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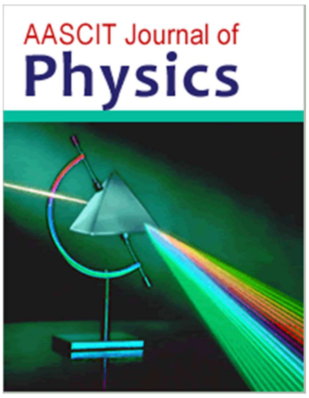

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New Properties of Reactive Elements, Lines of Transmission of Energy and the Relaxation Properties of Electronic Fluxes and Conductors

F. F. Mende

B. Verkin Institute for Low Temperature Physics and Engineering NAS Ukraine, Kharkov, Ukraine

Email address
mende_fedor@mail.ru

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Abstract
It is shown that such reactive elements as capacities and inductances can play the role of effective resistance, which depends on time. The processes of propagation in the long lines with the connection to them of dc power supplies are examined. The concept of the potential and kinetic flows of charges is introduced. In the article the new law, which determines the dependence of the specific resistance of electron beam on a potential difference between the electrodes and the distances between them, is obtained. This made possible to give the phenomenological explanation to the jumps of the resistance of the thin superconductive channels in the intermediate state.

1. Introduction

In radio engineering and electronics have long ago been used such concepts as capacity, inductance and the line of transmission of energy. And, it would seem, anything new apropos in the properties and characteristics of such elements to add difficultly. But in actuality this not thus. It is customary to assume capacity and inductance as the reactive elements, which in the alternating current circuits cannot absorb energy. But this concerns only that case, when the time of the action on them of periodic processes approaches infinity. However, in the case of the limited time of action this principle is not carried out. In order to be convinced of this, it suffices to the network of alternating current to connect capacitor. With its turning off from the network, depending on the moment of turning off, on it the specific charge will remain, and this means that the capacitor took away from the network some energy. The same relates also to the inductance. It is obvious and the fact that capacitor will be, being charged by that connected to the source of direct current, taking away in the source energy. In this case the capacitor presents for the source resistive load with the specific properties. The same relates also to the inductance, connected to the dc power supply.

The long lines, utilized for the transfer of energy and signals, have long ago been investigated, but also here are questions, to which, until now, there are no answers. The processes of propagation in the long lines describe the wave of the equations, which require the knowledge second derivative voltages and currents. But there are cases, when such derivatives cannot be determined. This is the case, when dc power supply is connected to the line. It is incomprehensible so, as should be solved problem in the case, when to the line is connected the source of voltage, whose voltage linearly depends on time, since in this case the second derivative is equal to constant. Answer to a question about how should be examined the processes of propagation in the line in this case, in the scientific literature is absent.

The properties of long lines are characterized by such parameters as linear capacity and inductance, which do not consider the kinetic properties of charges. This connected with the fact that linear field inductance in the long lines considerably exceeds linear kinetic inductance. This condition can not be observed when as the conductors of line it serves electronic or ionic flux. This special feature of such lines in the existing publications also is not examined.

The motion of charges in the normal conductors is accompanied by the loss of energy, connected with the relaxation processes. Relaxation processes occur, also, with the propagation of electronic fluxes vacuum, and also in the superconductive films in the intermediate state. But thus far no one turned attention to the fact that these processes have much in common. On this thematics contributor published a number of works [1-6], which are condemned in the article.

2. Active and Reactive Self-Induction

The Kirgof's laws they indicate that in that locked value, that has the voltage sources, the sum of all voltagees on its elements it is equal to zero. This means that network elements answer the action of the voltage source the reverse reaction, which exactly compensates the action of the voltage source. This phenomenon is similar to third Newton's law, when action is equal to opposition, and bears the name of self-induction.

If we to the effective resistance connect the power source, then Ohm's law is carried out

$$U = IR ,$$

or

$$U - IR = 0 .$$

This means that with the connection of the voltage source to the effective resistance in this resistance is established such current, which during the resistance R gives the voltage drop, equal to the voltage, connected to the resistance.

