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DEVELOPMENT OF A METHODOLOGICAL APPROACH TO THE RESEARCH OF SPECIAL PURPOSE COMMUNICATION SYSTEMS

Hierarchical construction of special purpose systems, a large number of different types of communication devices that are the part of them necessitates the need to justify the order of research of special communication systems. Existing approaches to conduct research on special purpose communication systems are narrowly focused and aimed at researching certain types of communication. A large number of destabilizing factors affecting the functioning of special purpose communication systems and a priori uncertainty about the conditions of its application only complicate the mentioned issue. Also, the experience of the full-scale armed aggression of the armed forces of the Russian Federation on the territory of Ukraine showed the need to change approaches to the research of special purpose communication systems. That is why the issue of improving the effectiveness of the management of forces and devices of communication of groups of troops (forces) during operations is an important and urgent issue. The object of the research is the communication system of the group of troops (forces). The subject of the research is the effectiveness of the communication system of the group of troops (forces) in accordance with the purpose of the operation. The research developed a methodical approach to the research of special purpose communication systems. The novelty of the proposed methodical approach consists in taking into account the efficiency while choosing this or that method while investigating the state of a special-purpose communication system and the ability to calculate the reliability while choosing this or that method while investigating the state of a special-purpose communication system. Also, the element of novelty of this methodical approach is taking into account the efficiency of the decisions made regarding the assessment of the state of the special purpose communication system while choosing one or another research method. It is advisable to implement the mentioned approach in algorithmic and program software while studying the state of the special purpose communication system.

Keywords: *forces and devices of communication, research methods, grouping of troops (forces), operational management.*

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1. Introduction

The most characteristic features of the construction of special purpose communication systems of groups of troops (forces) during the conduct of hostilities (operations) are a high degree of a priori uncertainty regarding the operational situation and a small amount of initial data for communication planning.

A special purpose communication system is characterized by the complexity of the building architecture and the various types of the transmitted information. Also, the experience of the full-scale armed aggression of the armed forces of the Russian Federation on the territory of Ukraine showed the need to change approaches to the research of special purpose communication systems.

In such conditions, it is important to correctly choose the apparatus for evaluating the made management decisions, which will allow the officials of the bodies (points) of the control system of the communication system of the groups of troops (forces) to be confident in the decisions being made [1–3].

The work [4] proposed adaptive algorithms for adjusting threshold values of radio communication system parameters. This research allows distinguishing a useful signal against the background of noise, to adapt to the signal situation. At the same time, the mentioned research does not allow to control the parameters of special purpose radio communication systems in a complex manner.

The work [5] proposed algorithms for improving the tactical and technical characteristics of radio communication tools. At the same time, these algorithms do not take into account the peculiarities of the use of radio communication devices.

Taking into account the fact that for the management of channel and network resources it is necessary to process input data of different units of measurement and origin, therefore it is proposed to conduct an analysis of algorithms for processing different types of data.

The work [6] developed generalized metric in the task of analyzing multidimensional data with various characteristics. The essence of the proposed metric is that the specified metric allows building clustering, classification and association algorithms based on it, using classical processing methods. However, the specified metric does not allow functioning effectively in conditions of shortage of computing resources.

The work [7] proposed an approach to in-depth analysis of various types of data affecting the energy efficiency of buildings based on the representation of the hierarchy of factors in the form of a multidimensional cube with different levels of abstraction. The specified approach allows building a multi-level description of the object, but does not take into account the uncertainty about the state of the monitoring object, which does not allow a full assessment of its state. The specified approach is aimed at use with a sufficient number of computing resources.

The work [8] considered the problem of processing information from various technical monitoring devices. As a possible option for solving the problem, the application of a generalized method of information processing based on the method of clustering of territorially combined information sources of monitoring and the use of a frame model of the knowledge base for the identification of monitoring objects is proposed. The clustering technique was formed on the basis of the Lance-Williams hierarchical agglomerative procedure using Ward's metric. The frame model of the knowledge base is built using object-oriented modeling tools. Disadvantages of the proposed generalized method include not taking into account the relative importance of the events that occur and the inability to work in conditions of a shortage of computing resources. Also, the impossibility of redistributing computing resources between elements to increase the efficiency of information processing should be attributed to the shortcomings of the mentioned method.

The work [9] proposed a method for determining the type of signal modulation based on a convolutional neural network using the analysis of various signal parameters. The specified method is highly effective, but can only be used to solve radio monitoring tasks, requires significant computing resources, and does not take into account the degree of uncertainty about the state of the monitoring object.

