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Protection of Radio-Electronic Equipment of The Robotic Ground Complex by Electromagnetic Radiation

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ABSTRACT

This paper analyzes the problem of protection from powerful electromagnetic radiation on radio electronic means systems of the robotic ground complex. 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.

The basic calculation rations for the determination of the ways and composition of the means of protection, depending on the energy parameters of the robotic ground complex the destructive effects of electromanite radiation of various origins.

The main requirements for the protection of means of protection of radio-electronic equipment of energetic objects from the destructive effects of electromanite radiation of various origins.

Keywords: radio electronic means, electromagnetic radiation, ultrashort pulse duration, plasma protection technologies, gaseous plasma media, electromagnetic gas valve, mobile robotic complex.

1. INTRODUCTION

This paper analyzes the problem of protection from powerful electromagnetic radiation on radio electronic means (REM) systems of the robotic ground complex. A robotic ground complex is a machine that can move in space and perform certain functions due to its specialization. The development and construction of mobile robotic systems is developing in two directions: the first is based on the creation of unique (mechanized) platforms, the second - on the use of serial chassis or products in general.

Examples of robotic systems on specialized chassis are:product "Adunok" [28] for military purposes (Belarus), multifunctional robots for security services QinetiQ (Great Britain) [29], mobile robot for extinguishing fires (Russia) [30]. Most automakers create their own robotic concept cars that can drive on the road without a driver and even "follow" traffic rules.

As a rule, such robotic cars are created to test new technologies, and individual options are then introduced into production vehicles. So, automatic transmission, cruise control, direction of movement, engine start-stop, parking sensors, recognition of road signs, prevention of a head-on collision with an obstacle, etc., which are integral functions of the integrated control system of a mobile robot, have already entered into everyday life.However, domestic mobile robotic systems of serial or small-scale production,available for mass use in agriculture, utilities and / or law enforcement agencies, yet. In this work, developed countries announce a project for creating mobile robots based on the chassis of serial mini-tractors and outlines the concept of controlling such a robot.

These robotic ground complexes on board have a large number of semiconductor and microprocessor technology for control and communication. As an example, the electric scheme of the bumper sensors is presented in Figures 1, 2.

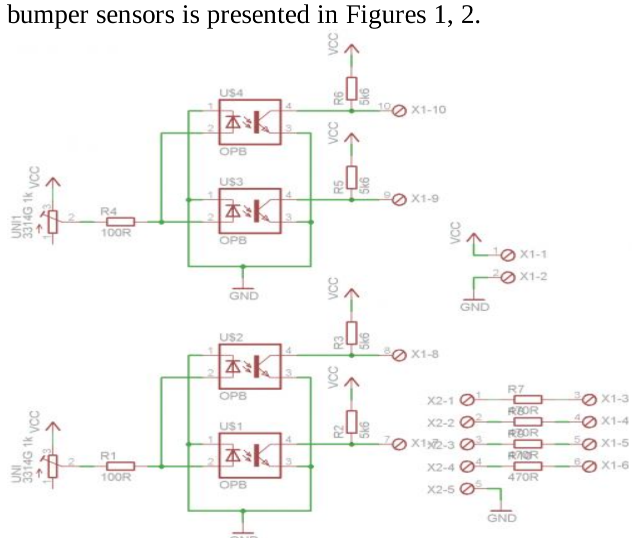

Figure 1. Electric scheme of the bumper sensors of the robotic ground complex

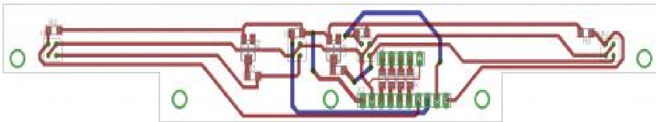

Figure 2. Assembly scheme of the bumper of the robotic ground complex

In this regard, there is a need to protect the semiconductor and microprocessor base from the destructive effects of electromanitic radiation of various origins, capable of outputting and negatively affecting the performance of the tasks of the robotic ground complex.

The purpose of the article is to develop requirements for the protection of a robotic ground complex from the destructive effects of electromanite radiation of various origins.

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).

Taking into account the primary purpose of REM, we shall use the probability of completing a functional task ($P_{BФЗ}$) 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 $P_{BФЗ}$ in the following form:

$$P_{BФЗ} = f(P_{HФ}; P_H; P_{EMR}; P_{MY}; P_{П}), \quad (1)$$

where $P_{HФ}$ – is the probability of normal functioning of REM;

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

$P_{BФЗ}$ – electromagnetic radiation of different origins;

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

$P_{HBП}$ – the probability of unintentional interference with obstacles;

Assuming that the REM functioning is operated only by terroristic means of electromagnetic influence, $P_{BФЗ}$ will be determined by the spatial and energetic characteristics of the electromagnetic radiation of different origins. Based on this, we will write $P_{BФЗ}$ in the following form:

$$P_{BФЗ} = f\left(П_{BX_{EMR}}\right), \quad (2)$$

where $П_{BX_{EMR}}$ – is the flux of incident power generated by the electromagnetic radiation of different origins of the EMR.

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

$$П_{BX_{EMR}} \geq П_{ПОР}, \quad (3)$$

where $П_{ПОР}$ is the threshold value of the flux of incident power at which the functional affection of REM is carried out.

Taking into account (3) $P_{BФЗ}$ in the conditions of influence of the electromagnetic radiation of different origins will be determined as follows:

$$P_{BФЗ} = P\left(П_{BX_{EMR}} \leq П_{ПОР}\right). \quad (4)$$

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

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

$$П_{ПОР} = K_B \frac{P_{випр}\tau_i G}{4\pi R^2} e^{-\alpha R}, \quad (5)$$

where $P_{випр}\tau_i = W_{випр}$ is the radiation energy of the pulse generator of the electromagnetic radiation of different origins, which is determined by the power and duration of the pulse radiation, respectively;

G – antenna strengthening coefficient of the electromagnetic radiation of different origins;

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

R – distribution distance;

K_B – coefficient of EMR usage;

– for laser influence:

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

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:

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

– for laser influence:

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

The expressions (7), (8) allow to determine the distance at which the functional affection of the electromagnetic radiation of different origins 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.

$$R_{\max} = \sqrt{\frac{W_{випр} K_B}{\Pi_{\Pi OP}\Omega} e^{-\alpha R} 10^{-0.1K_E}}. \tag{9}$$

Let us consider that

$$\Pi_{BX} = [E \times H] = \frac{E^2}{Z},$$

where $Z = 377\Omega$.

Then taking into consideration (5) we will write:

$$R_{\max} = \sqrt{\frac{30 P_{ВИПР} G K_B}{E_{\Pi OP}\tau_i^{\,2}} e^{-\alpha R} 10^{-0.05K_E}} \; . \tag{10}$$

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 electromagnetic radiation of different origins, radio-frequency and laser radiation, provided in the literature [1, 4, 5, 17, 18-28].

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 $\tau_i=10^{-9}$s), as well as the values of the electromagnetic radiation of different origins power from 1 to 100 GW and more [1, 2, 4, 6,29,30], 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 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 $\tau_i=10^{-9}$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, 12-18], 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 EMR 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 electromagnetic radiation of different origins, 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 electromagnetic radiation of different origins 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, 20-27]:

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 К).
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.

5. CONCLUSION

A generalized stochastic model of REM of the robotic ground complex 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 the destructive effects of electromanite radiation of various origins.

The criterion for estimating the effectiveness of REM of the robotic ground complex functioning under conditions of electromagnetic radiation, 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 the robotic ground complex from the destructive effects of electromanite radiation of various origins.

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