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JUSTIFICATION OF THE METHODOLOGICAL BASES FOR THE MANAGEMENT OF THE RADIO RESOURCE OF SPECIAL PURPOSE RADIO COMMUNICATION SYSTEMS UNDER CONDITIONS OF PRIOR UNCERTAINTY

The problem of substantiation of methodological bases of radio resource management of military radio communication systems in the conditions of a priori uncertainty is solved in the work. The object of research is the military radio communication system. One of the most problematic places in the management of military radio resources is the inability to carry out a hierarchical management of the parameters and modes of operation of both individual radios and the military radio system as a whole. This reduces the efficiency of the system itself and the efficiency of its application.

The scientific problem is solved by substantiating the methodological principles of radio resource management of military radio communication systems in conditions of a priori uncertainty. During the research, the authors used the main provisions of the theory of queuing, the theory of automation, the theory of complex technical systems, as well as general scientific methods of cognition, namely analysis and synthesis. The novelty is that in the course of work:

– the purpose of functioning of an operative management subsystem of a radio resource of military radio communication systems is formulated;

– indicators and criteria of functioning efficiency of military radio communication systems are determined;

– decomposition of the solution of this problem into problems depending on the signal and noise situation is carried out.

An approach based on the hierarchical decomposition of the functional structure of networks, the behavior of which is described by stochastic differential (or difference) equations of the high dimension state, into a number of interconnected but simpler functional structures is used for the functional description of military radio communication systems. It will allow to make a decomposition of the state of the military radio system and increase the efficiency of decision-making on adjusting the modes of operation and parameters of the military radio system in real time. The research results should be used at the stage of operational management of parameters and modes of these systems operation.

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

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1. Introduction

According to the experience of local wars and armed conflicts in recent decades, radio communication devices are usually the basis of any control and communication system during operations (combat operations). 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 devices in the management and communication system of the group, there is a need to find new ways to increase their efficiency. In this article, the probability of bit error will be considered as the criterion of military radio communication systems efficiency [3, 4]. It should be noted that in modern military conflicts, radio communications are used to meet the needs of mobile groups of troops (forces).

As it is known, the military radio system consists of a stationary and a field component (mobile component). Peculiarities of combat use of the mobile component (MC) of military radio communication systems (MRCS) provide the creation of a control system characterized by adaptability, reliability, as well as a given quality of operation in conditions of a priori uncertainty about the state of the communication system.

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The most appropriate way to manage the radio resource is to use operational management. The operational control system has a number of interrelated functions [5, 6]:

– operational control of radio communication devices and quality of service (QoS);
– collection of official (control) information on the status of radio communication channels and radio communication devices;
– management of construction and maintenance of information transmission routes between radio devices;
– management of the topology of the military radio communication network;
– security management of the military radio network;
– radio resource management of the military radio network;
– load management on radio routes and the radio network as a whole;
– management of energy costs of the military radio network;
– correction of operational management processes based on the results of forecasting the state of radio communication and planning of the combat use of radio communication devices.

The state of MRCS is influenced by a large number of conditions and factors that determine the conditions of combat use of MRCS and individual elements of MRCS. Combat use of MRCS takes place in conditions of scarcity of various resources allocated for the organization of radio communication. Many researches have been devoted for improving the efficiency of special purpose radio communication systems [7, 8]. However, they are limited to the control of one parameter at a particular level of the interaction model of open systems.

Given the above, it is advisable to conduct a comprehensive hierarchical management of MRCS, namely: management of the structure of MRCS, parameters and modes of MRCS operation. This will ensure the required quality of radio communication of information exchange at the minimum necessary cost of all MRCS resources.

Thus, *the object of research* is the military radio system. And *the aim of research* is to increase the efficiency of the military radio communication system by substantiating the new principles of radio resource management.

2. Methods of research

Given the above, it is proposed to consider MRCS as an object of management in terms of managing the use of MRCS radio resource [3, 4].

A radio resource is a certain number of radio communication equipment combined into one or more information or energy exchange systems with a given quality in a given frequency range, taking into account their technical characteristics and spatio-temporal coordinates [9, 10].

