ISSN 2664-9969

UDC 621.391
DOI: 10.15587/2706-5448.2021.233852
Article type «Reports on Research Projects»

Andrii Shyshatskyi,
Vitalii Hasan,
Anatolii Hasan,
Serhii Kravchuk,
Yuriy Shidlovsky,
Andrii Opalak,
Oleksandr Modlinskyi,
Oleksii Kobylynskyi,
Ihor Bezstrochnyi,
Yaroslav Onbinskyi

DEVELOPMENT OF THE METHOD OF STRUCTURAL-PARAMETRIC SYNTHESIS OF THE SUBSYSTEM OF INTERFERENCE OF SPECIAL PURPOSE RADIO COMMUNICATION SYSTEMS

The object of research is the military radio communication system. One of the most problematic areas in the management of military radio resources is the interference of military radio systems and facilities. A number of works have been devoted to the research of ways to increase the noise immunity of military radio communication systems and facilities. However, the known works contain some results of research by scientists aimed at increasing the noise immunity of military radio systems and facilities and do not have a comprehensive approach. In this article, the problem of developing a method of structural-parametric synthesis of the noise protection subsystem of special purpose radio communication systems is solved.

The scientific problem is solved by formalizing the problem of structural-parametric synthesis of the noise protection subsystem of military radio communication systems, starting with its mathematical description and synthesis of the quantitative and qualitative structure of the noise protection subsystem. In the course of the research, the authors used the main provisions of the queuing theory, the theory of automation, the theory of complex technical systems and general scientific methods of cognition, namely analysis and synthesis. The novelty of this technique is the synthesis of the structure of the military radio system and the parameters of the radio system in the context of electronic conflict. This technique is multi-criteria, in which the parameters are different in importance. The basis of this technique is the principle of nonlinear scheme of A. Voronin compromises. This technique allows to:

– *to synthesize the structure of the radio communication system in the conditions of electronic conflict;*
– *to determine the optimal number of radio communication devices to ensure management tasks in the conditions of electronic conflict;*
– *to substantiate a set of mechanisms to increase the noise immunity of the noise protection subsystem in the conditions of electronic conflict.*

The results of the research should be used at the stage of planning and operational management of the structure and parameters of military radio communication systems.

Keywords: *military radio communication system, hierarchical decomposition, functional structure of networks, electronic suppression, destabilizing factors.*

Received date: 01.02.2021
Accepted date: 12.03.2021
Published date: 30.06.2021

How to cite
Shyshatskyi, A., Hasan, V., Hasan, A., Kravchuk, S., Shidlovsky, Y., Opalak, A., Modlinskyi, O., Kobylynskyi, O., Bezstrochnyi, I., Onbinskyi, Y. (2021). Development of the method of structural-parametric synthesis of the subsystem of interference of special purpose radio communication systems. Technology Audit and Production Reserves, 3 (1 (59)), 40–44. doi: http://doi.org/10.15587/2706-5448.2021.233852

1. Introduction

According to the experience of local wars and armed conflicts in recent decades, during operations (combat operations), radio communication systems usually consist the basis of any military and weapons control system, as well as communication and information transmission systems. It happens because of the high dynamics of hostilities, long range and the ability to work in motion [1, 2].

Given the great importance of military radio communication systems in the management and communication system of the troops (forces) group, there is a need to find new ways to increase their effectiveness. It should be noted that in modern military conflicts, radio communication systems are used to meet the needs of mobile groups of troops (forces).

As it is known, the military radio communication system consists of a stationary and a field component (mobile component). At the same time, the stationary component of the military radio communication system is the primary target of high-precision devices. Peculiarities of combat use of the mobile component (MC) of military radio communication systems (MRCS) involve the creation of a control system characterized by adaptability, reliability and a given quality of operation in conditions of a priori uncertainty about the communication system state [3, 4].

The MRCS state is influenced by a large number of conditions and factors that determine the conditions of MRCS combat use and individual MRCS elements. Particular attention should be paid to the fact that the combat use of MRCS takes place in conditions of various resources shortage allocated for the organization of radio communication systems, as well as in the conditions of the use of electronic warfare by the enemy. Given all the above, the topical issue is the search for new ways to increase the noise immunity of radio communication systems, operating under the influence of electronic warfare and the shortage of radio resources. This will ensure the required quality of information exchange radio communication at the minimum necessary cost of all MRCS resources.

