The Method of Detecting Radio Signals Using the Approximation of Spectral Function

Oleksandr Laptiev [1], Valentyn Sobchuk [1], Igor Subach [2], Andrii Barabash [2] and Ivanna Salanda [3]

[1] Taras Shevchenko National University of Kyiv, Volodymyrska St., 60, Kyiv, 03056, Ukraine
[2] National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Victory Avenue, 37, Kyiv, 01033, Ukraine
[3] Ternopil Regional Council Taras Shevchenko Regional Humanitarian-Pedagogical Academy of Kremenets, prov. Lyceiny, 1, Kremenets, Ternopil region, 47003, Ukraine

Abstract

The article has developed a new method of detecting radio signals of unspoken information that is used to transmit intercepted information via radio channels. The novelty of the method is the synergy of two different methods. The first method of differential transformations and the second is the method of optimizing the spectral function, which is based on the use of functions of transmission of resonance units of the second order. The first method is the method of differential transformations, used directly to solve nonlinear equations of radio signal models, its advantage, is the fact that this method allows the resolution of the equation without preliminary linearization. This method is used to determine the range of radio signals. That is, using the differential transformation method, we get a signal spectrum. The second pronounced method is used to obtain radio signal parameters on which an unknown radio signal is detected. It is for the detection of signs of solid information. The main advantage of the general method developed is the significant decrease in the quantity of computing. This reduces the time of analysis of the parameters of radio signals and allows to detection short -term, impulse signals that can be radio signals of unspoken information. Mathematical modeling was performed in order to test the developed methodology. The exponential function signal was selected as a simulator signal. The results of the modeling are obtained in the form of adequate graphic materials and the efficiency of the developed method to identify radio signals as the means of silent information.

Keywords

Approximation, integral transformations, spectrum, signal modeling, formant, linearization, resonant links

1. Introduction

The study of information technologies leads not only to positive but also to negative consequences. The role of the information component in the life of society and the state is growing sharply. Ensuring the safety of society and the state as a whole depends on the information component. In this connection, the importance and value of information increase. As the value of information grows, so does the importance of protecting it. In addition, now information has a large economic component. Violation of confidentiality or integrity of information will lead to material losses. One of the directions for obtaining confidential information is the use of means of secretly obtaining information. The rapid development of technologies and element bases made it possible to take a big step in the development of devices and means of secretly obtaining information. For example, this refers to the actively used in the modern period means of secretly obtaining information with the accumulation of intercepted information, its compression, and subsequent extremely short transmission in time. The study of the elemental base for household devices simultaneously leads to the use of the same elemental base for the means of tacitly obtaining information. That is, the next danger is that the means of secretly obtaining information work in the general radio range and are disguised under known radio transmission standards.

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EMAIL: oalaptiev@knu.ua (O. Laptiev), v.v.sobchuk@gmail.com (V. Sobchuk) , igor_subach (I.Subach), andrew.barbsh@gmail.com (A. Barabash), salanda.ivanna@gmail.com (I. Salanda)
ORCID: 0000-0002-4194-402X (O. Laptiev); 0000-0002-4002-8206 (V. Sobchuk).0000-0002-9344-713X (I. Subach); 0000-0001-8433-2827 (A. Barabash); 0000-0002-5697-8564 (I Salanda)

Under channels of DECT, Bluetooth, Wi-Fi, GSM, etc. standards. The existing hardware and software and other complexes of detection and localization of these means do not always keep up with the intelligence of the means of covertly obtaining information. Therefore, there is a contradiction between the existing scientific and methodological support of hardware and software complexes for the detection and localization of means of covertly obtaining information and new principles and methods of the possibility of obtaining confidential information by means of covertly obtaining information. To solve this urgent scientific problem, a method of detecting signals of the means of covert information acquisition has been developed, based on the synergy of two methods of differential transformation of a function and approximation of a spectral function based on the transfer functions of second order resonant links.

2. Literature review and problem statement

Currently, most of the known scientific and methodological approaches and methods of modeling the process of detecting random radio signals differ in input parameters. That is, which parameters in the simulation are used as input information, and which parameters of the radio signals of the system are calculated. Derived for the purpose of further analysis. Most often, models are built that are based on and use probability theory, graph theory, and fuzzy sets [1]. An attempt to develop a mathematical apparatus for differential transformations of mathematical functions and its application to the class of random or stochastic functions and processes was made in [2]. The mathematical apparatus of differential transformations were applied to the vector random function, which underwent the differentiation procedure the required number of times. This event significantly limited the possibilities of differential transformations within the local area of the intersection of the random process for each fixed moment of time. Therefore, this application of differential transformations provided only an approximate method of modeling random radio signals.

