UDC 621.391

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METHODOLOGICAL SUBSTANCES OF MANAGEMENT OF THE RADIO-RESOURCE MANAGING SYSTEMS OF MILITARY RADIO COMMUNICATION

Article analyzes the problems that arise in the process of functioning of military radiocommunication systems in the conditions of a priori uncertainty and radio-electronic suppression, in terms of communication, signaling and interference conditions. The substantiation of the basic principles of radio resource management of multi-antenna systems of military radio communication in a complex electronic environment is carried out. The basic principles of building the subsystem of radio resource management of multi-antenna systems of military radio communication are substantiated, the basic stages of radio resource control of multi-radio systems of military radio communication are described in order to achieve extreme or support of the set values of indicators of communication efficiency. Article uses methods of the theory of signals, the theory of noise-blocking coding, the theory of probability, the theory of information, the theory of potential impedance, graph theory, the theory of Markov processes, the theory of optimal linear filtration, the theory of matrices, the theory of decision making, the theory of games, the theory of automatic control, methods of mathematical programming and simulation techniques. In the article, presented in the article, the methodological principles of management of radio resources indicate that using of only traditional approaches for radio resource management of military radio communication systems does not allow us to rationally use available radio resources. One of the directions of increasing the efficiency of radio resource utilization of military radiocommunication systems is the use of hybrid information technologies based on multi-antenna systems of military radio communication. The results obtained in the article can be used in the development of scientific and methodical apparatus for increasing the noise immunity of military radiocommunication systems in a complex electronic environment.

Keywords**:** *mathematical modeling, system of radiocommunication, radioelectronic suppression, radio resource.*

Introduction

The peculiarities of the construction, functioning and conditions of the military application of the mobile component (MC) of the military radiocommunication systems (MRCS) undeniably foresee the creation of such a system of control of it, which would be characterized by a high degree of adaptability, reliability and quality of operation under uncertainty.

The system of operational control implements a number of functions that can be grouped into the following relatively independent groups [1–20]:

control of elements of MC and quality of service of data flows;

collection of official (control) information about the status of MC;

management of the construction and support of routes;

managing topology MC;

security management;

radio resource management;

load management;

management of energy costs;

correction of processes of operational management on the basis of forecasting and planning of actions on MC.

Given the presence of a large number of random factors that determine the conditions for the functioning of the MRCS, and the limited resources allocated for the organization of radio communication, it is expedient to introduce the management of the structure, parameters and modes of work of MRCS in order to maintain the necessary quality of information exchange in changing conditions, their functioning at the least necessary costs of all system resources.

This leads to the necessity of considering MRCS as an object of management and formulation of tasks for the development of a management system using the radio resource of the MRCS [10–17].

Under the radio resource is understood the potential possibility of a certain number of radio communication facilities, united in one or more systems for the exchange of information or energy with a given quality in a given frequency range, taking into account their technical characteristics and spatial and temporal coordinates [1–27].

Therefore, ***aim of this work*** is to develop development of a methodological substances of management of the radio-resource managing systems of military radio communication.

Exposition of the main material of the research

In fig. 1 is given to the components of the radio resource. Obviously, for the effective functioning of MRCS, complex coordination of frequency, energy, time and space resources of radio channels is necessary taking into account the characteristics of the complex of external conditions of their implementation.

Ensure stable, continuous and concealed control of troops in a priori uncertainty about the conditions of communication, signaling and interference is impossible without an efficient subsystem of operational management of the radio resource of the MRCS (fig. 2–3).

