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Determination of Requirements for the Protection of Radio-Electronic Equipment from the Terroristic Influence by Electromagnetic Radiation

Maksym Iasechko[1], Yurii Gnusov[2], Iryna Manzhai[3], Oleh Uhrovetskyi[4], Vladimir Manoylo[5], Alexander Iesipov[5], Oleksii Zaitsev[6], Maksym Volk[7], Oleksii Vovk[8]

[1]Doctoral Candidate, Ivan Kozhedub Kharkiv National Air Force University, Ukraine, maxnik8888@gmail.com

[2]Department of Information Technologies and Cybersecurity, Kharkiv National University of Internal Affairs, Ukraine, duke6969@i.ua

[3]Department of Educational, Kharkiv National University of Internal Affairs, Ukraine, ir.lily@i.ua

[4]First Deputy Director, Hon. Prof. M. S. Bokarius Kharkiv Research Institute of Forensic Examinations, Ukraine, oleg0023@i.ua

[5]Department of Tractors and Cars, Kharkiv Petro Vasylenko National Technical University of Agriculture, Ukraine vladimir.m.manoylo@gmail.com, tiaxntu@gmail.com

[6]Department of Guarding of Intellectual Property, Civil-Law Disciplines, Kharkiv National University of Internal Affairs, Ukraine, zal2007zal@ukr.net

[7]Department of Electronic computers, Kharkiv National University of Radio Electronics, Ukraine, maksym.volk@nure.ua

[8]Chief of flight department, Ivan Kozhedub Kharkiv National Air Force University, Ukraine, aponnik@ukr.net

ABSTRACT

The article draws attention to the problem of protection, ensuring survivability in the face of electromagnetic terrorism and, due to the lack of universal means of protection, the importance of developing a methodology of the justification of requirements and calculation of effectiveness of existing means of protection, taking into account the energetic capabilities of means of electromagnetic terrorism.

A generalized stochastic model and criterion for the effectiveness of the operation of radio-electronic means (REM) in the conditions of electromagnetic terrorism has been proposed. The basic calculation rations for the determination of the ways and composition of the means of protection, depending on the energy parameters of the means of electromagnetic terrorism, have been given.

The main requirements for the protection of means of protection of radio-electronic equipment of energetic objects from the terroristic influence by electromagnetic radiation have been formulated.

Key words: radio electronic means, electromagnetic radiation, ultrashort pulse duration, plasma protection technologies, gaseous plasma media, electromagnetic gas valve.

1. INTRODUCTION

This paper analyzes the problem of protection from electromagnetic terrorism associated with the influence of powerful electromagnetic radiation on REM systems for various purposes.

The lack of a universal REM protection means from powerful electromagnetic radiation and the importance of developing a methodology of the justification of requirements and calculation of effectiveness of existing means of protection, taking into account the energetic capabilities of means of electromagnetic terrorism, has been indicated.

The methodology in question is based on a generalized stochastic model of REM functioning in the conditions of electromagnetic terrorism.

The criterion for estimating the effectiveness of REM functioning under conditions of electromagnetic terrorism has been developed, namely, taking into account the stochastic model of the REM functioning process, it has been proposed to use the probability of fulfilling the task in the conditions of possible influences.

The basic calculation ratios for the determination of the ways and composition of the means of protection, depending on the energy parameters of the means of electromagnetic terrorism, have been given.

The main requirements for the protection of radio-electronic equipment of energetic objects from the terroristic influence by electromagnetic radiation have been formulated.

1.1 Problem analysis

For the time being, the solution to the problem of protection from electromagnetic terrorism is becoming increasing relevant, which is due, on the one hand, to the availability of special equipment for carrying out the electromagnetic terrorist attacks and, on the other hand, to the lack of universal means which are capable of providing one-hundred percent protection.

The distribution on this kind of special equipment is facilitated by the widespread usage of new technologies in the army and in the police. Portable generators of powerful electromagnetic radiation, the usage of which easily provides for not only stopping the criminal's car by burning all on-board electronics but also completely destroying electronic monitoring and control systems at power facilities (gas electromagnetic metering valve), security systems, communications, etc. if they fall into the hands of a criminal or a terrorist, are known [20, 22].