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 the capacity C is charged to a potential difference U, then the charge Q, accumulated in it, is determined by the relationship

$$Q_{C,U} = CU .$$

If the value of a voltage drop across capacity or capacity itself depends on time, then the strength of current, which flows in the chain, which includes the voltage source and capacity, is determined by the relationship:

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

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.

When the capacity C_0 is constant, we obtain expression for the current, which flows in the chain:

$$I(U) = C_0\frac{\partial U}{\partial t} \quad (2.1)$$

when changes capacity, and at it is supported the constant voltage U_0, we have:

$$I(C) = U_0\frac{\partial C}{\partial t} \quad (2.2)$$

This case to relate to the parametric capacitive self-induction, since the current strength it is connected with a change in the capacitance value.

Let us examine the consequences, which escape from relationship (2.2).

If we to the capacity connect the direct-current generator of I_0, then voltage on it will change according to the law:

$$U(t) = \frac{I_0 t}{C_0} \quad (2.3)$$

Using to this relationship Ohm's law

$$U = IR ,$$

we obtain the value of the effective resistance of the chain in question[1-6]

$$R(t) = \frac{t}{C_0} .$$

Thus, the capacity, connected to the current source, plays the role of the effective resistance, which linearly depends on the 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].

From a physical point of view this property of capacity is connected with the fact that, charging capacity, current source to expend energy. Capacity itself in this case performs the role of storage battery.

Charging capacity, current source expends the power

$$P(t) = \frac{I_0^2 t}{C_0} \tag{2.4}$$

The energy, accumulated by capacity in the time t, we will obtain, after integrating relationship (2.4) with respect to the time:

$$W_C(t) = \frac{I_0^2 t^2}{2C_0}.$$

Substituting here the value of current from relationship (2.3), we obtain the dependence of the value of the accumulated in the capacity energy from the instantaneous value of voltage on it:

$$W_C(U) = \frac{1}{2} C_0 U^2.$$

Now we will support at the capacity constant voltage U_0, and change capacity itself, then

$$I(C) = U_0 \frac{\partial C}{\partial t}.$$

Using to this relationship Ohm's law

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

plays the role of the resistance [1-6]. The derivative, entering this expression can have different signs. This result is intelligible. Since with a change in the capacity change the energy accumulated in it, capacity, it can extract energy in the current source, or return energy into the external circuit. The power, expended by current source, or output into the external circuit, is determined by the relationship:

$$P(C) = \frac{\partial C}{\partial t} U_0^2.$$

Let us examine one additional process, which earlier the laws of induction did not include, however, it falls under for our extended determination of this concept. It is evident that if the charge, accumulated in the capacity, remains constant, then voltage on it can be changed by changing the capacity. In this case the relationship will be carried out:

$$Q_0 = C_0 U_0 = CU = const,$$

where C, U are instantaneous values, and C_0, U_0 are initial values of these parameters. The voltage on the capacity and the energy, accumulated in it, will be in this case determined by the relationships:

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

$$W_c(C) = \frac{1}{2} \frac{(C_0 U_0)^2}{C}. \tag{2.5}$$

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.

Let us examine the processes, proceeding in the inductance. If the current strength through the inductance or inductance itself depend on time, then the value of voltage on it is determined by the relationship:

$$U(t) = L\frac{\partial I}{\partial t} + I\frac{\partial L}{\partial t}$$

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

$$U(I) = L_0 \frac{\partial I}{\partial t} \tag{2.6}$$

After integrating expression (2.6) on the time, we will obtain:

$$I(t) = \frac{Ut}{L_0} \tag{2.7}$$

Using to this relationship Ohm's law, we obtain, that the inductance, connected to the dc power supply, presents for it the resistance

$$R(t) = \frac{L_0}{t}.$$

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

$$P(t) = \frac{U^2 t}{L_0} \tag{2.8}$$

After integrating relationship (2.8) on the time, we will obtain the energy, accumulated in the inductance

$$W_L(t) = \frac{1}{2}\frac{U^2 t^2}{L_0} \tag{2.9}$$

After substituting into expression (2.9) the value of voltage from relationship (2.7), we obtain the value of the energy, accumulated in the inductance:

$$W_L(I) = \frac{1}{2} L_0 I^2.$$

Let us examine the case, when the current I_0, which flows through the inductance, is constant, and inductance itself can change. In this case we obtain

$$U = I_0 \frac{\partial L}{\partial t} \quad (2.10)$$

Consequently, the value

$$R(t) = \frac{dL}{dt}$$

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.

