VOL. 14, NO. 20, OCTOBER 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

INFLUENCE OF IONIZATION SOURCE ONTO MACROSCOPIC PARAMETERS OF THE AIR MEDIA IN THE HOLES IN COPS-SCREENS OF RADIO ELECTRONIC MEANS

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ABSTRACT

As the result of the present research, a general formula, for function of charged particles' distribution in the holes in cops-screens of radio electronic means (REM) that appear under the influence of the radioisotope source's energies localized in space and distributed flow, has been devised. The analytical connection between concentration of the charged particles and non-equilibrium parameter has been established. This connection is defined by the intensity of the radioisotope source that allows evaluating the conditions of emerging circuits EMR in the holes in corps-screens of REM depending on the power of EMR.

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

INTRODUCTION

A promising area in creation of electric hermetic screens for lowering the influence of strong electromagnetic radiation (EMR) onto radio electronic means (REM) is the use of nature-like technologies, such as radioisotope plasma technologies, which are more likely to correspond to the set of requirements of the protection methods. The basis of radioisotope plasma technologies is the use of physical mechanisms, which are capable to provide an effective absorption, reflection or diversion of strong EMR. For creation of electric hermetic screens it is suggested to perform a preliminary ionization with the help of radioisotope sources in holes, gaps or cable ducts of the input. This provides the needed concentration of charged particles in the place of REM protection for creation of a circuit of EMR in case of its emergence and its further diversion.

Consequently, the aim of the present research is to define macroscopic parameters of the preliminary ionized with a radioisotope source air media of holes, gaps or cable ducts of the input, which would allow implementing a guaranteed protection of REM.

As a source of ionization the following materials can be used: polonium-210 (Po-210), strontium-90 (St-90) and plutonium-238 (Pu-238). The preference should be given to St-90 and PU-238 with the regard to the lower biological danger [1]. Half-life period of St -90 is 28 years, and Pu-238 - 90 years. These materials are waste products which appear due to operating nuclear reactors that is they can be used to create sold-state plasma materials and are affordable.

It is important to note that as usual $\alpha -$ decay is accompanied with a strong $\gamma-$radiation that is not a characteristic of Pu-238. The energy of quanta, that accompany the decay of nuclei Pu-238, is not strong, thus it is easy to protect from. Isotope Pu-238 is widely used in current sources and medical science [1].

LITERATURE REVIEW

The scientific basis for the study of the state of electronic subsystem of air media in holes, gaps and cable ducts of the input of corps-screens REM 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 the researches on the non-equilibrium states of electronic subsystem of condensed media, which appear under the influence of ionization sources. The peculiarities of the unbalanced fixed processes in conditions of steady sources of particles or energy have been studied in the numerous publications by Moiseiev S.S., Karas V.I., Novikov V.I., Kats A.V., Kontorovych V.M., Yanovskyi V. V.

In the meanwhile, there are still some problems unsolved, which are important for defining the conditions of emerging a high-conductivity electronic channel in holes, gaps or cable ducts of the input of corps-screens, for instance, what the output macroscopic parameters of the preliminary ionized air media should be like to create a guaranteed protection of REM under the influence of a strong EMR.

MATERIALS

The source of ionisation of the air media in a hole is a thin film or separate stains, placed onto the surface of a rib of a hole, gap or cable ducts of the input of corps-screens of REM.

Consequently, used in this way sources of ionization are localized in the space of energies. According to the results of well-known papers, sources with different localization width in impulse space are characterized by an exponent function:

$$S_{\pm} \sim I_{\pm} \exp\{-\alpha_1 (v - v_{\pm})^2\}.$$

But the degree of localisation of an ionization source is not very significant, so for convenience exponent function can be replaced by a delta function as:

$$S_{\pm} \sim I_{\pm} \delta(v - v_{\pm}) / v^2 \tag{1}$$

or

$$S_{\pm} \sim I_{\pm} \frac{\delta(v - v_{\pm})}{v^2} f(v_-, t). \tag{2}$$

If $I_+ = I_-$ – a flow of energy from a source to the drain emerges.

If $I_+ = I_- \frac{v_-^2}{v_+^2}$ – a flow of particles emerges.

The direction of the flow of charged particles depends on the position of v_- та v_+.

The source of ionization in the form of radioisotope film is a localized source in the space of energies. Thus, model of a localized in a space of energies source can be represented as follows:

$$Q(x)=\begin{cases} 0, & x \le x_i - \Delta_i,\ x \ge x_i + \Delta_i; \\ G\frac{1}{2\Delta_i}, & x_i - \Delta_i < x < x_i + \Delta_i, \end{cases} \tag{3}$$

where G is the intensity of ionization source;

Δ_i is half-width of the energy area in which source works.

