Introduction

Formulation of the problem. The influence on the system of control of military units and weapons by conducting electronic warfare (EW) is an integral part of modern confrontation of any scale. Accordingly, an important direction in modern conflicts is the confrontation of radio-electronic systems. Against the background of the rapid development and implementation of modern information technologies, automated systems, and global telecommunication networks in all spheres of society, a set of fundamentally new problems arose in the field of protecting the radio communication system of troops (forces) from the enemy's radio-electronic influence.

Modern complexes (means) of radio-electronic intelligence and radio suppression have characteristics that allow performing tasks of radio suppression and intelligence while remaining undetectable. The task of ensuring the necessary indicators of immunity, namely, immunity and immunity of the radio communication system in such conditions is the main task in the organization of the radio communication system.

The experience of performing service and combat tasks (SCT) during the Joint Forces Operation (JFO) showed that standard radio equipment, which is in the service of troops (forces), is not capable of providing protection against the influence of enemy radio suppression and radio reconnaissance in conditions of direct confrontation [1-2]. The analysis of possible means and methods of ensuring the jamming protection of radio equipment showed that, under today's conditions, it is possible only thanks to the use of the energy method of countering the means of radio suppression and the enemy's Electronic signals intelligence (ESI)).

Analysis of recent research and publications. [1-2] provides an analysis of the experience of operating regular radio equipment under the influence of the enemy's radio suppression and radio reconnaissance
equipment. In the works of M. Orlov, an analysis of the existing operational-tactical level management system and the influence of the communication subsystem on its indicators is given [3–4]. In [5], the theoretical foundations of radio-electronic warfare are given. In the works of scientists O. Iokhov and S. Herasimov, the task of optimizing the functioning of active and passive radio cloaking means in the conditions of the enemy’s radio reconnaissance is given.

The purpose of the article is to analyze the process of optimization of the parameters of radio exchange under the influence of intentional interference.

Main material

In the task of protecting radio communication systems from intentional interference, the main task is to ensure interference-resistant radio communication on a larger area of deployment of its troops (forces). So, as a criterion for the effectiveness of the method of increasing the stability of radio communication of security and defense forces, it is possible to take the objective function, according to which it is necessary to find the maximum ratio between the areas of interference-resistant radio exchange with and without the involvement of protective measures [3–4]:

$$\text{max}[F(X) = S_2(X)/S_0(X)], X \in D,$$  \hspace{1cm} (1)

$$X$$ – is the vector of parameters providing the maximum value of the optimality criterion;

$$D$$ – area of permissible values of elements of the vector $$X$$;

$$S_2$$ – area of interference-resistant radio exchange with protection;

$$S_0$$ – area of interference-resistant exchange without protection.

The result of solving the problem (1) is significantly influenced by a number of parameters of means of radio-electronic influence (number of sources of interference, their power, location relative to the transmitter of the useful signal, etc.).

Limited operational space, especially when tasks are performed by tactical units of military formations in urban conditions, requires accurate definition of the boundaries of the interference-resistant radio exchange zone.

The ratio of interference power and signal under the conditions of radio-electronic countermeasures to the information transmission system is

$$K_n = \frac{P_2}{P_c} = \frac{P_{\text{prod}}G_{\text{prod}}G_{\text{prod}}\eta_2R_c^2}{P_{\text{prod}}G_{\text{prod}}G_{\text{prod}}\eta_2R_c^2},$$  \hspace{1cm} (2)

which makes it possible to calculate the suppression coefficient at each individual point of the operative space.

An analytical approach to solving a separate problem of determining the boundaries of the interference-resistant radio exchange zone is demonstrated in [5, p. 108]. In the case of a single source of interference without protection of the means of radio exchange of a unit of troops (forces), from ratio (2) it is possible to obtain (Fig. 1):

$$R_s = R_c\sqrt{\frac{P_{\text{prod}}G_{\text{prod}}G_{\text{prod}}\eta_2}{P_{\text{prod}}G_{\text{prod}}G_{\text{prod}}K_n}},$$  \hspace{1cm} (3)

$$R_s = R_c\sqrt{\frac{P_{\text{prod}}}{P_{\text{prod}}K_n}} = R_c\sqrt{\beta}.$$  \hspace{1cm} (4)

If we have $$\beta < 1$$, so when the energy potential of the interference station is small, the suppression zone of the radio electronic means of the unit of troops (forces) is a circle with a radius of

$$R = R_{c-\beta} = \frac{\beta}{1-\beta^2},$$  \hspace{1cm} (4)

Fig. 1. Partial task of calculating the interference-resistant radio communication zone command point
Source: developed by the authors.
$R_{c,-}$ is the distance between signal transmitters and interference, the center of the suppression zone is $1 < \beta$ shifted in the direction of $R_{\beta}$, the base line that unites the signal transmitters and interference to the side of the command point (Fig. 1, circle on the right). At $\beta > 1$, when the energy potential of the interference transmitter exceeds the power of the command point signal transmitter, the suppression zone occupies the entire plane, excluding the reach zone - a circle with a radius of

$$R = R_{c,-} \frac{\beta}{\beta^2 - 1} \quad (5)$$

The disadvantages of the classic method of determining the zone of suppression of radio communication

**Disadvantages**

- Limitation on the number of interference sources
- Impossibility to consider the mutual location of objects
- Does not take into account the shape of the directional diagrams of antennas
- Determines the shape of the zone in the form of a circle

**Ways of improvement**

- Determination of the formalized criterion of the optimality of the functioning of means of protection against intentional interference
- Improvement of the simulation model under conditions of radio suppression
- Development of a method for determining the maximum size of the zone of stable radio communications

Taking into account the listed factors leads to the fact that, in the general case, the shape of the reach zone ceases to be a regular circle, and this method cannot be applied in the conditions of a real interference situation.