The analysis of scientific works, which researched the issues of increasing the noise immunity of MRCS [1, 2, 5], showed that the work in this direction is mainly aimed at studying the issues of the noise protection adaptive control during destructive exposure to electronic warfare. However, some scientists in the works [1, 3, 6] conducted research on optimizing the MRCS topology and choosing the optimal route for information transmission in order to maximize the MRCS throughput. However, the issues of structural-parametric synthesis of the MRCS noise protection subsystem under the influence of destabilizing factors remain little studied and require further research.

Thus, *the object of research* is the military radio communication system. And *the aim of research* should be considered to increase the efficiency of the military radio communication system through the structural and parametric synthesis of the noise protection subsystem of the military radio system.

2. Methods of research

During the research, the authors used the main provisions of queuing theory, automation theory, theory of complex technical systems, information transfer theory, theory of signal-code structures, as well as general scientific methods of cognition, namely analysis and synthesis.

3. Research results and discussion

In the general case, the structure synthesis of the MRCS noise protection subsystem requires the universe definition of its elements and the relationship between them [7]. It provides the properties of the MRCS noise protection subsystem that meet the requirements of the synthesis. Therefore, the universe of elements M and the relationship between them R determine the universe of properties that are realized on these elements and relations, and the Cartesian product determines the universe of the MRCS noise protection subsystem S. Then, a specific MRCS subsystem noise protection is uniquely defined if subsets of elements $\mu=\{\mu_1,\ldots,\mu_i\}$, $\mu\subset M$ are given, relationship between them $R=\{R_1,\ldots,R_i\}$, $R\subset R$ and properties $\Phi=\{p_1,\ldots,p_k\}$, $\Phi\subset P$. The sets μ, R, Φ are finite and ready to information description, if the level of the elements detail of the MRCS noise protection subsystem is determined.

Parametric synthesis involves determining the elements parameters of the noise MRCS known structure protection subsystem [7, 8].

The mathematical formulation of the parametric synthesis problem is formulated as follows. Let the requirements to the noise protection subsystem MRCS in the form of the parameters values set G_0 (including the criteria for them). The initial parameters of the MRCS noise protection subsystem are a set of characteristics G. The task of parametric synthesis is to find the following parameters of the MRCS noise protection subsystem that satisfy the requirement [9, 10]:

$$G_l \le G_{0l},\ l=1\ldots m,$$

where G_l, G_{0l} are the components of sets G and G_0 respectively, so $G_l\in G$, $G_{0l}\in G_0$. From the set of criterion requirements to G_0 the well-founded rule, the objective function S is formed. Then the parameters of the MRCS noise protection subsystem will be determined from the condition of minimizing or maximizing the function S.

To synthesize the structure and determine the parameters of a complex ergodic distributed information and control subsystem of MRCS noise protection need:

- to form a general view of the MRCS noise protection subsystem;
- to define its functions;
- to put forward system requirements for it;
- to determine the constituent elements, etc.

Further, the task of structural-parametric synthesis of the MRCS noise protection subsystem is formalized, starting from its mathematical description.

The description of the electronic conflict between the radio communication system and the electronic suppression system is implemented as follows. Let the i-th $(i=1\ldots I)$ radio-electronic conflict KS_i is characterized by a set consisting of three elements [11, 12]:

1) P_{ks} is the sign of electronic conflict, which is a unique for each type of alphanumeric combination;

2) T_{ks} is the set (list) of MRCS partial tasks on elimination of electronic conflict (it is formed, proceeding from MRCS tasks as a whole and tasks of separate MRCS elements);

3) I_{ks} is the set (list) of MRCS information needs on conflict resolution. Then the electronic conflict is described by the set:

$$KS_i=\left\{P_{ks\,i},T_{ks\,j}^{KS},I_{ks\,f}^{KS}\right\},\ i=1\ldots I,$$
$$j=1\ldots J,\ f=1\ldots F. \quad (1)$$

Then, the set of partial problems for the elimination of electronic conflict and the list of information needs for the i-th electronic conflict can be represented as subsets:

$$T_{ks\,j}^{KS}=\left\{T_{ks\,i1},T_{ks\,i2},T_{ks\,i3},\ldots,T_{ks\,il},\ldots,T_{ks\,iL_i}\right\},\ l=1\ldots L_i,$$
$$I_{ks\,f}^{KS}=\left\{I_{ks\,i1},I_{ks\,i2},I_{ks\,i3},\ldots,I_{ks\,ik},\ldots,I_{ks\,iK_i}\right\},\ k=1\ldots K_i. \quad (2)$$