For ionization conditions in air media $\Delta_i \to 0$. In this case the expression looks as $L(x) = G\delta(x - x_i)$. Model of drain is used in the form

$$-\frac{1}{\tau(x)} f(x). \tag{4}$$

Taking into account (1) and (2), the expression that describes sources and drains, can be represented as follows:

$$L(x) = Q(x) - \frac{1}{\tau(x)} f(x), \tag{5}$$

where $\tau(x)$ – is a typical time of loss of a charged particle in energy area of a drain functioning.

There may exist two types of drain:

a) fully distributed (τ-drain) – $\frac{1}{\tau(x)} = \frac{1}{\tau} = const$;

b) fully concentrated – $\frac{1}{\tau(x)} = \frac{1}{\tau_c} \delta(x - x_c)$,

where X_c is the value of energy in the place of drain localization;

τ_c is a typical time of absorption of particles in the drain.

For the problem which is being solved, drains are fully distributed.

Let's assume that one localized source Q_D in the point $X_д$ and two drains Q_{C_1} and Q_{C_2} in the points x_{c_1} and x_{c_2}.

For these conditions the equation for density and energy of ionized air medium is the following:

$$x_D Q_D - x_{c_1} Q_{c_1} - x_{c_2} Q_{c_2} = 0. \tag{6}$$

Taking into account, that he intensity of the drain is connected with function of distribution with the proportion $Q = \frac{1}{\tau_c} f(x)$, the system of equations should be solved as follows:

$$f(x_{c_1}) = \frac{x_{c_2} - x_D}{x_{c_2} - x_{c_1}} Q_D \tau_c,$$

$$f(x_{c2}) = \frac{x_D - x_{c1}}{x_2 - x_{c1}} Q_D \tau_c.$$

Let's assume, that $x_{c1} < x_D < x_{c2}$.

The solution exists only for conditions ($x_{c1}, x_D \to 0$; $x_{c2} \to \infty$), for which the flow of electrons $\Pi(x)$ on the whole axis is positive and equals:

$$\Pi(x) = \frac{x_D - x_{c1}}{x_{c2} - x_{c1}} Q_D. \tag{7}$$

Let's take into consideration that in weak-ionized plasma the main contribution into the electron relaxation is made by their collision with neutral molecules of gas. During the collision neutral molecules are polarized and the interaction between electrons and molecules occurs according to the polarization potential, which coincides

ARPN Journal of Engineering and Applied Sciences

with the interaction of Maksvel type. Polarized component can be represented by an equilibrium distribution function. The use of the model of an equilibrium distribution function gives the opportunity to use integral transformations for Maksvel molecules

0

$$ {}_0F_1(\frac{3}{2},-xy)=\frac{1}{2\sqrt{xy}}\sin(2\sqrt{xy}), \tag{8}$$

$$ f(x)=\hat{R}^{-1}\{\Phi(y)\}=\frac{1}{\Gamma^2\left(\frac{3}{2}\right)}\int_0^\infty dy_0F_1(\frac{3}{2},-xy)\sqrt{xy}\Phi(y) \tag{9}$$

where $\Gamma(\alpha)$ is a gamma function;

${}_pF_q$ is a generalized hyper geometric function.

Function $\Phi(y,t)$ is an initial function for defining its moments. This property comes from defining $\Phi(y)$, by substitution with a hyper geometric function in the form of expansion into a power series, then integrating by parts and defining moments:

$$ \Phi(y,t)=\sum_{n=0}^{\infty}\frac{(-1)^n}{n!}M_n(t)y^n, $$

$$ M_n(t)=\frac{1}{\left(\frac{3}{2}\right)_n}\int_0^\infty F(x,t)x^n dx\ ,) $$

Let's consider that the flow of particles for the fixed unbalanced state is specified by equation, which, according to (5), can be represented as follows:

$$ \Pi\{f,f,x\}=\int_0^x dx'L(x'). \tag{11}$$

For the model τ - drain (11) rewrite as:

$$ \Pi\{f,f,x\}=Q_D-\frac{1}{\tau}\int_0^x dx'L(x') \tag{12}$$

The research of the fixed states requires solving a nonlinear problem. For the states with a wide inertial interval due to the use of asymptotics of the distribution function the solution of this problem can be significantly simplified.

The asymptotics of the distribution function are obtained $G(z)$.

In a wide inertial interval the functions of the flow are simplified and have asymptotics $\psi(z)=\frac{P}{z^2}$, $P=\pm Q_i$.