In [3], the mathematical modeling process is considered the process of mathematical modeling of specific parameters, but some parameters are probabilistic. Therefore, there is an error, an error that is embedded already at the initial stage. This work does not consider the issue of correlation of input parameters when modeling processes and the depth of their relationship in the model. But these factors of correlation and interaction can significantly distort the modeling results and call into question the adequacy of the model and the obtained results. That is, the process of modeling according to such principles is not final.

In [4, 5] there are generalized methods of detecting signals of means of tacit information. According to the principle of operation of these methods, all identified signals are entered into the database. Then the signals undergo a sequential spectral or another method of analysis. However, the issue of analyzing the parameters of complex radio signals. As a result, significant mathematical and technical resources are used. This leads to an increase in the time of analysis and searches for dangerous radio signals, which can lead to omission and, as a consequence, the inability to determine short-term pulse signals, which can be signals of covert means of obtaining information. In [6], a general approach is proposed, which does not allow for accurate modeling of random processes. This approach has a very large number of limitations. But for private cases, this possibility of more precise determination of modeling parameters exists. It exists because differential transformations belong to exact operational methods, but this possibility is not considered in this material.

The approach to the detection of radio signals proposed in [7] significantly complicates the analysis of modern radio monitoring in the interest of ensuring the detection of radio signals by means of clandestine information acquisition. The problem is that today's covertly installed or embedded devices that transmit information over a radio channel increasingly use the same information transmission standards as the signals of devices that must work in the same radio range and are located in rooms where the means of stealth detection and blocking are carried out obtaining information. Thus, previous radio monitoring methods are unable to detect and identify embedded devices that are masquerading as signals from devices that are legally operating in a given frequency range. Therefore, it is necessary to develop new devices and methods of finding secret means of obtaining information that works in the permitted frequency ranges.

The above factors allow us to conclude that at the current stage of the development of society, the process of searching for dangerous signals is moving to a qualitatively different level. The problem is that it is very difficult to distinguish between a legitimate device that works as intended and a classified information device.

The analysis carried out in this way proved that there is a contradiction between the existing scientific and methodological support of hardware and software complexes for detecting and localizing the means of covertly obtaining information and new principles and methods of the possibility of obtaining confidential information by means of covertly obtaining information. Therefore, the issue of solving this scientific and applied task is very urgent.

3. Formulation of the problem

The conducted analysis proved that there is a contradiction between the existing scientific and methodological support of the hardware and software complexes of detection and localization of means of clandestine information acquisition and new principles and methods of the possibility of obtaining confidential information by means of clandestine information acquisition. Therefore, the issue of solving this scientific and applied task is very urgent.

4. The main section

To detect the signals of covert means of obtaining information, it is proposed to use in the first stage, in order to obtain a spectrum of signals (spectral function), the method of differential transformations. But in the second stage, in order to obtain the component signals, use the method of approximation of the spectral function in the basis of the transfer functions of the resonant units of the second order.

In order to determine the spectral function, random signals, which are possible and are signals of covert means of obtaining information. We will use the method of differential transformations at the first stage [8]. Therefore, the main advantage of this method is that it can be used directly to solve nonlinear equations without prior linearization. Allows you to get results in analytical form and reduces the amount of computational work. In General, the differential transformations have the form:

$$X(k) = \underset{\sim}{x}(k) = \frac{H^k}{k!}\left[\frac{d^k(x(t))}{dt^k}\right]_{t=0} \cdot x(t) = \sum_{k=0}^{k=\infty}\left(\frac{t}{H}\right)^k X(k), \tag{1}$$

where:

$x(t)$ is the original, which is continuous, differentiated an infinite number of times, and limited together with all its derivatives, the function of the real argument t;

$X(k)$ and $\underset{\sim}{x}(k)$ are equivalent notation of the differential image of the original, which represents a discrete function of the integer argument $k = 0,1,2$ ...;

H – scale, which has the dimension of the argument t, is often chosen equal to the segment $0 \leq t \leq H$, on which the function $x(t)$ is considered;

● is the correspondence symbol between the original $x(t)$ and its differential image $X(k) = \underset{\sim}{x}(k)$.

In transformations (1) to the left of the symbol ● there is a direct transformation, which allows the original $x(t)$ to find the image $X(k)$, and to the right the inverse transformation, which allows the image $X(k)$ to obtain a signal $x(t)$ in the form of a power series which is nothing but a Taylor series with center at point $t = 0$. The value H must be less than the convergence radius of the series ρ, which can be determined on the basis of the convergence sign d'Alembert:

$$\rho = \lim_{k\to\infty}\left|\frac{X(k)}{H^k} : \frac{X(k+1)}{H^{k+1}}\right| = H \lim_{k\to\infty}\left|\frac{X(k)}{X(k+1)}\right|. \tag{2}$$

