UDC 621.391

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METHOD OF HIERARCHICAL MANAGEMENT BY CHANNEL AND NETWORK RESOURCES OF MILITARY RADIO COMMUNICATION SYSTEMS

Experience of carrying out an antiterrorist operation on the theory of Donetsk and Luhansk oblasts shows that the existing order of management of military radiocommunication systems does not satisfy the modern requirements, that put forward for them. The classic centralized approach to the management of channel and network resources of military radio communication systems does not satisfy the requirements of the present, therefore the authors of this article are proposed as a basic principle of construction to take the mobile self-organizing networks of the MANET class. Authors propose the method of hierarchical control of channel and network resources of military radiocommunication systems, the essence of which is to provide support for the set values of indicators of the functioning of military radio communication systems at an appropriate level. Under the channel and network resources, we will understand the radio resource of the network, its topology, the order of construction and support of routes. In the article, the management principle described in the reference network model of the interaction of open OSI systems, but with some additions and changes, is taken as a basis. This approach as a whole allows for continuous management of channel and network resources of military radio communication systems in a complex electronic environment. In this article we used the apparatus of fuzzy logic, neural networks, the theory of noise immunity, the theory of antennas, noise immunity coding, and others. Practical significance of this research is that the scientific result obtained will allow the development of a new one and the modernization of existing communications technology, thereby increasing the efficiency of the using of radio resources, the efficiency of managing the network and channel resources of military radio communication systems, reducing the amount of service information circulating in the network military radiocommunication, to form a rational topology of military radiocommunication systems, to form and maintain a rational quantity of route information transfer, subject to continuous electronic suppression zones, assign operating frequencies between network nodes based electronic suppression of certain frequencies (frequency groups) and the degree of utilization of operating frequencies other network nodes.

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

Introdaction

Conducting an antiterrorist operation on the territory of Donetsk and Luhansk regions showed the imperfection of the existing system of management and communication, the basis of which are radio communication (RC).

The main disadvantages of the existing tactical communication system of the Armed Forces of Ukraine are [1–3]:

low mobility of communication nodes management points;

low productivity, reliability, dilution and noise protection;

low automation of installation and maintenance of radio communication.

The basic technical requirements for the next generation of tactical communication systems are [1–3]:

integration of all kinds of traffic (language, data, video, video conferencing);

full mobility of all subscribers and system elements;

provision of the given quality of service to users;

guaranteed secrecy of all types of information.

The analysis of possible variants of building the architecture of networks of the tactical level of management of the leading countries of the world [1–3] demonstrated the advantages of using mobile radio networks or MANET (Mobile Ad-hoc Networks) in comparison with other approaches.

Therefore, aim of this work is the development of hierarchical management techniques for channel and network resources of military radiocommunication systems.

Exposition of the main material of the research

In this method, it is proposed to conduct a hierarchical hierarchical control of the channel and network resources of the MANET system of military radio communication with the relative observance of the hierarchy at each of the level of the standard open system interconnection of open system OSI (open systems interconnection basic reference model), as the concepts are indicated in the interaction model of open OSI systems are relative.

Therefore, it is proposed to manage the systems of military radio communication on a hybrid principle, centralized with correction on each (aggregate) levels of the network.

Essence of the method of hierarchical control of channel and network resources of military radio communication systems is to support the maintenance of indicators of the radio communication system functioning at the given level.

By managing channel and network resources, we will understand the management of the radio resource of the network, topology and routing [4–6].

Radio resource management is the management of the frequency, code, time and energy resources between the nodes of the MSRC, as well as the determination of the degree of influence of the electronic propagation of the enemy/

Topology management consists of operational reconfiguration of the MSRC topology and the connection of backup elements (channels, mobile base stations and nodes) in changing situation in order to meet the maintenance of a given quality of service.

Routing management obligation is to build and maintain routes, to transfer information flows at given topology in order to meet the quality of service flow rates.

We will formalize hierarchical control of channel and network resources of military radiocommunication systems. System of military radio control is represented by a hierarchical structure with vertical links, which determines the subordination of solved problems (at the lower level, the tasks of managing the subscriber of the l-th level of military radiocommunication system (MSRC) are solved, on the upper one - the task of managing the l - th level of MSRC).

