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The Model of a Medium for Creation of Electric Hermetic Screens of the Radio Electronic Means

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ABSTRACT

The subject of the present research is a formalized descriptive model of the interaction between electromagnetic radiation (EMR) with ultrashort pulse duration (UPD) and weak ionized air, and forming of the high-conductivity state in the discharge gap. The aim of the paper is to work out a description of the interaction between EMR UPD and weak ionized air and forming of a high-conductivity state in the discharge gap.

The objectives of the article can be stated as follows: to analyze the well-known scientific results in the sphere of developing and investigating the materials and media with the use of plasma technologies, and their interaction with EMR UPD, to analyze the process of the EMR UPD reflection from artificially created high-conductivity channels in the constructive holes and cable channels of the input of corps-screens; to develop a system of physical model for the constructive holes and cable channels' input protection, taking into account the hole air state's change under the influence of a radioisotope source, electromagnetic wave (EMW) and EMR UPD; to work out a formalized descriptive model of the interaction between EMR UPD and weak ionized air, and formation of a high-conductivity state in the discharge gap.

The results of the research are as follows: in the article has been suggested the descriptive model of the interaction between EMR UPD and weak ionized air, and the formation of a high-conductivity state in the discharge gap. The novelty of the research lies in taking into account the physical processes on the initial plasma, plasma-living and plasma-stripped stages, which influence the change of the hole air's conductivity state, and are determined by the time and energetic conditions of high-conductivity channel's formation in the hole air of cops-screens, cable channels of the radio electronic means' (REM) input on the condition of interaction between EMR UPD and weak ionized air, depending on the intensity of a source of ionization, EMR parameters, and also the value of athmospheric pressure lead to the evolution of EMR impulse.
Findings of the reseach: the suggested solution gives the opportunity to assert the emergence of a guaranteed highly conductive channel to carry out a circuit of RMR in a hole (gap) and the prevention of further penetration and distructive impact on REM.

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

1. INTRODUCTION

Development, creation and use of generators with a radiation power of the order of and more than 1 GW with pulse duration of 10^{-9} to 10^{-15} seconds necessitates the further development of methods and devices for the protection of radio electronic means. This is due to the possibility of both accidental and deliberate (as a result of terrorist acts) use of such generators, which can lead to the REM disruption at considerable distances. At the same time, the threat of REM serviceability disruption is usually created when electromagnetic radiation (EMR) interacts with antennas, communication lines, conductors and radioelements of equipment. This interaction leads to the transformation of the electromagnetic field into voltages and currents.

The most vulnerable to the EMR influence are the REM elements directly connected to the antenna output, to the cables and conductors. In addition to these elements, the cables themselves are exposed to impulse voltages, which in certain cases can damage their insulation and cause a short circuit between its cores and the sheath. The most dangerous in terms of its impact on radio electronic equipment (REE) is a EMR of the ultrashort pulse duration (UPD) [1].

The solution suggested in the article is based on the implement of the nature-like (plasma) protection technologies using gaseous media.

1.1 Problem analysis

The research of elecrophysical characteristics of the media based on nature-like plasma technologies has its certain history and level of development. There are significant findings in the sphere of plasma physics, distribution and absorbtion of EMW in it. There are a lot of scientific papers, dedicated to the gas discharge physics, to the fundamental methods of theoretical and experimental research of the discharge plasma.The scientific basis for the study of the unbalanced state of charged particles in different media is the kinetic theory, the main achievements of which are connected with such outstanding physisists as Hinzburh, Boltsman, Landau, Lenard, Balesku, Akhiiezer, Artsymovych, Sahdieiev, Boholiubov, Silin, Vlasov, Klimontovych, Kirkvud, Ivon, Fokker, Plank and others. These famous scientists have created a theory which is now the basis of most specific researches on the unbalanced processes. The peculiarities of the unbalanced fixed processes in conditions of steady sources of particles or energy have been studied in the numerous publications by Moiseieva S.S., Karasia V.I., Novikova V.Ie., Katsa A.V., Kontorovycha V.M., Yanovskoho V. V., Sotnikova O.M.