Transformation (2) is called differential Taylor transformations, or more simply T–transformations. Differential images $X(k)$ are called differential T–spectrums, and the values of T–functions $X(k)$ at specific values of the argument k are called discrete [9–11]. To detect signals of covert means of obtaining information, it is proposed to determine the range of signals, i.e. $X(k)$. The signals of the means of covert retrieval of information can be approximated by exponential or harmonic series [12]. Then, for further presentation of the method, we define the differential spectrum of exponential and harmonic functions. For an exponential function of the form $x(t) = e\omega t = exp\,(\omega t)$, where ω is the signal frequency, using expression (1), we obtain:

$$\frac{H^k}{k!}\left[\frac{d^k e^{\omega t}}{dt^k}\right]_{t=0} = \frac{(\omega H)^k}{k!}. \tag{3}$$

For harmonic functions such as $x(t) = \sin(\omega t)$ and $x(t) = \cos(\omega t)$, where ω is a constant, using expression (1), we obtain:

$$\frac{H^k}{k!}\left[\frac{d^k \sin(\omega t)}{dt^k}\right]_{t=0} = \frac{(\omega H)^k}{k!}\sin\frac{\pi k}{2}. \tag{4}$$

$$\frac{H^k}{k!}\left[\frac{d^k \cos(\omega t)}{dt^k}\right]_{t=0} = \frac{(\omega H)^k}{k!}\cos\frac{\pi k}{2}. \tag{5}$$

Expressions (3–5) are expressions of T–differential spectra, respectively for exponential and harmonic functions. This completes the first stage. The first stage allowed us to obtain a differential spectrum of random signals that are approximated by exponential or sinusoidal components. The second stage is to approximate the spectral function in the basis of the transfer functions of the resonant units of the second order [13–15, 20]. The spectral slice of a random signal is defined at the first stage, we denote it – $S(\omega k, tl)$.

Assume that the random signal model has the form:

$$x(t) = \sum_{k=0}^{\infty} e^{k\omega t}, \tag{6}$$

where $k = [l, \infty]$, l – signal analysis interval.

The differential spectrum for this signal takes the form of expression (3).

Let us construct model $Z(\omega k, tl)$ of the function $S(\omega k, tl)$, in the form of the product n of the modules of the second-order transfer units on the spectrum:

$$Z(\omega_k, t_l) = |S(\omega_k)|^2 \prod_{i=1}^{n} |W_i(\omega)|^2, \tag{7}$$

where $t_i - l$ l-th signal analysis interval.

$$W_i(p) = \frac{c_i\,(\alpha_i\ + p)}{\beta_i^2 + p^2 + 2p\alpha_i + \alpha_i^2}. \tag{8}$$

$$|W_i(\omega)|^2 = \frac{{c_i}^2({\alpha_i}^2 + \omega_i^2)}{(\beta_i^2 + \alpha_i^2 - \omega_k^2)^2 + (2\omega_k\alpha_i)^2}. \tag{9}$$

Then we get:

$$Z(\omega_k, t_l) = |S(\omega_k)|^2 \prod_{i=1}^{n} |W_i(\omega)|^2 = \frac{(\omega_i H)^{2k}}{k!} \prod_{i=1}^{n} \frac{{c_i}^2({\alpha_i}^2 + \omega_i^2)}{\left(\beta_i^2 + \alpha_i^2 - \omega_k^2\right)^2 + (2\omega_k\alpha_i)^2}. \tag{10}$$

or:

$$\ln Z(\omega_k, t_l) = 2k\ln\left(\frac{\omega_i H}{k!}\right) + \sum_{i=1}^{n}\left[2\ln c_i + \ln\left({\alpha_i}^2 + \omega_i^2\right)\right] - \left[\ln\left(\left(\beta_i^2 + \alpha_i^2 - \omega_k^2\right)^2 + (2\omega_k\alpha_i)^2\right)\right]. \tag{11}$$

Coefficients H, a_i, B_i, c_i we will look by the method of least squares. The error estimate will then look like:

$$\sigma_i^2 = \sum_{k=1}^{N}[\ln S(\omega_k, t_l) - \ln Z(\omega_k, t_l)]^2, \tag{12}$$

$$\frac{\partial\sigma_i^2}{\partial H} = \sum_{k=1}^{N} 2\left(\ln S(\omega_k, t_i) - 2k\ln\left(\frac{\omega_i H}{k!}\right) - \sum_{i=1}^{n}\left[2\ln c_i + \ln\left({\alpha_i}^2 + \omega_i^2\right)\right] - \left[\ln\left(\left(\beta_i^2 - \omega_i^2\right)^2 + (2\omega_k\alpha_i)^2\right)\right]\left(\frac{\omega_i H}{k!}\right)\right), \tag{13}$$