We represent the specified functional structure from the position of the theory of graphs in the form of a tree. In this case, the root of the tree will be placed in accordance with the second-level control subsystem (I_2, U_2), and the vertices of this tree, which are located on a distance from the root of one edge - Q subsystem management of first level $(I_{11}, U_{11}),...,(I_{1q}, U_{1q}),...,(I_{1Q}, U_{1Q})$ (fig. 1). Each subsystem has in its structure a control unit (identification)I and control unit U. Let's introduce to consideration Q subsystems of the zero level, which are located at the root of the tree at a distance of two edges. These subsystems represent interacting processes for the exchange of operational and service information flows in SM P_1, ..., P_q, …, P_Q.[4–6].

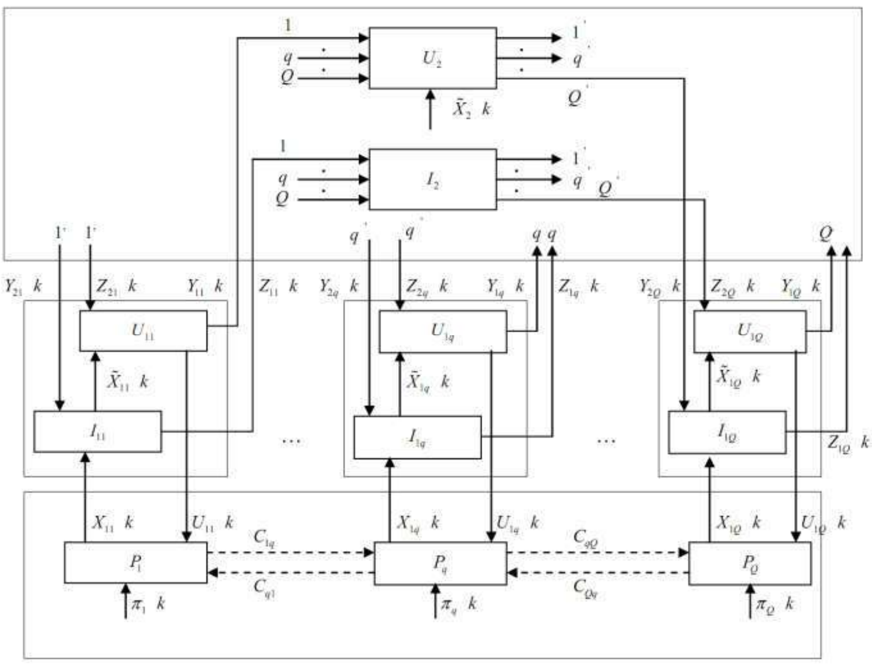

Fig. 1. Hierarchical structure of the control system MSRC

For q-th subsystem management of first level $(I_{1q}, U_{1q}), q = \overline{1, Q}$, enter the following symbols: $X_{1q}(k)$ - set of vectors, state of q-th controlled subnet, where $x_{1q}(k) = \{x_{1q}^a(k)\}, a = \overline{1, a_{1q}}$, dimension $a_{1q} \times 1$; $\tilde{X}_{1q}(k)$ - set of evaluation vectors $\tilde{x}_{1q}(k) = \{\tilde{x}_{1q}^a(k)\}$, $a = \overline{1, a_{1q}}$, dimensionality $a_{1q} \times 1$; $U_{1q}(k)$ - plural vector control q-th managed subnet $u_{1q}(k) = \{u_{1q}^b(k)\}, b = \overline{1, b_{1q}}$, dimensionality $b_{1q} \times 1$;

$Y_{1q}(k)$ - set of vectors of local variables that are issued in the upper level management subsystem $y_{1q}(k)=\{y_{1q}^{d}(k)\}$, $d=\overline{1,d_{1q}}$, dimensionality $d_{1q}\times 1$; $Z_{1q}(k)$ - set of vectors of local output variables $z_{1q}(k)=\{z_{1q}^{d}(k)\}$, $d=\overline{1,d_{1q}}$, dimensionality $d_{1q}\times 1$.

