The Central Research Institute
of the Armed Forces of Ukraine

Military Science. Vol. 1 No. 1 (2023)

DOI: 10.62524/msj.2023.1.1.11

An approach to assessing the impact of radio interference on the means of radio technical and artillery radar reconnaissance in operations (combat actions) of troops (forces)

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Abstract. The article discusses one of the approaches to taking into account the influence of radio interference during radio engineering and artillery radar reconnaissance in the mathematical model of the operation (combat operations) of troops (forces). An assessment of opportunities has been carried out and directions for the practical implementation of these issues have been determined. The relevance of the topic is due to the need to improve (develop) tools for calculating (modeling) operations (combat operations), taking into account the impact of radio interference on the means of radio engineering and artillery radar reconnaissance. It is established that to date, taking into account the conduct of radio and artillery radar reconnaissance by means of radio interference during the simulation of operations (combat operations) occupies an important place in the practical activities of headquarters at all levels (strategic, operational and tactical) when playing out options (plans) at the stages of preparation and planning of the use of the Armed Forces (Semenenko, Kirsanov, Mashkin, Pravdyvets, Petrozhalko, 2022). The analysis showed the lack of a unified approach to mathematical modeling of operations (combat operations), taking into account the capabilities of radio engineering and artillery radar reconnaissance in the conditions of radio interference in general. And the issues of assessing such an impact on the course and results of operations (combat operations) of troops (forces) do not have a practical content (contribution) at the stages of playing out options (plans). In addition, some of the existing mathematical models allow for typical calculations for specific types samples of weapons (means) for radio engineering purposes (support) or specific tasks for electronic warfare and reconnaissance support with the participation of existing means and complexes, which significantly limits the research (accounting) of both individual means and the system as a whole, in order to form requirements for promising samples. The aim of the article is to

consider the approach to taking into account the influence of radio interference on the means of radio engineering and artillery radar reconnaissance in the mathematical model of the operation (combat operations) of troops (forces). Assessment of opportunities and determination of directions for practical implementation of these issues. The article discusses the solution of the issues of modular integration of mathematical calculations (expressions) of the radio-electronic situation (radio intelligence, radio communication, radio interference) into the simulation mathematical model of operations (combat operations), the exclusion of logical incidents of the iterative approach in simulation models and the sequence of calculations in the interaction of modules. The practical results of the implementation of these issues on the basis of the mathematical model of the operation (combat operations) are presented, the analysis of the possibilities and significance of such implementation as an element of improvement. It is also found that the obtained result clarifies the model time of the operation (combat operations) of the grouping of troops (forces), which makes it possible to analyze in detail the contribution of each module in stages, details the simulation of the operation (combat operations), increases the reliability of the modeling results, allows to assess the impact of radio interference during radio engineering and artillery radar reconnaissance on the basis of a mathematical model of operations (combat operations) both by partial indicators (range reconnaissance, probability of detection, secrecy, survivability, etc.), and in terms of effectiveness for the entire grouping of troops (losses of the parties, combat potential, depth of the offensive).

Keywords: mathematical model, radio interference, electronic intelligence, artillery radar reconnaissance.

Introduction

An overview of the work of military authorities, especially during the war in Ukraine, formulated acute problems in making calculations and taking into account the impact of radio interference on certain variants of operation (combat operations) scenarios. In particular, during the planning and practical conduct of electronic intelligence, artillery radar reconnaissance, proposals are developed, as a rule, based on experience, sometimes even on intuition, and in some cases, approximate express calculations are carried out (Semenenko, Marko, Chernyshova, Koverga, Pekuliak, 2021). In addition, the issues of taking into account radio interference to such means both on their own side and on the side of the enemy are taken into account conditionally at the level of generalized coefficients.