For each electronic conflict, the number of elements of the sets $T_{ks\,j}^{KS}$ and $I_{ks\,f}^{KS}$ may be different, which is reflected

 ISSN 2664-9969

in the upper limits of the change of the coefficients l and k. Partial problems in the set (2) are unequal, and a higher priority (importance for implementation on the contribution to the elimination of electronic conflict) has a problem with the highest number in the list. Information on electronic conflicts is stored in a database (DB), which is modified and updated during the MRCS operation. As an example, the structure of the database can be given in the form of a geometric model (Fig. 1).

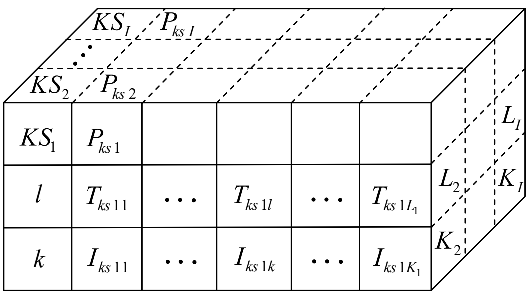

Fig. 1. Geometric model of the database structure

In the database, the elements of the sets $KS_i - T_{ks\,il}$, $I_{ks\,ik}$ acquire binary values of one in the presence of a corresponding task in the list for the elimination of electronic conflict $(T_{ks\,il}=1)$ and the corresponding information needs $(I_{ks\,ik}=1)$ and zero in the opposite case.

In the general case, the noise protection subsystem of the synthesized MRCS must meet the following requirements:

1) to ensure the minimum time spent on resolving electronic conflicts, $t_{ks}\to\min$;

2) to have high reliability of the decisions formed for elimination of electronic conflict, $D_{ks}\to\max$;

3) to provide the best information redundancy for decision-making to eliminate electronic conflict $IN_{ks}\to\max$.

As a result, there are the criterion requirements for the implementation of structural-parametric synthesis of the MRCS noise protection subsystem:

$$\begin{cases} t_{ks}\to\min \quad \text{when } t_{ks}\le t_{ks\,por}, \\ D_{ks}\to\max \quad \text{when } D_{ks}\ge D_{ks\,por}, \\ IN_{ks}\to\max \quad \text{when } IN_{ks\min}\le IN_{ks}\le IN_{ks\max}. \end{cases} \tag{3}$$

The solution of the optimization problem can be carried out by discrete and analog form of the partial criteria change, which is regulated by the essence of the solved synthesis problem. For example, the task of determining the quantitative composition of the MRCS noise protection subsystem can be discrete, which requires the use of a discrete form of description of partial criteria (3) and a discrete form of convolution for their aggregation. The convolution for discretely given partial criteria has the form:

$$Y(y_0)=\sum_{m=1}^{b}\gamma_{0m}\left(1-y_{0m}\right)^{-1}\to\min, \tag{4}$$

where $m=1...b$ is the number of partial optimality criteria included in the convolution; γ_{0m} is the normalized weighting coefficient; y_{0m} is the normalized partial criterion of optimality. While forming the function of the generalized criterion for the analog method of presenting partial optimality criteria, a convolution of the form is used:

$$\chi^*=\underset{\chi\in G}{\arg\min}\sum_{m=1}^{b}\gamma_{m0}(1-\varphi_{0m}(\chi))^{-1}=F(\chi), \tag{5}$$

where χ is the optimized parameter; G is the set of admissible values of the functions of partial optimality criteria; $\varphi_{0m}(\chi)$ is the normalized function of the m-th partial criterion; χ^* is the optimal value of the required parameter.

The reduction to the convolution of contradictory partial criteria is carried out under the conditions of bringing them to a single scale and to a minimized form. For this purpose rationing of partial criteria of optimality on a limited interval $\varphi_m(\min\chi)\le\varphi_m(\chi)\le\varphi_m(\max\chi)$ is realized. For a discrete method of describing partial criteria, their rationing can be implemented according to the expressions [12–14]:

$$\varphi_{0m}=\frac{\varphi_{mp}^{\min}}{\sum\limits_{p=1}^{K_{\min}}\varphi_{mp}^{\min}},\ \varphi_{0m}=\left(\varphi_{mp}^{\max}\sum_{p=1}^{K_{\max}}\frac{1}{\varphi_{mp}^{\max}}\right)^{-1}, \tag{6}$$

where $p=K_{\min},K_{\max}$ is the number of discrete values in the sample, which characterizes the change of the criteria to be minimized $\varphi_{mp}^{\min}$ and maximized $\varphi_{mp}^{\max}$.