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

$$L_0 I_0 = const,$$

where L_0, I_0 are 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. In this case the relationship is fulfilled:

$$I_0 = \frac{I_1 L_1}{L_0},$$

where I_1 , L_1 are 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

$$W_L(L) = \frac{1}{2}\frac{(L_0 I_0)^2}{L}.$$

where L is the instantaneous value of inductance.

3. Propagation of Signals in the Long Lines

The processes of the propagation of voltages and currents in the long lines it is described with the aid of the wave equations

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

which are obtained from the telegraphic equations

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

But as to enter, if to the line is connected dc power supply or source of voltage, which is changed according to the linear law, when the second derivatives of voltages and currents do be absent? In existing publication before the appearance of works [1-6] answers to this question it was not.

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.

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 [1-2]. Let us assume that the linear capacity and the inductance of line compose C_0, L_0. If we to the line connect the dc power supply of U , thus will begin to charge the capacity of long line and the front of this voltage will be extended along the line some by the speed of v. The moving coordinate of this front will be determined by the relationship $z = vt$. In this case the total quantity of the charged capacity and the value of the summary inductance, along which it flows current, calculated from the beginning lines to the location of the front of voltage, will change according to the law :

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

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

The source of voltage of U will in this case charge the being increased capacity of line, for which from the source to the charged line in accordance with relationship (2.2) must leak the current:

$$I = U\frac{\partial C(t)}{\partial t} = UvC_0. \quad (3.1)$$

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 voltage, also increases, in accordance with relationship (2.10), on it will be observed a voltage drop:

$$U_1 = I\frac{\partial L(t)}{\partial t} = IvL_0 = v^2 U C_0 L_0.$$

But a voltage drop across the conductors of line in the absolute value is equal to the voltage, 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 voltage with the assigned linear parameters and when, on, the incoming line of constant voltage U is present, must compose

$$v = \frac{1}{\sqrt{L_0 C_0}}. \quad (3.2)$$

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 expansion of electrical pour on and the currents, which fill line with energy, and the speed of the front of constant voltage and current will be equal to the velocity of propagation of electromagnetic vibrations in this line. This wave we will call elektrocurrent wave [1-6]. It is interesting to note that the obtained result does not depend on the form of the function of U , 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 (2.2). 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 of U , 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 , 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 process of turning off of the voltage source from the line is also accompanied by the transient process, with which the voltage decreases on what that to law. This transient process in the form of the reverse wave front will be also extended along the line. This means that the single voltage pulse will be extended along the long line with the same speed as its front. Wave equations give formal answer to a question about propagations of signals in the long lines, the procedure examined reveals the physical the bases of this process.

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

$$I = U\sqrt{\frac{C_0}{L_0}},$$

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

The regularities indicated apply to all forms of transmission lines.

If we to the line with the length of z_0 connect the effective resistance, equal to line characteristic, then the voltage of the power source will appear on it with the time delay $\Delta t = \frac{z_0}{v}$. This resistance will be coordinated with the line and entire energy, transferred by the line, will be in it absorbed. This connected with the fact that the current, which flows in the line is equal to the current, which flows through the resistance, when voltage on it is equal to voltage on incoming line.

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 elektrocurrent spontaneous parametric self-induction. This name flow expansion they connected with the fact that occur spontaneously.

4. Properties of Static Charges and Their Flows

The capacity of the capacitor, which consists of the flat parallel plates, is determined by the relationship:

$$C = \frac{\varepsilon_0 S}{d},$$

where ε_0 , S , d are dielectric constant of vacuum, the area of plates and the distance between them respectively. Substituting in this relationship equality (2.5), we obtain

$$W_c = \frac{1}{2}\frac{d\left(C_0 U_0\right)^2}{\varepsilon_0 S}. \quad (4.1)$$

Is evident that with the constant charge, stored up in the capacitor, an increase in the distance between the plates leads to an increase in its energy. This is connected with the fact that in order to increase the distance between the plates, it is necessary to spend the work, which will pass into the energy of its electrical pour on. As this occurs, evidently from Fig.1.