Currently, the preparation and planning of operations (combat operations) in the Armed Forces is limited to the use of a mathematical model of the operation (combat operations), other calculation tasks (programs) at the level of calculating the ratio of the sides and further forecasting of possible losses, respectively. However, the issue of calculating support, especially radio engineering, and even in conditions of active radio interference, is advisory in nature, and the correct assessment of such an impact in terms of the effectiveness of the grouping of troops (losses of the parties, combat potential, depth of the offensive, etc.) is difficult. Therefore, taking into account the impact of radio interference on the means of radio engineering and artillery radar reconnaissance in the simulation of operations (combat operations) occupies an important place in the practical activities of headquarters when playing out options (plans) at the stages of preparation and planning of the use of the armed forces (Korniychuk, 2020), (Theses of reports, 2018), (Pushkov, 2021).

Analysis (Semenenko, Pavlovskyi, Solomitsky, Zvarych, Skurinevska, 2020), (Sova, Shyshatskyi, Ostapchuk, Trotsko, Pylypchuk, 2022), (Semenenko , Mashkin, Onofriichuk, Paiuk, Cherevatyi, 2021) indicates the lack of a unified approach to the mathematical modeling of operations (combat operations) taking into account the capabilities of radio engineering and artillery radar reconnaissance in the face of radio interference in general. The issues of assessing such an impact on the course and results of operations (combat operations) of troops (forces) according to the indicators

of the effectiveness of the grouping of troops (losses of the parties, combat potential, depth of the offensive, etc.) do not have a practical content (contribution) at the stages of playing out options (plans). Most of the sources describe the rules, approaches, methods, practical options for the implementation and application of a particular direction, with appropriate recommendations, for example, the calculation of electronic warfare zones, reconnaissance zones, artillery and electronic reconnaissance capabilities, etc. Other publications describe in detail the calculation of the ratios of the opposing sides, the simulation of combat operations (operations) without taking into account the calculations of the capabilities and results of the work of radio engineering and artillery radar reconnaissance in conditions of radio interference, or such consideration is carried out at the level of separate, veryclose (conditional) coefficients (Semenenko, Khomchak, Kirsanov, Dobrovolskyi, Shyhyda, 2021), (Butvin, Mashkin, Sobolev, Open'ko, Maslenko, 2022), (Semenenko, Mashkin, Onofriichuk, Paiuk, Cherevatyi, 2021).

Thus, the conditions of modern armed struggle (confrontation) are characterized by the widespread use of new radio-technical weapons (Romanchenko, Zagorka, Butenko, Deyneha, 2019) and difficult conditions of the radio-electronic situation (radio intelligence, radio communications, radio interference), and the rational application and further assessment of such actions require appropriate calculations. At the same time, due to the lack of a unified approach to the mathematical modeling of operations (combat operations). Taking into account the capabilities of electronic and artillery reconnaissance in the conditions of radio interference at the level of mathematical (simulation) models, the quality of justification of decisions on plans (plans) of the Armed Forces headquarters of all levels (strategic, operational and tactical) may decrease.

Thus, consideration of the issues of taking into account the impact of radio interference on the means of radio engineering and artillery radar reconnaissance in the mathematical model of the operation (combat operations) of troops (forces) is relevant and necessary and requires tools for calculations (modeling) of improvement (development).

Methodological Framework

The use of analytical modeling methods in existing mathematical models makes it possible to carry out typical calculations for specific types of weapons (means) for radio technical purposes (support) or specific tasks for electronic warfare and reconnaissance support with the participation of existing means and complexes (Ermak, 2019). However, the use of such research methods does not make it possible to form (specify) requirements for further improvement of such means (complexes, systems) or options for their use on the battlefield (in operation).

In general, in the study of the issue of approaches to taking into account the impact of radio interference during radio engineering and artillery radar reconnaissance in the mathematical model of the operation (combat operations) of troops (forces), the methods of the theory of simulation modeling were also used - during calculations (mathematical modeling) of operations (combat operations) of troops (forces) taking into account the relevant electronic situation and methods of operations research - in the formalization of the assessment of impact calculations radio interference during radio engineering and artillery radar reconnaissance on the basis of a mathematical model of operations (combat operations) both in terms of partial indicators and in terms of effectiveness for the entire grouping of troops (forces) (losses of the parties, combat potential, depth of the offensive, etc.).

