Methodological foundations of technical justification of indicators and criteria for evaluation the efficiency of radar complexes for detecting explosive devices with non-contact target sensors

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Abstract

Cardinal changes of the character and significant increase of the dynamics of mine warfare in modern military conflicts became a result of shifting priorities towards the use of the latest models of mines and improvised explosive devices with non-contact target sensors. Such a state of the issue raised exacerbation of the problem of countering explosive threats and the need to ensure the required level of efficiency, safety, and cost of search processes and detection of explosive devices with non-contact (electronic) target sensors. Existing technical means of search and detection of explosive devices, as a rule, mostly based on the use of active electromagnetic methods.

It is established that almost all non-contact target sensors are united by a common feature – the presence of semiconductor elements in their composition, or their transitions such as metal-oxide-metal. Specified peculiarity lies in the basis of modern means of detecting explosive devices with non-contact target sensors with the method of nonlinear radiolocation. However, the requirements for the safety of using search devices of this type in the manual version or on land vehicles still remain problematic. One way how to resolve this contradiction is to install search systems on the remote-controlled platform. In this case require an urgent need for technical justification of the requirements if the conditions and methods of their application are changing.

The methodical bases of construction of factor space for the further definition of indicators and criteria an estimation efficiency of functioning remotely controlled radar complexes of detection explosive devices with noncontact target sensors are discussed.

Key words: search and detection of explosive devices; explosive device with non-contact target sensor; nonlinear detection method; remotely controlled radiolocation complex, factor space.

Introduction

The reality of military conflicts of the late twentieth and early twenty-first centuries (Nizhalovs`kij, A. M., 1999; Zhukov, S., 1998; Ekzamenuet) has shown a significant increase in the intensity of the use of mine weapons. Anti-tank, anti-personnel mines and the rapidly growing use of improvised explosive devices pose a major threat for both the military and the civilian population of countries affected by military conflicts. This fact indicates an ever-increasing increase in the conduct of ground mine warfare, which in turn exacerbates the global problem of mine action, one of the most

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important measures of which is the demining of areas and facilities.

Demining as a process may have signs of combat (operational) or humanitarian nature (Svirskyi, S., 2003). Significant excess of the pace of development and intensity of use of mines (Salamaxin, T. M., 1983; Zhukov, N. K., 1990) in comparison with the means of demining determine the urgency of the problem of ensuring the required level of their technical excellence. New explosive detection devices (systems) developed in recent decades, based on various physical principles (Tursunxodzhaev, X. A., 2002; Grinev, A. Y., 2005; LANDMARC), significantly outperform standard metal detectors in the armies all of the world (LANDMARC).

At the same time, the growing share of the use of explosive devices with non-contact target sensors indicates an exacerbation of the need for in-depth study of the development of search and detection of explosive devices of this type. Herewith is a special requirement to ensure the required level of quality of the exploration process, to reduce to a minimum the level of explosive threats and to reduce the cost of demining works.

The method of nonlinear radar has a number of advantages in the search and detection of explosive devices with non-contact target sensors. Systems that use this method in combination with other system combine the advantages of different ranges of electromagnetic waves. They take into account the different physical properties of search objects, shelters, and have the greatest potential. At the stage of creating a promising model of a technical system for searching and detecting explosive devices with non-contact target sensors installed in the ground and near its surface, the technical requirements for this system must be formulated.

Material and methods

Analysis of previous studies by both foreign and domestic researchers has shown that the issue of subsurface location of anomalies has received much attention. Moreover, the most effective in the detection of explosive devices showed radar methods. However, the most expedient method of search and detection of explosive devices with non-contact target sensors is the method of nonlinear radiolocation.

The essence of this method is that some objects or their elements when irradiated with an electromagnetic wave have the ability to generate spectral components that are absent in the spectrum of the flux of the incident electromagnetic wave. Selective reception of these components allows expanding the capabilities of nonlinear radar stations in comparison with conventional stations that use a linearly reflected signal.

Analysis of the development of means (complexes, systems) of reconnaissance and demining showed a clear tendency to use unmanned and robotic systems to perform tasks of search, detection and destruction of explosive devices.

Along with this, previous studies have not taken into account the probabilistic indicators and requirements of guidance documents on the quality of demining (IMAS, 2001) and absence of comprehensive approach of justifying tactical and technical requirements for remote-controlled radar detection of explosive devices with non-contact target sensors.

