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Method of detecting signals of means of covert obtaining of information on the basis of approximation of T-spectrum

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ABSTRACT

The article proposes a new method of detecting signals of technical means that use a radio channel to transmit intercepted information. The novelty of the method is the combination of two methods: the method of differential transformations and the method of approximation of the spectral function in the basis of the transfer functions of resonant units of the second order.

The signals of the means of covert retrieval of information can be approximated by differential Taylor transformations, or more simply by T transformations. Moreover, differential images are differential T-spectra.

To detect signals of secret means of obtaining information, it is proposed to use:

- at the first stage, in order to obtain a spectrum of signals, the method of differential transformations;
- in the second stage, in order to obtain 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 confirm the proposed technique, modeling of the exponential function was performed. Graphical results are obtained, which fully confirm the reliability of the proposed method.

Key words: approximation, method, transformation, resonant links, T-spectrum.

1. INTRODUCTION

Over the past few years, the role of the information and technical sphere in the life of modern society has sharply increased. As the significance and value of information increases, so does the importance of protecting it. Information costs money. That is, leakage or loss of information will cause material damage.

Leakage of information from the technical channel means the uncontrolled spread of information from the protected information carrier through the physical environment to the technical means that intercepts the information.

According to research by foreign firms, 76% of international companies and government agencies have encountered industrial intelligence. With the help of technical means 80-90% of the necessary information is extracted.

Means of receiving and transmitting intercepted information have made a significant step in their development over the past few years. Many automated detection systems of these tools are simply unable to detect them with reasonable probability. With the development of the element base, several areas of creation of radio transmitting devices and transmission algorithms are actively developing. The main ones are the use of complex types of signals for the transmission of intercepted information (broadband, rubber - like, etc.), which make it difficult to detect them by existing automated radio monitoring systems. The latter also applies to actively used radio transmitting devices with the accumulation of intercepted information, its subsequent compression and extremely short transmission time. But the most dangerous other direction is the use of legal communication channels. These are the channels of the DECT, Bluetooth, Wi-Fi, GSM, 4G, 5G and other standards, which the means of secretly receiving information are used to transmit intercepted information.

There is a very important problem: to distinguish a legal device working for its intended purpose from a device used to secretly obtain information. Therefore, the development of methods and techniques for detecting covert means of obtaining information is very important.

1.1 Literature analysis and problem statement

Most of the known approaches and methods of detection of covert means of obtaining information differ in what parameters they use as input information in modeling and what characteristics of the simulated system are calculated and output (build models using probability theory, random processes, Petri nets, theory automata, graph theory, fuzzy sets, catastrophe theory, entropy approach, etc.) [1].

An attempt to develop a mathematical apparatus of differential transformations and its application to a class of random or stochastic functions and processes was made in [1 - 3]. The mathematical apparatus of differential transformations was applied to a vector random function that differentiated the required number of times. This requirement significantly limited the possibilities of differential transformations within the local area of intersection of a random process for each fixed point in time. But this application of differential transformations gave only an approximate method of modeling random processes.

However, in [4] 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 [5-7,14] methods of detection of signals of means of secret reception of the information and their generalization, entering into base with consecutive spectral and other methods of the analysis are resulted. However, the issue of signal analysis in order to separate real and complex radio signals is not touched upon. As a result, significant mathematical and technical resources are used and leads to an increase in the time to search for dangerous signals.

The approach proposed in [6] does not allow to implement accurate modeling of random processes. But this possibility exists because differential transformations are precise operational methods.

In [8-10,16] analyzes the complexity of modern radio monitoring in the interests of ensuring the detection of radio signals of covert means of obtaining 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 devices that are legally in the premises. 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 MCOI operating in the legal frequency bands.

The above factors allow us to conclude that at the present stage of development of technology the process of finding dangerous signals goes qualitatively to another level. The problem is that it is difficult to distinguish a legal device operating for its intended purpose from a device used to secretly obtain information, which makes the development of methods for detecting means of obtaining secret information very relevant.

