# The estimating method of probability of radar's suppression at the position

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***Abstract***

The article presents an approach to estimating the probability of suppression of a radar station at a position as a consequence of combat use. The idea of the technique is based on the description of stochastic characteristics of the enemy's ability to expose, identify the radar at the position or in the process of maneuvering and, accordingly, the issuance of information to the means of fire (electronic) suppression.

The presented technique is analytical and is based on a simplified theoretical-game model of the conflict situation "Radar – means of reconnaissance of the enemy", provides a forecast of the probability of electronic and fire impact on the radar within certain positions. The evaluation criterion is the minimum value of the probability of suppression of the radar station by options. The convenience of the described approach is determined by its simplicity and clear logic in determining the formal consequences of the accepted hypotheses and assumptions in the formation of the forecast of the results of combat use of the radar station. The methodology is of a recommendatory nature and can be used in the work of the relevant authorities in forecasting the loss of troops.

***Key words:*** radar's suppression, estimating method, theoretical-game model.

## Introduction

The experience of combat use of radio-technical units in local wars and armed conflicts in recent decades has shown that radar stations are the primary objects of fire and radio electronic suppression.

Under such conditions, there is a threat of failure of providing consumers with radar information. A reliable forecast of the threat of radio electronic and enemy fire influence on radar stations during combat missions is an important component of the study of survivability of radio-technical units.

This fact confirms the relevance of the issue of forecasting the consequences of combat use of radar in meeting the needs of consumers in radar data and forms the need for a scientific approach to solving the problem of stochastic indicators of threat of radio electronic and fire suppression of radars as well as making recommendations to ensure radar survivability in order to meet the needs of radar data consumers.

## Material and methods

The issues of ensuring the radar survivability, in various forms, were researched in the works of Rusnak P.V. (2010), Horodnov V.P. (2001–2004), Drobakha G. A. (2004), Yermoshyn M. O. (2004), Zahorka O. M. (2011), Hohonyants S. Yu. (2015–2020), and others, who have made a significant contribution to the development of the theory of survivability.

A detailed analysis of the approaches, models and methods of assessing the survivability of

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groups of troops proposed shows that they are not fully adapted to determine stochastic indicators of the threat of radio electronic and fire suppression of radar in current conditions of use of the Armed Forces, in particular, do not fully take into account the quality of equipment and the number of feigned positions, as well as their mutual distance.

Therefore, this requires the introduction of additional hypotheses and substantiation of additional assumptions to increase the objectivity of the assessment of the probability of radar detection at the position, as well as additional consideration of the impact of radio electronic and fire suppression of the radar on the feasibility of maneuvering the reserve position while meeting the needs of radar data consumers.

That is why the existing scientific and methodological apparatus in its current form cannot be used to predict the consequences of combat use of radar in meeting the needs of radar data consumers in research but can be used as a basis for further improvement.

The purpose of this article is to describe the main provisions of the evaluation method of the probability of suppression of the radar at the position while meeting the needs of radar data consumers.

## Results and discussion

Taking into account the above factors in fixed conditions allows us to explore the possibilities of grouping forces and means of the enemy reconnaissance, their ability to perform reconnaissance tasks of fire means at the appropriate stages of action.

The physical meaning of the probability of electronic and fire impact on the radar is a numerical characteristic of the enemy's ability to expose, identify the radar at position or in the process of maneuvering and, accordingly, the issuance of information to fire (radio electronic) suppression.

That is, the degree of compliance of the consequences of the enemy's reconnaissance system with the task of obtaining intelligence necessary to make decisions on inflicting damage is considered a threat of suppression of radar by radio electronic warfare and fire and forms the need for decisions in order to ensure maneuvering and pursuing favorable conditions for performing the tasks of providing consumers with radar data by the criteria of minimum probability of suppression.

An indicator of the threat of radio electronic and fire suppression is the probability ($P_q^I$).

This indicator performs a function of the probability of detecting the radar by the reconnaissance cycle ($P_в$), the number of reconnaissance cycles ($\text{п}_\text{р}$), the number of unmasking features of a typical radar and the number of pretended and spare positions.

