International Journal of
Science and Engineering Investigations vol. 8, issue 92, September 2019
Received on September 18, 2019 ISSN: 2251-8843

Analysis of Existing Signal Detection Methods, Development of a Technique for Calculating the Probability of Secret Information Capture

Alexander Laptev[1], Dmytro Kliukovskyi[2], Andriy Barabash[3], Amina Zidan[4]
[1]Ph.D., Senior Researcher, Associate Professor of the Department of Information and Cybersecurity Systems, State University of Telecommunications, Kyiv, Ukraine
[2]Postgraduate, State University of Telecommunications, Kyiv, Ukraine
[3]Student, NTUU "Igor Sikorsky Kyiv Polytechnic Inctitute", Kyiv, Ukraine
[4]Senior Teacher of State University of Telecommunications
([1]alaptev64@ukr.net, [2]d.klyukovskyy@gmail.com, [3]bar64@ukr.net, [4]amina.zidan13@gmail.com)

Abstract**-**The article describes the principles of receiving a signal and the method of excretion a radio bug signal, presenting this signal as a complex function, or a spline function of two variables, which is ultimately reduced to a tensor product of two spatial of one variable, which simplifies the task of analyzing the selected signal. Disadvantages of these methods are considered - the impossibility of solving the problem of recognition of the radio bug signal fully, using each of these methods separately is substantiated.

A model of discrete ergodic network of probability of successful information retrieval is developed and practical quantitative indicators that determinate probability estimation of successful secret information capture are obtained. Using the developed model, the processes of successful information retrieval were simulated. The result allows us to identify the most likely threats of information leakage for a particular case and to implement actions to prevent information leakage.

Keywords- *Signal Processing Methods, Spline Function, Model, Probability Estimation*

I. Introduction

A notable feature of this time is the transition from the industrial society to the information society, in which information becomes a more important resource than material or energy resources, so the number of those who want to obtain information and use it in their own or third party interests is increasing. One way of obtaining information is to get information using the means of silently receiving information from radio bugs or wiretap; radio bug - is technical tool that poses a threat to information [1]. Getting access to information, especially to information that is confidential and contains major competitive advantages, is a priority of the competition. Moreover, obtaining such information, in general, is associated with violation of the law and the use of special technical means of secret information capture(SIC). However, the main reason of industrial (economic) espionage is the pursuit of competitive advantage, the most important condition for success in a market economy.

Hunting for other people's secrets allows companies to save their own funds for development and basic research, to be aware of competitors' affairs, to use their scientific and technical achievements.

Industrial espionage today covers all areas of the market economy. Losses from economic espionage, such as in the banking sector, account for up to 30% of all losses incurred by banks today in the world. According to unofficial data, the theft of trade and industrial secrets cost US companies 200 billion in 2002. According to experts, by 2015, these losses will increase by another 75%. SIC tools are used to obtain the information. Amount of such devices is extremely large today. The rapid development of communications and technology has led not only to positive but also to negative results. Modern SIC tools are typically characterized by good masking quality, high performance characteristics, these tools are constantly being refined, so that the methods of identifying the means create great difficulty and need constant improvement.

II. Problem Statement

Contemporary SIC features are constantly being refined with high specifications and good masking quality. The detection of such eavesdropping and surveillance systems are becoming increasingly difficult, as their methods and modes are also complicated. The situation is intensified by the fact that the new generation of bugs operate in a completely legal range, and their detection in an area neighboring to other filled legal devices is problematic. Radio and radio data availability is constantly increasing. Now almost all available radio frequency spectrum is involved in the work of various radio transmitters. It is essential circumstances complications, especially in large cities. There are a lot of examples of a typical facility where tests are used. Dozens of computers, DECT radios, mobile phones of different standards (CDMA-

2000, GSM-900/1800, 3G (UMTS), 4G (WiMax)), mobile amplifiers (in some buildings there are amplifiers of all standards), legal radios, wireless headsets, Wi-Fi devices, various electronic readers of access control and control systems, wireless and wired security devices (which often have levels of side radiation comparable to the radiation of the radio bugs), etc.

