UDC 396.15(5); 396.18(1)

A. Sotnikov, M. Yasechko, V. Tarshyn

IMPACT OF POWERFUL ELECTROMAGNETIC RADIATION ON RADIOELECTRONIC MEANS

The article analyzes the ways and mechanisms of the effect of powerful electromagnetic radiation on radio electronic means and their element base. It is determined that the effect of high-power electromagnetic radiation of ultrashort duration, due to high penetrating power and threshold levels of failures and damage, is the most dangerous factor in relation to various types of electronic devices, as well as their components, primarily semiconductor devices and microelectronic elements. Analysis of available domestic and foreign literature has shown that there is no research into the ways and mechanisms of the electromagnetic radiation effect on radio electronic means. Differences between the electromagnetic radiation of the ultrashort range are revealed in terms of the impact on the radio electronic equipment. Significant influence on the efficiency of the radio electronic elements of means can be caused by microwave impulses on cable lines, antenna-feeder devices and interblock connections. In addition, induced voltages can change the operating modes of the nodes, which will lead to a temporary or catastrophic failure in general. It is pointed out that it is necessary to search for new technologies in solving the problem of their protection, while simultaneously preventing the effects of electromagnetic radiation of ultrashort duration on radio electronic means on all possible channels of passage.

Keywords: *the electromagnetic radiation of the ultrashort range, the radio electronic equipment, high-frequency radiation.*

Formulation of the problem

In order to achieve a radically new level of radar, radio communication, technology and other technical problems, generators of powerful electromagnetic pulses are being developed in a number of countries. Generators of high-power pulses from one to tens of nanoseconds (linear induction electron accelerators, relativistic generators with virtual cathode (vircators), relativistic magnetrons, generators based on superdimensional electrodynamic structures (Cherenkov generators and diffraction radiation generators) are being intensively developed. These generators have a gigawatt peak power, and there are real ways of increasing it tens of times [1–5]. The achieved and predicted radiation parameters of these devices make them dangerous when influencing radio electronic systems of the widest purpose. This is due to the fact that their mode of operation allows the generation and emission into the surrounding space of not only single electromagnetic pulses, but also their "packets" with a frequency of thousands of pulses per second or more. If other radioelectronic facilities get into the operation zone of such generating systems, it may happen that not only the infringement of the information reception process, but also a violation of their functional integrity. The impact of high-power electromagnetic radiation on high-sensitivity electronic equipment leads to a change in parameters or complete failure of devices, which is associated with the transition of the receiving and amplifying paths into a mismatched mode and the occurrence of overvoltages in the element base. In this case, the value of the amplitude or power of electromagnetic radiation, which affects, can be much less than the threshold values that determine the occurrence of degradation effects in individual elements and nodes. The significance of these effects increases with the increase in the functional complexity of radio electronic equipment [6–9].

Ensuring the reliable operation of radio electronic means in conditions of external influences, including powerful pulsed electromagnetic radiation, necessitates the use of appropriate means of protection. However, as shown by the analysis [10–14], the methods and means of protecting radio electronic means developed to date can not provide the required effectiveness of their protection in terms of their characteristics, and even more so in view of the prospects for the development of means for generating powerful pulsed electromagnetic radiations. This circumstance requires research aimed primarily at finding fundamentally new approaches to the effective protection of radioelectronic means from powerful pulsed electromagnetic radiation, which puts forward the task of investigating the ways and mechanisms of the action of powerful electromagnetic radiations on radio electronic means.

Analysis of recent research and publications

Analysis of available domestic and foreign literature has shown that at present there is a significant number of publications devoted to the generation of electromagnetic radiation [1–5], the use of generators of powerful electromagnetic radiation, including for conducting armed struggle [3–5], the influence of high-power electromagnetic radiation on the elemental base of radio electronic means [7–10; 18], as well as data on traditional methods and means of protecting radio electronic means from electromagnetic radiation [10–14]. There are separate publications devoted to the analysis of the effect of high-power electromagnetic radiation on radioelectronic facilities [15–22], however, systematized data on the investigation of the ways and mechanisms of the effect of electromagnetic radiation on radio-electronic means are not necessary for determining the ways of protecting radioelectronic facilities.

The purpose of the article is to analyze the ways and mechanisms of the impact of powerful pulsed electromagnetic radiation on radio electronic means and their element base.