For the second-level control subsystem, respectively: $\tilde{X}_2(k)$ - set of vectors of generalized evaluations $\tilde{x}_2(k)=\{\tilde{x}_2^{l}(k)\}$, $l=\overline{1,l_r}$, dimensionality $l_r\times 1=\left(\sum_{q=1}^{Q}a_{1q}\right)\times 1$; $Y_{2q}(k)$ - set of vectors that are issued in the lower level control subsystem $y_{2q}(k)=\{y_{2q}^{d}(k)\}$, $d=\overline{1,d_{2q}}$, dimensionality $d_{2q}\times 1$; $Z_{2q}(k)$ - set of vectors that coordinates the output variables issued in the lower level control subsystem $z_{2q}(k)=\{z_{2q}^{d}(k)\}$, $d=\overline{1,d_{2q}}$, dimensionality $d_{2q}\times 1$.

As a result for q-th subsystem of the zero level P_q, $q=\overline{1,Q}$, have:

$C_{qp}(k)$ – set of communication vectors $c_{qp}(k)=\{c_{qp}^{mn}(k)\}$, $m=\overline{1,m_q}$, $n=\overline{1,n_q}$, between p-th and q-th subsystems ($p,\ q=\overline{1,Q},\ p\neq q$);

$\Pi_q(k)$ – set of vectors of external influences $\Pi_q(k)=\{\pi_q^{l}(k)\}$, $l=\overline{1,l_q}$, dimensionality $l_q\times 1$.

To the set of state vectors $X(k)=\bigcup_{q=1}^{Q}X_{1q}(k)$ may include vectors of any state variables that affect the link quality and the efficiency of the MK operation process. Main ones include:

vector of parameters of information load MK

$$\Lambda(k)=\left\|\Lambda_1(k),\ ...,\ \Lambda_q(k),\ ...,\ \Lambda_Q(k)\right\|^{T};$$

vector delays in the transmission of information messages

$$H(k)=\left\|H_1(k),\ ...,\ H_q(k),\ ...,\ H_Q(k)\right\|^{T};$$

vector of parameters of radio frequency environment in the network

$$\aleph(k)=\left\|\aleph_1(k),\ ...,\ \aleph_q(k),\ ...,\ \aleph_Q(k)\right\|^{T};$$

vector of frequency resources of the network

$$\Im(k)=\left\|\Im_1(k),\ ...,\ \Im_q(k),\ ...,\ \Im_Q(k)\right\|^{T};$$

vector of energy network resources

$$\Re(k)=\left\|\Re_1(k),\ ...,\ \Re_q(k),\ ...,\ \Re_Q(k)\right\|^{T};$$

hardware resource vector

$$\mathrm{A}(k)=\left\|\mathrm{A}_1(k),\ ...,\ \mathrm{A}_q(k),\ ...,\ \mathrm{A}_Q(k)\right\|^{T}$$ and etc.

Method of hierarchical control of channel and network resources of military radio communication systems, the algorithm of which is shown in fig. 2, consists of the following steps.

1. Entering the output data (action 1 on fig. 2). Parameters of the radio communication system $\Psi=\{\psi_i\}$ are entered, as well as the value of the admissible value of the probability of erroneous reception of signals $P_{\text{error allowable}}$ and the minimum required speed of transmission of information $v_{\text{i allowable}}$ for each of the elements of the MSRC.

2. Assessment of the electronic environment in the network as a whole and for each individual radio direction (action 2 on fig. 2).

At this stage, the estimation of the radio-electronic situation is carried out on separate sections of the network – the coordinate nodes for adjacent nodes, and in the ornaments of the radios – the nodes transmitting the information using one of the known methods or with the help of the non-standard method of evaluation, developed in [7].

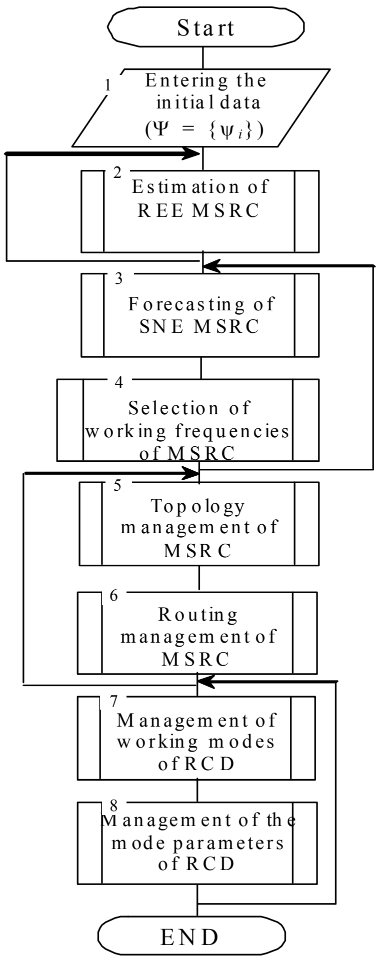

Fig. 2. Algorithm of implementing the method of managing parameters MSRC

3 rediction of the state of the radio-electronic situation of the radio communication system and for the individual radio direction of the network (action 3 on fig. 2).