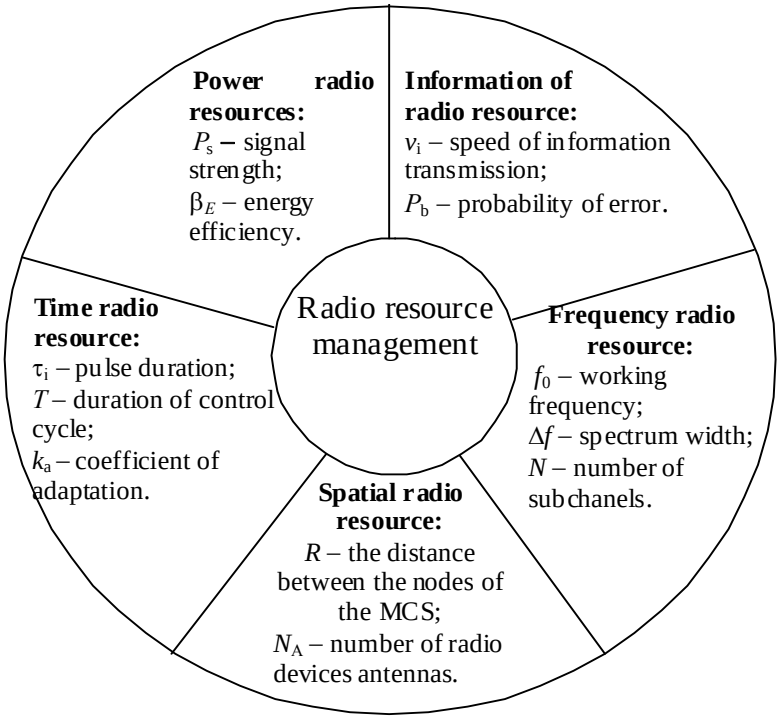

Fig. 1. Components of the radio resource [1–8; 11; 13; 26–27]

The structure of the subsystem of management of the radio resource of the MRCS is presented on fig. 4, where X(T) – vector of the given influences; Y(T) – vector of output effects; Σ(T) – vector of the error (deviation) of system parameters from the given value; $B_0(T)$, $B_n(T)$, μ(T) – vectors of noise, intentional noise and selective fading; H(t) – vector of estimations of parameters of the communication channel and state of the MRCS.

System of operative management of each node of the MRCS can functionally be represented as a plurality of subsystems (fig. 4).

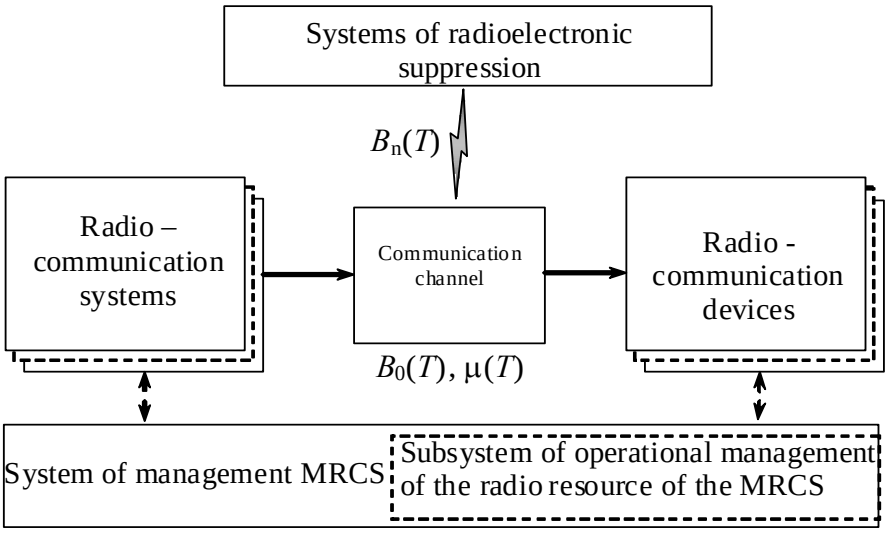

Fig. 2. Place of the subsystem of operational management of the radio resource in the structure of the MRCS

