New method of obtaining the wave equation, the potential and kinetic flows of charges

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Abstract

Until now, was considered that the capacity and inductance are reactive elements and cannot consume active power. In the work it is shown that under specific conditions the capacity and inductance can be the effective resistance, whose value depends on time. These special features of capacity and inductance made possible to obtain the wave equations of long lines. Is shown also, that the electron beams can possess both the kinetic, and by potential properties.

1. Electrical self-induction

To the laws of self-induction should be carried those laws, which describe the reaction of such elements of radio-technical chains as capacity, inductance and resistance with the galvanic connection to them of the sources of current or voltage. These laws are the basis of the theory of electrical chains. The results of this theory can be postponed also by the electrodynamics of material media, since. such media can be represented in the form equivalent diagrams with the use of such elements.

the motion of charges in any chain, which force them to change their position, is connected with the energy consumption from the power sources. The processes of interaction of the power sources with such structures are regulated by the laws of self-induction.

Again let us refine very concept of self-induction. By self-induction we will understand the reaction of material structures with the constant parameters to the connection to them of the sources of voltage or current. to the self-induction let us carry also that case, when its parameters can change with the presence of the connected power source or the energy accumulated in the system. This self-induction we will call parametric [1-3]. Subsequently we will use these concepts: as current generator and the voltage generator. By ideal voltage generator we will understand such source, which ensures on any load the lumped voltage, internal resistance in this generator equal to zero. By ideal current generator we will understand such source, which ensures in any load the assigned current, internal resistance in this generator equally to infinity. The ideal current generators and voltage in nature there does not exist, since both the current generators and the voltage generators have their internal resistance, which limits their possibilities.

If we to one or the other network element connect the current generator or voltage, then opposition to a change in its initial state is the response reaction of this element and this opposition is always equal to the applied action, which corresponds to third Newton's law.

if at our disposal is located the capacity C, and this capacity is charged to a potential difference U, then the charge Q, accumulated in the capacity, is determined by the relationship:

$$Q_{C,U} = CU . \tag{1.1}$$

The charge $Q_{C,U}$, depending on the capacitance values of capacitor and from a voltage drop across it, we will call still the flow of electrical self-induction.

When the discussion deals with a change in the charge, determined by relationship (1.1), then this value can change with the method of changing the potential difference with a constant capacity, either with a change in capacity itself with a constant potential difference, or and that and other parameter simultaneously.

If capacitance value or voltage drop across it depend on time, then the current strength is determined by the relationship:

$$I = \frac{dQ_{C,U}}{dt} = C\frac{\partial U}{\partial t} + U\frac{\partial C}{\partial t}.$$

This expression determines the law of electrical self-induction. Thus, current in the circuit, which contains capacitor, can be obtained by two methods, changing voltage across capacitor with its constant capacity either changing capacity itself with constant voltage across capacitor, or to produce change in both parameters simultaneously.

For the case, when the capacity C_1 is constant, we obtain known expression for the current, which flows through the capacity:

$$I = C_1\frac{\partial U}{\partial t}. \qquad (1.2)$$

When capacity with the constant stress on it changes, we have:

$$I = U_1\frac{\partial C}{\partial t}. \qquad (1.3)$$

This case to relate to the parametric electrical self-induction, since the presence of current is connected with a change in this parameter as capacity.

Let us examine the consequences, which escape from relationship (1.2). If we to the capacity connect the direct-current generator I_0, then stress on it will change according to the law:

$$U = \frac{I_0 t}{C_1}. \qquad (1.4)$$

Thus, the capacity, connected to the source of direct current, presents for it the effective resistance

$$R = \frac{t}{C_1}, \tag{1.5}$$

which linearly depends on time. The it should be noted that obtained result is completely obvious; however, such properties of capacity, which customary to assume by reactive element they were for the first time noted in the work [1-3].

This is understandable from a physical point of view, since in order to charge capacity, source must expend energy.