In [11-13,15], based on research conducted in MATLAB, an optimization model was developed to measure power in circuits. The proposed algorithms can be used to develop the characteristics of various information signals, including signals from the covert means of obtaining information.

From the analysis of the modern literature, it is possible to draw a conclusion that questions of detection of signals which have the features in the course of detection of covert means of obtaining information are practically not considered. Therefore, to date, it is advisable to investigate the detection of signals of covert means of obtaining information, especially indirect methods.

1.2 Aim of the article

The purpose of the article is to consider the radio signals of the means of covert obtaining information as random signals of different power on the basis of approximation of T - spectrum.

Conduct computer simulations in the MATLAB environment according to the proposed and existing methods in order to evaluate the effectiveness of the proposed method.

2. THE MAIN SECTION

To detect signals of secret means of obtaining information, it is proposed to use:

- at the first stage, in order to obtain a spectrum of signals (spectral function), the method of differential transformations;
- in the second stage, in order to obtain 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 of random signals, which may be signals of covert means of obtaining information, we will at the first stage use the method of differential transformations [18]. The main advantage of this method is that it can be used directly to solve nonlinear equations without prior linearization. This allows you to get results in an analytical form, and reduces the amount of computational work. In General, the differential transformations have the form:

$$X(k) = \underline{x}(k) = \frac{H^k}{k!}\left[\frac{d^k(x(t))}{dt^k}\right]_{t=0} \bullet$$
$$\bullet x(t) = \sum_{k=0}^{k=\infty}\left(\frac{t}{H}\right)^k X(k) \qquad (1)$$

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

$X(k)$ and $\underline{x}(k)$ - equivalent notation of the differential image of the original, representing a discrete function of the integer argument $k = 0,1,2,...$;

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

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

In the transformations (1) to the left of the symbol $\bullet$ is a direct transformation, which allows the original $x(t)$ to find the image $X(k)$, and to the right of 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 else Taylor centered 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:

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

Transformations (2) are called differential Taylor transformations, or T-transformations for short.

Differential images $X(k)$ are called differential T-spectra, and the values of T-functions $X(k)$ at specific values of argument k are called discrete [9-11].

To detect the signals of the means of covert receipt of information, it is proposed to determine the spectra of the signals, i.e. $X(k)$.

The signals of the means of secretly obtaining information can be approximated by exponential or harmonic series [19,20]. Then, for further presentation of the method, we define the differential spectrum of exponential and harmonic functions.

For an exponential function of type $x(t) = e^{\omega t} = \exp(\omega t)$, where ω is the frequency of the signal, using expression (1), we obtain:

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

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:

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

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

(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]. The spectral slice of a random signal is determined at the first stage, we denote it - $S(\omega_k, t_l)$.

Assume that the random signal model has the form:

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

where: $k = [l, \infty)$, l - signal analysis interval.

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

Let's construct model $Z(\omega_k, t_l)$ of function $S(\omega_k, t_l)$, in the form of product n of modules of transfer links of the second order on a spectrum:

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

where: t_l – l-th signal analysis interval.

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

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

Then we get:

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

or:

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

Coefficients $H, \alpha_i, \beta_i, c_i$, we will look for the method of least squares. The error estimate will then look like:

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

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

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

$$\frac{\partial \sigma_i^2}{\partial \beta_i} = \sum_{k=1}^{N}\begin{pmatrix} \{\ln S(\omega_k, t_i) - 2k\ln(\frac{\omega_i H}{k!}) - \\ -\sum_{i=1}^{n}[2\ln c_i + \ln(\alpha_i^2 + \omega_i^2)] - \\ -[\ln((\beta_i^2 - \omega_i^2)^2 + (2\omega_k \alpha_i)^2)\} \times \\ \times(\frac{2\alpha_i}{\alpha_i^2 + \omega_i^2} + \frac{4\beta_i(\beta_i^2 - \omega_k^2)^2 + 8\alpha_i^2\omega_k^2}{(\beta_i^2 - \omega_k^2)^2 + (2\alpha_i^2\omega_k^2)^2}] \end{pmatrix} \qquad (15)$$