Rationing of partial criteria for their analog description can be carried out as follows:

$$\varphi_{0m}(\chi)=\frac{\varphi_m^{\max}(\min\chi)}{\varphi_m^{\max}(\chi)},\ \varphi_{0m}(\chi)=\frac{\varphi_m^{\min}(\chi)}{\varphi_m^{\min}(\max\chi)}. \tag{7}$$

The rationing of weights is carried out in relation to the sum of their values set for all partial criteria included in the convolution:

$$\gamma_{0m}=\frac{\gamma_m}{\sum\limits_{m=1}^{b}\gamma_m}. \tag{8}$$

Synthesis of the quantitative structure of the noise protection subsystem. This stage is implemented as a determination of the optimal quantitative composition of the noise protection subsystem N_{RCD} (synthesis of the structure of the subsystem by quantitative composition on the optimal number of radio devices (RCD) in MRCS) is implemented in accordance with system requirements (3). It is possible to show heuristically, and for a specific subsystem of MRCS noise protection to prove experimentally and mathematically that the indicators included in (3) depend on the parameter N_{RCD}. Therefore, the refined system of criteria (3) for the analog method of their description will take the form:

$$\begin{cases} t_{ks}\left(N_{RCD}\right)\to\min, \quad \text{when } t_{ks}\left(N_{RCD}\right)\le t_{ks\,por}\left(N_{RCD}\right), \\ D_{ks}\left(N_{RCD}\right)\to\max, \quad \text{when } D_{ks}\left(N_{RCD}\right)\ge D_{ks\,por}\left(N_{RCD}\right), \\ IN_{ks}\left(N_{RCD}\right)\to\max, \\ \text{at } IN_{ks}\left(\min N_{RCD}\right)\le IN_{ks}\left(N_{RCD}\right)\le IN_{ks}\left(\max N_{RCD}\right). \end{cases} \tag{9}$$

Thus, taking into account (3) according to the discrete method of presenting partial optimality criteria in the form of (3) let's obtain *a mathematical optimization model for the structural synthesis of the noise protection subsystem in terms of the number of RCD in MRCS*:

$$\delta_{RCD}=\gamma_{t0}\left(1-t_{ks0}\right)^{-1}+\gamma_{D0}\left(1-D_{ks0}\right)^{-1}+$$
$$+\gamma_{ID0}\left(1-IN_{rs0}\right)^{-1}\to\min. \tag{10}$$

The zero indexes in the components of model (10) characterize their normalization in accordance with (6) for partial optimality criteria. The parameters $\gamma_{t0}, \gamma_{D0}, \gamma_{ID0}$ are normalized by the weight coefficients of the relevant criteria rule (8). The optimal amount of RCD in MRCS N_{RCD}^{opt} according to model (10) is determined in such way that provides a minimum value δ_{RCD} on a limited interval of change of the varied parameter N_{RCD}:

$$N_{RCD}^{opt} = N_{RCD} \quad \text{when} \quad \delta_{RCD} = \min. \qquad (11)$$

For an analog method of describing partial optimality criteria (9) using (5) let's obtain *an optimization mathematical model* of the form:

$$\begin{aligned} F(N_{RCD}) &= \gamma_{t0}(1 - t_{ks0}(N_{RCD}))^{-1} + \\ &+ \gamma_{D0}(1 - D_{ks0}(N_{RCD}))^{-1} + \\ &+ \gamma_{ID0}(1 - ID_{ks0}(N_{RCD}))^{-1} \to \min, \end{aligned} \qquad (12)$$

where the rationing of weights is carried out according to (8), and the criterion functions $t_{ks0}(N_{RCD})$, $D_{ks0}(N_{RCD})$, $ID_{ks0}(N_{RCD})$ according to (9). The optimal number of RCD using model (12) is the solution of equation $\mathrm{d}F(N_{RCD})/\mathrm{d}N_{RCD} = 0$ with rounding of the received number N_{RCD}^* to an integer value according to the rule:

$$N_{RCD}^{opt} = \min F\left(\min N_{RCD}^* \ \text{ or } \ \max N_{RCD}^*\right). \qquad (13)$$

Thus, the optimization models (10) and (12) provide the determination of the optimal number of RCD in MRCS. It solves the first stage of structural-parametric synthesis of the noise protection subsystem.