The power, output by current source, is determined in this case by the relationship:

$$P(t) = \frac{I_0^{\ 2} t}{C_1}. \tag{1.6}$$

The energy, accumulated by capacity in the time t, we will obtain, after integrating relationship (1.6) with respect to the time:

$$W_C = \frac{I_0^{\ 2} t^2}{2C_1}.$$

Substituting here the value of current from relationship (1.4), we obtain the dependence of the value of the accumulated in the capacity energy from the instantaneous value of stress on it:

$$W_C = \frac{1}{2} C_1 U^2.$$

Using for the case examined a concept of the flow of the electrical induction

$$\Phi_U = C_1 U = Q(U) \tag{1.7}$$

and using relationship (1.2), obtain:

$$I_0 = \frac{d\Phi_U}{dt} = \frac{\partial Q(U)}{\partial t} \ , \tag{1.8}$$

i.e., if we to a constant capacity connect the source of direct current, then the current strength will be equal to the derivative of the flow of capacitive induction on the time.

Now we will support at the capacity constant stress U_1, and change capacity itself, then

$$I = U_1 \frac{\partial C}{\partial t} . \tag{1.9}$$

It is evident that the value

$$R_C = \left(\frac{\partial C}{\partial t} \right)^{-1} \tag{1.10}$$

plays the role of the effective resistance [1-3]. This result is also physically intelligible. This result is also physically intelligible, since. with an increase in the capacitance increases the energy accumulated in it, and thus, capacity extracts in the voltage source energy, presenting for it resistive load. The power, expended in this case by source, is determined by the relationship:

$$P(t) = \frac{\partial C}{\partial t} U_1^{\ 2} \tag{1.11}$$

from relationship (1.11) is evident that depending on the sign of derivative the expendable power can have different signs. When the derived positive, expendable power goes for the accomplishment of external work. If derived negative, then external source accomplishes work, charging capacity.
Again, introducing concept the flow of the electrical induction

$$\Phi_C = CU_1 = Q(C),$$

obtain

$$I = \frac{\partial \Phi_C}{\partial t} \ . \tag{1.12}$$

Relationships (1.8) and (1.12) indicate that regardless of the fact, how changes the flow of electrical self-induction (charge), its time derivative is always equal to current.

Let us examine one additional process, which earlier the laws of induction did not include, however, it it falls under for our extended determination of this concept. From relationship (1.7) it is evident that if the charge, left constant (we will call this regime the regime of the frozen electric flux), then stress on the capacity can be changed by its change. In this case the relationship will be carried out:

$$CU = C_0 U_0 = const \, ,$$

where C and U - instantaneous values, C_0 and U_0 - initial values of these parameters.

The stress on the capacity and the energy, accumulated in it, will be in this case determined by the relationships:

$$U = \frac{C_0 U_0}{C} , \tag{1.13}$$

$$W_C = \frac{1}{2} \ \frac{\left(C_0 U_0\right)^2}{C} \ .$$

It is natural that this process of self-induction can be connected only with a change in capacity itself, and therefore it falls under for the determination of parametric self-induction.

Thus, are located three relationships (1.8), (1.12) and (1.13), which determine the processes of electrical self-induction. We will call their rules of the electric flux. Relationship (1.8) determines the electrical self-induction, during which there are no changes in the capacity, and therefore this self-induction can be named simply electrical self-induction. Relationships (1.3) and (1.9-1.11) assume the presence of changes in the capacity; therefore the processes, which correspond by these relationships, we will call electrical parametric self-induction.

2. Current self-induction

Let us now move on to the examination of the processes, proceeding in the inductance. Let us introduce the concept of the flow of the current self-induction

$$\Phi_{L,I} = LI \, .$$

If inductance is shortened outed, and made from the material, which does not have effective resistance, for example from the superconductor, then

$$\Phi_{L,I} = L_1 I_1 = const \ ,$$

where L_1 and I_1- initial values of these parameters, which are located at the moment of the short circuit of inductance with the presence in it of current. This regime we will call the regime of the frozen flow [1]. In this case the relationship is fulfilled:

$$I = \frac{I_1 L_1}{L} , \tag{2.1}$$

where I and L - the instantaneous values of the corresponding parameters.