Main part

Superhigh-frequency energy can propagate to sensitive elements of radio-electronic means along two main paths:

– through the reception circuits – the transmission of electromagnetic energy associated with free space through the antenna-feeder path (the "front-door" path);

– through the structural elements of radioelectronic facilities (panels, windows, unshielded conductors, etc.) (the way of penetrating the radiation "back-door").

Radiation power, which affects the internal circuits of radioelectronic means P_{imp}, is related to the flux of incident power $\Pi_{(r)}$ by the following relation [18]:

$$P_{imp} = \Pi_{(r)} * S_{eff}(f),$$

where $\Pi_{(r)}$ – the Umov-Poynting vector;

$S_{eff}(f)$ – effective surface of the object.

For the "front-door" path, $S_{eff}(f)$ is usually the effective surface of the object as a receiving antenna. Therefore, in order to increase the security of radio electronic equipment from the impact of powerful electromagnetic pulses, when receiving through the antenna, the operating frequency band is usually limited. In the case of short and ultrashort pulses, this approach leads to a significant decrease in their power spectral density.

Under the influence of electromagnetic radiation on the input circuits of the receiving path, there are two modes: band and out-of-band [5; 7]. A particular feature of the band-pass action is the minimum energy loss of electromagnetic radiation when passing through an agreed receiving path, even with band-pass filters at the input. Losses in this case are determined by the ratio between the bandwidth of the input filter or the low-noise amplifier and the width of the spectrum of the influencing electromagnetic radiation. In most cases, these losses do not exceed 10–15 dB [18].

Out-of-band electromagnetic radiation is effected outside the passband of the receiver. It is more universal than a band-pass, since a sufficiently powerful pulse can affect a number of RESs whose receiving paths are not sufficiently well protected from out-of-band action. In this case, it is necessary to take into account the power losses in the tract. The resulting losses in this case can be up to 40-60 dB [18].

The state of the radio electronic means under the action of pulsed electromagnetic radiation is usually described in the form of setting the levels of impact characterizing the degree of efficiency of the radio electronic means.

Ascending levels of exposure are distinguished by [6]:

– a level characterizing the normal operation of the system;

– the level at which temporary violations of the standard mode occur (the level of recoverable failures);

– the level at which stable changes in parameters are observed, leading to a partial loss of system operability (level of steady failures);

– the level at which irreversible catastrophic degradations occur, leading to a complete loss of system performance (level of failure).

Thermal effects, as the final link of the energy absorption process, play a decisive role in the degradation phenomena of the element base due to the processes of local energy absorption and heat removal. Accordingly, the conditions of stationary and short-term energy release are distinguished. The first corresponds to stationary or long-pulse actions, and the second - to the effects of ultrashort duration, when the absorbed radiation energy is localized and does not have time to transmit to the surrounding elements of the structure during the time of the pulse. A higher energy density in the second case contributes to more efficient defect formation in sensitive zones of heat generation [11; 13].

The foregoing is characteristic of the action of one pulse. If the time between impact pulses is sufficiently small, then a regime of thermal energy storage is possible. This time scale corresponds to the time of interstructural thermal relaxation in the radioelectronic medium - the millisecond range, therefore at frequencies of repetition more than 1 kHz, an additional impact factor is usually realized.

The causes of the phenomena characterizing the ultra-threshold modes of action of electromagnetic radiation of the ultrashort range on radio electronic means and its elements can be reduced to the following main effects:

– antenna mechanism of currents and voltages excited in external and internal structures of radioelectronic facilities;

– the plurality of dimensional and orientational resonances due to the complexity of radioelectronic facilities and broadband radiation;

– a large spectrum of destructive phenomena of impact thermal type in the areas of energy release;

– the multiplicity of simultaneous localizations of defects formed in structures in the process of a single exposure to electromagnetic radiation of the ultrashort range;

– characteristic spatial zoning of defects – the periphery of energy release and defect formation.

Thus, the impact of high-power electromagnetic radiation of the ultrashort range, due to high penetrating power and threshold levels of malfunctions and damages, is the most dangerous factor in relation to various types of electronic devices, as well as their components, primarily semiconductor devices and microelectronic elements.