$$\frac{\partial \sigma_i^2}{\partial \alpha_i} = \sum_{k=1}^{N}\begin{pmatrix} \{\ln S(\omega_k, t_i) - 2k\ln(\frac{\omega_i H}{k!}) - \\ -\sum_{i=1}^{n}[2\ln c_i + \ln(\alpha_i^2 + \omega_i^2)] - \\ -[\ln((\beta_i^2 - \omega_k^2)^2 + (2\omega_k \alpha_i)^2)\} \times \\ \times(\frac{2\alpha_i}{\alpha_i^2 + \omega_i^2} + \frac{8\alpha_i^2\omega_k^2}{(\beta_i^2 - \omega_k^2)^2 + (2\alpha_i^2\omega_k^2)^2}] \end{pmatrix} \qquad (16)$$

The system of algebraic equations (13-16) has $3n+1$ unknowns, which are constrained by $n=3$: $0<H<1,\ 0<\alpha_i<1,\ \beta_1, \beta_2 < 1200\,Гц,\ \beta_3 > 1200\,Гц$. These constraints give reference to the frequencies of the first and second formants of vowel sounds and the position of the maximum in the spectrum for noise sounds. In the works of Professor Grischuk R.V. and my previous work [6,7,15-17] proved that three components of signal approximation are enough to fully establish a significant signal. Therefore, the next limitation will be this 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, according to which we will differentiate. Then equation (13) will take the form:

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

$$\begin{aligned} &= (\ln S(\omega_k, t_i) - 2\ln c_i - \ln(\alpha_i^2 + \omega_i^2) - \\ &- \ln(\beta_i^2 - \omega_i^2)^2 - 4\omega_i^2\alpha_i^2)\omega_i H + +(\ln S(\omega_k, t_i) - \\ &- 4\ln c_i - \ln(\alpha_i^2 + \omega_i^2) - \ln(\beta_i^2 - \omega_i^2)^2 - 4\omega_i^2\alpha_i^2)\frac{(\omega_i H)^2}{2} \\ &+ (\ln S(\omega_k, t_i) - 6\ln c_i - \ln(\alpha_i^2 + \omega_i^2) - - \ln(\beta_i^2 - \omega_i^2)^2 - \\ &- 4\omega_i^2\alpha_i^2)\frac{(\omega_i H)^3}{6} = (\ln S(\omega_k, t_i) - 2\ln c_i - \ln(\alpha_i^2 + \omega_i^2) - \\ &- \ln(\beta_i^2 - \omega_i^2)^2 - 4\omega_i^2\alpha_i^2)(\omega_i H + \frac{(\omega_i H)^2}{2} + \frac{(\omega_i H)^3}{6}) - \\ &- 2\ln c_i \frac{(\omega_i H)^2}{2} - 4\ln c_i \frac{(\omega_i H)^3}{6}. \end{aligned} \qquad (17)$$

Let's build a graph that will clearly show the accuracy of the approximation when calculating the coefficient H.

Graph of convergence of a series of approximations of a function with its original:

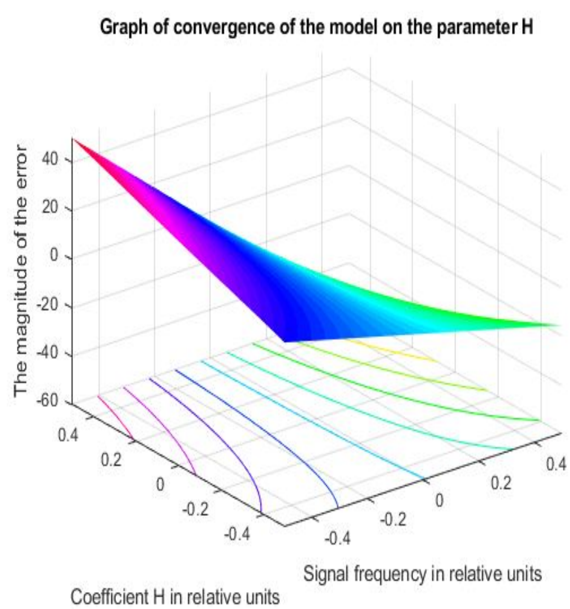

Figure 1: Graph of convergence of the model on the parameter H

As you can see from figure 1, for the given parameters of the first vowel formants, the error does not exceed 10%. This indicates the adequacy of the proposed model for estimating the parameter of approximation H.