The purpose of the article is to highlight the methodological basis of technical justification of indicators and criteria for evaluating the effectiveness of remote-controlled radar detection of explosive devices with non-contact target sensors.

Results and discussion

Analysis of available materials and research on the creation of tools (complexes, systems) for search and detection of explosive devices of previous years allow us to formulate the basic properties of them, which are crucial for their conceptual image.

These means (complexes, systems) of search and detection have many heterogeneous properties that can be manifested in their creation and operation. They are determined mainly by their purpose, principle of operation and conditions of use in performing tasks. The properties of the means (complexes, systems) of search and detection of explosive devices with non-contact sensors targets can include: productivity, maneuverability, transportability, survivability (stability), versatility, adaptability, autonomy, reliability, ergonomics and economy (Mashiny, 1986).

The process of search and detection of explosive devices with non-contact target sensors as a set of electromagnetic, mechanical, electrical, and other phenomenon belongs to a class of complex systems characterized by a significant number of interrelated factors.

To determine the indicators and criteria for evaluating the effectiveness of remote-controlled radar detection systems for the detection of explosive devices with non-contact target sensors, the following method of constructing factor space is proposed (figure 1).

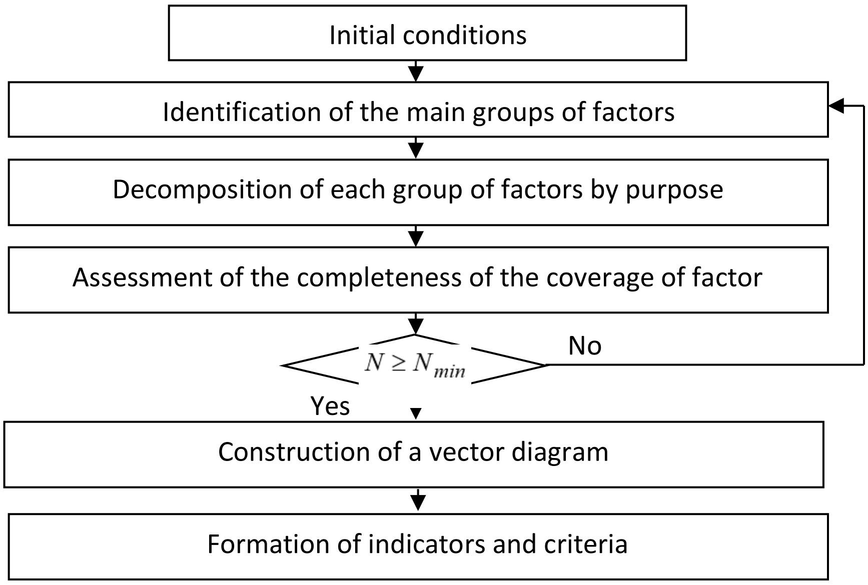

Figure 1 – Method of constructing factor space

To study the process of search and detection of explosive devices with non-contact target sensors, it is advisable to use experimental and statistical research methods. In the course of research, real processes are considered as probabilistic processes, and the object of study is represented as a cybernetic system (black box), which is studied using mathematical planning of the experiment (Vajnberg, D., 1979).

The analysis of factors that can have a significant impact on the search and detection of explosive devices with non-contact target sensors by the method of nonlinear radar using remote-controlled radar systems showed that in general the set of input data can be represented as a vector of action factors:

$$\overline{\mathrm{X}} = \left[\overline{\mathrm{A}}, \overline{\mathrm{B}}, \overline{\mathrm{C}}, \overline{D}, \overline{E}, \overline{H}\right] \quad (1)$$

$\overline{\mathrm{A}}$ – vector of parameters of design and technological characteristics of the search device (nonlinear radar system);

$\overline{\mathrm{B}}$ –vector of parameters of constructive and technological characteristics of the platform;

$\overline{\mathrm{C}}$ – vector of design features of the search object;

$\overline{D}$– vector of parameters of quality of preparation of a complex for performance of search;

$\overline{E}$ – vector of search technique parameters;

$\overline{H}$ – vector of environmental parameters and other conditions.