$$\frac{\partial\sigma_i^2}{\partial c_i}=\sum_{k=1}^{N}2\left\{\ln S(\omega_k,t_i)-2k\ln\left(\frac{\omega_i H}{k!}\right)-\sum_{i=1}^{n}[2\ln c_i+\ln({\alpha_i}^2+\omega_i^2)]-\right. \qquad (14)$$

$$\left.-[\ln((\beta_i^2-\omega_i^2)^2+(2\omega_i\alpha_i)^2)]\right\}/c_i\,,$$

$$\frac{\partial\sigma_i^2}{\partial\beta_i}=\sum_{k=1}^{N}\left(\ln S(\omega_k,t_i)-2k\ln\left(\frac{\omega_i H}{k!}\right)\right.$$

$$-\sum_{i=1}^{n}[2\ln c_i+\ln({\alpha_i}^2+\omega_i^2)]-\ln((\beta_i^2-\omega_i^2)^2+(2\omega_k\alpha_i)^2)\left(\frac{2\alpha_i}{\alpha_i^2+\omega_i^2}\right. \qquad (15)$$

$$\left.\left.+\frac{4\beta_i(\beta_i^2-\omega_k^2)^2+8\alpha_i^2\omega_k^2}{(\beta_i^2-\omega_k^2)^2+(2\alpha_i^2\omega_k^2)^2}\right)\right),$$

$$\frac{\partial\sigma_i^2}{\partial\alpha_i}=\sum_{k=1}^{N}\left(\ln S(\omega_k,t_i)-2k\ln\left(\frac{\omega_i H}{k!}\right)\right.$$

$$-\sum_{i=1}^{n}[2\ln c_i+\ln({\alpha_i}^2+\omega_i^2)]-[\ln((\beta_i^2-\omega_k^2)^2+(2\omega_k\alpha_i)^2)]\times$$

$$\left.\times\left[\frac{2\alpha_i}{\alpha_i^2+\omega_i^2}+\frac{8\alpha_i^2\omega_k^2}{(\beta_i^2-\omega_k^2)^2+(2\alpha_i^2\omega_k^2)^2}\right]\right).$$

(16)

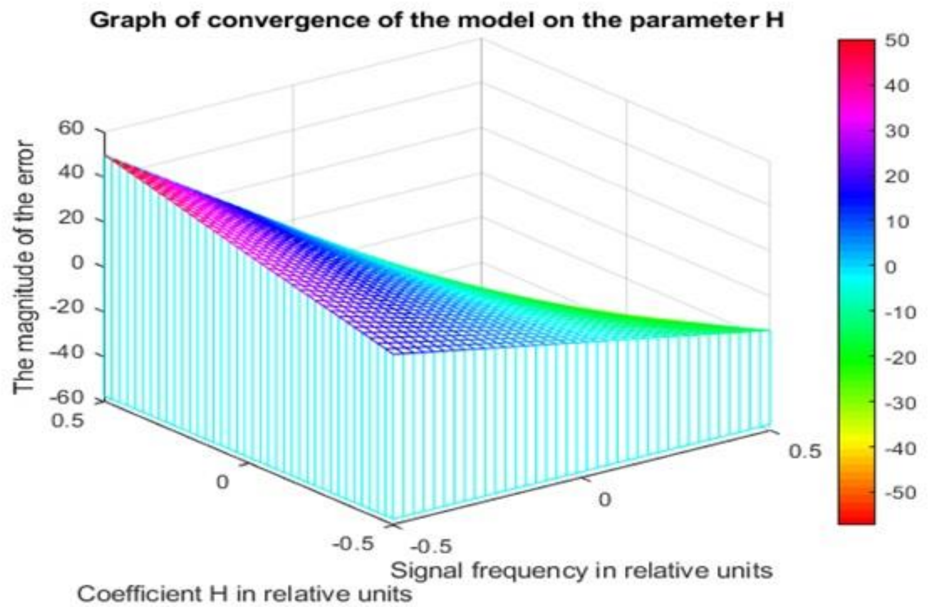

Figure 1: Graph of convergence of the model on the parameter H

The system of algebraic equations (13–16) has $3n+1$ unknowns, which are limited by $n=3$:

$$0<H<1,\qquad 0<\alpha_i<1,\qquad \beta_1,\qquad \beta_2<1200Hz,\qquad \beta_3>1200Hz,$$

these constraints give a reference to the frequencies of the first and second forms of accented sounds and the position of the maximum in the spectrum for noisy sounds. In the works of Professor Hryshchuk R.V. and my previous work [6, 7, 15–19] proved that three components of signal approximation are enough to fully establish a significant signal. Therefore, the next limitation will be the choice, i.e. we are limited to three components. In order to confirm the proposed method, we will perform mathematical modeling using the above restrictions.