Equation (14) will take the form:

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

$$
\begin{aligned}
&=(\ln S(\omega_k,t_i)-2\ln c_i-\ln(\alpha_i^2+\omega_i^2)-\\
&-\ln(\beta_i^2-\omega_i^2)^2-4\omega_i^2\alpha_i^2)\frac{1}{c_i}+(\ln S(\omega_k,t_i)-4\ln c_i-\\
&-\ln(\alpha_i^2+\omega_i^2)-\ln(\beta_i^2-\omega_i^2)^2-4\omega_i^2\alpha_i^2)\frac{1}{c_i}+\\
&+(\ln S(\omega_k,t_i)-6\ln c_i-\ln(\alpha_i^2+\omega_i^2)-\\
&-\ln(\beta_i^2-\omega_i^2)^2-4\omega_i^2\alpha_i^2)\frac{1}{c_i}=\\
&=(\ln S(\omega_k,t_i)-2\ln c_i-\ln(\alpha_i^2+\omega_i^2)-\\
&-\ln(\beta_i^2-\omega_i^2)^2-4\omega_i^2\alpha_i^2)\times(\frac{1}{c_i})-\frac{6\ln c_i}{c_i}.
\end{aligned}
\qquad (18)
$$

Let us construct a graph that will clearly show the accuracy of the approximation when calculating the coefficient C.

Graph of convergence of a series of approximations of a function with its original:

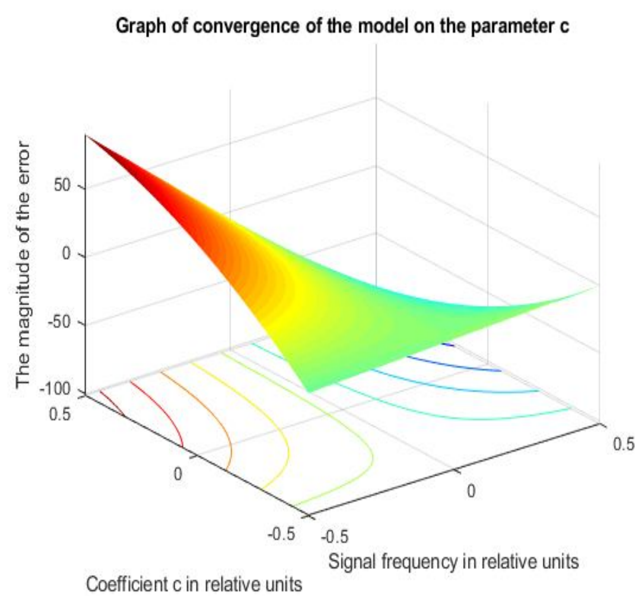

Figure 2: Graph of convergence of the model on the parameter C

As you can see from graph on the figure 2, with the given parameters of the first vowel formants, the error does not exceed 9.5%. This indicates the adequacy of the proposed model for estimating the approximation parameter C.

Equation (15) will take the form:

$$
\frac{\partial\sigma_i^2}{\partial\beta_i}=\sum_{k=1}^{N}2\begin{pmatrix}\{\ln S(\omega_k,t_i)-2k\ln(\frac{\omega_i H}{k!})-\\ -\sum_{i=1}^{n}[2\ln c_i+\ln(\alpha_i^{\ 2}+\omega_i^2)]\\ -[\ln((\beta_i^2-\omega_k^2)^2+(2\omega_k\alpha_i)^2)\}\times\\ \times(\frac{2\alpha_i^2}{\alpha_i^2+\omega_i^2}+\frac{4\beta_i(\beta_i^2-\omega_i^2)+8\omega_i^2\alpha_i^2}{(\beta_i^2-\omega_i^2)^2+4\omega_i^2\alpha_i^2})\end{pmatrix}=
$$