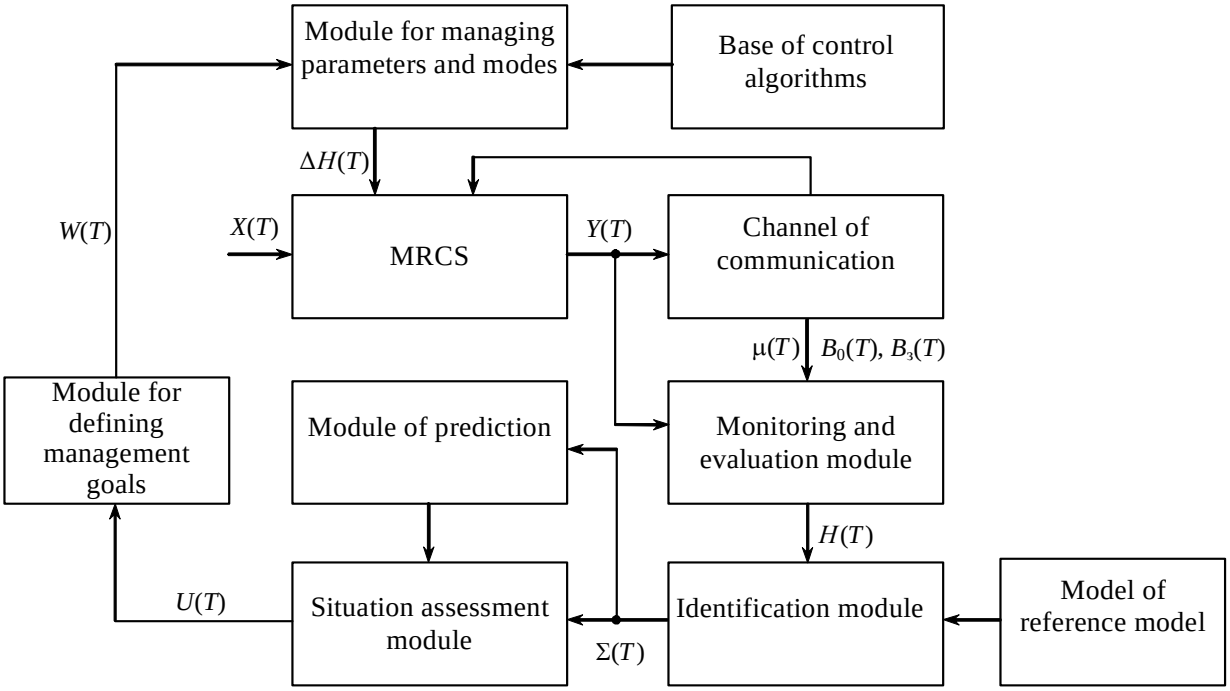

Fig. 3. Structure of the subsystem of management of the radio resource of the MRCS