In flow regime examined of current induction remains constant, however, in connection with the fact that current in the inductance it can change with its change, this process falls under for the determination of parametric self-induction. The energy, accumulated in the inductance, in this case will be determined by the relationship

$$W_L = \frac{1}{2}\frac{\left(L_1 I_1\right)^2}{L} = \frac{1}{2}\frac{(const)^2}{L}.$$

Stress on the inductance is equal to the derivative of the flow of current induction on the time:

$$U = \frac{d\Phi_{L,I}}{dt} = L\frac{\partial I}{\partial t} + I\frac{\partial L}{\partial t}.$$

let us examine the case, when the inductance of is constant. L_1

$$U = L_1\frac{\partial I}{\partial t}. \tag{2.2}$$

designating $\Phi_I = L_1 I$, we obtain $U = \frac{d\Phi_I}{dt}$. After integrating expression (2.2) on the time, we will obtain:

$$I = \frac{Ut}{L_1}. \tag{2.3}$$

Thus, the capacity, connected to the source of direct current, presents for it the effective resistance

$$R = \frac{L_1}{t}, \tag{2.4}$$

which decreases inversely proportional to time.

The power, expended in this case by source, is determined by the relationship:

$$P\left(t\right) = \frac{U^2 t}{L_1}. \tag{2.5}$$

This power linearly depends on time. After integrating relationship (2.5) on the time, we will obtain the energy, accumulated in the inductance of

$$W_L = \frac{1}{2}\frac{U^2 t^2}{L_1}. \tag{2.6}$$

After substituting into expression (2.6) the value of stress from relationship (2.3), we obtain:

$$W_L = \frac{1}{2} L_1 I^2 .$$

This energy can be returned from the inductance into the external circuit, if we open inductance from the power source and to connect effective resistance to it.

Now let us examine the case, when the current I_1, which flows through the inductance, is constant, and inductance itself can change. In this case we obtain the relationship

$$U = I_1 \frac{\partial L}{\partial t} . \qquad (2.7)$$

Thus, the value

$$R(t) = \frac{\partial L}{\partial t} \qquad (2.8)$$

plays the role of the effective resistance [1-3]. As in the case the electric flux, effective resistance can be (depending on the sign of derivative) both positive and negative. This means that the inductance can how derive energy from without, so also return it into the external circuits.

Introducing the designation $\Phi_L = LI_1$ and, taking into account (2.7), we obtain:

$$U = \frac{d\Phi_L}{dt} . \qquad (2.9)$$

Of relationship (2.1), (2.6) and (2.9) we will call the rules of current self-induction, or the flow rules of current self-induction. From relationships (2.6) and (2.9) it is evident that, as in the case with the electric flux, the method of changing the flow does not influence eventual result, and its time derivative is always equal to the applied potential difference.

Relationship (2.6) determines the current self-induction, during which there are no changes in the inductance, and therefore it can be named simply current self-induction. Relationships (2.7,2.8) assume the presence of changes in the inductance; therefore we will call such processes current parametric self-induction.

3. New method of obtaining the wave equation, the potential and kinetic flows of charges

The processes, examined in two previous paragraphs, concern chains with the lumped parameters, when the distribution of potential differences and currents in the elements examined can be considered uniform. However, there are chains, for example the long lines, into which potential differences and currents are not three-dimensional uniform. These processes are described by the wave equations, which can be obtained from Maxwell equations or with the aid of the telegraphic equations, but physics of phenomenon itself in these processes to us is not clear.

We will use the results, obtained in the previous paragraph, for examining the processes, proceeding in the long lines, in which the capacity and inductance are the distributed parameters. Let us assume that linear (falling per unit of length) capacity and inductance of this line are equal C_0 and L_0. If we to this line connect the dc power supply U_1, then its front will be extended in the line some by the speed v, and the moving coordinate of this front will be determined by the relationship $z = vt$. In this case the summary charged capacity and the summary inductance, along which flows the current, will change according to the law [1]:

$$C(t) = zC_0 = vt\ C_0,$$

$$L(t) = zL_0 = vt\ L_0.$$

The source of voltage U_1 will in this case charge the being increased capacity of line, for which from the source to the charged line in accordance with relationship (11.9) must leak the current:

$$I_1 = U_1 \frac{\partial C(t)}{\partial t} = vU_1C_0 . \qquad (3.1)$$

This current there will be the leak through the conductors of line, that possess inductance. But, since the inductance of line in connection with the motion of the front of stress, also increases, in accordance with relationship (2.7), on it will be observed a voltage drop:

$$U = I_1 \frac{\partial L(t)}{\partial t} = vI_1L_0 = v^2U_1C_0L_0 .$$

But a voltage drop across the conductors of line in the absolute value is equal to the stress, applied to its entrance; therefore in the last expression should be placed $U = U_1$. We immediately find taking this into account that the rate of the motion of the front of stress with the assigned linear parameters and when, on, the incoming line of constant stress of is present, must compose

$$v = \frac{1}{\sqrt{L_0C_0}} . \qquad (3.2)$$

This expression corresponds to the signal velocity in line itself. Consequently, if we to the infinitely long line connect the voltage source, then in it will occur the self-expansion of electrical pour on and the currents, which fill line with energy. It is interesting to note that the obtained result does not depend on the form of the function U_1, i.e., to the line can be connected both the dc power supply and the source, whose voltage changes according to any law. In all these cases the value of the local value of voltage on incoming line will be extended along it with the speed, which follows from relationship (3.2). This result was obtained previously only by method of solution of wave equation. This examination indicates the physical cause for this propagation, and it gives the physical picture of process itself. Examination shows that very process of propagation is connected with the energy processes of the filling of line with electrical and current energy. This process occurs in such a way that the wave front, being extended with the speed of v, leaves after itself the line, charged to a potential difference U_1, which corresponds to the filling of line with electrostatic electric field energy. However, in the section of line from the voltage source also to the wave front flows the current I_1, which corresponds to the filling of line in this section with energy, which is connected with the motion of the charges along the conductors of line, which possess inductance.

The current strength in the line can be obtained, after substituting the values of the velocity of propagation of the wave front, determined by relationship (3.2), into relationship (3.1). After making this substitution, we will obtain

$$I_1 = U_1 \sqrt{\frac{C_0}{L_0}},$$

where $Z = \sqrt{\frac{L_0}{C_0}}$ - line characteristic.

In this case

$$U_1 = I \ \frac{\partial L}{\partial t} = \frac{d\Phi_L}{dt}.$$

So accurately

$$I_1 = U_1 \frac{\partial C}{\partial t} = \frac{d\Phi_C}{dt}.$$

It is evident that the flow rules both for the electrical and for the current self-induction are observed also in this case.

Thus, the processes of the propagation of a potential difference along the conductors of long line and current in it are connected and mutually supplementing each other, and to exist without each other they do not can. This process can be called electric-current spontaneous parametric self-induction. This name connected with the fact that flow expansion they occur arbitrarily and characterizes the rate of the process of the filling of line with energy. From the aforesaid the connection between the energy processes and the velocity of propagation of the wave fronts in the long lines becomes clear.

That will, for example, when as one of the conductors of long line take it did compress? Obviously, in this case the velocity of propagation of the front of stress in this line will decrease, since the linear inductance of line will increase. This propagation will accompany the process of the propagation not only of external with respect to the solenoid pour on and currents, but both the process of the propagation of magnetic flux inside the solenoid itself and the velocity of propagation of this flow will be equal to the velocity of propagation of electromagnetic wave in line itself.

Knowing current and voltage in the line, it is possible to calculate the specific energy, concluded in the linear capacity and the inductance of line. These energies will be determined by the relationships:

$$W_C = \frac{1}{2} C_0 U_1^{\ 2}, \tag{3.3}$$

$$W_L = \frac{1}{2} L_0 I_1^{\ 2}. \tag{3.4}$$

it is not difficult to see that $W_C = W_L$.