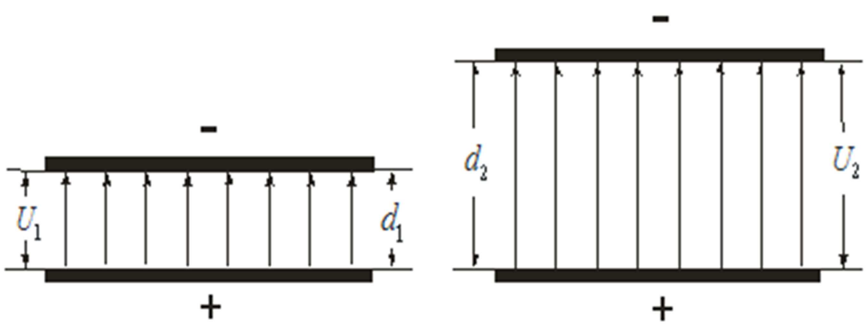

Fig 1. *The electric fields of parallel-plate capacitor with the different distance between its plates.*

Taking into account that the work of capacity and voltage is equal to charge, accumulated in the capacitor, relationship (2.9) can be rewritten

$$W_c = \frac{1}{2}\frac{d\left(Q_0\right)^2}{\varepsilon_0 S} = \frac{1}{2}\varepsilon_0 E^2 Sd \quad (4.2)$$

where E is tension of electric field in the line.

From relationship (2.12) follows

$$E = \frac{Q_0}{\varepsilon_0 S}.$$

This means that in the parallel-plate capacitor the field strength does not depend on the distance between the plates, but it is determined by the surface density of charge on them. Let us note that with this examination we do not consider edge effects that correctly when the distance between the plates much less than their length and width. Consequently, voltage across capacitor is determined by the distance between the plates

$$U(d) = \frac{Q_0 d}{\varepsilon_0 S}.$$

From the carried out analysis escapes the interesting property of the electrons, which compose the charge Q_0. A total quantity of electrons is equal

$$N = \frac{Q_0}{e},$$

where e is a charge of one electron. Thus, energy of one electron, which is located on the plate of capacitor, is equal

$$W_e = \frac{de}{\varepsilon_0 S}.$$

This energy depends on the distance between the plates, but since no limitations on d they are superimposed, this energy can be as desired to large.

In the case examined the electric fields of each separate electron are located in the tube, located between the planes of capacitor. The cross-sectional area of this tube is equal and its height it is respectively equal: $\frac{S}{N}$ and d. When an increase in the size occurs d, volume of this tube increase, and therefore it grows and energy pour on. In this case the mechanical energy, spent on the displacement of the plate of capacitor, passes into the energy of electrical pour on electron. Analogous situation will be observed, also, in the coaxial capacitor. Difference will be only the fact that the fields of electron will occupy not tube with the constant section, but annular disk.

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.

If charges can move without the losses, then equation of motion takes the form:

$$m\frac{d\vec{v}}{dt} = e\vec{E},$$

where m is the mass electron, e is the electron charge, $\vec{E}$ is the tension of electric field, $\vec{v}$ is speed of the motion of charge.

Using an expression for the current density

$$\vec{j} = ne\vec{v},$$

we obtain the current density of the conductivity

$$\vec{j}_L = \frac{ne^2}{m}\int \vec{E}\,dt = \frac{1}{L_k}\int \vec{E}\,dt,$$

where

$$L_k = \frac{m}{ne^2}$$

is kinetic inductance of charges [7-9].

Maxwell's equations for this case take the form:

$$rot\ \vec{E} = -\mu_0 \frac{\partial \vec{H}}{\partial t}, \qquad rot\ \vec{H} = \varepsilon_0 \frac{\partial \vec{E}}{\partial t} + \frac{1}{L_k}\int \vec{E}\,dt, \tag{4.3}$$

where ε_0, μ_0 are dielectric and magnetic constant of vacuum.