Taking into account the significant degree of danger of the effects of powerful electromagnetic radiation on energy supply, control, protection and many other systems, special units have been created in the special services of developed countries in order to counter such attacks. For example, in the United States, a number of governmental organizations deal with this problem, including a special department at the FBI. After a cyberattack from Iran launched in 2003 at the Israel Electric Company, a special unit was created in the Israeli internal security service SHABAK. A similar unit was created at the Atlas Science and Technology Center under the Federal Security Service of Russia [1, 19, 22, 23].

A number of means that provide a significant weakening of the effect of powerful high-frequency radiation on electronic equipment are known. Firstly, in the field of special communications, special devices have been long used in order to prevent the emission of high-frequency signals from computers and communication means on the air and into power networks to prevent leakage of important information. In the same communication systems, a motor-generator unit with a dielectric shaft connecting the motor to the generator is used for complete galvanic separation from 220 V power supply networks. The same kind of technical solutions can be used to protect electronic equipment from the penetration of high-frequency radiation from outside. In recent years, optical current and voltage transformers have appeared on the market of electric power equipment [10], which are available for all voltage classes, for example, Canadian transformers NxtPhase (www.nxtphase.com), which, along with fiber-optic lines instead of electric wires, can significantly reduce the influence of powerful electromagnetic radiation.

Nowadays, the whole industry aimed at the production of power high-frequency filters of various sizes and capacities, industrial surge protection elements and combined devices comprising high-performance filters with high-speed arresters is rapidly developing in the West. Special metal cabinets that provide the complete protection from high-frequency radiation are produced. Special conductive rubber gaskets and conductive lubricants are also created to increase the degree of protection of conventional metal cabinets.

Along with special measures that must be taken to ensure proper safety in the electric power industry, there are also long-known and trivial methods, for instance, such as reducing the impedance of ground circuits, especially at high frequencies. It is a mora balanced and cautious approach to the issue of replacing old electromechanical protection relays with new microprocessor ones.

Publications on the use of radioisotope technologies to protect REM from exposure to EMR, which are nature-like, have recently appeared [1, 6, 9, 13-19, 21, 23]. However, the use of certain means of protection, defining the concept of protection in general, require a joint consideration of means of electromagnetic influence of REM and the capabilities of the means of protection, which determines the necessities of development of an appropriate methodology of justification of requirements and calculation of effectiveness of existing means of protection, taking into account the energetic capabilities of electromagnetic means.

The aim of the paper is to develop a methodology for justification of the requirements and calculation of effectiveness of existing means of protection, taking into account the energetic capabilities of electromagnetic terrorism.

2. MAIN MATERIAL

Let's consider the approaches to defining the requirements for REM protection from EMR from a general perspective. To do this, we shall consider a generalized stochastic model for the operation of radio-electronic means (REM) in the conditions of electromagnetic terrorism.

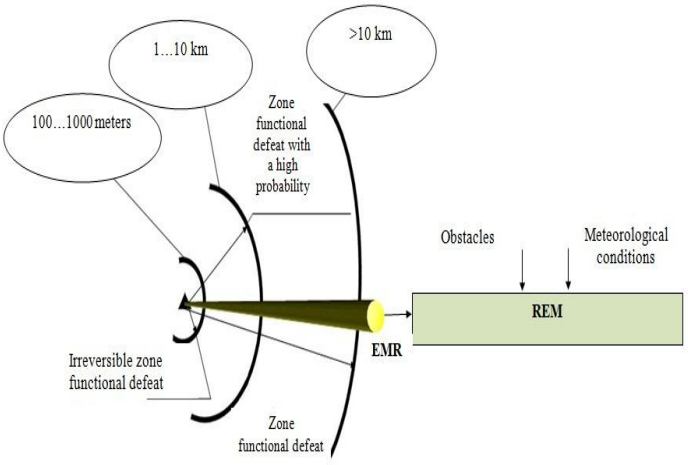

Figure 1: Generalized stochastic model for the operation of radio-electronic means (REM) in the conditions of electromagnetic terrorism