Results and Discussions

The peculiarity of the armed struggle today is the use of a number of high-tech new radio equipment for both reconnaissance and electronic warfare. Neglect of the capabilities of the latter in the calculations or their conditional declaration leads to the disclosure to the enemy of their positions, places of redeployment, loss of communication, incorrect assessment of the situation, losses of

military equipment and manpower. The use of unmanned aerial vehicles for electronic reconnaissance, jamming, and fire strikes are everyday occurrences in modern warfare and international conflicts, and the development of new models for creating radio interference is one of the first points in the development (rearmament) programs of modern armed forces.

Thus, the issue of special calculations during the planning and conduct of radio engineering and artillery radar reconnaissance in conditions of active radio interference is very acute for the headquarters of the armed forces. In addition, their solution requires a significant number of calculations of the radio-electronic situation in a certain operational zone (battlefield) (Menshakov, 2008), (Movchan, Brazhnikova, Bogucharsky, 2018).

An accessible and sufficient way to solve this problem is the modular integration of mathematical expressions of calculations of the radio-electronic situation (radio intelligence, radio communications, radio interference) into the simulation mathematical model of operations (combat operations) (Osinovy, Subach, Bykov, Kolchygin, 2018). A successful combination of mathematical expressions in the general process of modeling (simulation) of an operation (battle) will allow only half to satisfy all aspects of planning and conducting radio engineering and artillery radar reconnaissance in conditions of active radio interference. As a result, the issues of excluding logical incidents of the iterative approach in simulation models (Military Standard 01.101.003, 2008), (Tyapkin, Fomin, Garin, 2011) will remain open. A separate point is the sequence of calculations and the interaction of modules. Such problematic issues are related, first of all, to the different effects of electronic warfare on objects of destruction (suppression), the degree of suppression of which depends on the interaction of the latter with other targets, as evidenced by the general formulas for suppression of receivers of radar systems of artillery reconnaissance (formula 1) and means of passive electronic intelligence (formula 2) (Romanchenko, Zagorka, Butenko, Deyneha, 2019):

$$D\ radar\ min = \sqrt[4]{\frac{P_{radar} \cdot G_{radar} \cdot \sigma_n \cdot K_n \cdot \Delta f_n \cdot D_n^2}{P_{nn} \cdot G_{nn} \cdot 4\pi \cdot \Delta F_{np} \cdot \nu_n}}\ , \quad (1)$$

where $D_{\text{radar min}}$ is the minimum range of artillery radar reconnaissance during electronic warfare, D_n is the range from the radar station to electronic warfare, P_{radar} is the radar power, P_{nn} is the power of the radio jammer, G_{nn} and G_{radar} – the gain of the antennas of the radio jammer in the direction of the radar receiver and the receiving antenna in the direction of the radar transmitter, respectively, σ_n is the effective scattering surface of the target, ΔF_{np} and $f\Delta_n$ are the bandwidth of the receiver and the jammer, respectively, is the polarization coefficient. ν_n

$$D_n = D_p \sqrt{\frac{P_{nn} \cdot G_{nn} \cdot G_{np}(\beta) \cdot \Delta F \cdot \nu_n}{P_{nc} \cdot G_{nc} \cdot G_{np} \cdot \Delta f \cdot K_n}}\ , \quad (2)$$

where D_n is the jamming range of the signals intelligence stations, D_p is the passive signal reconnaissance range of the target, P_{nc} is the power of the target radio signal transmitter, G_{nc} is the gain of the antenna of the radio signal transmitter in the direction of the radio receiver , $G_{np}(\beta)$ is the gain of the radio receiver antenna in the direction of the radio interference transmitter, G_{np} is the gain of the radio receiver antenna in the direction of the target radio signal transmitter, K_n *is* the suppression factor.

Also, in addition to the basic conditions for modeling radio interference for the mentioned systems (complexes), where each object is simultaneously subjected to different influences and calculated for each whole separately, it is also necessary to take into account the orientation of antenna systems in space (2), as well as to carry out such analysis (correction) of work at each iteration in a dynamically changing environment (Semenenko, Baranov, Shyhyda, Remez, Momot,2023).