The above factors make it possible to conclude that at the present stage of society development the process of searching for the means of secret information capture goes to a qualitatively different level, therefore, the analysis of methods of detecting and allocating signals of a radio bugs is very important, and the development of a method for determining the quantitative indicators of the successful estimation of successful information capture is very relevant.

III. ANALYSIS OF PUBLICATIONS

A considerable number of publications are devoted to the protection of information, search and localization of radio bugs. In [2] described the search for radio bugs by means of search complexes and auxiliaries. However, only the principles embedded in the software are used to detect radio bug signals, and the issues of signal allocation for further recognition and sorting are not considered.

[3] Describes methods for finding radio bugs signals by means of search equipment (manual methods) and search complexes (semi-automatic methods). Using a radiometer rangefinder, however, these methods also do not reflect the radio bookmark signal itself, that is, the embedded algorithm detection is based more on the practical experience of the specialist and the acoustic features of the equipment.

[4] Describes methods for detecting radio bug signals and generalizing them. Adding to the database with sequential spectral and other methods of analysis. However, there is no information of analyzing signals to separate real and complex radio signals. As a result, considerable mathematical and technical resources are used. Which increases the search time for radio bugs.

The issue of determining the likelihood of using a particular method of capturing information is practically not addressed in the literature.

Based on the above analysis of the methods of detecting and isolating signals of the radio bookmark is very important, and the development of a methodology for determining the quantitative indicators of the successful evaluation of successful secret information capture.

IV. THE PURPOSE OF THE ARTICLE

Analyze the methods of detecting and isolating signals of a radio bug, to develop a methodology for determining the quantitative indicators of the probable estimation of successful secret information capture on the basis of the developed model of ergodic Markov network of the probability of successful information capture.

V. PRESENTING MAIN MATERIAL

When searching for the means of secret information capture, the main task is to detect the signal of the radio bug, to select this signal, if possible, to determine the mode of its operation (frequency of airing).

Moreover, if the signal-to-noise ratio is small, then you can consider the signal in the form:

- signal;
- signal + noise;
- latent period signal (as an example, noisy at the beginning or end of a radio bug signal).

In general, detecting a radio bug signal (BS) is a hypothesis-making process, that is why this process will always be error-prone.

In order to reduce these errors, we introduce the concept of an optimal threshold, exceeding which signal (according to one of the hypotheses) will be considered a radio bug signal. The concept of the optimal threshold will be applied to both the output signal and its parametric (spectral) representation.

A simple kind of threshold is the difference between a latent envelope (some average estimate is taken as the initial signal base) and an envelope on the signal. For spectral time representation, this will be the bypass of the maxima of the spectra of the initial signal base to the bypassed maxima of the signal spectra.

Thresholds are introduced to cut off noisy latency periods and to determine the signal of radio bugs, in order to solve the problem of signal recognition.

The problem of signal localization is solved with the help of an optimal linear filter that suppresses the spectral components of the noise and emits a radio bug signal.

Consider an example where a regular signal operates on the system

$$S(t) = \int_{-\infty}^{+\infty} S_0(\omega) e^{j\omega t} d\omega \quad (1)$$

With an arbitrary spectrum, instantaneous intensity $I_0(t) = S^2(t)$ and power

$$Q(t) = \int_{-\infty}^{+\infty} I_0(t) \mathrm{dt} = 2\pi \int_{-\infty}^{+\infty} |S_0(\omega)|^2 d\omega \quad (2)$$

Let with the signal $S(t)$ input stationary noise with zero mean and spectral density $G(\omega)$. The optimal filter transfer function $K(\omega)$ is the transfer function for which the signal-to-noise ratio will be the highest possible for $G(\omega) = \text{const}$ (white noise). The value will be described by the expression:

$$K(\omega) = K_{\text{opt}}(\omega) = S_0\ (\omega) e^{j\omega t_0} = S_0(-\omega) e^{-j\omega t_0} \quad (3)$$

where t_0 - an arbitrary constant.