Taking into account the primary purpose of REM, we shall use the probability of completing a functional task ($P_{B\Phi 3}$) in the condition of potential influences as a general criterion for evaluating its effectiveness. Based on this, given the state of normal functioning and reliability of the element REM base we will present $P_{B\Phi 3}$ in the following form:

$$P_{B\Phi 3} = f(P_{H\Phi}; P_H; P_{EMR}; P_{MY}; P_{\Pi}), \quad (1)$$

where $P_{H\Phi}$ – is the probability of normal functioning of REM;

P_H – is the probability of trouble-free functioning of REM

$P_{B\Phi 3}$ – the probability of terroristic REM;

P_{MY} – the probability of influence of meteorological conditions;

$P_{HB\Pi}$ – the probability of unintentional interference with obstacles;

Assuming that the REM functioning is operated only by terroristic means of electromagnetic influence, $P_{B\Phi 3}$ will be determined by the spatial and energetic characteristics of the TC of the EMR. Based on this, we will write $P_{B\Phi 3}$ in the following form:

$$P_{B\Phi 3} = f\left(\Pi_{BX_{EMR}}\right), \quad (2)$$

where $\Pi_{BX_{EMR}}$ – is the flux of incident power generated by the TC of the EMR.

The functional lesion of REM is carried out under the following condition:

$$\Pi_{BX_{EMR}} \geq \Pi_{\Pi OP}, \quad (3)$$

where $\Pi_{\Pi OP}$ is the threshold value of the flux of incident power at which the functional affection of REM is carried out.

Taking into account (3) $P_{B\Phi 3}$ in the conditions of influence of the TC the EMR will be determined as follows:

$$P_{B\Phi 3} = P\left(\Pi_{BX_{EMR}} \leq \Pi_{\Pi OP}\right). \quad (4)$$

Taking into account the distance R between REM and the means of the TC of the EMR, the attenuation of the EMR energy during the distribution in the space of the power of the TC of the EMR, the duration of EMR pulse τ_i, we shall represent the flux of incident power $P_{вип}$ at the REM input in the following way:

– for radio-frequency influence of the non-directional action:

$$\Pi_{\Pi OP} = K_B \frac{P_{вип}\tau_i G}{4\pi R^2} e^{-\alpha R}, \quad (5)$$

where $P_{вип}\tau_i = W_{вип}$ is the radiation energy of the pulse generator of the TC of the EMR, which is determined by the power and duration of the pulse radiation, respectively;

G – antenna strengthening coefficient of the TC of the EMR generator;

α – running coefficient of attenuation of EMR on distribution path;

R – distribution distance;

K_B – coefficient of EMR usage;

– for laser influence:

$$\Pi_{\Pi OP} = K_B \frac{W_{вип}}{\Omega R^2} e^{-\alpha R}. \quad (6)$$

Taking into account the EMR shielding according to (2), (3), (5), we will present (4) as follows:

– for radio-frequency influence of the non-directional action:

$$P_{B\Phi 3} = P\left(\Pi_{BX} \leq K_B \frac{P_{вип}\tau_i G}{4\pi R^2} e^{-\alpha R} 10^{-0.1K_E}\right). \quad (7)$$

– for laser influence:

$$P_{B\Phi 3} = P\left(\Pi_{BX} \leq K_B \frac{W_{вип}}{\Omega R^2} e^{-\alpha R} 10^{-0.1K_E}\right). \quad (8)$$

The expressions (7), (8) allow to determine the distance at which the functional affection of the TC of the EMR with the corresponding energetic parameters of a particular REM will be made, depending on the stability of its element base, which determines the threshold value of the flux of incident power at which the functional affection of the REM as well as REM shielding settings will be realized.

$$R_{\max} = \sqrt{\frac{W_{випр} K_B}{П_{ПОР}\Omega} e^{-\alpha R} 10^{-0.1K_E}}. \qquad (9)$$

Let us consider that

$$П_{ВХ} = [E \times H] = \frac{E^2}{Z},$$

where $Z = 377\Omega$.

Then taking into consideration (5) we will write:

$$R_{\max} = \sqrt{\frac{30 P_{ВИПР} G K_B}{E_{ПОР} \tau_i^2} e^{-\alpha R} 10^{-0.05K_E}}. \qquad (10)$$

Let us determine the basic requirements for protection means, based on the most common assumptions about the characteristics of the objects of protection and the TC of the EMR, radio-frequency and laser radiation, provided in the literature [1, 4, 17, 18].

