The new method for detecting signals of means of covert obtaining information

Oleksandr Laptiev
Doctor of Technical Sciences., Senior Researcher, State University of Telecommunications
Kyiv, Ukraine
alaptev64@ukr.net

Savchenko Vitalii
Doctor of Technical Sciences, Professor, Director of the Educational and Scientific Institute of Information Protection
State University of Telecommunications
Kyiv, Ukraine
savitan@ukr.net

Serhii Yevseiev
Doctor of Technical Sciences, Professor
S.Kuznets Kharkiv National University of Economics,
Kharkiv, Ukraine,
serhii.yevseiev@hneu.net

Halyna Haidur
Doctor of Technical Sciences, Professor, Head of Cybersecurity Department, State University of Telecommunications. Kyiv. Ukraine
gaydurg@gmail.com

Sergii Gakhov
Philosophy Doctor, Associated Professor of Cybersecurity Department, State University of Telecommunications. Kyiv. Ukraine
gakhov@ukr.net

Spartak Hohoniants
Philosophy Doctor, Senior Researcher, Chief of scientific and research department,
National Defense University of Ukraine named after Ivan Cherniakhovskyi.
Kyiv. Ukraine
hohoniants@gmail.com

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

To detect the signals of the secret means of obtaining information, it is proposed to determine at the first stage the spectrum of signals. The signals of the means of secretly obtaining information can be approximated by differential Taylor transformations, or more simply by T transformations. Moreover, differential images are differential T - spectra. Subsequently, an approximation of the already spectral function is performed in order to extract the components of the essential signal.

In order to confirm the proposed technique, modeling of the exponential function was performed. The received graphic materials. Graphic materials fully confirm the reliability of the proposed method.

Keywords*— *model, approximation, T - spectrum, differential transformations, signal.Introduction

I. 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 importance and value of information increases, so does the importance of protecting it. So leakage or loss of information will cause material damage. The technical means of transmitting intercepted information over the past few years have made a step forward in their development that many radio monitoring systems are simply unable to detect them with reasonable probability[1]. The main ones are the use of complex types of signals for the transmission of intercepted information , which make it difficult to detect them by means of radio monitoring. The latter also applies to actively used radio transmitting devices with the accumulation of intercepted information, its compression and subsequent extremely short transmission time. But the most dangerous other direction is the use of legal communication channels (DECT, Bluetooth, Wi-Fi, GSM, etc.) to transmit intercepted information.Therefore, it is difficult to determine the legal device from the device used for covert receipt of information, which makes the development of methods for detecting means of covert retrieval of information very relevant.

II. MAIN PART

Most of the known approaches to modeling differ in what parameters they use as input information in modeling and what characteristics of the simulated system are calculated and output to the model (build models using Probability Theory, Random Processes, Petri networks, Automata Theory, Graph Theory, fuzzy sets, catastrophe theory, entropy approach, etc.).

In this case, the analytical models considered from the standpoint of theoretical mathematics are not identical to reality, given the limited accuracy of the results.

However, in all these sources, mathematical modeling is considered as a mathematical model of specific parameters (some parameters are probabilistic) [2]. 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.

Therefore, 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.

Formulation of the problem

In the process of information protection there is a problem of determining the critical threats of information leakage. One of the methods of unauthorized leakage of information is the means of obtaining information using a radio channel. Reliable detection of covert means of obtaining information using a radio channel is a very difficult task. Therefore, the question of developing new methods for detecting means of covert information is very relevant.

A method for detecting means of covertly obtaining information with the spectral function of radio signals

In order to determine the spectral function, random signals, which are possible and are signals of the means of covert obtaining of information, we will at the first stage use the method of differential transformations [3-7]. Because 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:

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

where $x(t)$ – the original, which is a continuous, differentiated by infinitely many times, and limited together with all its derivatives function of a valid argument t ;

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

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

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

In transformations (1) to the left of the symbol $\bullet$ 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 the signal $x(t)$ in the form of a power a series which is nothing but a written Taylor`s series with center at point t=0. The value of H must be less than the radius of convergence of the series ρ, which can be determined on the basis of the sign of convergence of D'Alembert:

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

Transformation (2) is called differential Taylor transformations, or more simply T-transformations.