The frequency response is close to the signal spectrum. In this case, (3) includes a complex-coupled value of the spectral amplitude. The estimation of the parameters of the latent periods is carried out by the methods of periodogrammanalization, with the help of correlation functions, finite functions, finite differences and methods of Bruns, Künen, Lagrange-Dilachi, by correlation functions.

After solving the problem of signal selection, the task of presenting the signal in analytical form, ready for analysis by various software tools and methods, appears. To resolve that task we consider different methods of signal presentation.

The radio bug signal in general has the form of a complex function, this is conditioned to the fact that the bug developers use different combined methods of concealing the work of the secret information capture. So the signal can only be represented by the composition of several functions.

If the set Y_i values of the function f_i contained in many definitions X_{i+1} of the function f_{i+1}, namely f_i, $f_i: X_i \to Y_i \subset X_{i+1}, i = 1,..., n-1$, then their composition will be determined by the expression:

$$(f_n \circ f_{n-1} \circ ... \circ f_1)(x) = f_n(f_{n-1}(...f_1(x))...), x \in X_i \quad (4)$$

Every rational function of any number of variables is a composition of four arithmetic actions, a composition of functions

The complex function thus retains the properties of the function of which it is. Kolmogorov AM showed that any continuous function defined on an n-dimensional cube is a composition of continuous functions of three variables, then Arnold VI reduced the number of variables from three to two. In general, this series of works is completed by Kolmogorov's AM theorem:

Theorem 1: Any continuous function of n variables can be obtained by means of compositions of continuous functions of one variable and a single function of two variables $g = (x, y) = x + y$

This theorem allows us to represent any function f continuous on an n-dimensional cube in the form:

$$f(x_1,..., x_n) = \sum_{i=1}^{2n+1} h_i \quad (5)$$

Where functions h_i, ϕ_{ij} continuous, and function ϕ_{ij} in addition, standard and independent of selected function f.

Expression (5) provides the opportunity to present a signal of the means of secret information capture in a form convenient for further analysis by software.

Another method of presentation of signal is the method of representation, in the form of a spline function of two variables. A two-dimensional spline function made of pieces of two-dimensional algebraic polynomials. Different generalizations of the spline function in the case of many variables are characterized by two features: the shape of a given region - its division into sub regions and the definition of the spline space.

Suppose a given area is a rectangle with a rectangular grid on it. In the rectangular area: $\Omega = [a, b] \times [c, d]$, the grid is entered $\Delta = \Delta_x \times \Delta_y$, where $\Delta_x: a = x_0 \le x_1 \le ...x_N = b$ and $\Delta_y: a = y_0 \le y_1 \le ...y_N = d$

That divides the area into rectangular cells

$$\Omega_{ij} = \{(x, y) \vee x \in [x_i, x_{i+1}], y \in [y_j, y_{j+1}]\}, \quad (6)$$

Where $i = 0,..., N-1; j = 0,..., M-1$

For integers $k \ge 0$ and $l \ge 0$ thorough $C^{k,l}[\Omega]$ we denote the set of continuous functions $f(x, y)$, that have continuous frequency derivatives and mixed derivatives $D^{r,s}f(x, y)$ $r \le k, s \le 1$.

By symbol $C^{-1,-1}[\Omega]$ denotes many piece wise continuous functions with first-order discontinuities on some closed lines containing may be boundaries of the region.