The modern electromagnetic environment is characterized by the presence of natural sources and artificial radiation, which in many cases have a destructive effect on the element base of the radio electronic means and on the conditions of its functioning. Since the value of the radiation energy flux density in the far zone of the source of electromagnetic radiation is proportional to the square of the current derivative in the antenna [18]:

$$|\Pi| = E^2 / 2Z_0 \propto (dI/dt)^2 ,$$

where Z_0 – the impedance of free space.

Then from the energy point of view the magnitude of the effect of electromagnetic radiation is inversely proportional to the duration of the pulse and its front.

The most dangerous types of electromagnetic radiation include impulse radiation of ultrashort duration, created by the following types of sources of artificial origin:

– powerful high-voltage modulators and electrophysical installations for special purposes, using the processes of the ultrashort range (high-power electronics elements);

– emitters of ultra-wideband radar systems used in high-resolution radar;

– some types of high-voltage improper or superficial gas discharges and transient processes initiated by high-energy particle fluxes or laser radiation.

The interaction of ultrashort-range radiation with a relatively narrow spectrum or with a broadband spectrum with a radio electronic means is manifested qualitatively differently from traditional long-duration radiation or stationary radiation. This is due, first of all, to short exposure times in comparison with the characteristic times of relaxation mechanisms in materials and semiconductor structures of radioelectronic means and its components. On the other hand, this type of influencing factor, due to the small pulse duration, is characterized by a larger spectral width, which causes a high penetrating power and intense character of the action of ultrashort pulse duration propagating in the device structures. This leads to the fact that, in spite of the relatively lower energy potential, the ultrashort range pulses can in some cases prove to be a more effective destructive factor than the traditional ultrahigh-frequency signals.

The interaction mechanisms of electromagnetic radiation and superhigh-frequency pulse with radio electronic means have a number of significant differences. From the point of view of the field structure, these differences are primarily due to spectral characteristics: electromagnetic radiation does not have high-frequency filling and their spectrum is mainly concentrated in the region of sufficiently low frequencies (1 ÷ 100 MHz), while ultrahigh-frequency pulses are generated at a certain Carrier frequency, and their spectrum can occupy any place within the entire radio-frequency range (from units to hundreds of gigahertz).

The low-frequency nature of electromagnetic radiation poses serious problems for its directional sewerage in space, while for super-high-frequency pulses such sewerage is realized both by conventional antenna systems and by the use of radio-transparent lenses.

In addition, due to the relatively low-frequency nature of electromagnetic radiation, its effect on the radio electronic means is due to the penetration of fields through technological openings and slots in the housings, as well as by pick-ups that appear on housings, wires and connectors. Ultrahigh-frequency radiation, along with spatial selectivity, also has a frequency-selective effect, which significantly increases its efficiency when passing through the input circuits of radio electronic means.

The most sensitive elements of the radio electronic means are semiconductor elements. In connection with the variety of destructive phenomena in semiconductor devices, the determination of the exact value of the energy (power) of damage is associated with considerable difficulties. Often, the energy characteristics, obtained as a result of analyzing the thermal processes in the instruments, are used to estimate the level of the damage power. This allows us to reduce the secondary effects in semiconductor elements to the time distribution in the energy volume.

Significant influence on the performance of the radio electronic means can be imposed by superhigh-frequency impulses on cable lines, antenna-feeder devices and interconnection connections. In addition, induced voltages can change the operating modes of the nodes, which will lead to a temporary or catastrophic failure in general.

Conclusions

1. Within the framework of the energy approach, the refusal or violation of the standard operating mode of the radio electronic means is uniquely associated with the change in parameters or the failure of individual elements and (or) nodes (mainly containing semiconductor elements) under the influence of electromagnetic

radiation or an ultrahigh-frequency pulse with an amplitude exceeding the permissible threshold values.

2. The large number presence of a functional connections (delay lines, waveguide paths, feedback loops, etc.) in modern radio electronic means leads to the fact that the impact can be carried out through separate elements and nodes, when they act as receptors of electromagnetic energy , transform it and then, in themselves, are the sources of influence for the elements of the radio electronic means, thereby creating an internal unfavorable electromagnetic environment.