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 [4].

To detect the signals of the secret means of obtaining information, it is proposed to determine the range of signals, i.e. $X(k)$.

The signals of the means of obtaining information secretly can be approximated by exponential or harmonic series [11-15,30-35]. Then, for further presentation of the method, we define the differential spectrum of the exponential function.

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:

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

Expression (3) is an expression of the T-differential spectrum for an exponential function. This completes the first stage[8-10].

The first stage allowed us to obtain a differential spectrum of random signals that are approximated exponentially.

The second stage is to approximate the spectral function on the basis of the transfer functions of the second-order resonant units. The spectral slice of the 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:

$$x(t\ ) = \sum_{k=0}^{\infty} e^{k\omega t} , \quad (4)$$

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

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

Let us construct model $Z(\omega_k, t_l)$ of the function $S(\omega_k, t_l)$, in the form of the product of n modules of second-order transmission units on the spectrum:

$$Z(\omega_k, t_l) = \left|S(\omega_k)\right|^2 \prod_{i=1}^{n}\left|W_i(\omega)\right|^2 , \quad (5)$$

where $t_l - l -$ signal analysis interval.

$$W_i(p) = \frac{c_i\,(\alpha_i + p)}{\beta_i^2 + p^2 + 2p\alpha_i + \alpha_i^2} . \quad (6)$$

$$\left|W_i(\omega)\right|^2 = \frac{c_i^2(\alpha_i^2 + \omega_i^2)}{\left(\beta_i^2 + \alpha_i^2 - \omega_k^2\right)^2 + \left(2\omega_k\alpha_i\right)^2} . \quad (7)$$

Then we get:

$$Z(\omega_k, t_l) = \left|S(\omega_k)\right|^2 \prod_{i=1}^{n}\left|W_i(\omega)\right|^2 = = \frac{(\omega_i H)^{2k}}{k!}\prod_{i=1}^{n}\frac{c_i^2(\alpha_i^2 + \omega_i^2)}{\left(\beta_i^2 + \alpha_i^2 - \omega_k^2\right)^2 + \left(2\omega_k\alpha_i\right)^2} . \quad (8)$$

or:

$$\ln Z(\omega_k, t_l) = 2k\ln(\frac{\omega_i H}{k!}) + +\sum_{i=1}^{n}[2\ln c_i + \ln(\alpha_i^2 + \omega_i^2)] - -[\ln(\left(\beta_i^2 + \alpha_i^2 - \omega_k^2\right)^2 + \left(2\omega_k\alpha_i\right)^2)] . \quad (9)$$

Coefficients H, c_i , we will look for the method of least squares.

The error estimate will then look like:

$$\sigma_i^2 = \sum_{k=1}^{N}\left[\ln S(\omega_k t_l) - \ln Z(\omega_k t_l)\right]^2 , \quad (10)$$

$$\frac{\partial \sigma_i^2}{\partial H} = \sum_{k=1}^{N} 2 \begin{pmatrix} \{\ln S(\omega_k, t_i) - 2k \ln(\frac{\omega_i H}{k!}) - \\ -\sum_{i=1}^{n} [2 \ln c_i + \ln(\alpha_i^{\,2} + \omega_i^2)] - \\ -[\ln((\beta_i^2 - \omega_i^2)^2 + (2\omega_k \alpha_i)^2)\} \times \\ \times(\frac{\omega_i H}{k!})] \end{pmatrix} \quad (11)$$

$$\frac{\partial \sigma_i^2}{\partial c_i} = \sum_{k=1}^{N} 2 \begin{pmatrix} \{\ln S(\omega_k, t_i) - 2k \ln(\frac{\omega_i H}{k!}) - \\ \sum_{i=1}^{n} [2 \ln c_i + \ln(\alpha_i^{\,2} + \omega_i^2)] - \\ -[\ln((\beta_i^2 - \omega_i^2)^2 + (2\omega_i \alpha_i)^2)\} / c_i] \end{pmatrix} \quad (12)$$

The system of algebraic equations (11-12) has $3n+1$ unknowns, which are limited by $n=3$:

$0 < \alpha_i < 1, \quad \beta_1, \beta_2 < 1200\,Гц, \quad \beta_3 > 1200\,Гц$, these constraints give a reference to the frequencies of the first and second formants of accented sounds and the position of the maximum in the spectrum for noisy sounds. Therefore, the simulation will be performed with fixed parameters.