Now let us discuss a question about the duration of the front of electric-current wave and about which space will occupy this front in line itself. Answer to the first question is determined by the properties of the very voltage source, since local derivative $\frac{\partial U}{\partial t}$ at incoming line depends on transient processes in the source itself and in that device, with the aid of which this source is connected to the line. If the process of establishing the voltage on incoming line will last some time Δt, then in the line it will engage section with the length $v\Delta t$. If we to the line exert the stress, which is changed with the time according to the law $U(t)$, then the same value of function will be observed at any point of the line at a distance z rel.un. of beginning with the delay $t = \frac{z}{v}$. Thus, the function of

$$U(t,z) = U\left(t - \frac{z}{v}\right) \tag{3.5}$$

can be named propagation function, since. it establishes the connection between the local temporary and three-dimensional values of function in the line. Long line is the device, which converts local derivative stresses on the time on incoming line into the gradients in line itself. On the basis propagation function (3.5) it is possible to establish the connection between the local and gradients in the long line. It is obvious that

$$\frac{\partial U(z)}{\partial z} = \frac{1}{v} \frac{\partial U(t)}{\partial t} .$$

Let us note the fact that for solving the wave equations of the long lines

$$\begin{aligned} \frac{\partial^2 U}{\partial z^2} &= \frac{1}{v^2} \frac{\partial^2 U}{\partial t^2} \\ \frac{\partial^2 I}{\partial z^2} &= \frac{1}{v^2} \frac{\partial^2 I}{\partial t^2} \end{aligned} \tag{3.6}$$

obtained from the telegraphic equations

$$\begin{aligned} \frac{\partial U}{\partial z} &= -L \frac{\partial I}{\partial t} \\ \frac{\partial I}{\partial z} &= -C \frac{\partial U}{\partial t} \end{aligned},$$

the knowledge second derivative voltages and currents is required.

But what is to be done, if to incoming line is supplied voltage, whose second derivative is equal to zero (case, when the voltage of source it does change according to the linear law)? Answer to this question equation (3.6) they do not give. The utilized method gives answer also to this question.

With the examination of processes in the long line figured such concepts as linear capacity and inductance, and also currents and stress in the line. However, in the electrodynamics, based on the Maxwell equations, there are no such concepts as capacity and inductance, and there are concepts of the electrical and magnetic permeability of medium. In the carried out examination such concepts as electrical and magnetic fields also was absent. Let us show how to pass from such categories as linear inductance and capacity, current and stress in the line to such concepts as dielectric and magnetic constant, and also electrical and magnetic field. For this let us take the simplest construction of line, located in the vacuum, as shown in Fig. 1.

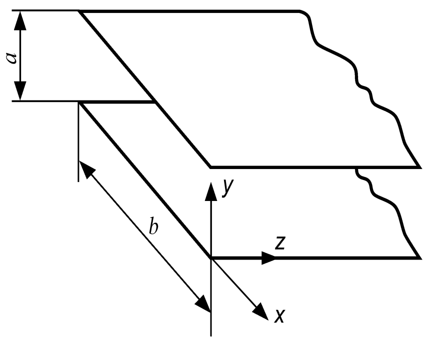

Fig. 1. The two-wire circuit, which consists of two ideally conducting planes.

We will consider that $b \gg a$ and edge effects it is possible not to consider. Then the following connection will exist between the linear parameters of line and the magnetic and dielectric constants:

$$L_0 = \mu_0 \frac{a}{b} \tag{3.7}$$

$$C_0 = \varepsilon_0 \frac{b}{a}, \qquad (3.8)$$

where μ_0 and ε_0 - dielectric and magnetic constant of vacuum.

The phase speed in this line will be determined by the relationship:

$$v = \frac{1}{\sqrt{L_0 C_0}} = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = c,$$

where c - velocity of propagation of light in the vacuum.

The wave drag of the line examined will be equal

$$Z = \frac{a}{b}\sqrt{\frac{\mu_0}{\varepsilon_0}} = \frac{a}{b} Z_0,$$

where $Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}}$ - wave drag of free space.

This with the observance of the condition $a = b$ we obtain the equality $L_0 = \mu_0$. This means that magnetic permeability μ_0 plays the role of the longitudinal specific inductance of vacuum. In this case is observed also the equality $C_0 = \varepsilon_0$. This means that the dielectric constant ε_0 plays the role of the transverse specific capacity of vacuum. In this interpretation both μ_0 and ε_0 acquire clear physical sense.