Synthesis of the qualitative structure of the MRCS noise protection subsystem. This stage is realized by searching for such RCD composition and the necessarily for their operation of the auxiliary elements (at a known value N_{RCD}^{opt}), which *the best* reflects the electronic conflict that has arisen. The concept of *the best* reflection of electronic conflict in the cluster requires clarification in the form of criteria. Thus, there is a system of criteria for the implementation of structural-parametric synthesis of the noise protection subsystem:

$$\begin{cases} T_{S\,j} \to \max, \\ I_{S\,j} \to \max, \\ TX_{S\,j} \to \max, \end{cases} \qquad (14)$$

where $T_{S\,j}$ is the number of mechanisms to increase the noise immunity of RCD; $TX_{S\,j}$ is the number of technical characteristics of RCD; $I_{S\,j}$ is the number of mechanisms used to minimize the destructive effects of increasing the noise immunity of RCD.

Comparing the system of partial criteria (3) and (14) reveals the contradiction of the latter, which is a sign of multicriteria. Therefore, the solution of the multicriteria problem of structural-parametric synthesis will be carried out using a nonlinear scheme of compromises in the form of a discrete convolution (4). This is determined by the discrete nature of the description of the partial criteria change. Implementing the rationing of partial criteria (14) and weights in accordance with (6) (within the change *j*), let's obtain *an optimization mathematical model of structural-parametric synthesis of ergodic distributed information and control system of noise protection with individual features*:

$$\begin{aligned} \Psi_j &= GT_{j0}\left(1 - T_{S\,j0}\right)^{-1} + GI_{j0}\left(1 - I_{S\,j0}\right)^{-1} + \\ &+ GTX_{j0}\left(1 - TX_{S\,j0}\right)^{-1} \to \min. \end{aligned} \qquad (15)$$

The structure of the configured system and its parameters are Pareto-optimal by a set of contradictory criteria (3) or (9) and (14).

4. Conclusions

In the course of the research the method of structural-parametric synthesis of the noise protection subsystem of special radio communication systems was developed.

The essence of this technique is to synthesize the structure of the military radio communication system and the parameters of the radio communication system in the conditions of electronic conflict. This technique is multi-criteria, in which the parameters are different in importance. The basis of this technique is the principle of nonlinear scheme of A. Voronin compromises.

This technique allows to:
- to synthesize the structure of the radio communication system in the conditions of electronic conflict;
- to determine the optimal number of radio communication devices to ensure management tasks in the conditions of electronic conflict;
- to substantiate a set of mechanisms to increase the noise immunity of the noise protection subsystem in the conditions of electronic conflict.

The results of the research will be useful in:
- the definition of mechanisms of the noise immunity increase of radio communication devices;
- the substantiation of recommendations for increasing the noise immunity of radio communication facilities;
- the analysis of the electronic situation during hostilities (operations);
- creating promising technologies to increase the noise immunity of radio communication devices.

Areas of further research will focus on the development of a methodology for the operational management of interference protection of intelligent military radio systems.

References

1. Shishatskiy, A. V., Bashkirov, O. M., Kostina, O. M. (2015). Development of integrated communication systems and data transfer for the needs of the Armed Forces. *Weapons and military equipment, 1 (5),* 35–39.
2. Romanenko, I. O., Shyshatskyi, A. V., Zhyvotovskyi, R. M., Petruk, S. M. (2017). The concept of the organization of interaction of elements of military radio communication systems. *Science and Technology of the Air Force of the Armed Forces of Ukraine, 1,* 97–100.
3. Romanenko, I., Zhyvotovskyi, R., Petruk, S., Shishatskiy, A., Voloshin, O. (2017). Mathematical model of load distribution in telecommunication networks of special purpose. *Information Processing Systems, 3,* 61–71. doi: http://doi.org/10.30748/soi.2017.149.13
4. Zhuk, O. V., Romaniuk, V. A., Sova, O. Ya. (2008). Systema upravlinnia taktychnymy sensornymy merezhamy. *Zbirnyk naukovykh prats VITI NTUU «KPI», 2,* 88–96.
5. Sokolov, K. O., Hudyma, O. P., Tkachenko, V. A., Shyiatyi, O. B. (2015). Main directions of creation of IT infrastructure of the Ministry of Defense of Ukraine. *Zbirnyk naukovykh prats Tsentru voienno-stratehichnykh doslidzhen, 3 (6),* 26–30.
6. Kuvshynov, O. V. (2009). Adaptyvne upravlinnia zasobamy zavadozakhystu viiskovykh system radiozviazku. *Zbirnyk naukovykh prats VIKNU, 17*, 125–130.