3. The effect of a sufficiently weak external electromagnetic radiation of the ultra-short range on the sensitive elements of the radio electronic means can also lead to instability of the system and an increase in the time of its relaxation to the state of normal (regular) reception and processing of information. Most significantly, these effects are manifested in the input and amplifier cascades, and the main factors of their occurrence include:

– distortion of the spectrum and delay of electromagnetic radiation of the ultrashort range in passive and active filtering elements (in the waveguide channel, protective devices with resonators, bandpass filters, path matching elements, etc.);

– excitation of long-lived stochastic oscillations when the power of electromagnetic radiation of the ultrashort range is limited in the threshold memory device;

– imperfect coordination of elements, leading to the appearance of reflections and the excitation of long-lived stochastic oscillations;

– excitation of long-lived stochastic oscillations caused by interaction in the active elements of different spectral groups of electromagnetic radiation of the ultrashort range.

4. The ways and mechanisms of the action of powerful electromagnetic radiation of the ultrashort range on the radio electronic means differ significantly from the paths and mechanisms of the action of microwave radiation. Ensuring the normal operation of the radio electronic means under the influence of electromagnetic radiation of the ultrashort range necessitates the search for new technologies in the solution of the problem of their protection, which at the same time prevents the effect of electromagnetic radiation on the radio electronic means on all possible channels of passage.

References

1. Taylor, C.D. and Giri, D.V. (1994), *High-Power Microwave,* A. Summa Book, Taylor-Frankis, 280 p.

2. Benford, J. (1991), *High-Power Microwave*. Artech House, 412.

3. Kovtunenko, O.P., Bohucharskyi, V.V., Sliusar, V.I. and Fedorov, P.M. (2006), "*Zbroia na netradytsiinykh pryntsypakh dii (stan, tendentsii, pryntsypy dii ta zakhyst vid nei*" [*Weapon on non-traditional principles of action (state, trends, principles of action and protection against it*], PVIZ, Poltava, 247 p.

4. Kravchenko, V.I. (2008), "*Elektromagnitnoe oruzhie*" [*Electromagnetic weapon*], NTU "KhPI", Kharkov, 185 p.

5. Dobykin, V.D., Kupriyanov, A.I., Ponomarev, V.G. and Shustov, L.N. (2007), "*Radioelektronnaya bor'ba. Silovoye porazheniye radioelektronnykh sistem*" [*Electronic Warfare. Power failure of electronic systems*], High school book, Moscow, 487 p.

6. Starostenko, V.V., Grigoriev, V.V. and Taran, E.P. (1996), "Vliyanie ehlektromagnitnyh polej na stojkost' IMS" [Influence of electromagnetic fields on the stability of IC], *Int. Crimean microwave conference*, September 16-19, 1996, Sevastopol, pp. 188-191.

7. Gadecki, N.P., Kravcov, K.A. and Magda, I.I. (1996), "Issledovanie vozdejstviya ehlektromagnitnyh izluchenij UKD impul'sa na radioehlektronnuyu apparaturu SVCH diapazona" [Investigation of the effect of ultra short pulse duration on electromagnetic radiation on microwave radio electronic equipment], *Int. Crimean microwave conference*, September 16-19, 1996, Sevastopol, pp. 141-146.

8. Myrova, L.O. and Chepizhenko, A.Z. (1988), "*Obespechenie stojkosti apparatury svyazi k ioniziruyushchim i ehlektromagnitnym izlucheniyam*" [*Ensuring the stability of communication equipment to ionizing and electromagnetic radiation*] Radio and communication, Moscow, 296 p.

9. Magda, I.I., Bludov, S.P., Gadetski, N.P. (1993), Studes on electronic device degradation phenomena under interference of pulsed-power electromagnetic fields, *3-rd Int. Crimian Conf. "UNF Tech. and satellite reception"*, Sevastopol, v.5, pp. 523-526.

10. Lebedev, I.V. and Semencha, M.V. (2001), "Kvaziaktivnyj zashchitnyj ogranichitel' SVCH moshchnosti" [Quasi-active protective limiter of microwave power], *Radio Engineering*, No. 2, pp. 17-21.

11. Krutov, A.V., Mitmen, V.A. and Rebrov, A.S. (2002), "Zashchitnoe ustrojstvo malogo urovnya moshchnosti" [Low-power protective device], *12th Int. Crimean Conference "Microware Telecommunication Technology"*, September, 9-13, 2002, Sevastopol, p. 93.

12. Rikkets, L.U., Bridzhes, Dzh. and Majletta, Dzh. (1979), "*Elektromagnitnyj impul's i metody zashchity*" [*Electromagnetic pulse and methods of protection*], Atomizdat, Moscow, 328 p.