The work [10] proposed a method of identifying signals for unmanned aircraft complexes. The method is based on an artificial neural network and uses the knowledge base of radio wave propagation taking into account geographic coordinates. The disadvantages of the specified method are that the method is limited to solve radio monitoring tasks, requires significant computing resources, and does not take into account the degree of uncertainty about the state of the monitoring object.

The existing approaches to the research of special purpose communication systems are narrowly focused and aimed at the research of certain types of communication and do not allow:

– to justify the method of researching the state of the special purpose communication system;
– to determine the necessary error of assessing the state of the special purpose communication system while using one or another research method;
– to justify the efficiency of the decisions made regarding the assessment of the state of the special purpose communication system while using one or another research method.

Taking into account the above, *the aim of the research* is to develop a methodical approach to the research of special purpose communication systems.

The object of the research is the communication system of a group of troops (forces).

The subject of the research is the effectiveness of the communication system of the group of troops (forces) in accordance with the purpose of the operation.

2. Materials and Methods

In the course of the conducted research, classical methods of analysis were used to solve the problem of analyzing the conditions and factors affecting the communication system of a group of troops (forces), as well as resource optimization were used to make managerial decisions on the management of the communication system of a group of troops (forces).

3. Results and Discussion

3.1. Development of a methodical approach to the research of special purpose communication systems. The method for solving the problem of optimizing the management of the structure and parameters of a special purpose communication system [11–13] is aimed at maximizing its effectiveness according to selected factors, given in Fig. 1.

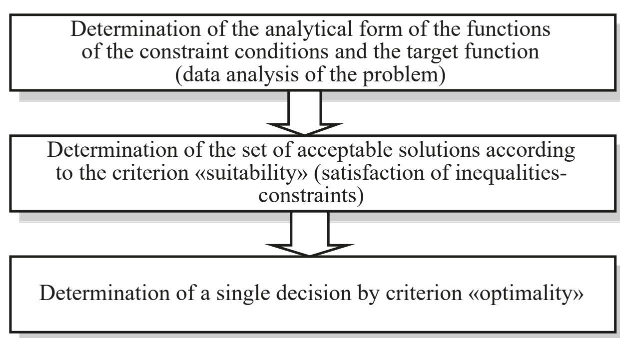

Fig. 1. Algorithm of the method for solving the problem of optimizing the structure and parameters of the special purpose communication system

The general statement of the problem is based on the set of admissible solutions $\{X\}$, each of which X satisfies the restriction condition (criterion of suitability of solutions):

$$G(X) \le G^{\max}; \text{ or } G(X) = G^{nes}; \text{ or } G(X) \ge G^{\min}, \quad (1)$$

find the following (optimal) solution $X^o \subset \{X\}$, in which the objective function acquires an extreme value (criterion of optimality):

$$W(X^o) = \underset{(X)}{extr}\, W(X). \quad (2)$$

This problem is guaranteed to be solved at the «conditional» (under the conditions-constraints) extremum by the method of «full search» (FS) of the space of admissible solutions to find a single optimal solution among them, or by special methods of optimization (mathematical programming). But the FS method requires preliminary «discretization» of solution components and the correct organization of a non-trivial procedure of «sorting» solutions, therefore it is associated with large labor costs for solving the problem.

If the analytical form of the functions $G(X)$ of the constraint conditions and the target function $W(X)$ is determined, then the problem is solved by special methods of mathematical programming – linear (for the linear form of the constraint functions and the target function) and nonlinear (in the opposite case) programming. If the nonlinear functions have an analytical form, then the problem is solved by an analytical method (for example, the method of «undefined Lagrange multipliers»). In case of transcendence of derivative data of functions, the problem is solved by the methods of «directed search» (reduced sorting – for example, by the method of «gradient» or «directing vector»). When the component of the solution is discrete (for example, integer), the problem is solved by the adapted (to «specific efficiency») method of «finite differences» (for convex envelopes of «lattice» effect functions) and by the dynamic programming method (for non-convex envelopes of «lattice» effect functions).

It is clear that the solution of extremely complex multi-dimensional optimization problems in operational-tactical calculations is possible only on computer devices of automating the management of troops and weapons.

The «operational research» method is the implementation of the «systemic approach» in military-scientific research; «operation» is considered a set of measures to solve a certain problematic scientific task of object improvement (in our case, a special purpose communication system). This method provides:

– selection of the content of indicators of «target effect» and «resource costs» in relation to the result of the operation (main performance indicators);
– selection of constraint functions (for the suitability criterion) and objective function (for the optimality criterion) of the research plan;
– substantive and formal statement of the task of optimal organization of the operation (mathematical research model);
– choosing a suitable method and solving a problem;
– detailing the optimal plan-decision that maximizes the target effectiveness of the research, as recommendations for its appropriate organization.