At this stage, there is a prediction of the signal-interference situation for the network as a whole and for each individual radio direction of the network. Above procedure differs from those known in that it additionally contains operations [8–9]:

recirculation of input data for one count;

resampling the output process at logarithmic time scale;

finding the energy spectrum of the received signal, determining the response;

finding the entropy of the energy spectrum of the corresponding sample, which is subject to resampling;

calculation of the maximum value of entropy reviews;

finding a forecast for implementing the maximum entropy value;

reindexing the result of the forecasting on the exponential time scale.

This procedure has the following sequence of actions [9]:

1. There is an input of initial data.

2. The time compression of the process, which is predicted, is necessary for real-time signal processing. At the same time, at each step, the implementation is updated to one count. Thus, a class of implementations is formed that differ from each other by shifting by one count. For the formation of the class of discrete counters, each implementation is subjected to the logarithm and sampling operation.

Maximum value of entropy is determined according to the ratio:

$$H(f) = -\int_{-1/2}^{1/2} \ln\left(\frac{X(f)}{\int_{-1/2}^{1/2}(X(f))df}\right) df \ ,$$

where $X_n(f) = \frac{X(f)}{\int_{-1/2}^{1/2}(X(f))df}$ – normalized energy spectrum of the sample, $X(f) = \sum_{n=-\infty}^{\infty} r_{ss}(n)\exp(-2\pi fn)$, $r_{ss}(n)$ – correlation function of the process. Using the proposed procedure allows you to obtain a more accurate forecast than with other known procedures.

3. Selection of operating frequencies with accounting the strategy of radio-electronic suppression (action 4 on fig. 2).

On the basis of the scientific-methodical apparatus developed in the works [10–11], the choice of working frequencies for military radio communication equipment is carried out by analyzing the radio frequency resource during which the definition of suppressed frequency ranges, the strategy of the complexes of the radio-electronic suppression of the enemy and the continuous suppression ellipses are carried out.

On the basis of this information, there is the formation of a rational topology of MSRC.

4. Formation of the MSRC topology (action 5 on fig. 1).

Task of managing the topology of the network is to ensure the transmission of the maximum number of messages with the required quality (reliability, efficiency, reliability, etc.).

Topology determines the potential of the network to deliver data between the interacting nodes [5; 12]. Mobility (failure, packet destruction) of nodes leads to different network topology configurations. In such circumstances, changing the network topology may have a greater effect, unlike routing.

Efficient functioning of mobile self-organizing radio networks depends on the structure of its subsystems, as well as on the compliance of these structures with the conditions of the environment, first of all, the electronic environment.

Methods of the rational topology synthesis of the mobile radio network, developed up to now, mainly using source data a limited number of possible variants of the electronic environment, which are determined, as a rule, on the basis of subjective assessments of decision makers. Investigation of the entire space of decisions in determining the rational topology is usually complicated by the too much volume of necessary calculations and the impossibility of an analytic description of the target function.

In recent years, the methods of artificial intelligence have been developed, which allow with sufficient speed to find quasi-optimal solutions in systems whose target functions do not have an analytical description.

This makes it relevant to conduct research on the application of these methods for the synthesis of rational network topology values.

5. Routing management (action 6 on fig. 2).

In the indicated on the basis of the formed topology of the network and the signal-to-noise situation in the network is managing the routes of information transmission.

In the indicated procedure it is proposed to using the results that were developed in the papers [13–19].

6. Selecting the mode of operation (action 7 on fig. 2).

In order to choose the mode of operation of the REE, it is proposed to use energy and frequency efficiency of system resources utilization. These performance indicators are complex and contradictory. Boundaries between energy and frequency efficiency do not meet the requirements for changing the operating mode, therefore, to specify the rules for choosing the modes of operation of the military radio communication facilities, it is proposed to introduce an additional indicator, namely the importance of the REE.