13. Alybin, V.G. (2002), "Problemy sozdaniya SVCH zashchitnyh ustrojstv dlya radiolokacii i svyazi" [Problems of creation of microwave protective devices for radar and communication], *12th Int. Crimean Conference "Microware Telecommunication Technology"*, September, 9-13, 2002, Sevastopol, pp. 15-21.

14. Ropij, A.N., Starik, A.M. and Shutov, K.K. (1993), "*Sverhvysokochastotnye zashchitnye ustrojstva*" [*Ultra-high-frequency protective devices*], Radio and communication, Moscow, 128 p.

15. Gadetski, N.P. Kravtsov, K.A., Magda, I.I. (1996), *Studies on electromagnetic radiation of ultrashort duration pulse interference on UHF electronic devices*, AMEREM'96, Albuquerque, New Mexico, p. 79.

16. Bludov, S.P., Gadetski, N.P. and Kravtsov, K.A. (1994), Generation of high-power ultrashort microwave pulses and their effect on electronic devices, *Plasma Phys*, 20, pp. 643-647.

17. Antipin, V.V., Godovicyn, V.A. and Gromov, D.V. (1995), "Vliyanie moshchnyh impul'snyh mikrovolnovyh pomekh na poluprovodnikovye pribory i integral'nye mikroskhemy" [Influence of powerful pulsed microwave interference on semiconductor devices and integrated circuits], *Foreign radio electronics*, No. 1, Moscow, pp. 37-53.

18. Yasechko, M.N., Dohov, A.I., Ivanec, M.G. and Teslenko, O.V. (2015), "*Metody formirovaniya i fokusirovki ehlek-tromagnitnogo izlucheniya dlya vozdejstviya na radioehlek-tronnye sredstva*" [*Methods of forming and focusing electromagnetic radiation for exposure to radio-electronic means*], Disa plyus, Kharkov, 216 p.

19. Yarosh, S. and Tesenchuk, O. (2017), "Otsiniuvannia efektyvnosti protydii vysokotochnii zbroi protyvnyka pid chas orhanizatsii zenitnoho raketnoho prykryttia obiektiv ta uhrupovan viisk" [Estimation of the efficiency of co-operation to high-speed arms of the opponent at the jrganization of the anti-aircraft missile opening of objects and grouping of troops], *Science and Technology of the Air Force of Ukraine*, №2, pp. 79-83.

20. Shamko, V., Zharik, A. and Koval, V. (2017), "Osnovni osoblyvosti zastosuvannia Povitrianykh Syl v suchasnykh umovakh vedennia zbroinoi borotby" [Basic features of use of the air force under present-dayconditions during armed struggle], *Science and Technology of the Air Force of Ukraine*, №2(27), pp. 15-18.

21. Tarshyn, V.A., Sotnikov A.M. and Sydorenko, R.G. (2016), "Rozrobka typovykh modelei opysu zobrazhen poverkhni vizuvannia v umovakh yii spotvorennia" [Development models description images of surface boresighting in the conditions its distortion], *Information Processing Systems*, №7(144), pp. 75-78.

22. Alimpiev, A., Barannik, V., Belikova, T. and Sidchenko, S. (2017), "Teoretychni osnovy stvorennia tekhnolohii protydii prykhovanym informatsiinym atakam v suchasnii hibrydnii viini" [Theoretical foundations of the establishment of the technologies of co-operation to the hidden information attacks in the modern hybrid war], *Information Processing Systems*, №4(150), pp. 113-121.

Надійшла до редколегії 29.05.2017
Схвалена до друку 3.08.2017

Відомості про авторів:
Сотніков Олександр Михайлович
доктор технічних наук професор
провідний науковий співробітник Харківського національного університету Повітряних Сил ім. Івана Кожедуба,
Харків, Україна
orcid.org/0000-0003-2985-3704
e-mail: alexsot@ukr.net

Ясечко Максим Миколайович
кандидат технічних наук
старший викладач Харківського національного університету Повітряних Сил ім. Івана Кожедуба,
Харків, Україна
orcid.org/ 0000-0001-5643-0059
e-mail: maxnik8888@gmail.com

Таршин Володимир Анатолійович
доктор технічних наук доцент
професор Харківського національного університету Повітряних Сил ім. Івана Кожедуба,
Харків, Україна
orcid.org/0000-0001-7059-6354
e-mail: vratar-73@ukr.net