The analysis of the main framework of the plasma media theory has revealed that one of the crucial problems in it is to solve the problem of providing the required reflecting and circuit poperties of a medium.

2. MAIN MATERIAL

The use of ionization sourse in the form of a radioisotope film leads to the emergence of weak ionized plasma in the air $n_{e0}=10^3$ sm^{-3}…$10^5 sm^{-3}$, which, according to its properties, in case of being used for the protection of antenna waveguiding channel, will not lead to the diversity in the coordinate system and, consequently, to the distortion of a useful signal. Besides, radioisotope film with a small thickness also will not lead to the increase of the mass and size characteristics of an object of protection [2].

Under the influence of the pulsed high-power EMR the concentration of charged particles in the weak ionized plasma will be growing, that under the certain conditions will lead to the emergence of an artificially created high-conductivity channel, which is an electric penetration of an air gap between the hole walls or between a cable and the hole walls.

The development of a penetration to create a high-conductivity channel is determined by a lot of factors. They include EMR parameters (the duration of EMR impulse, the frequency of the impulses' repetition and their energy), and also physical processes, that take place on the different stages of the penetration, and determine the conditions of its occurance. In other words, the creation of a high-conductivity channel is determined by the process of interaction between EMR UPD and gaseous plasma media.

Thus, in the result of creation of a high-conductivity channel there will occur either circuit or resistance and rejection of EMR UPD from the corps-screens.

The structure of a physical model of the constructon holes' protection and cable input channels taking into account the change of air state in the hole under the influence of a radioisotope source, electromagnetic wave (EMW) and EMR UPD is shown at the Fig. 1.

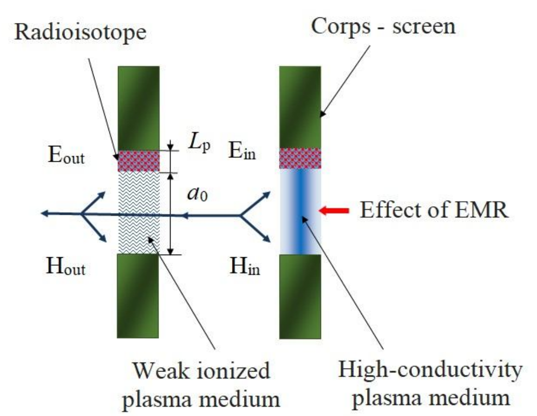

Figure 1: The structure of a physical model of the constructon holes' protection and cable input channels taking into account the change of air state in the hole under the influence of a radioisotope source, electromagnetic wave (EMW) and EMR UPD

2.1 The principle of the system

It is known, that the discharges of atmospheric pressure are characterised by strips, threads, sparks and their dynamic spacial structures, which are characterized by sharp spacial gradients and quick plasmochemical processes. As usual, strips and sparks develop in highly unbalanced electric fields with needle elecrodes. They usually expand in the form of narrow channels with plasma density varying in the range of particles' concentration 10^{19} m^{-3}-10^{21} m^{-3}. Due to the high conductive capacity of plasma, the electic field adopts greater values in the area of a strip's head, where strong ionization by electrons' collisions leads to its further development.

By its nature strip is a highly diverse, unbalanced, unstable plasma, which requires a multilevel analysis. The basis of the phenomenon description is the classical theory of the gas gap hole by Taunsend based on the living mechanism of elecrons' creation in the result of direct ionization, when the voltage of the electric field gives an elecrone the opportunity to collect the energy enough for the further ionization (for slowly changing voltage) at the length of the electron's free path.

In the result, a penetration occurs (in the homogeneous field under the atmospheric pressure air density stands 30 kV/sm, and the minimal value is U= 300 V), that is expressed in a sharp exponential increase of electron concentration and current density. The consequence is Pashen's law, which represents the dependence of the penetration voltage on the length of interelectron gap and is coordinated with the corresponding experimentally derived Pashen's curves (for $pd \le 200 torr \cdot sm$). In case when the source of the secondary electrons is electron emission by iones from the cathod's surface, Taunsend or diffuse penetration is realized [6].