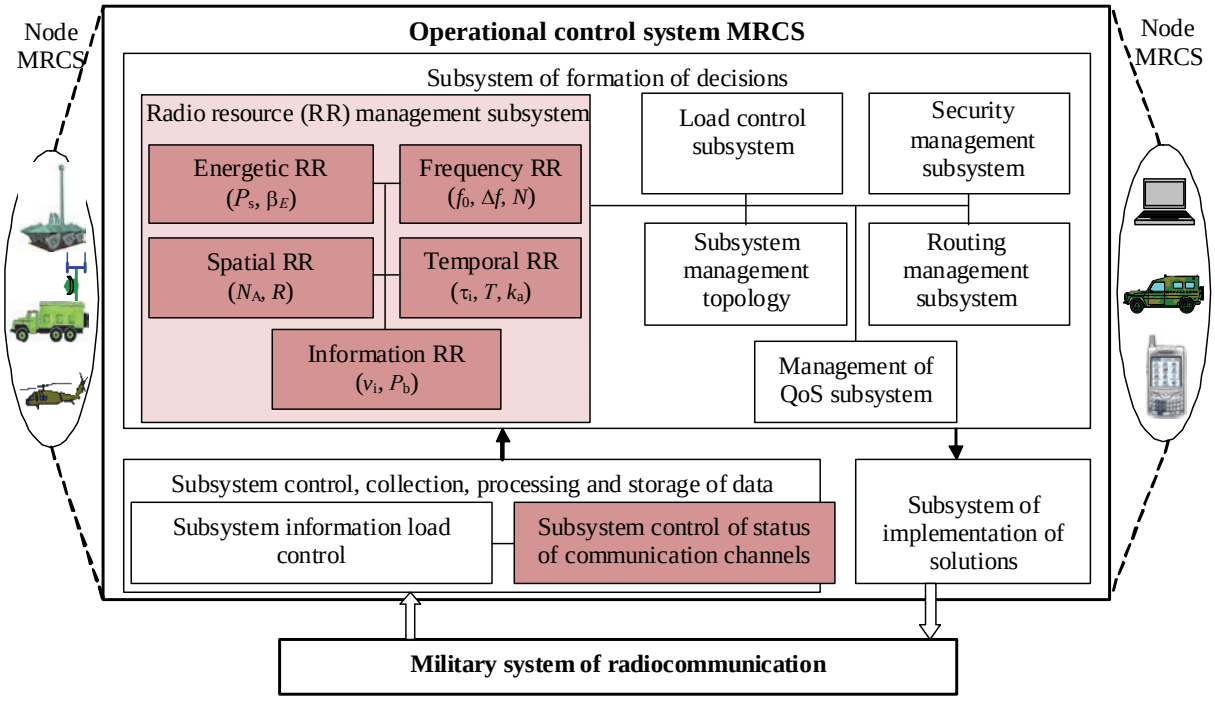

Fig. 4. Functional model of the control system of the MRCS

A common feature of the subsystems of operational management is the reflection of the dynamic nature of the functioning of the MRCS.

The routing management subsystem uses a plurality of routing methods and ensures their use depending on the operating conditions.

Subsystem control topology perceives the MRCS as a developing system (the construction of the MRCS is a process of its development from a certain initial topology to the final one). Topology determines the potential of the network to deliver data between interacting nodes. Mobility (refusal, destruction, movement) of nodes leads to a variety of network topologies MRCS.

One of the tasks of operational management of MRCS is to ensure the transfer of certain classes of traffic with a given quality of QoS service. Provision of a given quality of service in the MRCS should be carried

out on the functions with their implementation by the subsystem QoS management, the main elements of which is the base of management methods and the module for the adoption of QoS-solutions (contains knowledge about the objectives of management and methods for their achievement, as well as the database model of network resources).

Most types of traffic are sensitive to network overloads, latency and loss of data packets transmitted in it, and therefore require implementation of load management methods that would provide a full-fledged operation in MRCS networks. This task is performed by the load management subsystem, which implements functions: overload management, queue management, recovery management after loss of network connectivity, recovery recovery of lost packets and error-prone packets [12–30].

One of the tasks of managing MRCS is to distribute its resources between a plurality of independently functioning nodes, which implies at the channel level the application of appropriate access methods implemented by the subsystem of the management of the radio resource. Frequency, time, codes, space or their combinations may act as a resource.

Nodes MRCS operate in the general information environment and therefore they are vulnerable to potential attacks of the enemy. The results of destructive actions on the MRCS can become both listening (scanning) traffic, as well as complete disruption of its work. Attacks that are directed to the MRCS are classified as: external and internal, active and passive. Protection against attacks is carried out by methods that function in the security management subsystem.

The collection of information about the status of the node zone, or the entire network, its processing and storage is carried out by means of the subsystem of control, collection, processing and storage of data (SCCPS), which forms the information resource of the management system. The SCCPS maintains an up-to-date information resource.

Consider the basic principles of its construction [3–42].

1. Principle of management adaptability. The task of managing MRCS is to ensure the transmission of a specified number of messages with the required quality (reliability, efficiency, reliability, etc.). Its execution in conditions of complex electronic environment depends both on the topology of MRCS, the intensity of external influences, the intensity of message flows, the requirements for the quality of their services, and to a large extent on the efficiency of radio resource management.