Function $S_{n,m,\nu,\mu}(x, y)$ is called a spline of two variable powers n defect ν $(0 \le \nu \le n+1)$ on x and power of m defect μ $(0 \le \mu \le m+1)$ by y with gluing lines on the grid Δ, if:

The first condition. In every cell Ωij function $S_{n,m,\mu,\nu}(x, y)$ is a polynomial n power of x and m power of y, so:

$$S_{n,m,\mu,\nu}(x, y) = \sum_{\alpha=0}^{n} \sum_{\beta=0}^{m} a_{\alpha\beta}^{ij} \quad (7)$$

Where $i = 0,..., N-1; j = 0,...M-1;$

The second condition:

$$S_{n,m,\mu,\nu}(x, y) \in C^{n-\nu, m-\mu}[\Omega] \quad (8)$$

Suppose that two spaces are dependent on one variable $S_{n,\nu}(\Delta_x)$, and $S_{m,\mu}(\Delta_y)$.

Theorem 2. The space of splines of two variables coincides with the tensor product of two spaces of splines of one variable

$$S_{n,m,\mu,\nu}(\Delta) = S_{n,\nu}(\Delta_x) \otimes S_{m,\mu}(\Delta_y) \quad (9)$$

Based on the above, it is proposed to produce the signal of the radio bug using an optimal linear filter, with the subsequent presentation of this signal in the form of a complex function, expression (5) or a spline function of two variables, which is ultimately reduced to a tensor product of two spaces of one variable, expression (9), which simplifies the task of analyzing the selected signal. However, each of these methods considers the private aspects of the signal representations and cannot complete the recognition problem in its entirety.

The recognition of a radio bug signal is a complex problem that operates primarily with two factors:

- Processing the principle of receiving the signal.
- Signal structure processing

Consider the first factor processing the principle of receiving the signal (the second principle of processing the structure of the signal in this article will not be considered), because the attacker can use different methods of obtaining information. The process of removing information (receiving a speech signal) is random and can be described by the Stochastic model.

A stochastic model is a model that takes into account random factors. Random process $X(t)$ this is a function that at any point in time t takes a value, which is a random variable, since the principle of information retention remains constant, then we will consider a P-scheme, where t— a discrete value. The characteristics of a random process are the functions of an argument t, then:

- Mathematical expectation $m_x(t)$— this is an average function around which the deviation occurs $X(t)$, that is, a function $m_x(t)$ is no longer random. Function value $m_x(t)$ is the mathematical expectation of every section of a random process $X(t)$: $m_x(t) = M[X(t)]$, in our case for a discrete random process $M[X] = \sum_i x_i P_i$.
- Dispersion $D_x(t)$.. $D_x(t) = M$ That is, the variance of a random process is the same non-random variable, the variance of a random process $X(t)$ at time t.
- RMS deviation $\sigma_x(t) = \sigma_x[X(t)] = \sqrt{D[X(t)]}$

The purpose of our simulation is to find the characteristics of the signal at steady state (steady probability). If we take Kotelnikov's equation as the basis, then for a stationary model it is necessary to take into account that the derivative of the constant is zero. Then the Kotelnikov equations for the graph take the form that is convenient to solve. For modeling, we use Matlab software package.

We construct a graph of transition states to solve the problem of determining the probability of information capture by different methods and principles at a certain random time. The probabilistic parameters of a particular variant of unofficial information retrieval will be used from the practical base of search works accumulated over the last 10 years.

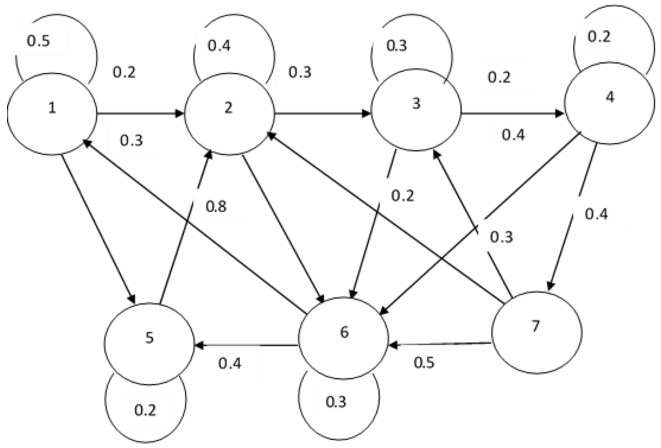

Figure 1. Graph of a discrete ergodic network of probability of successful capture of information.