Information about the authors:
Sotnikov Alexander
Doctor of Technical Sciences Professor,
Leading Researcher of Ivan Kozhedub Kharkiv National Air Force University,
Kharkiv, Ukraine
orcid.org/0000-0003-2985-3704
e-mail: alexsot@ukr.net

Yasechko Maksim
Candidate of Technical Sciences,
Senior Instructor of Ivan Kozhedub Kharkiv National Air Force University,
Kharkiv, Ukraine
orcid.org/ 0000-0001-5643-0059
e-mail: maxnik8888@gmail.com

Tarshyn Volodymyr
Doctor of Technical Sciences Associate Professor,
Professor of Ivan Kozhedub Kharkiv National Air Force University,
Kharkiv, Ukraine
orcid.org/0000-0001-7059-6354
e-mail: vratar-73@ukr.net

ВПЛИВ ПОТУЖНОГО ЕЛЕКТРОМАГНІТНОГО ВИПРОМІНЮВАННЯ НА РАДІОЕЛЕКТРОННІ ЗАСОБИ

О.М. Сотніков, М.М. Ясечко, В.А. Таршин

У статті проведено аналіз шляхів та механізмів впливу потужного електромагнітного випромінювання на радіоелектронні засоби та їх елементну базу. Виявлено відмінності між і ЕМІ УКТ з точки зору впливу на РЕА. Аналіз доступної вітчизняної та зарубіжної літератури показав, що дослідження шляхів і механізмів впливу електромагнітного випромінювання на радіоелектронні засоби відсутні. Визначено, що вплив потужного електромагнітного випромінювання ультракороткою тривалості, завдяки високій проникаючої здатності і граничним рівням збоїв і поразки, виявляються найбільш небезпечним фактором по відношенню до різних видів електронних пристроїв, а також їх компонентів, в першу чергу, напівпровідникових приладів і елементів мікроелектроніки. Істотний вплив на працездатність елементів радіоелектронних засобів можуть надавати наведення НВЧ-імпульсу на кабельні лінії, антено-фідерні пристрої та міжблочні з'єднання. Крім того, наведені напруги можуть змінити режими роботи вузлів, що призведе до тимчасовому або катастрофічного відмови в цілому. Вказано на необхідність пошуку нових технологій у вирішенні завдання їх захисту, що дозволяють одночасно запобігти впливу електромагнітного випромінювання ультракороткою тривалості на радіоелектронні засоби по всіх можливих каналах проходження.

Ключові слова: *радіоелектронні засоби, електромагнітне випромінювання ультракороткого діапазону, надвисокочастотне випромінювання.*

ВОЗДЕЙСТВИЕ МОЩНОГО ЭЛЕКТРОМАГНИТНОГО ИЗЛУЧЕНИЯ НА РАДИОЭЛЕКТРОННЫЕ СРЕДСТВА

А.М. Сотников, М.Н. Ясечко, В.А. Таршин

В статье проведен анализ путей и механизмов воздействия мощного электромагнитного излучения на радиоэлектронные средства и их элементную базу. Выявлены отличия между и ЭМИ УКД с точки зрения воздействия на РЭА. Анализ доступной отечественной и зарубежной литературы показал, что исследование путей и механизмов воздействия электромагнитного излучения на радиоэлектронные средства отсутствуют. Определено, что воздействие мощного электромагнитного излучения ультракороткой длительности, благодаря высокой проникающей способности и пороговым уровням сбоев и поражения, оказываются наиболее опасным фактором по отношению к различным видам электронных устройств, а также их компонентам, в первую очередь, полупроводниковым приборам и элементам микроэлектроники. Существенное влияние на работоспособность элементов радиоэлектронных средств могут оказывать наводки СВЧ-импульса на кабельные линии, антенно-фидерные устройства и межблочные соединения. Кроме того, наведенные напряжения могут изменить режимы работы узлов, что приведет к временном или катастрофическому отказу в целом. Указано на необходимость поиска новых технологий в решении задачи их защиты, позволяющих одновременно предотвратить воздействия электромагнитного излучения ультракороткой длительности на радиоэлектронные средства по всем возможным каналам прохождения.

Ключевые слова: *радиоэлектронные средства, электромагнитное излучение ультракороткого диапазона, сверхвысокочастотное излучение.*