In the future, under the operational management of radio resources, we will understand the process of dynamic organization and correction of such purposeful action on the elements of MRCS (object of management), which results in the maximum value of the indicator of the efficiency of the functioning of the MRCS. Operational management involves solving the following tasks: the formation and issuance of managing actions in accordance with the plan for changing the state of MRCS; control of the state MRCS; the formation and issuance of additional control effects, designed to eliminate the effects of the effect on the MRCS of various perturbations, which lead to a decrease in the quality of radio communications.

The purpose of management, depending on the performance indicator, is formulated in the form

$$\begin{aligned} W^*(T) &= \arg \min_{W(T)\in\Omega} P_b(\psi_i(T), W(T)); \\ W^*(T) &= \arg \max_{W(T)\in\Omega} \beta_E(\psi_i(T), W(T)); \\ W^*(T) &= \arg \min_{W(T)\in\Omega} k_a(\psi_i(T), W(T)), \end{aligned} \qquad (1)$$

where Ω – restrictions imposed on management choices, $i = \overline{1, m}$. They relate to the quality requirements of data flow and the capabilities of MRCS.

2. Principle of management adequacy. Insufficient reliability and instability of the operation of the radio lines is caused by the unsteadiness of the radio channels, caused by the multipath of the propagation of signals and associated with the effects of fading and Doppler shifting of the spectrum, as well as signals of natural and intentional interference from third-party sources. Therefore, the MRCS must provide control over the status of the radio channels and the quality of its operation, as well as the transmission of official (control) information about the state of the radio networks and individual radio communication facilities.

Adequacy of management lies in the ability of this process to turn state information into a command, on the basis of which the operational control subsystem becomes in a state that corresponds to the current situation. It is obvious that if the correctness of all transformations of information will be in the team, but inaccurate information and (or) incorrect purposes, management will not be adequate. Thus, the adequacy of management to a significant extent depends on the reliability and completeness of information, the correctness of operations of information transformation and their sequence, as well as the correctness of management objectives and trajectories of their achievement.

3. Principle of optimality of management. Adaptive radio resource management provides appropriate correction of MRCS modes and algorithms for the functioning of its elements at any change in signaling and interference in the communication channel and to the greatest extent meets the requirements of continuity and operational efficiency. The ultimate goal of functioning of the subsystem of operational management of the radio resource can be the extremum of some functional, which is defined for MRCS (see expressions (1)).

The adoption of a feasible and well-grounded solution in a complex electronic environment is a rather complicated task. The quality of management depends on the reasonableness and timeliness of the managing actions. To implement the principle of optimality of management, it is necessary to collect a large amount of information about the state of MRCS and the solution of two interrelated tasks [15–45].

1) Managing influences in most management methods are based on information on the state of MRCS and the external environment. The more information the operating system subsystem has, the more justifiable it can be. However, certain resources (energy, time, etc.) are spent on obtaining information. There is a permissible limit in their costs, for which ignorance of any information about the situation becomes more appropriate knowledge. Therefore, one of the conditions for effective management is to determine the optimal amount of service (command and measurement) information, which reflects the current state of MRCS (with optimum knowledge of the operational control subsystem).

Then the first condition of optimal control

$$W_0^I = \min_I \left\{ W_{decision}(I) + W_{awareness}(I) \right\}, \quad T = const,$$

where $W_{awareness}$ – the cost of obtaining information on the state of MRCS, $W_{decision}$ – losses from unjustified decisions, I – volume processed by the subsystem of operational information management, so T – the time of collection and processing of information and the formation of control impacts.

2) Along with the knowledge of the subsystem of operational management, the operational efficiency of management is important, that is, the efficiency of collecting and processing state information and management outputs. Therefore, the second condition of optimality is the timeliness of collection, delivery, processing of official information

$$W_0^T = \min_T \left\{ W'_{decision}(T) + W'_{awareness}(T) \right\}, \quad I = const,$$

where $W'_{decision}(T)$ – reflects the type of dependence of losses in the effectiveness of management from the time of the implementation of the managing actions; $W'_{awareness}(T)$ – dependence of the cost of collecting and processing information status.