Effective use of MRCS radio resource provides comprehensive management of frequency, energy, time and space resources of MRCS as a whole and in separate radio directions.

3. Research results and discussion

Fig. 1, 2 shows the structure of the system of operational management of the MRCS radio resource.

The structure of the subsystem of MRCS radio resource management is presented in Fig. 1, where $B_0(T)$, $B_з(T)$, $\mu(T)$ are the vectors of destabilizing factors affecting the quality of military radio communication devices; $H(t)$ is the vector of assessments of the MRCS state as a whole and in separate radio directions.

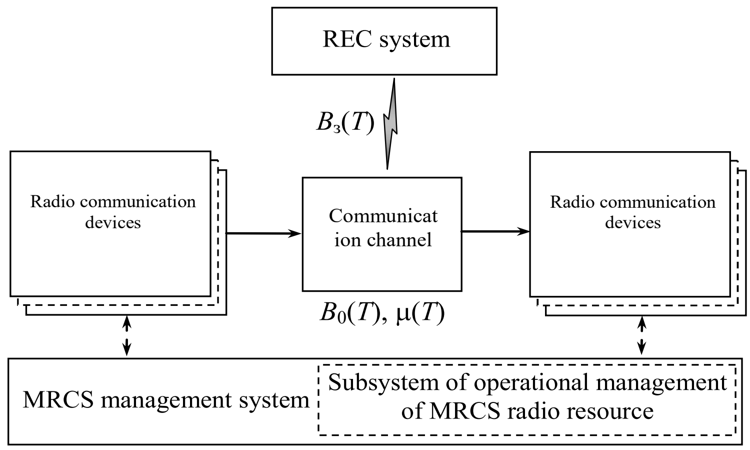

Fig. 1. Graphic representation of the place of operative management system of radio resource in the general structure of military radio communication systems (MRCS): REC is the radio electronic counteraction

The system of operational control of each MRCS node can be functionally represented as a set of separate and interconnected subsystems (Fig. 2).

A common feature of operational management subsystems is the reflection in them of the dynamic nature of the MRCS operation.

The routing management subsystem uses a variety of routing methods and provides the transfer of information from sender to receiver depending on the conditions of combat use (operation).

The topology management subsystem uses a set of methods for forming the MRCS topology. The topology determines the difficulty of delivering data between the interacting devices of radio communication. The high dynamics of combat operations by units leads to a change in the topology of MRCS.

MRCS nodes operate in a general information environment, so they are vulnerable to potential enemy attacks. The results of destructive actions on MRCS can listen (scanning) to the traffic and complete disorganization of its work. Attacks that are aimed at MRCS are classified as external and internal, active and passive. Protection against attacks is carried out by methods that operate in the security management subsystem.

Collection of information about the state of the node zone, or the entire network, its processing and storage is carried out by the subsystem devices of control, collection, processing and storage of data (SCCPS), which forms the information resource of the control system. SCCPS maintains an up-to-date information resource. Let`s consider the basic principles of its construction [9, 10].