Using integral transformations (8, 9) and the Laplas transformation for δ-formed sources and drains, find supplements to the equation for $\Phi(y)$ and $G(z)$:

$$ \psi_D^\delta=Q_D\ {}_0F_1(\frac{3}{2};-x_Dy)=\frac{Q_D}{2\sqrt{x_Dy}}\sin(2\sqrt{x_Dy}), \tag{12}$$

$$ \psi_D^\delta(z)=\hat{L}_z(y\psi_D^\delta)=Q_D\frac{1}{z^2}\ {}_1F_1(2;\frac{3}{2};-\frac{x_D}{z}). \tag{13}$$

In the result, the kinetic equation for G (z) in the inertial interval will look as Rikkati equation:

$$ M_{0st}\frac{¶G}{¶z}+G^2+\frac{P}{z^2}=0. \tag{14}$$

Solution (14) looks as:

$$ G(z)=\frac{M_0}{z}\frac{c_1s_1z^{s1}+c_2s_2z^{s2}}{c_1z^{s1}+c_2z^{s2}}, \tag{15}$$

where $s_1=\frac{1-\nu}{2}$; $s_2=\frac{1+\nu}{2}$; $\nu=\sqrt{1-\frac{4P}{M_0^2}}$;

c_1, c_2 are arbitrary constants.

For defining $\Phi(y)$ expand function G(z) into combined power series by $\frac{1}{z^\nu}$ and perform by parts a reversed Laplas transformation. In the result the following expression is obtained:

$$ \Phi(y)=cM_0s_1+M_0(s_2-cs_1)E_\nu(-\frac{y^\nu}{c};1), \tag{16}$$

$E_\nu(x;\mu)=\sum_{k=0}^{¥}\frac{x^k}{\Gamma(\mu+k\frac{1}{\nu})}$ – all-zero function of Mittah-Lefler type.

Distribution function f(x) can be found though one more reversed transformation (9).

For this purpose a new function $\Phi_s(y)=e^{sy}\Phi(y)$ is introduced, this function coincides when $s\to 0$ with $\Phi(y)$. The introduction of function of this form $\Phi_s(y)$ gives the opportunity to expand $E_\nu(x;1)$ by parts in a series and apply the reversed transformation.

In the result the distribution function in the following form is obtained:

$$ f_s(x)=\frac{cM_0s_1}{\Gamma(3/2)}\frac{\sqrt{x}}{s^{3/2}}e^{-\frac{x}{s}}+ $$

VOL. 14, NO. 20, OCTOBER 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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$$+\frac{M_0(s_2-cs_1)}{\Gamma^2(3/2)}\frac{\sqrt{x}}{s^{3/2}}e^{-\frac{x}{s}}\sum_{n=1}^{\infty}\frac{(-1)^n}{c^n}\frac{\Gamma(\nu n+3/2)}{\Gamma(\nu n+1)s^{\nu n+3/2}}\,{}_1F_1(-\nu n;\frac{3}{2};\frac{x}{s}) \quad (17)$$

Take into account, that $f(x)=\lim_{s\to 0} f_s(x)$, and use the asymptotic expansion of the degenerate geometric function. In the result the expression for the asymptotics of the distribution function in the inertial interval is obtained:

$$F(x)\infty\frac{M_0(s_2-cs_1)}{\Gamma(3/2)}(-\frac{1}{c})\frac{\Gamma(\nu+3/2)}{\Gamma(\nu+1)\Gamma(-\nu)}\frac{1}{x^{\nu+1}}=A\frac{1}{x^{\nu+1}}. \quad (18)$$

Consider the formerly accepted conditions (x_{c_1}, X_D, $x_{c_1}, x_D\to 0;\ x_{c_2}\to\infty$), for which the flow of electrons $\Pi(x)$ on the whole axis is positive and the proportion is fulfilled :

$$\nu=\sqrt{1+\frac{4(x_{c_2}-x_D)Q_D}{(x_{c_2}-x_{c_1})M_0^2}}>1 .$$

For these conditions constant A in (18) is calculated, based on the condition of matching x_{c_2} :

$$A=\frac{x_{c_2}-x_D}{x_{c_2}-x_{c_1}}Q_D\tau_c x_{c_1}^{\nu+1} .$$

Taking into account that the inertial interval is wide and, consequently, makes the major contribution into the integrals calculated, find the density of particles and their energy:

$$M_0=\int_{x_{c_1}}^{x_D}dxA\frac{1}{x^{\nu+1}}\approx\frac{x_{c_1}}{\nu}\frac{x_{c_2}-x_D}{x_{c_2}-x_{c_1}}Q_D\tau_c=\frac{x_{c_1}}{\nu}\frac{x_{c_2}-x_D}{x_{c_2}-x_{c_1}}\frac{1}{\varepsilon\tau_c}, \quad (19)$$