But under management, both these conditions must be taken into account, i.e.

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

As can be seen, there is a contradiction between the completeness of the information on the state of MRCS and the timeliness of the elaboration of the governing actions. The solution to this dilemma is usually provided by a compromise between the operationality and validity of the managing operations, which is one of the most complex tasks to be addressed when building a subsystem of operational management of the radio resource of the military radiocommunication system.

4. Principle of stability control. The stability of control is determined by the ability of the operational control subsystem to perform its functions in a complex, rapidly changing environment, in the presence of natural impediments and active electronic counteraction to the opponent. Resilience is determined by survivability, noise immunity and reliability, which refers to the ability to control under the influence of all types of enemy weapons, under the influence of all types of noise and keeping within the established limits the value of all indicators of management, respectively.

5. Principle of management distribution. In the functional structure of the MRCS two functional levels are clearly visible, which are in a hierarchical subordination [46].

At the first (lower) level the tasks of control and management of separate radio lines or directions of radio communication are solved:

selection of radio equipment, determination of optimal modes of their work, formation of high-frequency paths;

automatic connection, maintenance and recovery;

operational control of the processes of information transmission by radio channels.

The specified tasks are solved decentralized for each direction or line of radio communication.

At the second (upper) level the tasks of control and management of a radiocommunication network are solved:

operational control and forecasting of conditions of radio communication (estimation of the electronic environment);

operational analysis of the information environment on the network (assessment of the status of information flows circulating between supporting communication centers);

reception of applications for communication and distribution of streams arriving at the radio center of messages in directions according to their priorities;

formation of bypass channels for the transmission of messages by radio channels;

relay information flows through spatial multiplexing;

redistribution of flows that flow to network elements;

distribution of frequency and energy resources.

The solution of the second level tasks requires a certain centralization (in a reasonable combination with decentralized methods) of control and management of the radio communication.

The multipurpose functional structure of the control system determines a sufficiently large number of possible options for constructing MRCS at the network level.

6. Principle of hierarchy of management processes. The most important property of MRCS, as organizational systems, is the hierarchy of the structure, that is, it determines the subordination of elements and subsystems.

Formalized description of the structure of the control system due to the mainly decentralized management of the MRCS is reduced to the construction of a mathematical model of geographically distributed nodes (subscribers) that interact with each other.

