\frac{dV_s(\varphi)}{d\varphi}\right)_{\varphi_m} = A_0\int_0^T x(t)F(t)\sin[\omega_0 t + \psi_0(t) - \varphi_m]dt = 0$$

(20)

Solving equation (20) with respect to the estimate φ_m we obtain:

$$\varphi_m = arctg \frac{\int_0^T x(t)F(t)\sin[\omega_0 t + \psi_0(t) - \varphi_m]dt}{\int_0^T x(t)F(t)\cos[\omega_0 t + \psi_0(t) - \varphi_m]dt} \qquad (21)$$

The block diagram of the phase deviation meter of the random signal, according to the obtained expression (21) is shown in Figure 3.

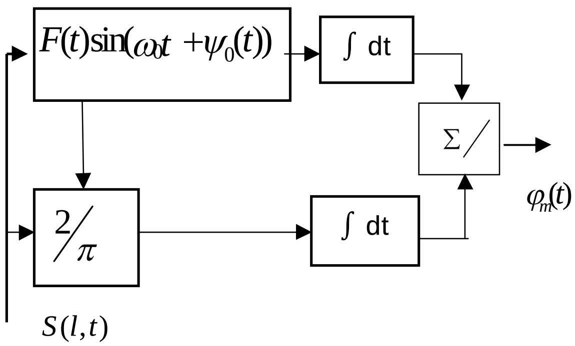

Figure 3: Block diagram of the meter of deviation of the phase of the random signal from the phases of «signals of devices legally operating in this radio range».

We will perform mathematical modeling of the process of detecting random signals by the method of determining the phase deviation of the signals. To do this, take a signal that will simulate a random signal, define the signals «signals of devices legally operating in this radio range». Let's compare the phases with the phases of the known signals and determine the value of the deviation of the phases from the «phases of the signals of devices legally operating in this radio range». The obtained graphic materials are shown in Pic. 4.

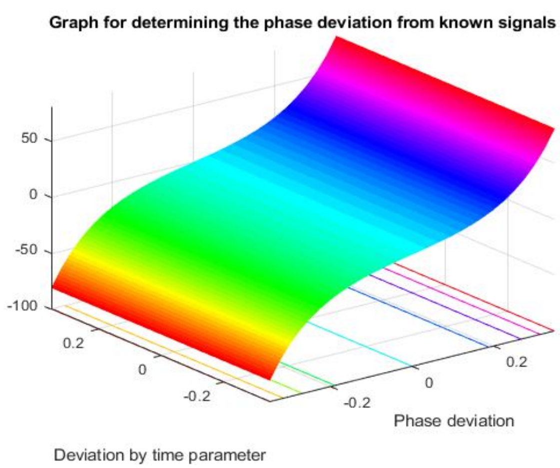

Figure 4: Graph for determining the deviation of the phases from the phases of the known signal.

The graphical results obtained as a result of mathematical modeling prove the reliability of the proposed method. The proposed method detects the deviation of the phase of the random signal, which simulates the signal of the means of unauthorized receipt of information, from the «signal phases of devices legally operating in this radio range». That is, in addition to the method of obtaining the deviation of the amplitude is the ability to detect signals of the means of covert receipt of information, the method of comparing the phases of the signals. The analysis is already performed on two parameters: the amplitude and phase of the signals, which significantly increases the probability of detecting dangerous signals.

The obtained simulation results fully confirm the proposed method of detecting random signals, signals of secret means of obtaining information. The graphical results confirm the advantages of the developed method over the classicalmethods of signal detection of means of covert obtaining of information.

3. CONCLUSIONS

A method for detecting signals of covert means of obtaining information, which consists of methods for detecting the deviation of the amplitude and a method for detecting the deviation of the phase of random signals from the «amplitude and phase signals of devices legally operating in this radio range».

This method allows to detect signals of covert means of receiving information with a probability 35% higher than the methods of classical detection of signals of covert means of obtaining information, which detect random signals by analyzing all signals exceeding a given scan threshold of a given radio range.

The proposed method allows to significantly reduce the time of analysis of signals of a given radio range and detection of dangerous signals. The reduction time can be from 30% to 50% depending on the load of a certain scanning radio range.

In general, the proposed method will detect signals of covert means of obtaining information twice as fast and 35% more likely than the method of detection by classical methods.

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