$$M_1=\frac{2}{3}\int_{x_{c_1}}^{x_D}dxxA\frac{1}{x^{\nu+1}}\approx\frac{2}{3}\frac{Q_D\tau_c}{(\nu-1)}\frac{x_D x_{c_1}^2}{x_{c_2}}=\frac{2}{3}\frac{x_{c_1}^2}{(\nu-1)}\frac{x_{c_2}-x_D}{x_{c_2}-x_{c_1}}\frac{1}{\varepsilon\tau_c} \quad (20)$$

where $\varepsilon=\frac{1}{Q\tau_c^2}$ is a parameter of non-equilibrium;

From (19), (20) obtain the expression for temperature:

$$T=\frac{2}{3}\frac{\nu}{(\nu-1)}x_{c_1} \quad (21)$$

and the equation of state

$$M_1=\frac{3}{2}\frac{\nu-1}{\nu^2}\frac{x_{c_2}-x_D}{x_{c_2}-x_{c_1}}T\frac{1}{\varepsilon\tau_c} \quad (22)$$

For the source with the finite width of τ-drain from the conservation stationary values for M_0 and M_1can be obtained:

$$M_{0st}=Q_D\tau_c\,,\qquad M_{1st}=\frac{2}{3}x_i Q_D\tau_c \quad (23)$$

The moments of the distribution function in stationary non-equilibrium state can be obtained from the system of recurrence relations:

$$b_n=\frac{\frac{1}{n-1}\sum_{k=1}^{n-1}b_k}{1+\frac{n+1}{n-1}\varepsilon}+\frac{\frac{n+1}{n-1}}{1+\frac{n+1}{n-1}\varepsilon}\varepsilon a_n\,, \quad (24)$$

$b_0=1$, .

Expression (24) shows that stationary non-equilibrium state for the opened system (for the Maksvel type of interaction) is described only with one non-equilibrium parameter.

When $\varepsilon\to 0$ the known expression for the equilibrium system is obtained. When ε has a large value, a stationary non-equilibrium state takes place.

The results of numerical calculations, the correlation of the first 30 moments with ε are given in Figure-1.

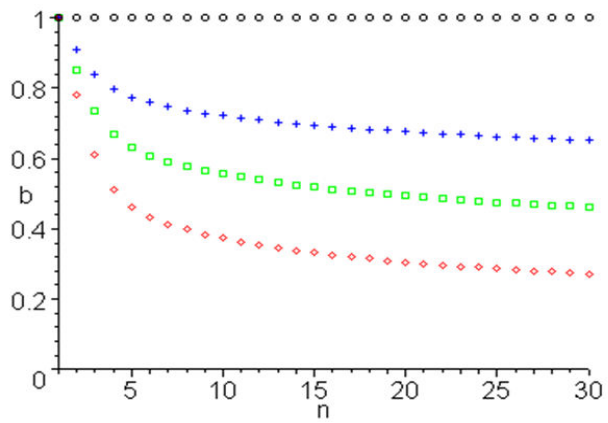

Figure-1. Correlation of the first 30 moments with non-equilibrium parameter ε (ε=0, ε=0,1, ε=0,2, ε=0,4.). Drain is distributed in the space of energy.

The numerical calculations of the correlation of distribution function with non-equilibrium parameter are given in Figure-2. The calculations are done for ε=0, ε=0,1, ε=0,2, ε=0,4.

ARPN Journal of Engineering and Applied Sciences

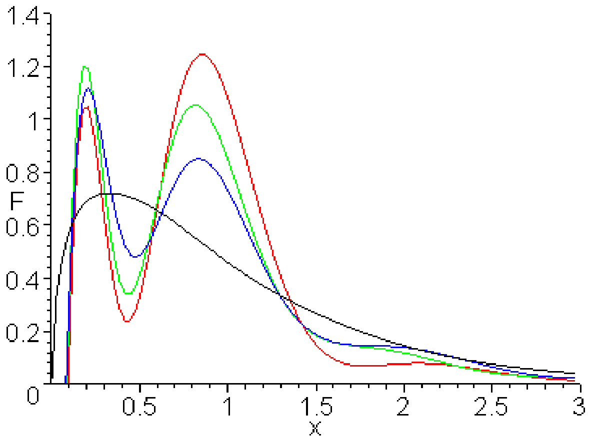

Figure-2. Correlation of the distribution function with non-equilibrium parameter ε (ε=0, ε=0,1, ε=0,2, ε=0,4.). Drain is distributed in the space of energy.