In the works of Professor R. Grischuk and my previous work [16,19-21,27-30] proved that three components of signal approximation are enough to fully establish a significant signal. Therefore, the next restriction will be the choice of $k = [1;3]$, i.e. we are limited to three components, then equation (11) will take the form:

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

$$= (\ln S(\omega_k, t_i) - 2 \ln c_i - \ln(\alpha_i^2 + \omega_i^2) -$$
$$- \ln(\beta_i^2 - \omega_i^2)^2 - 4\omega_i^2 \alpha_i^2)\omega_i H +$$
$$+ (\ln S(\omega_k, t_i) - 4 \ln c_i - \ln(\alpha_i^2 + \omega_i^2) -$$
$$- \ln(\beta_i^2 - \omega_i^2)^2 - 4\omega_i^2 \alpha_i^2)\frac{(\omega_i H)^2}{2} +$$
$$+ (\ln S(\omega_k, t_i) - 6 \ln c_i - \ln(\alpha_i^2 + \omega_i^2) -$$
$$- \ln(\beta_i^2 - \omega_i^2)^2 - 4\omega_i^2 \alpha_i^2)\frac{(\omega_i H)^3}{6} =$$
$$= (\ln S(\omega_k, t_i) - 2 \ln c_i - \ln(\alpha_i^2 + \omega_i^2) -$$
$$- \ln(\beta_i^2 - \omega_i^2)^2 - 4\omega_i^2 \alpha_i^2) \times$$
$$\times(\omega_i H + \frac{(\omega_i H)^2}{2} + \frac{(\omega_i H)^3}{6}) -$$
$$-2 \ln c_i \frac{(\omega_i H)^2}{2} - 4 \ln c_i \frac{(\omega_i H)^3}{6}. \quad (13)$$

The graph of convergence on the parameter H is shown in Fig.1.

Equation (12) will take the form:

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

$$= (\ln S(\omega_k, t_i) - 2 \ln c_i - \ln(\alpha_i^2 + \omega_i^2) -$$
$$- \ln(\beta_i^2 - \omega_i^2)^2 - 4\omega_i^2 \alpha_i^2)\frac{1}{c_i} +$$
$$+ (\ln S(\omega_k, t_i) - 4 \ln c_i - \ln(\alpha_i^2 + \omega_i^2) -$$
$$- \ln(\beta_i^2 - \omega_i^2)^2 - 4\omega_i^2 \alpha_i^2)\frac{1}{c_i} +$$
$$+ (\ln S(\omega_k, t_i) - 6 \ln c_i - \ln(\alpha_i^2 + \omega_i^2) -$$
$$- \ln(\beta_i^2 - \omega_i^2)^2 - 4\omega_i^2 \alpha_i^2)\frac{1}{c_i} =$$
$$= (\ln S(\omega_k, t_i) - 2 \ln c_i - \ln(\alpha_i^2 + \omega_i^2) -$$
$$- \ln(\beta_i^2 - \omega_i^2)^2 - 4\omega_i^2 \alpha_i^2) \times$$
$$\times(\frac{1}{c_i}) - \frac{6 \ln c_i}{c_i}. \quad (14)$$

Equations 13 and 14 are the equations of convergence of H and C. These equations are compatible with the proposed restrictions and are a new method of detecting signals of covert means of obtaining information based on differential transformations and approximation of the spectral function based on the transfer functions of second order resonant units.

III. ACKNOWLEDGMENT

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 with a given magnitude of the approximation error and the existing signal [17,22-27,35-38].