The examination of electromagnetic wave in the long line can be considered as filling of space, which is been located between its conductors, special form of material, which present the electrical and magnetic fields. Mathematically it is possible to consider that these fields themselves possess specific energy and with their aid it is possible to transfer energy by the transmission lines.

If we to the examined line of infinite length, or of line of that loaded with wave drag, connect the dc power supply U, then the field strength in the line will comprise:

$$E_y = \frac{U}{a},$$

and the current, which flows into the line from the power source, will be determined by the relationship:

$$I = \frac{U}{Z} = \frac{aE_y}{Z}. \tag{3.9}$$

Magnetic field in the line will be equal to the specific current, flowing in the line

$$H_x = \frac{I}{b} = \frac{aE_y}{bZ}.$$

substituting here the value Z, we obtain

$$H_x = \frac{E_y}{Z_0}. \tag{3.10}$$

The same connection between the electrical and magnetic field exists also for the case of the transverse electromagnetic waves, which are extended in the free space.

Comparing expressions for the energies, it is easy to see that the specific energy can be expressed through the electrical and magnetic fields

$$\frac{1}{2}\mu_0 H_x{}^2 = \frac{1}{2}\varepsilon_0 E_y{}^2. \tag{3.11}$$

This means that the specific energy, accumulated in the magnetic and electric field in this line is identical. If the values of these energies are multiplied by the volumes, occupied by fields, then the obtained values coincide with expressions (3.3-3.4).

thus, it is possible to make the conclusion that in the line examined are propagated the same transverse plane waves, as in the free space. Moreover this conclusion is obtained not by the method of solution the Maxwell equations, but by the way of examining the dynamic processes, which are related to the discharge of parametric self-induction. The special feature of this line will be the fact that in it, in contrast to the free space, the stationary magnetic and electric fields can be extended, but this case cannot be examined by the method of solution of Maxwell's equations.

If we to the line exert the stress, which is changed in the course of time according to any law $U(t) = aE_y(t)$, the like of analogy (3.5) it is possible to write down

$$E_y(z) = E_y\left(t - \frac{z}{c}\right). \tag{3.12}$$

Analogous relationship will be also pour on for the magnetic.

Is obvious that the work $I(t)U(t)$ represents the power P, transferred through the cross section of line in the direction z. If in this relationship current and stress was replaced through the tensions of magnetic and electrical pour on, then we will obtain $P = abE_yH_x$. The work E_yH_x represents the Poynting vector. Certainly, all these relationships can be written down also in the vector form.

Thus, all conclusions, obtained on the basis of the examination of processes in the long line by two methods, coincide. Therefore subsequently, without risking to commit the errors of fundamental nature, it is possible for describing the processes in the long lines successfully to use such parameters as the distributed inductance and capacity. Certainly, in this case one should understand that C_0 and this L_0 some integral characteristics, which do not consider structure pour on. It should be noted that from a practical point of view, the application of the parameters C_0 and L_0 has important significance, since. can be approximately solved the tasks, which with the aid of Maxwell equations cannot be solved. This, for example, the case, when spirals are the conductors of transmission line.

The importance of the obtained results consists in the fact that it is possible, without resorting to the Maxwell's equations, to solve the problems of propagation, is also shown that in the long lines and in the free space the electromagnetic processes are extended with the final speed.