The leader must take into account the shapes of the zones and have data for the optimal orientation of radio equipment when planning operations, especially when operating in a limited operational space, where the distances are tens and hundreds of meters.

This will allow the manager to determine possible options for the location of radio equipment, taking into account the characteristics of the area. Therefore, in order to increase the stability of radio reception in the radio communication networks of military units (forces), it is necessary to develop a method for determining areas of interference-resistant radio communication, taking into account the directional diagrams of hidden mobile directional antenna devices.

The process of optimizing the parameters of radio communications in the conditions of changing interference conditions is the process of accumulating and using information in the radio communication system, aimed at ensuring the immunity of radio communications, usually when reaching the optimal state of operation in the face of initial uncertainty and changing interference conditions.

During optimization, the parameters of the radio equipment and the structure of the radio communication system, the functioning algorithm, control actions, etc. may change.

Optimizing the parameters of the means of radio exchange in the conditions of a change in the interference situation is used in those cases when the factors of radio suppression and radio electronic intelligence of the enemy on means of radio communication are completely or partially unknown.

Let us consider the formulation of the problem of optimal protection of the radio communication network
under the conditions of operation of the enemy’s ground, mobile, or air means of radio-electronic intelligence [6]. Therefore, it is necessary to solve the task of complex radio masking in the conditions of action of tactical mobile and aerial means of radio-electronic reconnaissance of the enemy.

In the task of optimizing the complex radio masking system, it is necessary to distinguish two interrelated components: optimization of parameters of radio masking means and optimal placement of these means.

It should also be taken into account that the effectiveness of solving the problem of optimal setting of the parameters of the active radio masking jamming system elements for a defined plan of their placement depends on:
- directional diagrams orientations of antenna devices of means of radio exchange;
- power of radio communication transmitters;
- forms of directional diagrams antenna devices interfere with active radio masking.

Conclusions

In a real operational situation, the ability to control the power of transmitters and the shape of the directional patterns of a radio electronic device used in jamming active radio masking is limited.

Therefore, the best implementation of the task of active radio masking for effective combating the enemy's mobile and aerial means of radio electronic intelligence will be considered to be the selection of optimal sets of azimuth angles and the location of obstacles of active radio masking, such that ensure the minimum impact on the operation of the radio communication network between units of troops (forces) and at the same time – maximum suppression of the useful signal at the points of the trajectory of the enemy's radio electronic intelligence.

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АНАЛІЗ ПРОЦЕСУ ОПТИМІЗАЦІЇ ПАРАМЕТРІВ ЗАСОБІВ РАДІООБМІNU В УМОВАХ ВПЛИВУ НАВМИСНИХ ЗАВАД

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В статті наведено аналіз задачі захисту систем радіозв'язку від навмисних завад. Головним завданням є забезпечення завадостійкого радіозв'язку на більшій площі розміщення своїх військ (сил).

Вплив на систему управління військовими підрозділами та озброєння шляхом ведення радіоелектронної боротьби є невід'ємною частиною сучасного протистрійства будь-якого масштабу. Відповідно важливим напрямом у сучасних конфліктах є противодія радіоелектронним системам. На фоні бурхливого розвитку та втілення у всі сфери діяльності суспільства сучасних інформаційних технологій, автоматизованих систем, глобальних телекомунікаційних мереж виникає значна суккупність принципово нових проблем у галузі захисту систем радіозв'язку військ (сил) від радіоелектронного впливу противника.

Сучасні комплекси (zasoby) радіоелектронної розвідки та радіопридушення мають характеристики, які дозволяють виконувати завдання з радіопридушення та розвідки залишатися непомітними. Завдання забезпечення необхідних показників завадозахищеності, а саме, завадостійкості та розвідзахищеності системи радіозв'язку в таких умовах є головним завданням при організації системи радіозв'язку.

У реальній оперативній обстановці можливості управління потужністю передавачів і формою діаграми спрямованості радіоелектронного засобу, що застосовуються у завадах активного радіомаскування, є обмеженими. Тому, найкраще виконання завдань активного радіомаскування для ефективної боротьби з мобільними та повітряними засобами радіоелектронної розвідки, вирішувати завдання активного радіомаскування, таких, що забезпечують мінімальний вплив на роботу мережі радіозв'язку між підрозділами військ (cils) та одночасно максимально придушення корисного сигналу у точках траєкторії засобів радіоелектронної розвідки противника.

Ключові слова: завадозахищеність; захист систем радіозв'язку радіоелектронна боротьба; навмисні завади.