The presented technique is analytical and is based on a simplified theoretical-game model of the conflict situation "Radar – means of reconnaissance of the enemy", provides a forecast of the probability of radio electronic and fire impact on the radar within certain positions.

**General provisions of the method**

Step 1 – "Formation of initial data of the forces and means of reconnaissance of the enemy and grouping of radars, the distribution of their quantity by echelons of construction" is carried out using a geographic information system and determine the number of radar deployment lines *(S)* and their distance from collision lines *(L)*, radar $q$ type ($n_q$), conditions of intelligence *(K),* the quantity of unmasking signs to identify the radio technical data unit to identify typical intelligence objects ( $m_\Sigma$).

Based on the results of the formation of the initial data, a table of initial data is formed to evaluate the effectiveness of the detection of the radar group, which is given in Table. 1.

Step 2 – "Determining the ability of the enemy to detect typical unmasking signs of the radar and the average probability of their fixation by various types of reconnaissance" is to determine the probability of contact of the reconnaissance element with the radar – the object of reconnaissance.

Table 1 – Table of initial data of the deployment of the radar group

| S | 1 – *st* radar group line | | | | | | | | | | ... | S – *st* radar group line | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *q* | 1 radar type | | | 2 radar type | | | ... | *Q* radar type | | | ... | 1 radar type | | | 2 radar type | | | ... | *Q* radar type | | |
| $L_q$ (km) | $L_1$ | | | $L_2$ | | | ... | $L_Q$ | | | ... | $L_1$ | | | $L_2$ | | | ... | $\boldsymbol{L_q}$ | | |
| *K* | 1 | ... | *K* | 1 | ... | *K* | ... | 1 | ... | *K* | ... | 1 | ... | *K* | 1 | ... | *K* | ... | 1 | ... | *K* |
| *K* | $K_1$ | | | $K_2$ | | | ... | $K_Q$ | | | ... | $K_1$ | | | $K_2$ | | | ... | $K_Q$ | | |
| $n_q$ | $n_1$ | | | $n_2$ | | | ... | $n_Q$ | | | ... | $n_{pmn1}$ | | | $n_{pmn2}$ | | | ... | $n_{pmnQ}$ | | |
| $m_\Sigma$ | $m_{\Sigma 1}$ | | | $m_{\Sigma 2}$ | | | ... | $m_{\Sigma Q}$ | | | ... | $m_{\Sigma 1}$ | | | $m_{\Sigma 2}$ | | | ... | $m_{\Sigma Q}$ | | |

Each radar deployment line performs a corresponding task within its area of responsibility, and the depth (distance) of the line is compared with the detection range of unmasking signs, which is the basis for calculating the probability of contact:

$$P_k = \begin{cases} 1 - exp\left(-K\frac{D_k}{L+Vt_v}\right), L \le D_k \\ 0,\ else \end{cases} \quad (1)$$

where $D_k$ – range of detection *k* of the unmasking manifestation of the anti-aircraft missile unit (depth of tasks) by means of reconnaissance;

*L* – is the distance from the reconnaissance vehicle to the position of the radio technical missile unit;

*V* – is the speed of movement of the reconnaissance vehicle towards the radar;

$t_v$ – the average duration of the radar march to the reserve position;

*K* – coefficient that takes into account the influence of environmental conditions on the quality of intelligence.

Step 3 – "Determination of the generalized indicator of reconnaissance capabilities of intelligence means to detect the radar unit" is the calculation of the probability of detection of unmasking signs by the reconnaissance complex for reconnaissance cycles.

The average probability of detecting the *q* radar for $n_p$ reconnaissance cycles

$$P_B = 1 - \left(1 - P_k\frac{M_q}{m_{\Sigma q}}\right)^{n_p} \quad (2)$$

where $n_p$ – the quantity of reconnaissance cycles;

$M_q$ – the expectation of the quantity of detected unmasking signs of the *q* radar;

$m_{\Sigma q}$ – the quantity of detected unmasking signs which is necessary to identify the radar of the *q* type.