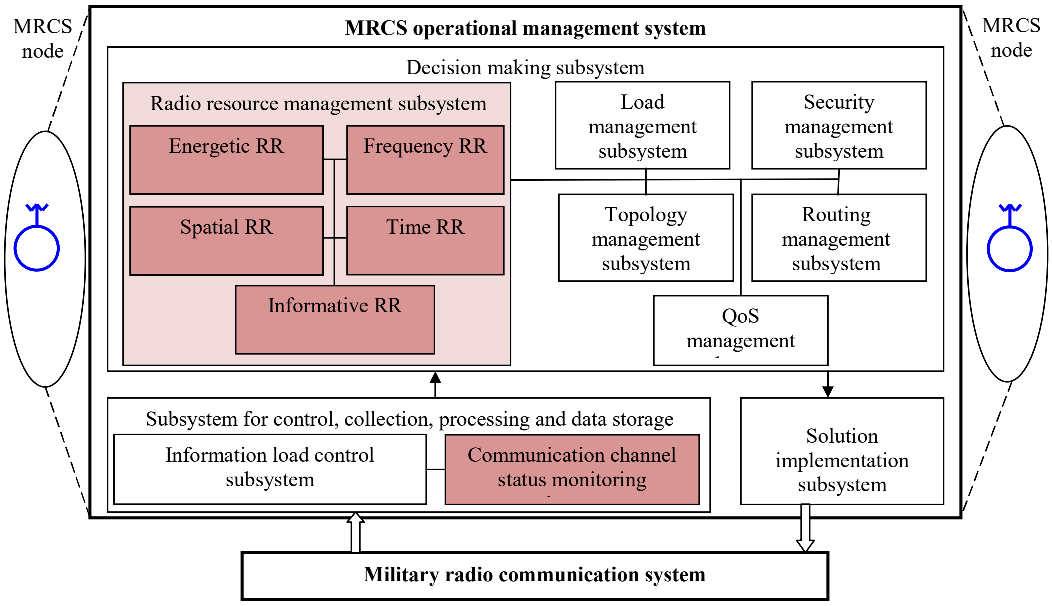

Fig. 2. Functional model of the military radio communication systems (MRCS) control system: RR is the radio resource of the radio communication system

1. The principle of adaptability in management. Management of MRCS radio resource consists in providing information exchange with the set indicators. This principle is fulfilled in the conditions of electronic suppression, MRCS topology, information load intensity in the network and QoS.

Operational management involves solving the following tasks:

– formation and issuance of management actions in accordance with the plan to change the state of MRCS;

– control of the MRCS state;

– formation and issuance of additional control effects that is designed to eliminate the effects of various disturbances on MRCS, which lead to a decrease in the quality of radio communication.

The purpose of MRCS management depending on an indicator of functioning efficiency is formulated in the form:

$$W^*(T)=\arg\min_{W(T)\in\Omega} P_{\text{error}}\left(\psi_i(T),W(T)\right);$$

$$W^*(T)=\arg\max_{W(T)\in\Omega} \beta_E\left(\psi_i(T),W(T)\right);$$

$$W^*(T)=\arg\min_{W(T)\in\Omega} k_{\text{a}}\left(\psi_i(T),W(T)\right), \qquad (1)$$

where Ω is the restrictions imposed on the choice of management, $i=\overline{1,m}$; P_{error} is the bit error probability; β_E is the energy efficiency of the radio communication system, $\psi_1 ... \psi_m$ are the parameters and modes of the radio devices operation; T is the duration of the control cycle; $W(T)$ is the decision on operational management of parameters and modes of MRCS operation. They are related to the requirements for the quality of service of data flows and the capabilities of MRCS.

2. The principle of adequacy in the course of management. MRCS should provide control of a condition of radio channels in a real-time mode and quality of the information exchange, and also transfer of service (control) information on a condition of radio networks and separate devices of radio communication.

3. The principle of optimality during management. Adaptive control of the MRCS radio resource is designed to correct the modes of MRCS operation while changing the signal and interference situation in the communication channel and in the system as a whole. The ultimate goal of operational management of radio resources is to achieve maximum efficiency (extremum of the function) of the radio resources use, which can be expressed by the efficiency functional.

To implement the principle of optimal management requires the collection, processing and generalization of information about the state of particular devices of radio communication and MRCS in general [3, 8].

The first condition for optimal management is:

$$W_0^I=\min_{\Theta}\left\{W_{\text{des}}(I)+W_{\text{inf}}(I)\right\}, \quad T=\text{const},$$

where W_{inf} is the computational complexity of assessing the MRCS state; W_{des} are the losses from wrong decisions; is the amount of processed information; T is the time of collection, processing and generalization of information and formation of control influences.

The second important factor is the efficiency of management. The efficiency of management characterizes the efficiency of the process of collecting, processing and summarizing information of the state and the formation of control effects:

$$W_0^T=\min_{T}\left\{W'_{des}(T)+W'_{\text{inf}}(T)\right\}, \quad I=\text{const},$$

where $W'_{des}(T)$ characterizes the dependence of losses in management efficiency on the time of the management actions implementation; $W'_{\text{inf}}(T)$ characterizes the dependences of the costs of collecting, processing and generalizing information about the MRCS state.