One of the approaches to the implementation of taking into account the impact of radio interference during the implementation of radio engineering and artillery radar reconnaissance on the basis of a mathematical model of operations (combat operations) is presented in Figure 1 in the form of a flowchart.

The main feature of this implementation is the parallel integration of mathematical calculations for the implementation of reconnaissance of radio engineering (blocks 2, 4, 6, 8), artillery radar (blocks 3, 5, 7, 9) and the impact of radio interference (block 1) at the stage of selection of reconnaissance targets for further development of a decision to defeat (block 11) of these targets (solving target distribution problems) in the mathematical model of operations (combat operations). An important functional block of the stage of selection of reconnaissance targets is taking into account the capabilities of radio communication facilities (block 10), again, in conditions of radio interference (block 1).

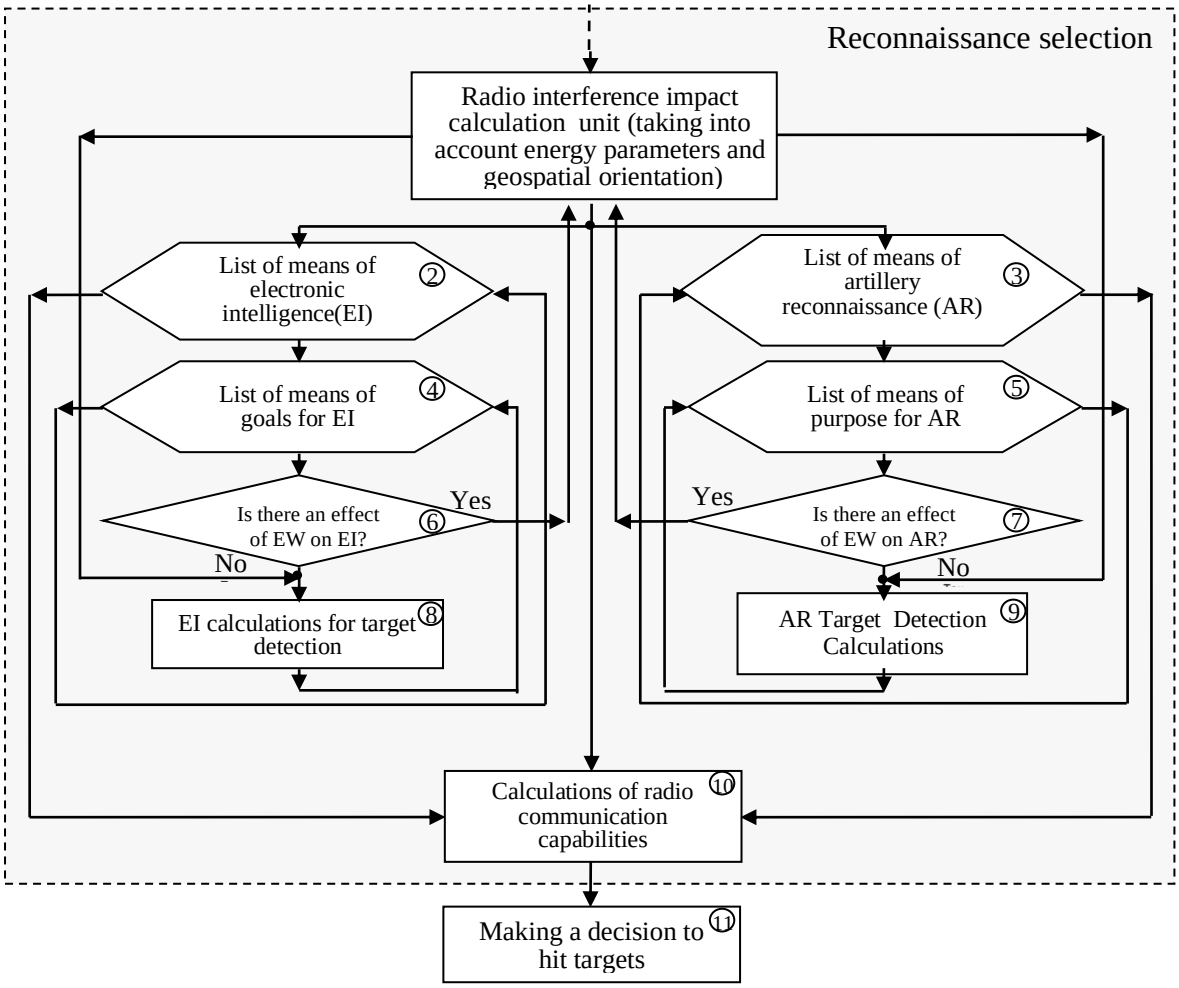


Figure 1. Block diagram of taking into account the influence of radio interference on the means of radio engineering and artillery radar reconnaissance based on a mathematical model of operations (combat operations)

The flowchart presented in Figure 1 allows to take into account all the above-mentioned features to avoid logical errors when choosing reconnaissance objects for further modeling of operations (combat operations), to calculate a single electronic situation (radio intelligence, radio communication, radio interference) and to minimize the number of iterative returns and