The matrix of transition states for Fig. 1 will have the form shown in table 1:

TABLE I. THE MATRIX OF TRANSITION STATES

	1	2	3	4	5	6	7
1	0.5	0.2	0	0	0.3	0	0
2	0	0.4	0.3	0	0	0.3	0
3	0	0	0.3	0.2	0.3	0.2	0
4	0	0	0	0.2	0	0.4	0.4
5	0	0.8	0	0	0.2	0	0
6	0.3	0	0	0	0.4	0.3	0
7	0	0.2	0.3	0	0	0.5	0

The average probability data for each vertex is based on a generalization of the search experience over the last 10 years, and the search team is licensed to conduct this type of work.

Vertex 1 - the probability of capturing information inside the room with a wired microphone;

Vertex 2 - digital radio bug;

Vertex 3 - probability of removing information by stethoscope outside the room;

Vertex 4 - probability of information being captured by a cable microphone outside the room;

Vertex 5 - probability of taking information over the electrical network;

Vertex 6 - the likelihood of pulsing information by radio bugs with impulse transmission of information;

Vertex 7 - Probability of directional microphone information capture.

$\pi^{(i)}$= (1,0,0,0,0,0,0) - state probability vector (indicates the probability that the information extraction will be performed using the state method,). is the intersection of the process of information capture.

In order to find the probabilities of possible data capture options, it is necessary to solve the equation system:

$$\{\pi_1 = P_{11} \cdot \pi_1 + P_{21} \cdot \pi_2 + ... + P_{n1} \cdot \pi_n$$
$$\{\pi_2 = P_{12} \cdot \pi_1 + P_{22} \cdot \pi_2 + ... + P_{1n} \cdot \pi_n \quad (10)$$

Write the expression (1) in matrix form:

$$(P^T - E) \cdot \pi = 0 \quad (11)$$

Where E-identity matrix

Add to the equations (2) normalization condition:

$$\pi_1 + \pi_2 + ... + \pi_n = 1 \quad (12)$$

To solve the matrix equations (11) and (12) and graphically represent the results we will use the Matlab software package, while the calculation will be considered complete when the standard deviation is less than or equal to the given ε, so $(\|\pi^{(n-1)} - \pi^n\|) \leq \varepsilon$. Set the standard deviation of 0.001398 and perform the simulation.

The state vector for the graph given in Fig. 1 and the given standard deviation will be:

$$\pi = |0.11900.30400.13610.03400.19490.19840.0136| \quad (13)$$

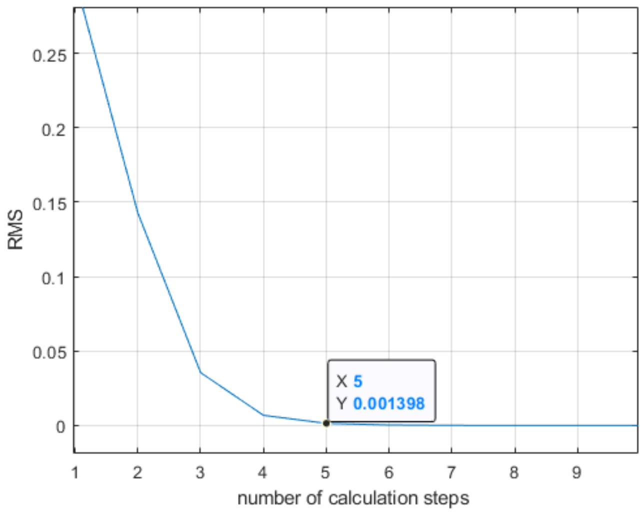

Figure 2. The graph of the RMS deviations from the set points for the graph presented in Fig. 1

From the received simulation results, the vector of probabilities for each of the methods of information capture is shown in the matrix (4), and the results of the simulation do not depend on the initial position of the state vector, it can be concluded that at the current stage of secret information capture can be performed with the highest probability digital radio bug, in the second place is the method of removing the bug information with impulse transmission of information, then the electric network, capture of information based on personal constructive structure and very low probability of interception is directional microphones.