The management must take into account the efficiency and computational complexity, so:

$$W^{opt}=\min_{I,T}\left(W_0{}^I+W_0{}^T\right). \qquad (2)$$

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4. The principle of stability in management. Stability is determined by the ability of the operational subsystem management of the radio resource to perform its functions in the conditions of dynamic change of the operational situation and in the conditions of influence of the radio electronic warfare devices.

5. The principle of distribution in management. In the functional structure of MRCS two functional levels which are in hierarchical subordination are clearly visible [10].

The lower level solves the problem of control and management of individual radio lines (radio directions), and the second level solves the problem of MRCS management as a whole.

6. The principle of hierarchical management processes. Each complex control system involves hierarchy (a certain subordination of elements and subsystems). According to this principle, the formalized description of MRCS is reduced to the construction of a mathematical model of geographically distributed radios that interact with each other.

Based on the above, let's define the main methods of increasing the noise immunity of MRCS [7, 9] (Fig. 3).

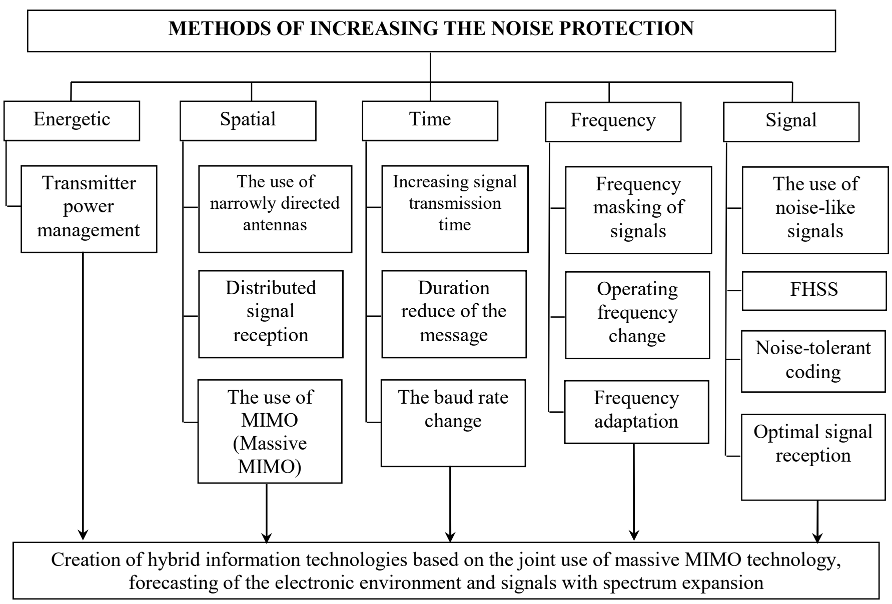

Fig. 3. The main methods of increasing the noise immunity of systems and radio communication devices: frequency-hopping spread spectrum

There is a need to ensure the requirements for the quality of operation of MRCS and create a set of functionalities of the operational management subsystem for the formation of appropriate behavior and planning the sequence of management operations. All this leads to the development of tools and methods of operational management, based on the integrated application of measures and tools to improve the MRCS efficiency in terms of active electronic countermeasures.

4. Conclusions

The analysis of the peculiarities functioning of military radio communication systems, tasks, stages and functions of its management allowed to determine the basic provisions of the methodology of operational management of the radio resource of military radio communication systems. Such provisions of a systematic approach substantiated and developed to solve the problem of operational management of MRCS radio resources:

– the tasks classification of operative management of radio MRCS resource is carried out;

– the scheme of the system analysis and synthesis of methods and techniques of operative management of MRCS radio resource is developed;

– the purpose of functioning of a subsystem of operative management of MRCS radio resource is formulated;

the principles of its construction and structure were substantiated;

– the indicators and criteria for the MRCS effectiveness were defined;

– the stages of solving the problem of developing a methodology for operational management of MRCS radio resources were substantiated;

– the requirements for management methods in MRCS were defined;

– decomposition of the problem solution depending on the signal and interference situation in the channel and the availability of information about the actions of the radio electronic suppression system.

In this work, a hierarchical approach is used to describe MRCS, which allows to describe a large number of processes occurring in MRCS due to a set of low dimensionality vectors.

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

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