The vector of parameters of design and technological characteristics of the search device is determined by the expression:

$$\overline{\mathrm{A}} = \left[a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9, a_{10}, a_{11}, a_{12}\right] \quad (2)$$

a_1– the weight of the search device;

a_2– dimensions of the search device;

a_3– search engine power;

a_4– the operating frequency of the

transmitter of the search device;

a_5– search signal irradiation signal strength;

a_6– signal gain of the antenna system of the search device;

a_7– features of placement of transmitting and receiving antennas of the search device (jointly, spaced);

a_8– the number of receiving paths of the search device;

a_9– the sensitivity of the receiver of the search device;

a_{10}– display of results (a-on the device, b-transfer to the remote control);

a_{11}– search device control (wire, radio, standalone program, artificial intelligence);

a_{12}– anti-jam protection of search device.

Evaluating these parameters, it should first be noted that none of them can be changed by and they remain constant. In other words, the parameters of this group belong to unmanaged parameters.

Other characteristic feature of these parameters is that they can be determined with sufficient accuracy before the search and taken into account in advance, so these parameters are controlled.

However, the significance of individual parameters of the design and technological characteristics of the search device is unequal. In other words, the role of parameters of design and technological characteristics of the search device is quite large and they must be taken into account when studying the detection of explosive devices with non-contact target sensors using remotely controlled radar systems with nonlinear radar.

The vector of parameters of structural and technological characteristics of the platform is determined by the expression:

$$\overline{B} = [b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8, b_9, b_{10,} b_{11}] \quad (3)$$

b_1 – platform weight;

b_2 – dimensions of the platform;

b_3 – platform power supply;

b_4 – type of platform (air, ground, etc.);

b_5 – platform speed;

b_6 – duration of the platform;

b_7 – flight altitude of the platform;

b_8 – load capacity of the platform;

b_9 – maneuverability of the platform;

b_{10} – method of platform control (wire, radio, autonomous program, artificial intelligence);

b_{11} – anti-jam protection.

The parameters of this group belong to the uncontrolled parameters, however, they can be determined with sufficient accuracy before the search and taken into account in advance, so they are controlled.

The vector of parameters of constructive properties of search object is defined by the expression:

$$\overline{C} = [c_1, c_2, c_3, c_4, c_5, c_6] \quad (4)$$

c_1– the presence of a nonlinear element;

c_2– size (square) of the nonlinear element;

c_3– conditions of the location nonlinear element (on the surface, above the surface, under the covering medium);

c_4– the presence of shielding objects of artificial origin;

c_5– sensitivity of the object to irradiation with a high-frequency signal (operation, failure);

c_6– radius of damage when the explosive device is detonated.

Evaluating these parameters, it should be noted that none of them can be changed it's remain constant for the object of search. The parameters of this group belong to the uncontrolled parameters.

The vector of parameters of quality preparation of a complex for performance of search is considered in narrow aspect, from the point of view of direct influence on search process. Therefore, from a wide variety of parameters, the following are selected:

d_1 – State of charge of batteries, refueling;

d_2 – Efficiency of control and data transmission means;

d_3 – Timely maintenance, verification and repair of equipment and platform;

The parameter vector will be determined by the expression:

$$\overline{D} = [d_1, d_2, d_3] \quad (5)$$

These parameters can be attributed to controlled and managed parameters. Moreover, the control and management of these parameters can and should be carried out before the search, maintaining them within certain optimal limits constant d_1, d_2= const.

Search and detection of explosive devices with non-contact target sensors by the method of nonlinear radar using remotely controlled radar systems provides an opportunity to use different options for their conduct. The influence of such factors in the construction of the model of their search is estimated by the vector of parameters of the search technique:

$$\overline{E} = [e_1, e_2, \dots, e_i] \quad (6)$$

All parameters that determine the vector $\overline{E}$, controlled and managed, their installation is done before the search.

Among other external actions that affect the process of search and detection of explosive devices with non-contact target sensors using remotely controlled radar systems by nonlinear radar should be noted parameters that are virtually uncontrolled and unmanageable. These parameters are combined into a group, which is determined by the vector of environmental parameters and other conditions:

$$\overline{H} = [h_1, h_2, h_3, h_4, h_5] \quad (7)$$

h_1–Complex environmental parameter that assesses the effects of temperature, humidity, mobility, etc. of the ambient air;

h_2 – Complex parameter that evaluates the effect of temperature, humidity, thickness, permeability, etc. of the covering surface;

h_3 – Complex parameter that estimates discrete random sources of uncertainty;

h_4– Complex parameter that evaluates continuous random sources of uncertainty;

h_5 – Complex parameter that evaluates other unaccounted for perturbations.