Moreover, we will assume that the variables will be the frequency and variable on which we will differentiate. Then equation (13) will take the form:

$$
\begin{aligned}
\frac{\partial\sigma_i^2}{\partial H} = \sum_{k=1}^{N} 2\Bigg(&\ln S(\omega_k,t_i) - 2k\ln\left(\frac{\omega_i H}{k!}\right) - \sum_{i=1}^{n}[2\ln c_i + \ln({\alpha_i}^2+\omega_i^2)] \\
&- [\ln((\beta_i^2-\omega_k^2)^2+(2\omega_k\alpha_i)^2)]\left(\frac{\omega_i H}{k!}\right)\Bigg) \\
&= (\ln S(\omega_k,t_i) - 2\ln c_i - \ln(\alpha_i^2+\omega_i^2) - \ln(\beta_i^2-\omega_i^2)^2 - 4\omega_i^2\alpha_i^2)\omega_i H \\
&+ (\ln S(\omega_k,t_i) - 4\ln c_i - \ln(\alpha_i^2+\omega_i^2) - \ln(\beta_i^2-\omega_i^2)^2 - 4\omega_i^2\alpha_i^2)\frac{(\omega_i H)^2}{2} \\
&+ (\ln S(\omega_k,t_i) - 6\ln c_i - \ln(\alpha_i^2+\omega_i^2) - \ln(\beta_i^2-\omega_i^2)^2 - 4\omega_i^2\alpha_i^2)\frac{(\omega_i H)^3}{6} \\
&= (\ln S(\omega_k,t_i) - 2\ln c_i - \ln(\alpha_i^2+\omega_i^2) - \ln(\beta_i^2-\omega_i^2)^2 - 4\omega_i^2\alpha_i^2) \\
&\times\left(\omega_i H + \frac{(\omega_i H)^2}{2} + \frac{(\omega_i H)^3}{6}\right) - 2\ln c_i\frac{(\omega_i H)^2}{2} - 4\ln c_i\frac{(\omega_i H)^3}{6}
\end{aligned} \tag{17}
$$

Let us construct a graph that will clearly show the accuracy of the approximation when calculating the coefficient H. The graph of the similarity of a number of approximations of the function with its original is shown in Fig. 1. This indicates the adequacy of the proposed model for estimating the parameter of approximation H. Equation (14) will take the form:

$$
\begin{aligned}
\frac{\partial\sigma_i^2}{\partial c_i} = \sum_{k=1}^{N} 2\Bigg(&\ln S(\omega_k,t_i) - 2k\ln\left(\frac{\omega_i H}{k!}\right) - \sum_{i=1}^{n}[2\ln c_i + \ln({\alpha_i}^2+\omega_i^2)] - \\
&[\ln((\beta_i^2-\omega_k^2)^2+(2\omega_k\alpha_i)^2)]\left(\frac{1}{c_i}\right)\Bigg) = (\ln S(\omega_k,t_i) - 2\ln c_i - \ln(\alpha_i^2+\omega_i^2) - \ln(\beta_i^2-\omega_i^2)^2 - \\
&4\omega_i^2\alpha_i^2)\frac{1}{c_i} + (\ln S(\omega_k,t_i) - 4\ln c_i - \ln(\alpha_i^2+\omega_i^2) - \ln(\beta_i^2-\omega_i^2)^2 - 4\omega_i^2\alpha_i^2)\frac{1}{c_i} + \\
&(\ln S(\omega_k,t_i) - 6\ln c_i - \ln(\alpha_i^2+\omega_i^2) - \ln(\beta_i^2-\omega_i^2)^2 - 4\omega_i^2\alpha_i^2)\frac{1}{c_i} = (\ln S(\omega_k,t_i) - 2\ln c_i - \\
&\ln(\alpha_i^2+\omega_i^2) - \ln(\beta_i^2-\omega_i^2)^2 - 4\omega_i^2\alpha_i^2)\left(\frac{1}{c_i}\right) - \frac{6\ln c_i}{c_i}.
\end{aligned} \tag{18}
$$