According to the results of the application of the special purpose communication system, the reasons for the discrepancy in the values of the operation efficiency indicators are determined and the typical mathematical model of the operation is corrected.

Optimal solutions to problems of maximizing the efficiency of a special purpose communication system are based on the properties of the Pareto set for compromise problems of synthesizing optimal «complex» systems with the «effect-cost» function of maximum efficiency.

Let's prove the following fundamental theorem for the problem of maximizing the efficiency of a complex system – the Pareto set forms the system function «effect – costs» of maximum efficiency (Fig. 2).

Fig. 2 shows:

– area (set) of solutions $\{X\}$ and system «indicators» of one of them X, as coordinates of a given point $\{WS(X),RS(X)\}$;
– «Pareto set» (optimal solutions) $\{X\}_o$, set of «heuristic» solutions $\{X\}_e$ and set of «wrong» solutions $\{X\}_n$;
– optimal solutions of direct X_{dir} and inverse X_{inv} problems, increase in functional effect ($+\Delta WS$) and cost reduction ($-\Delta RS$) of optimal X_o solutions against heuristic X_e. Indeed, if for a «complex system» of a special purpose communication system there is a set of $\{RS\}$ «cost» values and a corresponding set of $\{WS\}$ «effect» values, which are the main indicators of ES efficiency, then from the «set theory» it is known, that the «function» is the relationship of a certain «correspondence» between each pair of elements of the given sets.

Since this «ratio of pairs» can be represented geometrically (Fig. 2) by «points» with coordinates $X(RS,WS)$ for each, the set of these points forms a «graph» of the «effect-cost» function of maximum efficiency («Pareto functions») for this system.

Thus, the «Pareto function» contains a complete (for the imposed restrictions) dual set of optimal solutions of «direct» and «inverse» problems of optimal distribution of costs to achieve the maximum productivity of their use, that is, the maximum system efficiency. The theorem is proved.

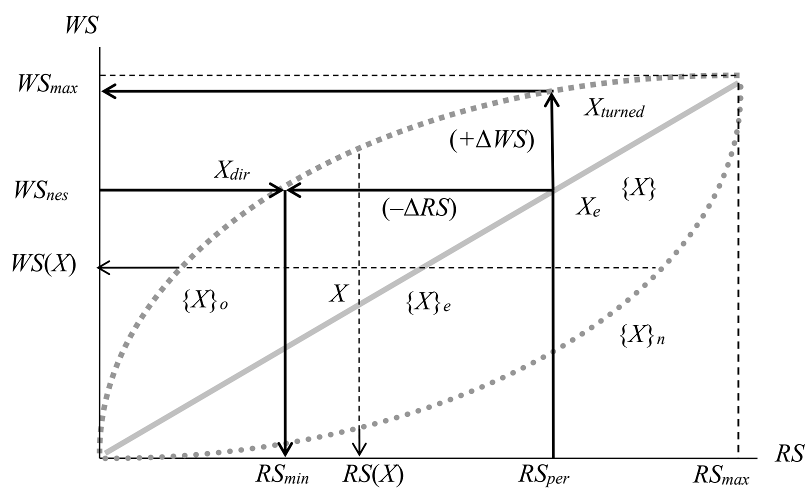

Fig. 2. The Pareto set as an «effect-cost» function of the optimal system (Pareto function)

The solutions of the Pareto set guarantee the maximum efficiency of the special communication system:

– for the direct task:

$$ES(X^o_{dir}) = WS(X^o_{dir}) / RS(X^o_{dir}) = \\ = WS_{\max} / RS_{per} = \max_{\{X\}_{dir}} ES(X); \qquad (3)$$

– for the inverse task:

$$ES(X^o_{turned}) = AS(X^o_{turned}) / CS(X^o_{turned}) = \\ = WS_{nes} / RS_{\min} = \max_{\{X\}_{turned}} ES(X). \qquad (4)$$

Let's mean that for the Pareto function, the «***RS*** costs» argument assumes only the optimal plan X^o for the distribution of cost data over the special purpose communication system with the ***WS*** effect. Thus, in fact the Pareto function is $WS\{RS(X^o)\}$. This graph shows that at «average» costs $RS(X)\approx 0.4\cdot RS_{max}$ (dashed vertical line) their optimal distribution (the upper point belonging to the graph of the Pareto function) gives a significant increase in the effect of $WS(0.4\cdot RS_{max})\approx 0.8\cdot WS(RS_{max})$ compared to the heuristic («mean») distribution.

Therefore, all iterative optimization methods use the operations of «hitting» the graph of the Pareto function and «moving» along it to the point of the «conditional» (for a system of constraints) optimum, which is the optimal solution to this problem.