The regularities indicated apply to all forms of transmission lines. For different types of lines the linear parameters depend on their sizes. For an example let us examine the coaxial line, whose linear capacity and inductance are expressed by the relationships:

$$C_0 = \frac{2\pi\varepsilon_0}{\ln\left(\frac{D}{d}\right)} \qquad L_0 = \frac{\mu_0}{2\pi}\ln\left(\frac{D}{d}\right)$$

where D and d the inside diameter of the cylindrical part of the coaxial and the outer diameter of central core respectively. The introduced linear parameters, can be named field, since the discussion deals with that energy, which is stored up in the electrical and magnetic fields. However, the circumstance is not considered with this approach that besides field inductance there is still a kinetic inductance, which is obliged to kinetic energy of the moving charges. In the real transmission lines kinetic inductance is not calculated on the basis of that reason, that their speed is small in view of the very high density of current carriers in the conductors and therefore field inductance always is considerably greater than kinetic.

with the current I, which flows along the center conductor of coaxial line, energy accumulated in the specific inductance and linear inductance are connected with the relationship

$$W_L = \frac{1}{2} L_0 I^2 = \frac{\mu_0}{4\pi} \ln\left(\frac{D}{d}\right) I^2$$

We will consider that the current is evenly distributed over the section of center conductor. Then kinetic energy of charges in the conductor of unit length composes

$$W_k = \frac{\pi d^2 n m v^2}{8} ,$$

where n, m, v - electron density, their mass and speed respectively.

If one considers that $I = \frac{nev\pi d^2}{4}$, then it is possible to write down

$$W_L = \frac{1}{2} L_0 I^2 = \frac{\mu_0}{4\pi} \ln\left(\frac{D}{d}\right) \frac{n^2 e^2 v^2 \pi^2 d^4}{16} .$$

From these relationships we obtain, that to the case, when

$$W_k \geq W_L ,$$

the condition corresponds

$$\frac{m}{ne^2} \geq \frac{\mu_0}{8} \ln\left(\frac{D}{d}\right) d^2$$

where $L_k = \frac{m}{ne^2}$ - specific kinetic inductance of charges.

Hence we find that the fulfillment of conditions is necessary for the kinetic beams

$$n \leq \frac{8m}{d^2 e^2 \mu_0}$$

in such a way that the flow would be kinetic, is necessary that the specific kinetic inductance would exceed linear inductance, which is carried out with the observance of the given condition. From this relationship it is possible to estimate, what electron density in the flow corresponds to this of the case.

Let us examine the concrete example: $d = 1мм$, $\ln\left(\frac{D}{d}\right) = 2$, then for the electron density in the beam must be satisfied the condition of

$$n \le \frac{8m}{e^2 \mu_0 \ln\left(\frac{D}{d}\right) d^2} \approx 10^{-20} \frac{1}{м^3}.$$

Such densities are characteristic to electron beams, and they are considerably lower than electron density in the conductors. Therefore electron beams should be carried to the kinetic flows, while electronic current in the conductors they relate to the potential flows. Therefore for calculating the energy, transferred by electromagnetic fields they use the Poynting vector, and for calculating the energy, transferred by electron beams is used kinetic energy of separate charges. This all the more correctly, when the discussion deals with the calculation of the energy, transferred by ion beams, since. the mass of ions many times exceeds the mass of electrons.

Thus, the reckoning of the flows of charges to one or the other form depends not only on density and diameter of beam itself, but also on the diameter of that conducting tube, in which it is extended. It is obvious that in the case of potential beam, its front cannot be extended at a velocity, which exceeds the speed of light. It would seem that there are no such limitations for the purely kinetic beams. There is no clear answer to this question as yet. The mass of electron to usually connect with its electric fields and if we with the aid of the external conducting tube begin to limit these fields, then the mass of electron will begin to decrease, but the decrease of mass will lead to the decrease of kinetic inductance and beam will begin to lose its kinetic properties. And only when the part of the mass of electron does not have electrical origin, there is the hope to organize the purely kinetic electron beam, whose speed can exceed the speed of light. If we take the beam of protons, then picture will be the same. But here, if we take, for example, the nuclei of deuterium, which contain the neutron, whose mass is located, but electrical pour on no, then with the aid of such nuclei it is possible to organize purely kinetic beams, and it is possible to design for the fact that such beams can be driven away to the speeds of the large of the speed of light. If we let out this beam from the limiting tube into the free space, i.e. to attempt to convert it from the kinetic into the potential, then Cerenkov radiation of the type of that can be obtained, when electronic flux falls on Wednesday, where the phase speed of electromagnetic wave is lower than the speed of electron beam.

REFERENCE

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