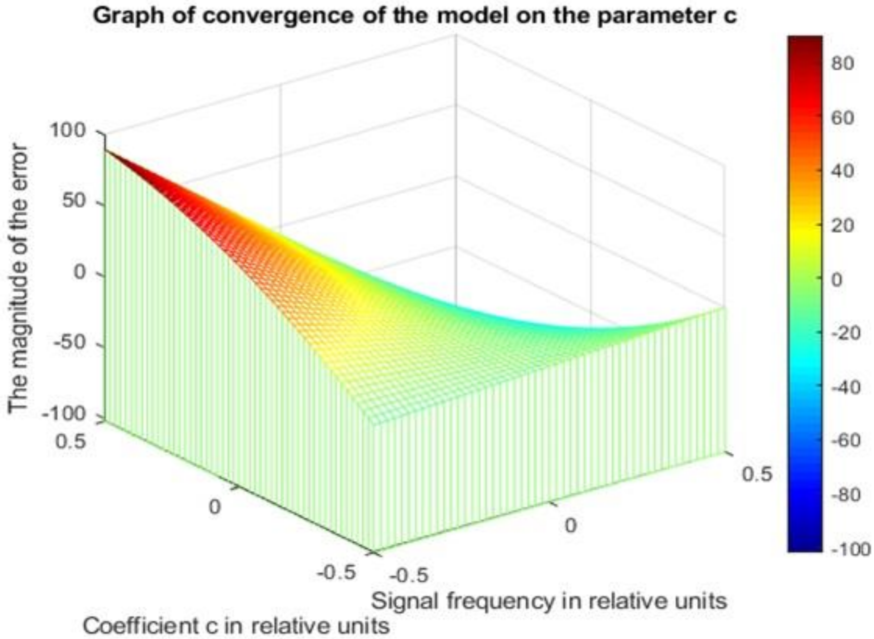

Figure 2: Graph of convergence of the model on the parameter C

Let us construct a graph, that will clearly show the accuracy of the approximation when calculating the coefficient C. Graph of the similarity of the series of approximation of the function with its original. As you can see from graph Fig. 2, for the given parameters of the first accented forms, the error does not exceed 9,5 %. This indicates the adequacy of the proposed model for estimating the parameter of approximation C. Equation (15) will take the form:

$$\begin{aligned}\frac{\partial\sigma_i^2}{\partial\beta_i} &= \sum_{k=1}^{N} 2\Bigg(\ln S(\omega_k,t_i) - 2k\ln\left(\frac{\omega_i H}{k!}\right) - \sum_{i=1}^{n}[2\ln c_i + \ln(\alpha_i{}^2+\omega_i^2)] \\ &\quad - \left[\ln\left(\left(\beta_i^2-\omega_k^2\right)^2 + (2\omega_k\alpha_i)^2\right)\right]\left[\frac{2\alpha_i^2}{\alpha_i^2+\omega_i^2} + \frac{4\beta_i(\beta_i^2-\omega_i^2) + 8\omega_i^2\alpha_i^2}{\left(\beta_i^2-\omega_i^2\right)^2 + 4\omega_i^2\alpha_i^2}\right]\Bigg) \\ &= \ln S(\omega_k,t_i) - 2k\ln\left(\frac{\omega_i H}{k!}\right) - \sum_{i=1}^{n}[2\ln\ c_i + \ln(\alpha_i{}^2+\omega_i^2)] \\ &\quad - \left[\ln\left(\left(\beta_i^2-\omega_k^2\right)^2 + (2\omega_k\alpha_i)^2\right)\right] \\ &\quad \times\left[\frac{2\alpha_i^2\left(\beta_i^2-\omega_i^2\right)^2 + 8\omega_i^2\alpha_i^4 + (\alpha_i^2+\omega_i^2) + 2[4\beta_i(\beta_i^2-\omega_i^2) + 8\omega_i^2\alpha_i^2]}{(\alpha_i^2+\omega_i^2)\ [\left(\beta_i^2-\omega_i^2\right)^2 + 4\omega_i^2\alpha_i^2]}\right] \\ &= \ln S(\omega_k,t_i) - 2\ln(\omega_i H) - 4\ln\left(\frac{\omega_i H}{2}\right) - 6\ln 6 \\ &\quad - 3\sum_{i=1}^{n}[2\ln c_i + \ln(\alpha_i{}^2+\omega_i^2)] - \left[\ln\left(\left(\beta_i^2-\omega_k^2\right)^2 + (2\omega_k\alpha_i)^2\right)\right] \\ &\quad \times\frac{2\alpha_i^2\left(\beta_i^2-\omega_i^2\right)^2 + 8\omega_i^2\alpha_i^4 + (\alpha_i^2+\omega_i^2)\ + 2[4\beta_i(\beta_i^2-\omega_i^2) + 8\omega_i^2\alpha_i^2]}{(\alpha_i^2+\omega_i^2)[\left(\beta_i^2-\omega_i^2\right)^2 + 4\omega_i^2\alpha_i^2]}.\end{aligned} \tag{19}$$