The formal formulation of optimization problems for the research of a special purpose communication system is impossible without defining the dependencies for the expressions of the system of constraints and objective functions. The laws of these dependencies follow from the content of the characteristics of the special purpose communication system:

$$ms(t)=\frac{d}{dt}w\{x(t)\}=\frac{\partial w(x)}{\partial x}\cdot\frac{dx(t)}{dt}=b(x)\cdot a(y,t). \qquad (5)$$

Here, according to the logical-mathematical analysis of the process of «synergistic» formation of the effectiveness of the special purpose communication system by the communication devices, the productivity of the devices for creating the effect $b(x)$ and the productivity of the system for applying the devices $a(t)$ (the first and second fundamental laws for a special purpose communication system) are equal, respectively:

$$b(x)=\frac{\partial w(x)}{\partial x}=\gamma\cdot v(x)\}; \qquad (6)$$

$$a(y,t)=\frac{dx(t)}{dt}. \qquad (7)$$

The solution of the differential equation (6), taking into account the connection equation (4), is a sequence of transformations:

$$\frac{w(x)}{x}=\frac{d}{dx}\left\{c-v(x)\right\}=-\frac{dv(x)}{dx}=\gamma\cdot v(x), \qquad (8)$$

$$\int\limits_{c}^{c-w}\frac{dv}{v}=-\int\limits_{0}^{\tau}\gamma dx, \qquad (9)$$

where c is the effect of using a special purpose communication system.

The integration of equation (9) gives the fundamental dependence of the realized effect on the costs of communication devices of the special purpose communication system (exponential regularity of the function):

$$w(x)=c\cdot\left\{1-\exp(-\gamma x)\right\}, \qquad (10)$$

where $-\gamma=\ln\{1-w(1)/c\}$; the «specific» effect of using a special purpose communication system $w(1)$ at a given c is determined by an expert.

It is considered that during the execution of an operational task, the productivity of a unit of forces remains «normative» $a(1)$, and therefore the solution (integration) of the differential equation (7) gives the dependence of the volume of the task (on the application of devices x) on the composition of forces y and time of their application τ for a special purpose communication system:

$$x(y,\tau)=\int\limits_{0}^{\tau}a(y,t)dt\approx\int\limits_{0}^{\tau}\left\{a(1)\cdot y\right\}\cdot dt\approx\left\{a(1)\cdot y\cdot\tau\right\}, \qquad (11)$$

thanks to which the labor intensity of the task is determined as the labor expenditure of forces for its execution:

$$\left\{x/a(1)\right\}=\omega=(y\cdot\tau). \qquad (12)$$

From this ratio follows the «hyperbolic» fundamental dependence of the duration of the task on the complexity of the task and the composition of forces and devices of the special purpose communication system:

$$\tau(y)=\omega/y. \qquad (13)$$

Increasing the efficiency of the special purpose communication system by the factor of «optimization» of the functioning process consists in its «intensification» – minimization of the composition of forces at the given duration of the process (maximization of the group productivity of the forces according to the scope of the task) or minimization of the duration of the process at the given composition of forces (maximization of the group productivity of the forces by the time of the task) with the existing labor intensity of the task.

3.2. Results of the analysis and discussion of the results. In the course of the research, the authors developed a methodical approach to the research of special purpose communication systems.

The proposed approach allows:
- to justify the method of researching the state of the special purpose communication system;
- to determine the necessary error in assessing the state of the special purpose communication system while using one or another research method;
- to justify the efficiency of the decisions made regarding the assessment of the state of the special purpose communication system while using one or another research method.

The advantages of this research include:
- consideration of efficiency while choosing one or another method while investigating the state of the special purpose communication system;
- calculation of the reliability while choosing one or another method while investigating the state of a special purpose communication system;
- taking into account the efficiency of the decisions made regarding the research of the state of the special purpose communication system while choosing one or another research method.

The shortcomings of the research are:
- the need for adequate software to implement possible research methods;
- the availability of time to carry out calculations on the distribution of forces and devices of communication of troop groupings (forces) in operations.

It is advisable to implement the mentioned approach in algorithmic and software while studying the state of the special purpose communication system.

The direction of further research should be considered further improvement of the specified approach for an objective and complete research of the state of the special purpose communication system.

4. Conclusions

1. The research developed a methodical approach to the research of special purpose communication systems.

2. The novelties of the proposed methodical approach are:
– consideration of efficiency while choosing one or another method while investigating the state of the special purpose communication system;
– the calculation the reliability while choosing one or another method while investigating the state of a special purpose communication system;
– taking into account the efficiency of the decisions made regarding the assessment of the state of the special purpose communication system while choosing one or another research method.

3. It is advisable to implement the specified approach in algorithmic and software while researching the state of the special purpose communication system.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has no associated data.

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