Solving tasks that require vector optimization consists in converting certain quality criteria into a general criterion, and choosing such a solution for a task that would be the best value for a general criterion (maximum or minimum). Roll-out of partial quality criteria to the general one is carried out using a certain compromise scheme that defines a specific principle of optimality.

Consequently, there is an urgent scientific task of multicriteria optimization of the process of choosing the modes of work, taking into account their importance for increasing the efficiency of the functioning of the RCD, which can be written as

$$F_{opt} = \max F\left(Im, \beta_E, \beta_F\right),$$

where F_{opt} – optimal working mode; Im – vector of coefficients of importance REE.

In [14–18] we consider approaches to the solution of the problems of multicriteria and the choosing of alternatives in technology, using the mathematical apparatus of utility theory, therefore, it is proposed to use known approaches to solve the problem.

According to [14–18], the importance of REE indicators can be considered as a non-metric utility criterion (NUC). The main difficulty in solving the problem is the submission of the NUC in quantitative form for the purpose of its subsequent introduction into the function of utility (FU).

As working modes, hybrid operating modes are selected based on multi-antenna systems, namely:

MIMO-OFDM (Multiple-Input Multiple-Output with Orthogonal Frequency Division Multiplexing);

MIMO-UWB (Multiple-Input Multiple-Output with Ulta wideband signal);

MIMO-FHSS (Multiple-Input Multiple-Output with Frequency-Hopping Spread Spectrum).

Numerical non-metric partial utility criteria (NPUC) that characterize the mode of operation are defined in order to represent the NUC quantitatively. In accordance with [14–18], the main NPUC are the frequency efficiency of RCD (β_F); energy efficiency of RCD (β_E); the degree of using of radio frequency resource by means of the REW (X_{REW}). Let's introduce the main NPUC with quantitative characteristics (table 1).

Table 1

NPUC	Quantitative characteristics	Areas of changing of input indicators	Indicators taken into account when determining the importance REE
β_E	Energy efficiency of RCD	0,1-0,4	MIMO-OFDM
		0,41-0,79	MIMO-UWB
		0,8-1,0	MIMO-FHSS
β_F	Frequency efficiency	0,8-1,0	MIMO-OFDM
		0,41-0,79	MIMO-UWB
		0,1-0,4	MIMO-FHSS
X_{REW}	Degree of using of radio frequency resources by the REW devices	0,1-0,8	Obstacles in the part of the lane
		0,81-1	Obstacle obstacles
k	Importance of the information	0,1-0,4	Low
		0,41-0,79	Medium
		0,8-1,0	High

In the general case, the theory of expert evaluation is used to quantify the non-metric criteria. The main reason for this is the absence of another general method of transforming nonmetric criteria into numerical values [14–18].

7. Select the signal parameters for the operating mode (action 8 on fig. 2).

After conducting an estimation of the influence of deliberate interferences and silence of the signal for each mode, a choosing of rational values of the signal parameters is made, where, by devices of the performed mathematical modeling, the initial input of the parameters of the RCD and the communication channel is carried out, the choosing of rational parameter values for each mode, as this is stated in works [20].

If the communication channel status is matched to parameters satisfying the type of information that is transmitted over the communication channel, the packet is transmitted, if not, the packet is transmitted and the current status of the communication channel is communicated to correct the choice of the operating mode of the RCD , which will reduce the time taken to decide on the feasibility of using the mode of operation.

Conclusion

In the article, the method of hierarchical control of channel and network resources of military radio communication systems is developed.

The difference between the above mentioned methodology and the known ones is the integrated management of channel and network resources of military radiocommunication systems.

Technique allows to increase the efficiency of the systems of radio communication with the possibility of self-organizing, functioning in a complex electronic environment.

The direction of further research should be considered the development of methods and methods for assessing the parameters of military radiocommunication systems.