VI. CONCLUSIONS

Based on the above, it is proposed to produce the signal of the radio bug using an optimal linear filter, with the subsequent presentation of this signal in the form of a complex function, expression (5) or a spline function of two variables, which is ultimately reduced to a tensor product of two spaces of one variable, expression (10), which simplifies the task of analyzing the selected signal. However, each of these methods considers the private aspects of the signal representations and cannot complete the recognition problem in its entirety.

A model of discrete ergodic network of probability of successful information capture is developed and practical quantitative indicators of determination of probabilistic estimation of successful secret information capture are obtained. Which make it possible to conclude that at the current level, the method of obtaining information through digital means of SIC is much more successful.

Prospective ways of further research in this direction may be simulation of processes of searching for the means of secret information capture which allow taking into account factors of processing the structure of the signal.

REFERENCES

[1] Захист інформації. Технічний захист інформації .Терміни та визначення (ДСТУ 3396.2-97) – [Дійсний від 01.01.1998]. – (Державний Стандарт України).

[2] Хорев А.А. Техническая защита информации: учебное пособие для студентов вузов. В 3 т. Т. 1./ Технические каналы утечки информации. - М: «НПЦ Аналитика», 2008 - 436 с.

[3] Ананский Е.В. Что такое радиозакладки и как их обнаружить? (часть2)/журнал «Служба безопасности» [Электронный ресурс] режим доступ: http://www.kvirin.com/articles/267/

[4] Поисковые комплексы . [Электронный ресурс]. https://www.das-ua.com/documents/catalog/search-appliances/search-complexes/page-01.php (03.05.2019)

[5] Колмогоров А.Н. О представлении непрерывных функций нескольких переменных в виде суперпозиции непрерывных функций одного переменного //Докл. АН ССр-1957.-Т.114,№5.-С.953-956.

[6] Де Бор К. Практическое руководство по сплайнам.-М.: Радио и связь,1985.-304с.

[7] Карпов О.Н., Габович А.Г., Марченко Б.Г. ,Хорошко В.А., Щербак Л.Н., Компьютерные технологии распознавания речевых сигналов. – Киев: Научное издание, 2005-138

[8] Вентцель Е. С. Теория вероятностей и ее инженерные приложения / Е. С. Вентцель, Л. А. Овчаров. М. : Наука, 1988. - 480 с.с

[9] Лаптєв О.А. Методика визначення ймовірності негласного отримання інформації потенційним порушником// Science and Education a New Dimension. Natural and Technical Sciences, VII(24), Issue: 200, 2019 July. www.seanewdim.com C.27-31.

[10] Лаптєв О.А. Модель інформаційної безпеки на основі марковських випадкових процесів// Зв'язок. – №6(136) – С.(нет в архиве)

[11] Laptev A.A.The method of searching for digital means of illegal reception of information in information systems in the working range of Wi-Fi /Laptev A.A., Barabash O.V., Savchenko V.V., Savchenko V.A., Sobchuk V.V. ISSN: 2350-0328 International Journal of Advanced Research in Science, Engineering and Technology– July 2019– Vol. 6, Issue 7– C. 10101-10105

[12] Borio, D. Asynchronous Pseudolite Navigation Using C/N0 Measurements / D. Borio, C. Gioia, G. Baldini // Journal of Navigation. – 2016 – Vol. 69, Issue 03 – P. 639–658.

How to Cite this Article:

Laptev, A., Kliukovskyi, D., Barabash, A. & Zidan, A. (2019) Analysis of Existing Signal Detection Methods, Development of a Technique for Calculating the Probability of Secret Information Capture. International Journal of Science and Engineering Investigations (IJSEI), 8(92), 99-103. http://www.ijsei.com/papers/ijsei-89219-12.pdf