recalculations. In addition, the proposed flowchart makes it possible to distinguish (separate) the work of different types of reconnaissance and electronic warfare for step-by-step (separate) variants of modeling (research).

The main advantage of the issue under consideration is the combination of reasonable mathematical calculations of radio engineering and artillery radar reconnaissance in the conditions of radio interference, which excludes coefficient (approximate) approaches of their logical iterative differentiation for the formation of a single radio-electronic space (radio intelligence, radio communication, radio interference), as well as data on explored objects for a mathematical model of operations (combat operations). This approach also makes it possible to evaluate the results of modeling (impact) of the mentioned radio equipment by indicators of the effectiveness of the grouping of troops (losses of the parties, combat potential, depth of the offensive, etc.).

The practical result of the work of the flowchart shown in Figure 1 on solving the issue of taking into account the impact of radio interference on the means of radio engineering and artillery reconnaissance in the mathematical model of operations (combat operations) of troops (forces) is presented in Figure 2.

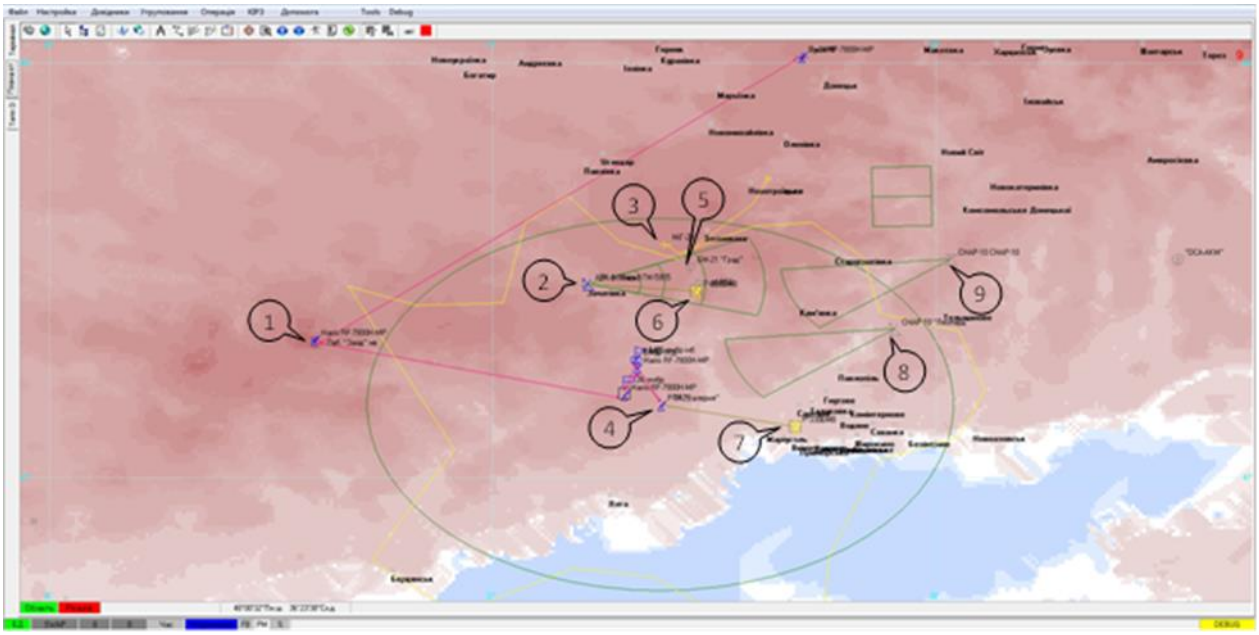


Figure 2. Taking into account the influence of radio interference on the means of radio engineering and artillery radar reconnaissance on the basis of a mathematical model of operations (combat operations)