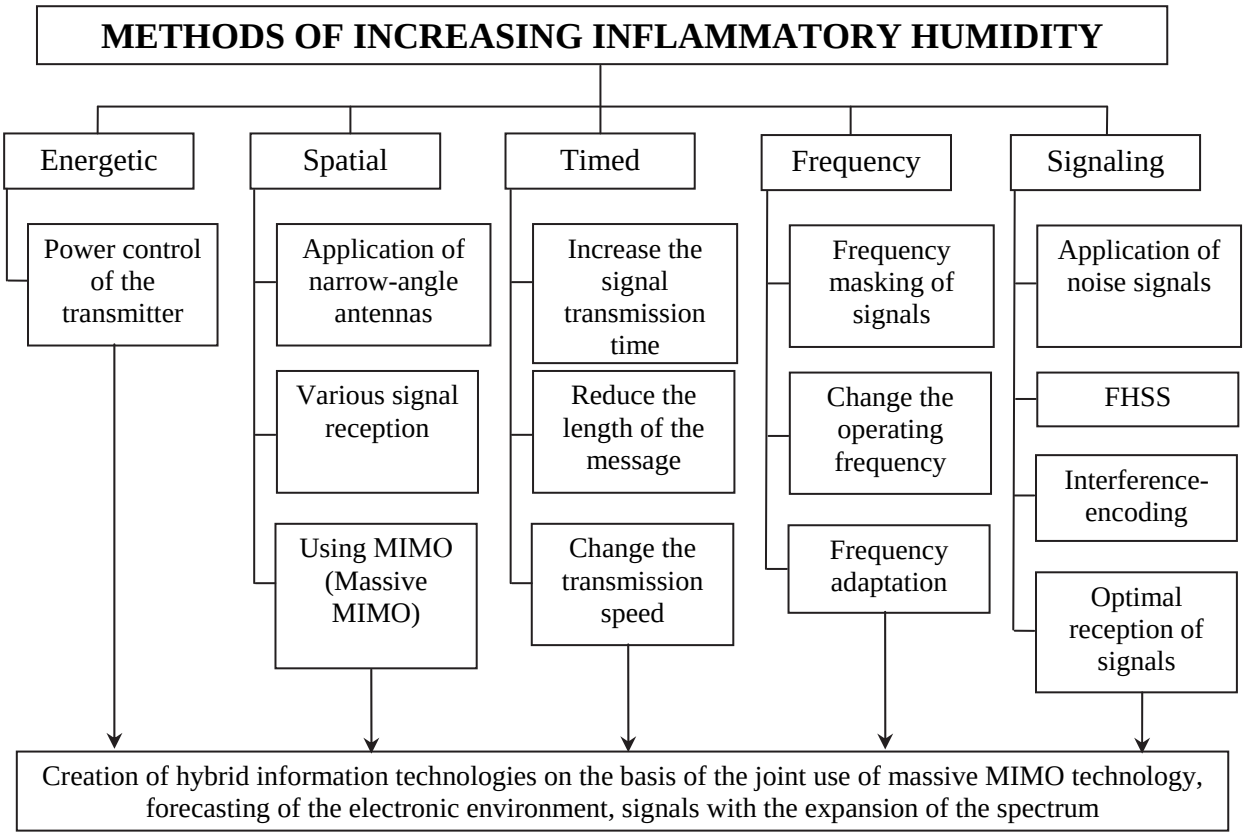

Fig. 5. Main methods of increasing the noise immunity of systems and radio communication facilities

Features of the construction, operation and conditions of military use of military radiocommunication systems of the operational and tactical level undeniably foresee the creation of such a system of management, which would be characterized by a high degree of adaptability, reliability and quality of functioning in conditions of uncertainty. At the same time, the main sources of manifestation of uncertainty in the tasks of management of the radio resource of the MRCS are the following main factors:

the complexity of the formal description of the military radiocommunication systems, its elements (as objects of management) and the problems of their management, taking into account the distortion in the information resource, which comes from the sources of information of the subsystem of operational management;

the presence of several goals and the set of tasks of operational management of the radio resource of the MRCS;

non-stationary parameters of both MRCS, its elements and the subsystem of operational control, which operates under the same conditions as the military radiocommunication system;

a priori uncertainty of the electronic environment and conditions of functioning of the MRCS;

the presence of random effects of the environment (intentional noise and selective shutdown of the signal in the channel).

Proceeding from the above, we will define the basic methods of increasing the noise immunity of MRCS [15–52]:

The need to ensure the requirements for the quality of the functioning of MRCS and the creation of a set of functional capabilities of the subsystem of operational management for the formation of reasonable behavior and planning sequence of management operations with active adaptation to the effects of the environment and variations in the current state of MRCS cause the development of tools and methods of operational management, based on the integrated application of measures and means of increasing the efficiency of the functioning of the MRCS in conditions of active electronic response.

Conclusion

Analysis of the peculiarities of the functioning of the military radiocommunication systems of the tasks,

stages and functions of its management allowed to determine the basic provisions of the methodology of operational management of radio resources of military radiocommunication systems.

The substantiated and developed provisions of the system approach to solving the problem of operational management of the radio resource of the MRCS:

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

the scheme of the system analysis and synthesis of methods and methods of operational management of the radio resource of the MRCS is developed;

the purpose of functioning of the subsystem of operational management of the radio resource of the MRCS is formulated,

the principles of its construction and structure are substantiated; certain indicators and criteria of the efficiency of the functioning of the MRCS are determined;

grounded stages of solving the problem of development of the methodology of operational management of the radio resource of the MRCS;

defined requirements for management methods in the MRCS of the tactical level of management; decomposition of the solution of the given problem to the problem is carried out, depending on signaling and interference in the channel and availability of information about the actions of the system of electronic suppressing.