$$
=\begin{pmatrix}\{\ln S(\omega_k,t_i)-2k\ln(\frac{\omega_i H}{k!})-\\ -\sum_{i=1}^{n}[2\ln c_i+\ln(\alpha_i^{\ 2}+\omega_i^2)]-\\ -[\ln((\beta_i^2-\omega_k^2)^2+(2\omega_k\alpha_i)^2)\}\times\\ \times(\frac{2\alpha_i^2(\beta_i^2-\omega_i^2)^2+8\omega_i^2\alpha_i^4+(\alpha_i^2+\omega_i^2)}{(\alpha_i^2+\omega_i^2)[(\beta_i^2-\omega_i^2)^2+4\omega_i^2\alpha_i^2]}+\\ +\frac{2[4\beta_i(\beta_i^2-\omega_i^2)+8\omega_i^2\alpha_i^2]}{(\alpha_i^2+\omega_i^2)[(\beta_i^2-\omega_i^2)^2+4\omega_i^2\alpha_i^2]})\end{pmatrix}=
$$

$$
=\begin{pmatrix}\{\ln S(\omega_k,t_i)-2\ln(\omega_i H)-4\ln(\frac{\omega_i H}{2})-6\ln(6)-\\ 3\times\sum_{i=1}^{n}[2\ln c_i+\ln(\alpha_i^{\ 2}+\omega_i^2)]-[\ln((\beta_i^2-\omega_k^2)^2+(2\omega_k\alpha_i)^2)\}\times\\ \times(\frac{2\alpha_i^2(\beta_i^2-\omega_i^2)^2+8\omega_i^2\alpha_i^4+(\alpha_i^2+\omega_i^2)}{(\alpha_i^2+\omega_i^2)[(\beta_i^2-\omega_i^2)^2+4\omega_i^2\alpha_i^2]}+\\ +\frac{2[4\beta_i(\beta_i^2-\omega_i^2)+8\omega_i^2\alpha_i^2]}{(\alpha_i^2+\omega_i^2)[(\beta_i^2-\omega_i^2)^2+4\omega_i^2\alpha_i^2]})\end{pmatrix}
\qquad (19)
$$

Let us construct a graph that will clearly show the accuracy of the approximation when calculating the coefficient β.

Graph of convergence of a series of approximations of a function with its original, figure 2:

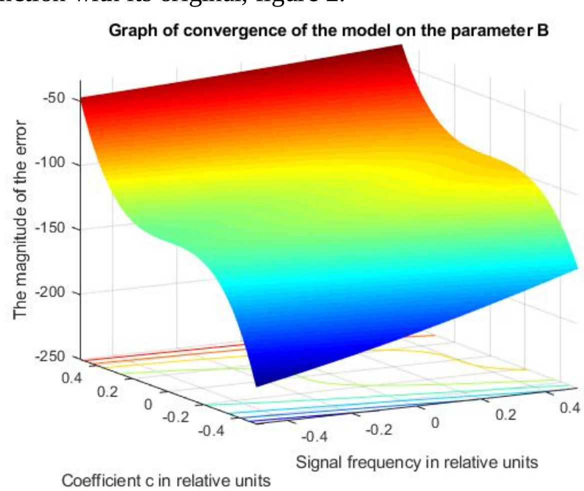

Figure 3: Graph of convergence of the model on the parameter β

As you can see from graph 3on the figure 3 that, given the parameters of the first vowel formants, the error does not exceed 14.5%. This is acceptable, and indicates the adequacy of the proposed model for estimating the approximation parameter β.