The simulation results are presented in figure 1 and figure 2. The simulation was performed at the given parameters of the first vowel formants. The graphs are given.

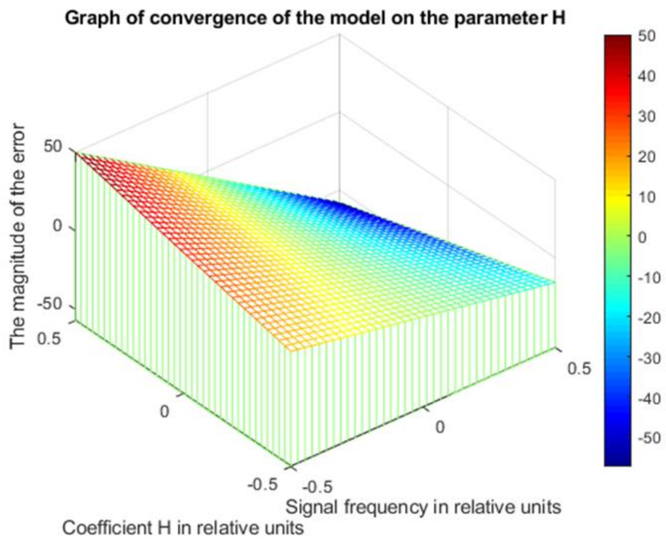

Figure 1. Graph of convergence of the model on the parameter H

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.

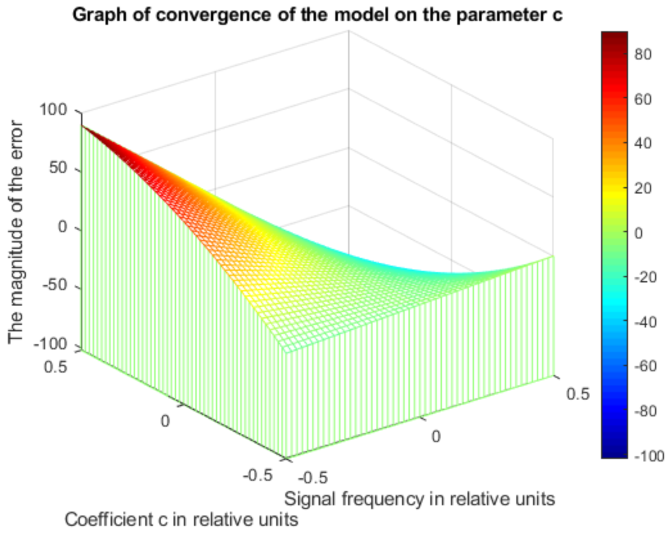

Figure 2. Graph of convergence of the model on the parameter c.

As you can see from Figure 2, for the given parameters of the first vowel formants, the error does not exceed 9,7 %. This indicates the adequacy of the proposed model for estimating the parameter of approximation c_i .

VI. CONCLUSIONS

For unauthorized receipt of information, means of covert receipt of information are used. The means of secretly obtaining information have significantly expanded the range, methods and means of camouflage. This forces us to look for fundamentally new ways to solve the problem of finding and blocking the work of these tools.

A new method of detecting technical means used to transmit intercepted information to a radio channel is proposed. The method is based on the method of differential transformations and approximation of the spectral function in the basis of the transfer functions of the second order resonant units.To detect the signals of the secret means of obtaining information, it is proposed to determine at the first stage the range of signals. The signals of the means of secretly obtaining information can be approximated by differential Taylor transformations, or more simply by T transformations. Moreover, differential images are differential T - spectra. Subsequently, an approximation of the already spectral function is performed in order to extract the components of the essential signal.

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 with a given magnitude of the approximation error and the existing signal.

The obtained results make it possible to determine the radio signals of the means of covert receipt of information, which have slight deviations in power, amplitude and other parameters from the parameters of the fixed signal.

The received graphic materials. Graphic materials fully confirm the reliability of the proposed method. The error is in the range of 9.7-10%, which is a very favorable result.

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