Figure 2 shows that the artillery reconnaissance station (mark 2) is under the influence of electronic warfare (mark 6), which makes it impossible to reconnoiter the multiple launch rocket system (mark 5). In addition, the passive signals intelligence station (mark 4) has a circular area of responsibility, but is under the influence of electronic warfare (mark 7), which makes it impossible to detect the enemy's radar station (mark 8). It should be noted that at the same time, active electronic warfare (marks 6, 7) and an aircraft with an active reconnaissance radar station (mark 3) are detected under these simulation conditions. Also, data on the enemy's reconnaissance objects, provided that they are not suppressed, are transmitted via the displayed communication channels to the command post (mark 1), after which the reconnaissance objects are highlighted in the color of the enemy and fall into the array of targets for destruction (destruction).

Such an analysis of the radio-electronic situation, the state of reconnaissance of enemy objects is repeated at each step of the simulation. This makes it possible to detail the simulation of the operation (combat operations), to increase the reliability of the simulation results, to evaluate the calculation of the impact of radio interference during the conduct of radio engineering and artillery radar reconnaissance on the basis of a mathematical model of operations (combat operations) both in terms of partial indicators (reconnaissance range, detection probability, secrecy, survivability, etc.) and in terms of effectiveness for the entire grouping of troops (forces) (losses of the parties, combat potential, depth of the offensive, etc.). In addition, such a practical implementation will enable the headquarters at all levels to fully conduct and, most importantly, take into account the considered components at all phases of preparation and planning of the operation (combat operations) (Tyapkin, Fomin, Garin, 2011). Also, the obtained result clarifies the model time of the operation (combat operations) of the grouping of troops (forces), which allows for a detailed analysis of the contribution of each module in stages.

Conclusions

Thus, the article considers an approach to taking into account the calculations of the impact of radio interference on the means of electronic and artillery reconnaissance in the mathematical model of operations (combat operations) of troops (forces), which will improve the quality of decision-making in the headquarters of the Armed Forces of all levels (strategic, operational and tactical). The solution of these issues allows to detail the simulation of the operation (combat operations), increase the reliability of the simulation results and increase the accuracy of the simulation model operations (combat operations), as well as to assess the impact of radio interference during the implementation of radio engineering and artillery radar reconnaissance on the basis of a mathematical model of operations (combat operations) both in terms of partial indicators and in terms of effectiveness for the entire grouping of troops (forces).

Preliminary analysis of the obtained results of mathematical modeling confirms the efficiency and feasibility of the considered issues regarding the impact of radio interference on the means of radio engineering and artillery radar reconnaissance. The implementation of a unified approach to the mathematical modeling of operations (combat operations) using the parallel integration of mathematical calculations will make it possible to eliminate significant differences in the ways of formalizing the solution of individual problems used in well-known specialized methods and models, and to integrate them.

Prospect for further research is the development of mathematical modeling of operations (combat operations) of troops (forces) taking into account the issues under consideration, which will provide reasonable recommendations to the headquarters and military command and control bodies.

Recommendations

The development of mathematical modeling of operations (combat operations) of troops (forces), taking into account the calculations of the impact of electronic warfare during radio and artillery reconnaissance in the mathematical model of the operation (combat operations) of troops (forces), as a prospect for further research, will provide reasonable recommendations to the headquarters and military command and control bodies regarding the consideration of a full range of intelligence support data in the conditions of radio interference during planning and conduct operations (combat operations) of groups of troops. In addition, it will make it possible to study the use of both individual tools and the system as a whole in order to form requirements for promising samples.

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