Equation (16) will take the form:

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

$$= \begin{pmatrix} \{\ln S(\omega_k, t_i) - 2k \ln(\frac{\omega_i H}{k!}) - \sum_{i=1}^{n} [2 \ln c_i + \ln({\alpha_i}^2 + \omega_i^2)] - \\ -[\ln(\left(\beta_i^2 - \omega_k^2\right)^2 + \left(2\omega_k \alpha_i\right)^2)\} \times \\ \times(\frac{2\alpha_i^2(\beta_i^2 - \omega_i^2)^2 + 8\omega_i^2 \alpha_i^4 + 8\omega_i^2 \alpha_i^2(\alpha_i^2 + \omega_i^2)}{(\alpha_i^2 + \omega_i^2)[(\beta_i^2 - \omega_i^2)^2 + 4\omega_i^2 \alpha_i^2]}) \end{pmatrix} = \quad . (20)$$

$$= \begin{pmatrix} \{\ln S(\omega_k, t_i) - 2 \ln(\omega_i H) - 4 \ln(\frac{\omega_i H}{2}) - \\ -6 \ln(6) - 3 \times \sum_{i=1}^{n} [2 \ln c_i + \ln({\alpha_i}^2 + \omega_i^2)] - \\ -[\ln(\left(\beta_i^2 - \omega_k^2\right)^2 + \left(2\omega_k \alpha_i\right)^2)\} \times \\ \times(\frac{2\alpha_i^2(\beta_i^2 - \omega_i^2)^2 + 8\omega_i^2 \alpha_i^4 + 8\omega_i^2 \alpha_i^2(\alpha_i^2 + \omega_i^2)}{(\alpha_i^2 + \omega_i^2)[(\beta_i^2 - \omega_i^2)^2 + 4\omega_i^2 \alpha_i^2]}) \end{pmatrix}$$

Let's construct a graph, which will clearly show the accuracy of the approximation when calculating the coefficient α.

Graph of convergence of a series of approximations of a function with its original, figure 4:

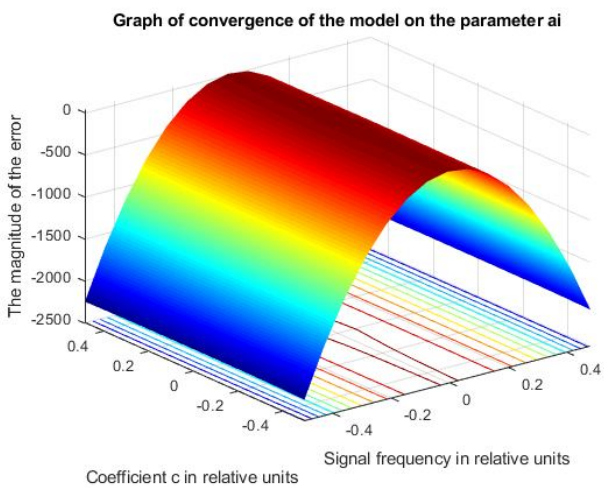

Figure 4: Graph of convergence of the model on the parameter α

As you can see from graph on the figure 4, with the given parameters of the first vowel formants, the error does not exceed 5.5%. This indicates the adequacy of the proposed model for estimating the parameter of approximation α.

3. CONCLUSIONS

A new method of detecting technical means that use a radio channel to transmit intercepted information is proposed. The method is based on the method of differential transformations and approximation of the spectral function in the basis of transfer functions of resonant units of the second order.

It is shown that the signals of the means of covert obtaining of information can be approximated by differential Taylor transformations, or more simply by T transformations. Moreover, differential images are differential T-spectra.

It is proposed to determine the spectrum of signals (spectral function) at the first stage. In the future, it is necessary to approximate the obtained spectral function in the basis of the transfer functions of the resonant units of the second order in order to extract the components of the essential signal. Further analysis of the extraction of the components of the essential radio signal is carried out in order to determine the signals of the means of covert receipt of information.

The obtained results make it possible to determine the radio signals of the means of covert receipt of information, which have slight deviations from the signals of technical means legally operating in a given radio range.

The effectiveness of the proposed approach was evaluated using computer simulations in the MATLAB environment. In order to confirm the proposed method, mathematical modeling was performed for the signals of the means of covert obtaining of information represented by the exponential function. The simulation was performed to determine the approximation error by the proposed method.

The magnitude of the approximation error in relative units, according to the approximation coefficients, differs by the first coefficient by 10%, by the second - by 9.5%, by the third - by 14% and by the fourth - by 5.5%.

Graphic materials are obtained which fully confirm that the approximation error is in the range of 5.5-14.5%. This is a good result and proves the reliability of the proposed method.

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