In this case, the factors that can significantly affect the process of search and detection of explosive devices with non-contact target sensors by nonlinear radar and the use of remote-controlled radar systems can be represented as a vector diagram of a set of structural and functioning factors (figure 2).

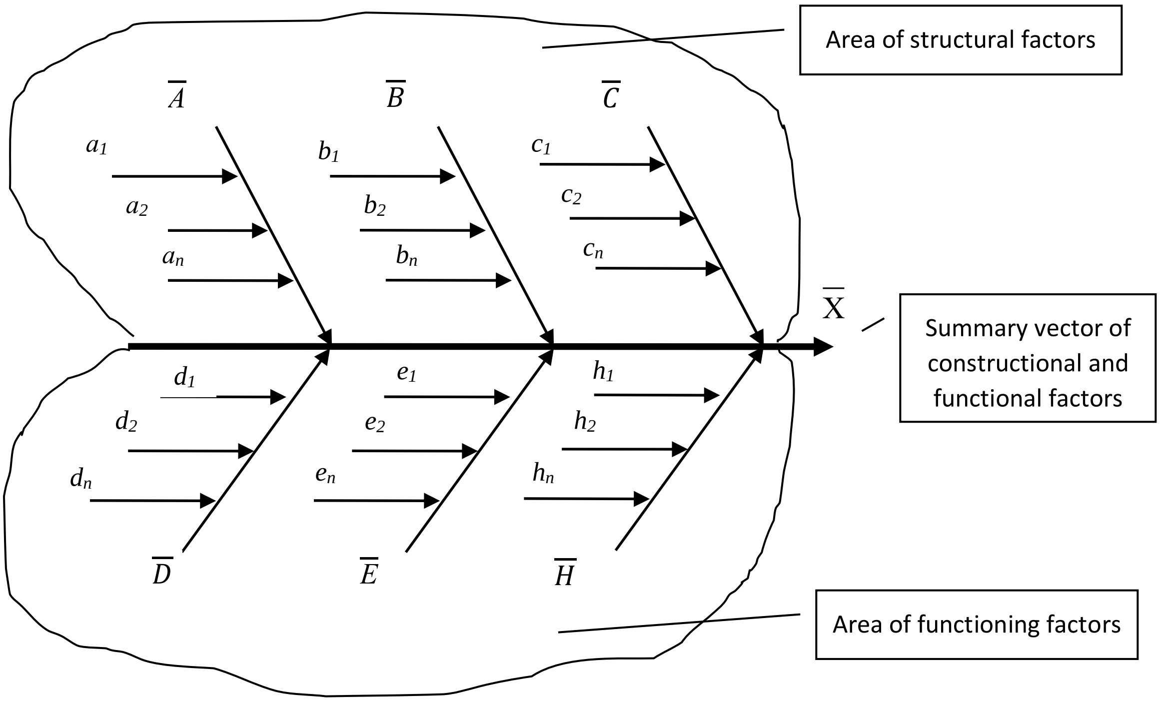

Figure 2 – Vector diagram of a set of sets of design factors and functioning factors

It is not possible to take into account the influence of absolutely all factors influencing the process of detecting explosive devices with non-contact target sensors using the method of nonlinear radar using remotely controlled radar systems.

Summarizing the results of the analysis of external actions, we can note the following. The process of detecting explosive devices with non-contact target sensors using remotely controlled radar systems by the method of nonlinear radar is a complex phenomenon with a large number of influencing factors.

A lot of interrelated factors are limitations for others. Some are managed and controlled, others are only controlled, and still others are neither controlled nor managed. The degree of controllability and controllability of some of them is different and depends on a number of conditions. It should also be noted that among the input factors are both quantitative and qualitative.

All of the above properties, which determine the conceptual image of a sample of promising remote-controlled radar systems for search and detection of explosive devices with non-contact target sensors by nonlinear radar, should be implemented by setting performance requirements that would provide certain properties. The main indicators are the following: functional; tactical; technical; constructive; temporary; ergonomic; operational.

Conclusions

The proposed technique allows forming a set of structural factors and factors of functioning and in accordance with the properties of the complex to determine the indicators and criteria for assessing the effectiveness of their functioning.

In the future, the main interest is both as theoretical and experimental studies of the operation of remote-controlled radar systems for search and detection of explosive devices with non-contact target sensors using the method of nonlinear radar. The results of the research will form the basis of the technical substantiation of the requirements to the main indicators of the functioning of these promising complexes.

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