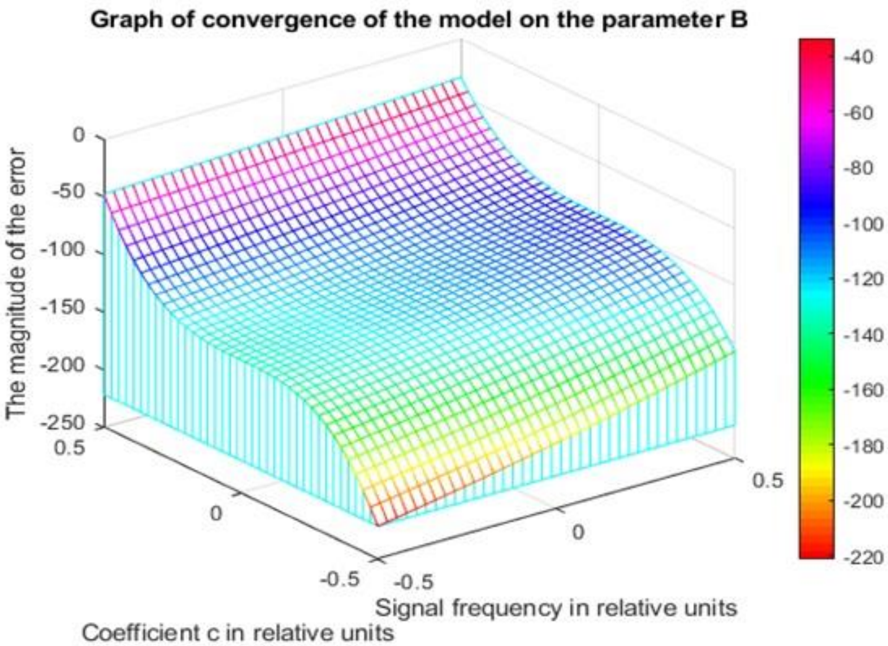

Figure 3: Graph of convergence of the model on the parameter B

Let us construct a graph that will clearly show the accuracy of the approximation when calculating the coefficient B. Graph of the similarity of the series of approximation of the function with its original. As you can see from graph Fig. 3, for the given parameters of the first accented forms, the error does not exceed 14,5 %. This indicates the adequacy of the proposed model for estimating the parameter of approximation B. Equation (16) will take the form:

$$
\begin{aligned}
\frac{\partial\sigma_i^2}{\partial\alpha_i} = \sum_{k=1}^{N} 2\Bigg(&\ln S(\omega_k,t_i) - 2k\ln\left(\frac{\omega_i H}{k!}\right) - \sum_{i=1}^{n}\left[2\ln c_i + \ln\left({\alpha_i}^2+\omega_i^2\right)\right] - \left[\ln\left(\left(\beta_i^2-\omega_k^2\right)^2 + (2\omega_k\alpha_i)^2\right)\right] \\
&\times\left[\frac{2\alpha_i^2}{\alpha_i^2+\omega_i^2} + \frac{8\omega_i^2\alpha_i^2}{\left(\beta_i^2-\omega_i^2\right)^2+4\omega_i^2\alpha_i^2}\right]\Bigg) = \ln S(\omega_k,t_i) - 2\ln(\omega_i H) - 4\ln\left(\frac{\omega_i H}{2}\right) - 6\ln 6 \\
&- 3\sum_{i=1}^{n}\left[2\ln c_i + \ln\left({\alpha_i}^2+\omega_i^2\right)\right] - \left[\ln\left(\left(\beta_i^2-\omega_k^2\right)^2 + (2\omega_k\alpha_i)^2\right)\right] \\
&\times\frac{2\alpha_i^2\left(\beta_i^2-\omega_i^2\right)^2 + 8\omega_i^2\alpha_i^4 + 8\omega_i^2\alpha_i^2(\alpha_i^2+\omega_i^2)}{(\alpha_i^2+\omega_i^2)\left[\left(\beta_i^2-\omega_i^2\right)^2+4\omega_i^2\alpha_i^2\right]}.
\end{aligned}
\tag{20}
$$

We construct a graph that will clearly show the accuracy of the approximation when calculating the coefficient α. The graph of similarity of a number of approximation of function with its original is given in Fig. 4. As you can see from graph Fig. 4, for the given parameters of the first accented forms, the error does not exceed 15,5%. This indicates the adequacy of the proposed model for estimating the parameter of approximation α.

5. Discussion of experimental results

The peculiarity of the method is that the developed method of detecting the signals of the means of covert obtaining of information allows detecting signals with greater efficiency by approximating the spectral function based on the transfer functions of the resonant units of the second order. The novelty of the method is a combination of two methods, the method of differential transformations and the method of approximation of the spectral function based on the transfer functions of resonant units of the second order. The signals of the means of covert information retrieval can be approximated by Taylor differential transformations, or, more simply, by T transformations. In addition, differential images are differential T spectra.