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Надійшла до редколегії 3.11.2017
Схвалена до друку 7.12.2017

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МЕТОДИКА ІЄРАРХІЧНОГО УПРАВЛІННЯ КАНАЛЬНИМИ ТА МЕРЕЖЕВИМИ РЕСУРСАМИ СИСТЕМ ВІЙСЬКОВОГО РАДІОЗВЯЗКУ

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Досвід проведення антитерористичної операції на території Донецької та Луганської областей свідчить, що існуючий порядок управління системами військового радіозв'язку не задовольняє сучасним вимогам, що висуваються до них. Класичний централізований підхід до управління канальними та мережевими ресурсами систем військового радіозвязку не відповідає вимогам сучасності, тому авторами зазначеної статті запропоновано в якості базового принципу побудови взяти мобільні самоорганізуючі мережі класу MANET. Авторами запропоновано методику ієрархічного управління канальними та мережевими ресурсами систем військового радіозв'язку, сутність якої полягає в забезпеченні підтримки заданих значень показників функціонування систем військового радіозв'язку на належному рівні. Під канальними та мережевими ресурсами будемо розуміти радіоресурс мережі, її топологію, порядок побудови та підтримки маршрутів. В статті за основу взятий принцип управління, що описаний в еталонній мережевій моделі взаємодії відкритих систем OSI, проте з деякими доповненнями та змінами. Зазначений підхід в цілому дозволяє здійснювати наскрізне управління канальними та мережевими ресурсами систем військового радіозв'язку в складній радіоелектронній обста-

новці. В зазначеній статті використаний апарат нечіткої логіки, нейронних мереж, теорії завадозахищеності, теорії антен, завадостійкого кодування та ін. Практична значимість зазначеного дослідження полягає в тому, що отриманий науковий результат дозволить провести розробку нової та здійснити модернізацію існуючої техніки зв'язку, тим самим підвищити ефективність використання радіо ресурсу, оперативність управління мережевими та канальними ресурсами систем військового радіозв'язку, зменшити кількість службової інформації, що циркулює в мережі військового радіозв'язку, формувати раціональну топологію систем військового радіозв'язку, формувати та підтримувати раціональну кількість маршрутів передачі інформації, з урахуванням зон суцільного радіоелектронного подавлення, а також розподілити робочі частоти між вузлами мережі з урахуванням радіоелектронного подавлення окремих частот (груп частот) та ступеня використання робочих частот іншими вузлами мережі.

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

МЕТОДИКА ИЕРАРХИЧЕСКОГО УПРАВЛЕНИЯ КАНАЛЬНЫМИ И СЕТЕВЫМИ РЕСУРСАМИ СИСТЕМ ВОЕННОЙ РАДИОСВЯЗИ

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Опыт проведения антитеррористической операции на территории Донецкой и Луганской областей свидетельствует, что существующий порядок управления системами военной радиосвязи не удовлетворяет современным требованиям, предъявляемым к ним. Классический централизованный подход к управлению канальными и сетевыми ресурсами систем военной радиосвязи не соответствует требованиям современности, поэтому авторами указанной статьи предложен, в качестве базового принципа построения, использовать мобильные самоорганизующиеся сети класса MANET. Авторами предложена методика иерархического управления канальными и сетевыми ресурсами систем военной радиосвязи, сущность которой заключается в обеспечении поддержания заданных значений показателей функционирования систем военной радиосвязи на должном уровне. Под канальными и сетевыми ресурсами будем понимать радиоресурс сети, её топологию, порядок построения и поддержания маршрутов. В статье за основу взят принцип управления, описанный в эталонной сетевой модели взаимодействия открытых систем OSI, однако с некоторыми дополнениями и изменениями. Указанный подход в целом позволяет осуществлять сквозное управление канальными и сетевыми ресурсами систем военной радиосвязи в сложной радиоэлектронной обстановке. В указанной статье использован аппарат нечеткой логики, нейронных сетей, теории помехозащищенности, теории антенн, помехоустойчивого кодирования и др. Практическая значимость указанного исследования заключается в том, что полученный научный результат позволит провести разработку новой и осуществить модернизацию существующей техники связи, тем самым повысив эффективность использования радио ресурса, оперативности управления сетевыми и канальными ресурсами систем военной радиосвязи, уменьшить количество служебной информации, циркулирующей в сети военной радиосвязи, сформировать рациональную топологию систем военной радиосвязи, формировать и поддерживать рациональную количество маршрутов передачи информации, с учетом зон сплошного радиоэлектронного подавления, а также распределить рабочие частоты между узлами сети с учетом радиоэлектронного подавления отдельных частот (групп частот) и степени использования рабочих частот другими узлами сети.

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