Thus, non-equilibrium state of the electronic subsystem in the discharge gap of a hole and its properties are defined with the non-equilibrium parameter ε.

Introduce the evolution in the form of surfaces in the space (n, ε) for the moments and in the space (x, ε) for the distribution function. For this purpose introduce the equation for the distribution function and its moments in the form of a system of equations:

$$\frac{db_n}{d\varepsilon}=\frac{\frac{1}{n-1}\sum_{k=1}^{n-1}\frac{db_k}{d\varepsilon}T_0^{n-k}+\frac{n+1}{n-1}a_n}{1+\frac{n+1}{n-1}\varepsilon}-\frac{n+1}{n-1}\frac{\frac{1}{n-1}\sum_{k=1}^{n-1}b_k T_0^{n-k}+\frac{n+1}{n-1}\varepsilon a_n}{\left(1+\frac{n+1}{n-1}\varepsilon\right)^2} \tag{25}$$

$$\frac{df(x)}{d\varepsilon}=f_0(x)\sum_{k=0}^{\infty}\left(\sum_{l=0}^{k}(-1)^l\binom{k}{l}\frac{db_l}{d\varepsilon}\right)L_k^{1/2}(x/T)\,. \tag{26}$$

The results of the calculations of correlation of moments of the distribution function with the non-equilibrium parameter ε in the form of a surface are given in the Figure-3.

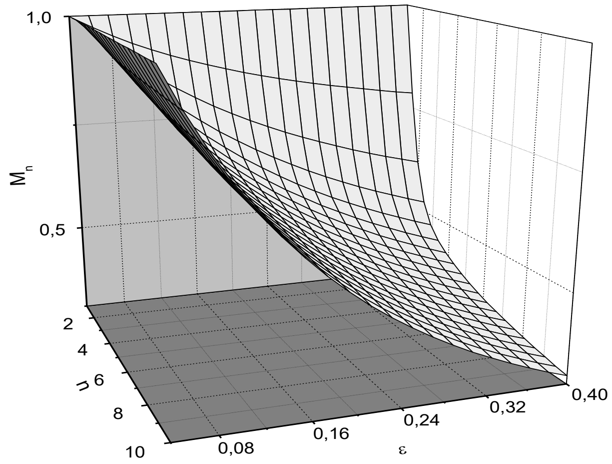

Figure-3. Surface, which demonstrates the evolution of moments of distribution function with the non-equilibrium parameter ε.

The results of the calculation of the correlation of the distribution function with non-equilibrium ε in the form of a surface are given in Figure-4.

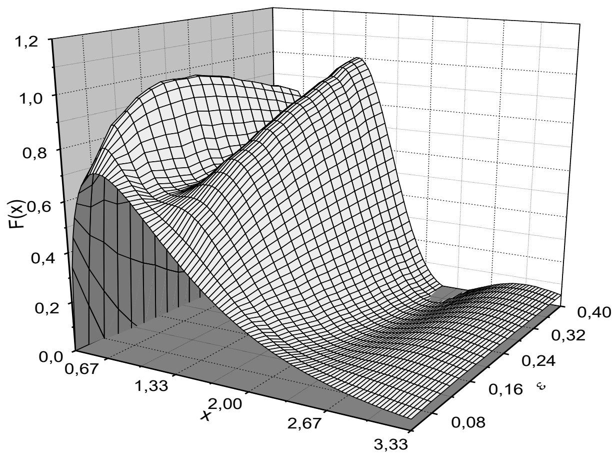

Figure-4. Surface, which demonstrates the evolution of distribution function from the non-equilibrium parameter ε.

Figures 3 and 4 show that the increase of non-equilibrium parameter leads to the boundary values of the moments of distribution function. Higher moments lower due to the growth of non-equilibrium. This means, that the space of low energies, which corresponds to the average values of a non-equilibrium parameter ε, has impact onto the physics of processes in a discharge gap.

Thus, in the result of the conducted research, we obtained the analytical expressions for calculation of charged particles concentration in holes depending on the intensity of the preliminary ionization source in the hole. These expressions are the initial data for the research of the interaction between EMR UPD with the ionized media of the hole.

CONCLUSIONS

a) There were defined moments of a non-equilibrium function of the charged particles' distribution for the localized in the energy space ionization source depending on its intensity.

b) There were obtained the analytical expressions for zero and first moment of distribution function. These expressions represent macroscopic parameters of ionized air media in holes, gaps, cable ducts of the input of corps-screens of REM. Te parameters are initial data for the further identification of conditions of forming a high-conductivity channel and performing a circuit of EMR. These parameters are concentration and charged particles' drift velocity.

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