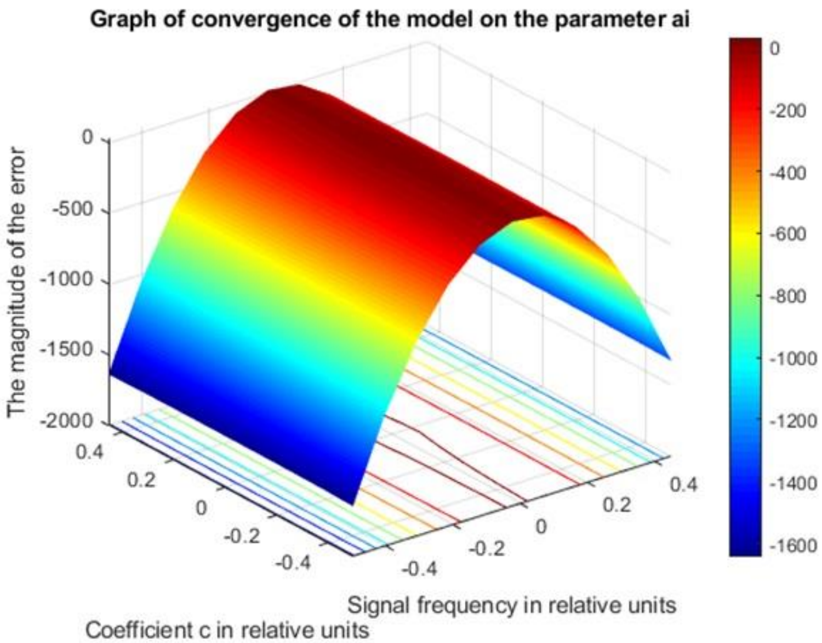

Figure 4: Graph of convergence of the model on the parameter a

An additional feature of the proposed method is that we use to detect the signals of the means of covert information is proposed to use in the first stage to obtain a range of signals, the method of differential transformations. In the second stage to obtain component signals using the method of approximation of the spectral function based on the transfer functions of resonant units of the second order. The main limitation, the use of components of the method is that we use only five components of approximations, determining the function of the signal. We choose five components because the calculations proved the sufficiency of the three components of the approximations, but in order to improve the results, we choose five components.

This allows you to reduce the number of calculations and take advantage of both methods.

The main advantage of the proposed method is that it can be applied directly to solving systems of nonlinear equations without their prior linearization, allows solutions in analytical form, which significantly reduces the amount of computational work, and significantly reduces the time to search for signals.

Method of differential transformations. Unlike the well-known Laplace and Fourier integral transformations, images are found by differentiation rather than integration operations. The advantage of this method is that it can be used directly to solve systems of nonlinear equations without their prior linearization. The method of approximation of the spectral function on the basis of the transfer functions of the second-order resonant units allows for the calculation of the parameters of the signals on the slice of the spectral function. Prior to that, the cut-off time or the time determined to determine the signal parameters is selected to determine the general comparative parameters of the spectrum. The parameters for selecting the cut time are set by the complex. It is set by selecting several parameters to determine the signals, such as exceeding the amplitude, determining the phase deviation, the presence of the second or third harmonic, and so on.To confirm the proposed developed method, the modeling of the method of signal detection of means of latent information retrieval on the basis of approximation of the spectral function in the basis of the transfer functions of resonant units of the second order is carried out. The simulation was performed in order to determine the approximation error by the proposed method. The obtained graphical materials, fully confirming the possibility of determining the signal of the means of concealed information by the proposed method, confirm that the approximation error is in the range of 5.5-14.5%, which is a good result and proves the reliability of the proposed method, proving the advantages of the developed method which exist today. Further ways to improve the method can be done, taking into account the noise of the device and interference from search signals.

6. Conclusions

A newly developed method of detecting modern technical means of clandestine information acquisition, which use a radio channel to transmit intercepted information, is proposed. The method is based on the synergy of two methods: the method of differential transformations and the method of approximation of the spectral function based on the transfer functions of second-order resonant nodes.

It is proved that the radio signals of means of covert information acquisition can be approximated by differential Taylor transformations, or more simply by T-transformations. In addition, it is shown that the differential images are differential T-spectra. The principle of the new method is as follows.

In the first step, the signal spectrum (spectral functions) is determined. The resulting spectral function is approximated using the transfer functions of second-order resonant nodes. This is done in order to detect signal parameters, parameters of all radio signals. We pay special attention to short-term random signals. We are conducting further analysis of the extraction of the components of the essential radio signal in order to determine the signals of means of clandestine information acquisition. The obtained results make it possible to determine the radio signals of means of covert information acquisition, which have deviations from the signals of technical means constantly working in the given radio range.

Mathematical modeling of the proposed approach was carried out according to the developed method. For this, the MATLAB software environment was used. Signals described by an exponential function were used as random signals imitating the signals of means of tacit information acquisition. During simulation, approximation errors were determined, based on the simulation results, the value of the approximation error in relative units did not exceed 10% on average. The simulation results are presented in analytical and graphical form. The obtained results confirm the adequacy of the developed method.

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