Considering the duration of the EMR pulse which lies in the range of tens of nanoseconds up to 10^{-18}s, the energy at which the degradation phenomena 10^{-4}…10^{-8}J occur in the most sensitive elements, and laser energy, at which the protective material will evaporate (0,2…2,5 J/sm^2 при τ_i=10^{-9}s), as well as the values of the EMR TC power from 1 to 100 GW and more [1, 2, 4, 6], the REM protection should be carried out in accordance with the principles of construction of REMs themselves, their purpose and the wide spread of EMR characteristics that can lead to REM functional affection.

A number of factors and tendencies that directly or indirectly reduce the effectiveness of the usage of devices and means of protection of REM from EMR have been recently identified. They may include the following:

– extension of the range of solved tasks by disabling REM;

– suddenness of usage;

– reducing requirements to the quality of information about the REM characteristics;

– extension of the types and further improvement of the TC of the EMR, which is aimed at increasing the energy of the electromagnetic radiation and reducing the pulse duration (10^{-9}…10^{-18}s);

Due to these factors, REM devices and REM protectors from EMR must provide a shielding level in the wide bandwidth at which the EMR energy transmitted to the REM elements will not exceed the value when degradation effects occur in them (max 10^{-8} J), and the reflection of the laser energy that will not evaporate the shielding material (>0,2…2,5J/sm^2 при τ_i=10^{-9}s).

The following points should be considered when justifying the requirements:

– based on the conditions of location on the air objects, the protective means and devices must cover a small portion of the total weight and volume discharged for the payload ((20 ... 40) g/m^2);

– in view of the tendency to increase the flight speed of aero-ballistic objects up to 1 km/s and more, the characteristics of the protective shielding should not depend significantly on the flight parameters, which are caused, first of all, by the temperature more of the shielding (up to 2000K) [3, 11, 12], that is, protection means should not severely limit the possibility of flight conditions; besides, the protection must be carried out repeatedly and without prior preparation.

– considering the possible rapid change of location of EMF means, protective means and devices should not require preparation to use them.

The creation of REM protection devices and means, in view of the basic characteristics, features of application and operation of the EMR TC, should be aimed at the optimal combination and implementation of the following principles:

– no influence on the process of REM functioning during the interaction with EMR;

– instantaneous response to EMR (providing the required performance based on the duration of the EMR pulse);

– energy independence or minimum allowable energy consumption;

– re-usability;

– constant or acceptable increase in the weight and overall characteristics of the objects of protection;

– practical implementation and possibility of application both on land and onboard objects.

The implementation of these principles is aimed to increase the effectiveness of REM protection from the destructive unintentional EMR and EMR TC to the maximum permissible, which will ensure the fulfillment of the functional task of REM $P_{ВФЗ} \approx 1$.

The main requirements for REM protection from the powerful EMR UPD are [1, 13-16]:

1. Range of operating wavelengths from 1 mm to 100 km.

2. Reducing the EMR energy level at the input at the REM access points to 10^{-8} J.

3. Activation time of at least 10^{-10}s for protection from radio-frequency EMR, and 10^{-19}s – for protection from optical radiation.

4. Ability to operate in a wide temperature range (240-2000 K).

5. Efficiency with taking into account the possibility of changes within a wide range of physical conditions of use (air pressure from 760 to 10 mm. mer. pil).

6. Minimum mass per unit area.

7. High strength of characteristics.

3. CONCLUSION

A generalized stochastic model of REM under conditions of electromagnetic terrorism has been developed. The basic calculation ratios for the determination of the ways and composition of the means of protection, depending on the energy parameters of the means of electromagnetic terrorism, have been given.

The criterion for estimating the effectiveness of REM functioning under conditions of electromagnetic terrorism has been developed, namely, taking into account the stochastic model of the REM functioning process, it has been proposed to use the probability of fulfilling the task in the conditions of possible influences. The main requirements for the protection of radio-electronic equipment of energetic objects from the terroristic influence by electromagnetic radiation have been formulated.

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