 ISSN 2664-9969

7. Shaheen, E. M., Samir, M. (2013). Jamming Impact on the Performance of MIMO Space Time Block Coding Systems over Multi-path Fading Channel. *REV Journal on Electronics and Communications, 3 (1-2),* 68–72. doi: http://doi.org/10.21553/rev-jec.56
8. Abdukhalil, T., Yadgarova, N. (2018). Study of the Application of Noise Immunity in Radio Communication Systems for Special Courses. *Bioprocess Engineering, 2 (2),* 20–23. doi: http://doi.org/10.11648/j.be.20180202.11
9. Makarenko, S. I. (2017). Prospects and Problems of Development of Communication Networks of Special Purpose. *Systems of Control, Communication and Security, 2,* 18–68. Available at: http://sccs.intelgr.com/archive/2017-02/02-Makarenko.pdf
10. Khan, M. N., Jamil, M. (2016). Adaptive hybrid free space optical/radio frequency communication system. *Telecommunication Systems, 65 (1),* 117–126. doi: 7http://doi.org/10.1007/s11235-016-0217-8
11. Adrat, M., Ascheid, G. (2015). Special Issue on Recent Innovations in Wireless Software-Defined Radio Systems. *Journal of Signal Processing Systems, 78 (3),* 239–241. doi: http://doi.org/10.1007/s11265-014-0968-y
12. Oshmarin, D. V. (2010). Raspredelenie kanalnykh resursov v setyakh kognitivnogo radio na osnove teorii igr. *Biznesinformatika, 4 (14),* 38–45.
13. Redi, J., Ramanathan, R. (2011). The DARPA WNaN networkarchitecture. *Proc. of the Military Communications Conference (MILCOM'2011),* 2258–2263. doi: http://doi.org/10.1109/milcom.2011.6127657
14. Voronin, A. N., Ziatdinov, Yu. K., Kozlov, A. I. (1999). *Vektornaya optimizatsiya dinamicheskikh sistem.* Kyiv: Tekhnika, 284.

Andrii Shyshatskyi, *PhD, Senior Researcher, Research Department of Electronic Warfare Development, Central Scientific Research Institute Armament and Military Equipment of the Armed Forces of Ukraine, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0001-6731-6390, e-mail: ierikon13@gmail.com*

Vitalii Hasan, *Institute for Support of Troops (Forces) and Information Technologies, The National Defense University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0002-2566-9144, e-mail: vitaliygasan@ukr.net*

Anatolii Hasan, *Institute for Support of Troops (Forces) and Information Technologies, The National Defense University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0003-0501-6119, e-mail: gasan212085@ukr.net*

Serhii Kravchuk, *Institute for Support of Troops (Forces) and Information Technologies, The National Defense University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine, ORCID: http://orcid.org/0000-0002-6042-154X, e-mail: sergeykravchuk@ukr.net*

Yuriy Shidlovsky, *Institute for Support of Troops (Forces) and Information Technologies, The National Defense University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0003-1746-1703, e-mail: yurishidlovski@ukr.net*

Andrii Opalak, *Institute for Support of Troops (Forces) and Information Technologies, The National Defense University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0002-5597-4182, e-mail: sapsan1100@ukr.net*

Oleksandr Modlinskyi, *Institute for Support of Troops (Forces) and Information Technologies, The National Defense University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0002-8289-265X, e-mail: Gastello1799@gmail.com*

Oleksii Kobylynskyi, *Institute for Support of Troops (Forces) and Information Technologies, The National Defense University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0003-1311-7120, e-mail: Gastello1799@gmail.com*

Ihor Bezstrochnyi, *Institute for Support of Troops (Forces) and Information Technologies, The National Defense University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0002-8507-7095, e-mail: Gastello1799@gmail.com*

Yaroslav Onbinskyi, *The Command-and-Staff Institute of the Troops (Forces) Combat Use, The National Defense University of Ukraine named after Ivan Cherniakhovskyi, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0003-1009-3709, e-mail: super.kozak1978@ukr.net*