When the quantity of electrons in the living is quite large, the division of charge occurs. It carries out the shielding of the outer field and creates a strip which moves with the speed exceeding the electrons drift velocity. The source of the secondary electrons is photoionisation, pushing electrons in the front of the main part of living and the runaway of the fast electrons. The criterion of the living-strip transition is quite relative and is based on the shielding of the outer field. The situation becomes more complex in case of impulse discharges with the regard to their diversity.

The particular importance when implementing the impulse discharges is given to the distribution of the charged particles in space and their potential in different time points. Strip penetration is realized on condition of high pressure, when there is a great concentration of the charged particles. However, in case of short interelectrode gaps living-strip transition may not be occurred.

As penetration mechanism of glow discharge has a living nature, thus in the present conditions it becomes possible to reveal and study the living-strip transition. This transition refers to the most widespread plasma models of gas penetration development, in which the two stages of penetration are introduced.

Thus, taking into account models' development, the three stages of the penetration formation should be recognized:

– plasma;
– plasma-living;
– plasma-stripped.

2.2 The results of development of a formalized descriptive model of the interaction between EMR UPD and weak ionized air, and formation of a high-conductivity state in the discharge gap.

The development of a formalized descriptive model of the process of reflection (circuit) EMR UPD from artificially created high-conductivity state of ionized medium (further description models of reflection (circuit) EMR UPD are implemented according to the process of the medium formation).

For this purpose let us conventionally represent the high-conductivity channel in the form of a structure, which includes the following stages of penetration development, and thereby the circuit of EMR UPD:

- plasma (under the influence of α-paricles source in the discharge gap there exists a fixed weak ionized quasi-balanced plasma).

The medium is characterized by the quasi-balanced (Maksvel) function of charged particles' distribution f_0, concentration of which is defined by the level of radioisotope sourse intensity $n_0 = n(Q)$, with the temperature of electrones T_e and particle diffusion D_p.

The plasma frequency is determined by the concentration of charged particles $f_{cr} = f(n)$. The conductivity of the weak ionized medium is negligible and determined by the concentration of electrons and neutral particles $\sigma = f(n_{en}) \approx 0$;

- plasma-living, when distortion of the outer field E_0 is still very small, and the pressure of the induced field $E_2/4\pi$ becomes considerable and has a significant impact on the dynamics of plasma living development, the manner of its radial expansion. On this stage evolves the high ionized medium, which is characterized by a nonequilibrium function of the charged particles distribution $f_1(t_l, \vec{v}, \vec{r}, E, \tau_i)$.

The formation time of plasma living is t_l and is determined by parameters EMR (E, τ_i) and the formerly formed at the first stage of penetration development the initial concentration of charged particles $n_0 = n(Q)$.

The living is characterized by $T_e = f(f_1)$; $D_e = f(T_e)$; $D_i = f(T_i)$

The concentration of the electrons in the living is $n_e = n_l = f(f_1)$.

Depending on the scope of frequencies EMR in plasma living there take place the processes of absorbtion of the outer field energy, which determine the time of the living development.

Consequently, the conductivity of plasma living can be represented as follows: $\sigma_l = f(n_l(f_1), \omega)$;

- plasma-stripped, when field E_1 completely compensate the outer field E_0. At this stage occurs the increase of the outer field behind the strip area, lengthening of the strip plasma and intensive recombination. In the result of absorbing the recombinated radiation there emerge new livings and the acceleration of their expansion in the electric field takes place.

The plasma parameters at the plasma-stripped stage of the penetration development are as follows:

1. Function of distribution of the charged paricles: $f_2(t_s, \vec{v}, \vec{r}, E, \tau_i)$.
2. Diffusion of electrons and positively charged ions $D_e = f(T_e);\quad D_i = f(T_i)$.
3. Critical concentration of electrones, in which the high-conductivity channel will be formed $n_{cr} = f(n_l, f_2, \alpha_r, p)$, where α_r, p is the rate of electrones' mobility and the atmospheric pressure that accompanies the formation of a high-conductivity channel.
4. The conductivity of a strip and the formed high-conductivity channel will be estimated as $\sigma_s = f(n_{cr}, \omega)$.