Step 4 "Prediction of the success of identifying the position of the radar as valid against a certain number of feigned positions"

$$P_q = \frac{1}{1+\begin{cases} \xi N_{yd}, \xi \ge 0{,}5 \\ 0, \xi \ge 0{,}5 \end{cases}} \quad (3)$$

where: $N_{yd}$ – the quantity of equipped pretended positions of a typical radar;

$\xi$ –the degree of plausibility of the equipped pretended positions of a typical radar.

The probability of electronic and fire suppression on the radar by the option of misleading the enemy has the form

$$P_q^I = P_q^{ID} P_q, q = \overline{1, Q}, \quad (4)$$

where $P_q^{ID}$ – probability of radar identification.

Step 4 "Formation of a matrix of threats of electronic and fire suppression" is a simplified theoretical-game model of the consequences of choosing the position of the radio technical unit to perform a maneuver in the form of a matrix.$|\Omega \times D|$ (table 2).

Given the uncertainty in the enemy's spatial constraints on the implementation of methods of exposing radar positions and determining clear reconnaissance tasks, the theoretical-game model of the consequences of choosing the position of *q* type radar will have the form of a time matrix and the corresponding dimension determined by the sum of reserve positions $|1 \times D|$ (table 3).

Table 2 – Theoretical-game model of the consequences of choosing the position of a typical radar

| Reconnaissance options q type radio technical unit ( $\omega$ ) | Options for misleading the enemy(d) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | … | D |
| 1 | $P_{11}^{I}$ | $P_{12}^{I}$ | $P_{13}^{I}$ | $P_{14}^{I}$ | $P_{15}^{I}$ | … | $P_{1D}^{I}$ |
| … | … | … | … | … | … | … | … |
| $\Omega$ | $P_{\Omega 1}^{I}$ | $P_{\Omega 2}^{I}$ | $P_{\Omega 3}^{I}$ | $P_{\Omega 4}^{I}$ | $P_{\Omega 5}^{I}$ | … | $P_{\Omega D}^{I}$ |

The criteria for choosing a position from the maximum is transformed into a minimum value of the probability of the threat of fire.

Step 5 "Decision taking of position for the maneuver" by criteria

$$P_{q0}^{I} = \min_{d} P_{qd}^{I}, q = \overline{1, Q}; d = \overline{1, D} \qquad (5)$$

Generalization of the results of calculations in order to select the position for the maneuver of the radio technical unit is carried out in step 6.

The indicator $P_{q0}^{I}$ satisfies the needs of the operational forecast of the risk of suppression of the radar by the enemy at the position.

Table 3 – Simplified theoretical-game model of the consequences of choosing the position of the q type radio technical unit for maneuver

| D | 1 | 2 | 3 | 4 | … | D |
|---|---|---|---|---|---|---|
| $P_{qd}^{I}$ | $P_{q1}^{I}$ | $P_{q2}^{I}$ | $P_{q3}^{I}$ | $P_{q4}^{I}$ | … | $P_{qD}^{I}$ |

The presented technique takes into account (describes) the influence of the number of characteristic unmasking features of typical radars, the number of reconnaissance cycles and the degree of plausibility of equipped feigned positions to mislead the enemy on the probability of fire on the radar and, unlike existing, sensitive to descriptions means of reconnaissance, duration and speed of the radar position on the probability of contact between the reconnaissance vehicle and the reconnaissance object, and is also based on a simplified theoretical-game model of the consequences of choosing the radio technical position of the unit to perform a maneuver.

## Conclusions

Thus, the proposed approach allows to increase the objectivity of the forecast of the probability of radar's suppression at the position and on the basis of the analysis of theoretical and game modeling to justify the choice of the position of the radio technical unit to perform a maneuver.

This approach forms the basis for determining the maneuverable methods of radar application and further substantiation of the recommendation, the practical implementation of which will increase the survivability of the radar group while meeting the needs of radar data consumers.

Thus, the improved technique is an adequate scientific tool for studying the survivability of the radar group and substantiation of recommendations for its increase when resisting the enemy air strike.

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