For the functional description of the MRCS, 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 state of high dimension, is applied to a number of interconnected but simpler functional structures characterized by vectors of a much smaller dimension.

This method of decomposition of the functional structure of the MRCS allows for the solution of the problems of synthesis of adaptive radio resource management algorithms at the first stage to consider MRCS as a set of isolated subnets, and on the second one - to take into account the influence of interaction between subnets.

The directions of further research will be directed to the development of methodological foundations for increasing the efficiency of the functioning of modern military radiocommunication systems under conditions of active electronic response, for the complex coordination of frequency, energy, time and spatial resources of radio channels, taking into account the characteristics of the complex of external conditions of their realization on the principles of operational (adaptive) management.

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Received by Editorial Board 7.08.2017
Signed for printing 19.10.2017

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МЕТОДОЛОГІЧНІ ОСНОВИ ПОБУДОВИ ПІДСИСТЕМИ УПРАВЛІННЯ РАДІОРЕСУРСОМ СИСТЕМ ВІЙСЬКОВОГО РАДІОЗВ'ЯЗКУ

О.Г. Жук, А.В. Шишацький, П.В. Жук, Р.М. Животовський

Проаналізовані задачі, які виникають в процесі функціонування військових систем радіозв'язку в умовах апріорної невизначеності та радіоелектронного подавлення, щодо умов ведення зв'язку, сигнальної і завадової обстановки. Проведено обґрунтування основних принципів управління радіоресурсом багатоантенних систем військового радіозв'язку в складній радіоелектронній обстановці. Обґрунтовані ключові принципи побудови підсистеми управління радіоресурсом багатоантенних систем військового радіозв'язку, описано основні етапи управління радіоресурсом багатоантенних систем військового радіозв'язку з метою досягнення екстремальних або підтримки заданих значень показників ефективності зв'язку. Представленні в статті методологічні засади управління радіоресурсом вказують на те, що використання лише традиційних підходів управління радіоресурсом систем військового радіозв'язку не дозволяє раціонально використовувати наявний радіоресурс. Отримані в статті результати можуть бути використані під час розробки науково-методичного апарату підвищення завадозахищеності систем військового радіозв'язку в складній радіоелектронній обстановці.

Ключові слова: *математичне моделювання, система радіозв'язку, радіоелектронне подавлення, радіоресурс.*

МЕТОДОЛОГИЧЕСКИЕ ОСНОВЫ ПОСТРОЕНИЯ ПОДСИСТЕМЫ УПРАВЛЕНИЯ РАДИОРЕСУРСОМ СИСТЕМ ВОЕННОЙ РАДИОСВЯЗИ

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Проанализированы задачи, которые возникают в процессе функционирования военных систем радиосвязи в условиях априорной неопределенности и радиоэлектронного подавления, по условиям ведения связи, сигнальной и помеховой обстановки. Проведено обоснование основных принципов управления радиоресурсом многоантенных систем военной радиосвязи в сложной радиоэлектронной обстановке. Обоснованны ключевые принципы построения подсистемы управления радиоресурсами многоантенных систем военной радиосвязи, описаны основные этапы управления радиоресурсом многоантенных систем военной радиосвязи с целью достижения экстремальных или поддержания заданных значений показателей эффективности связи. Представленные в статье методологические основы управления радиоресурсом указывают на то, что использование только традиционных подходов упраления радиоресурсами систем военной радиосвязи не позволяет рационально использовать имеющийся радиоресурс. Полученные в статье результаты могут быть использованы при разработке научно-методического аппарата повышения помехозащищенности систем военной радиосвязи в сложной радиоэлектронной обстановке.

Ключевые слова: *математическое моделирование, система радиосвязи, радиоэлектронное подавление, радиоресурс.*