In accordance with the above-mentioned, the high-conductivity channel is represented in the form of a three-layer structure, which is represented at the figure 2 [11].

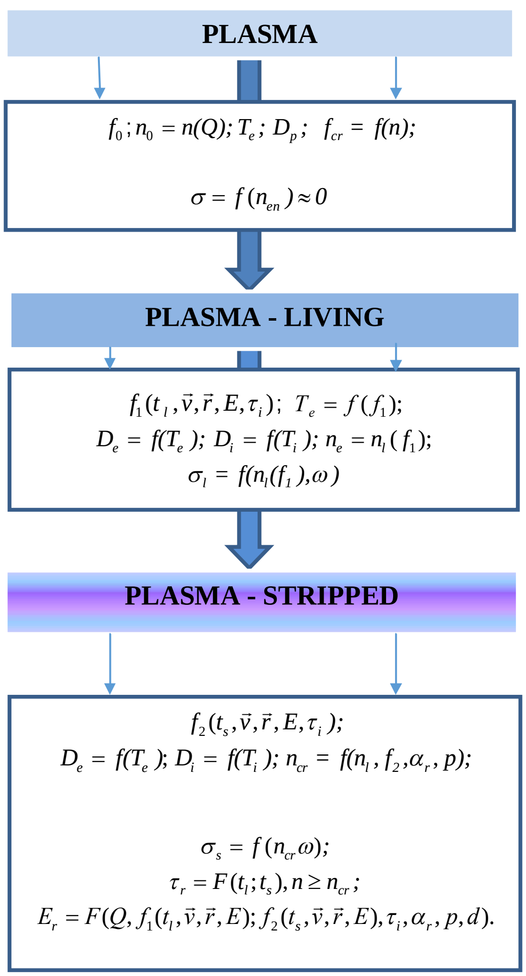

Figure 2: Three-level structure of a high-conductivity channel

Thus, a formalized descriptive model of the reflection (circuit) of EMR UPD from an artificially created high ionized medium for the hole protection can be represented as follows:

$$\sigma_s = f(n_{cr}, \omega);\ n_{cr} = f(n_l, f_2, \alpha_r, p); \quad (1)$$

$$\tau_r = F(t_l; t_s), n \ge n_{cr};$$

$$E_r = F(Q, f_1(t_l, \vec{v}, \vec{r}, E); f_2(t_s, \vec{v}, \vec{r}, E), \tau_i, \alpha_r, p, d). \quad (2)$$

The distinctive feature of this model lies in taking into account the physical processes which take place at the initial plasma, plasma-leaving and plasma-stripped stages, these influence the change of the conductive state of the air gap and the estimation of time and energetic conditions of forming of the high- conductivity channel in the air medium of the holes in the corps-screens, cable channels of REM input under the interaction of EMR UPD with weak ionized air medium depending on the source of ionization, EMR parameters, and also the volume of atmospheric pressure and lead to the evolution of EMR impulse.

3. CONCLUSION

The formalised descriptive model of a high-conductive state of weak ionised medium, that emerges under the impact of EMR UPD and provdes protection of the corps-screen holes by its circuit, has been worked out for the first time.

The distinctive feature of the model, which defines its novelty, lies in taking into account the physical processes at the plasma, plasma-living and plasma-stripped stages, that have impact onto the change of conductive state of the air gap, and also in the estimation of the time and energetic conditions of the formation of a high-conductivity channel in the air medium of the corps-screens' holes, cable channels of REM input under the interaction of EMR UPD with weak ionized air medium depending on the source of ionization, EMR parameters, and also the volume of atmospheric pressure and lead to the energetic and time evolution of EMR impulse.

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