The system of equations (4.3) completely describes all properties of the conductors, in which be absent the ohmic losses. From relationship (4.3) we obtain

$$rot\ rot\ \vec{H} + \mu_0\varepsilon_0 \frac{\partial^2 \vec{H}}{\partial t^2} + \frac{\mu_0}{L_k}\vec{H} = 0 \tag{4.4}$$

For the case pour on, time-independent, equation (4.4) passes into the London equations

$$rot\ rot\ \vec{H} + \frac{\mu_0}{L_k}\vec{H} = 0,$$

where $\frac{L_k}{\mu_0} = \lambda_L^2$. In this relationship of λ_L there is London depth of penetration.

Thus, it is possible to conclude that the equations of London being a special case of equation (4.4), and do not consider bias currents on Wednesday. Therefore they do not give the possibility to obtain the wave equations, which describe the processes of the propagation of electromagnetic waves in the superconductors.

Pour on wave equation in this case it appears as follows for the electrical:

$$rot\ rot\ \vec{E} + \mu_0\varepsilon_0 \frac{\partial^2 \vec{E}}{\partial t^2} + \frac{\mu_0}{L_k}\vec{E} = 0.$$

For constant electrical pour on it is possible to write down

$$rot\ rot\ \vec{E} + \frac{\mu_0}{L_k}\vec{E} = 0\,.$$

Consequently, dc fields penetrate the superconductor in the same manner as for magnetic, diminishing exponentially. However, the density of current in this case grows according to the linear law

$$\vec{j}_L = \frac{1}{L_k}\int \vec{E}\ dt \qquad (4.5)$$

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. Let us show this based on simple example.

Let us examine processes in the line, which consists of two superconductive planes (Fig. 2.)

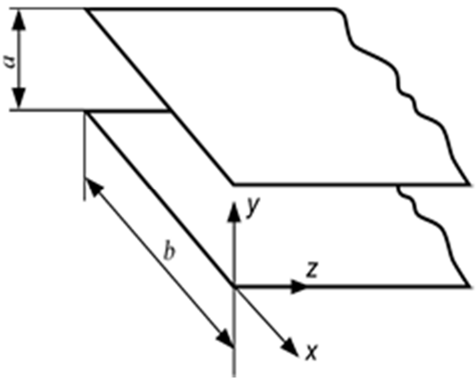

Fig 2. *The two-wire circuit, which consists of two ideally conducting planes.*

The magnetic field on the internal surfaces of this line, equal to specific current, is determined from the relationship:

$$H = nev\lambda = j\lambda\,,$$

where n, e, v are density, charge and the velocity of the superconductive electrons, and $\lambda = \sqrt{\frac{L_k}{\mu}}$ is depth of penetration of magnetic field into the superconductor.

If we substitute the value of depth of penetration into the relationship for the magnetic field, then we will obtain:

$$H = v\sqrt{\frac{nm}{\mu}}\,.$$

Thus, specific kinetic the kinetic energy of charges in the skin-layer

$$W_H = \frac{1}{2}\mu H^2 = \frac{nmv^2}{2} = \frac{1}{2}L_k j^2$$

is equal to specific the energy of magnetic fields. But magnetic field exists not only on its surface, also, in the skin-layer. If we designate the length of the line, depicted in Fig. 2, then the volume λ skin-layer in the superconductive planes of line will compose $2lb\lambda$. Energy of magnetic pour on in this volume we determine from the relationship:

$$W_{H,\lambda} = nmv^2 lb\lambda\,.$$

However, energy of magnetic pour on, accumulated between the planes of line, it will comprise:

$$W_{H,a} = \frac{nmv^2 lba}{2} = \frac{1}{2}lba\mu_0 H\,.$$

If one considers that the depth of penetration of magnetic field in the superconductors composes several hundred angstroms, then with the macroscopic dimensions of line it is possible to consider that the total energy of magnetic field on in it they determine by relationship.

Is obvious that the effective mass of electron in comparison with the mass of free electron grows in this case into $\frac{a}{2\lambda}$ of times. Thus, becomes clear nature of such parameters as inductance and the effective mass of electron, which in this case depend, in essence, not from the mass of free electrons, but from the configuration of conductors, on which the electrons move.

The kinetic flow of charges we will consider such flow, whose kinetic inductance is more than field. Let us examine this question in the concrete example.

For the evacuated coaxial line linear inductance is determined by the relationship

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

With the current I, which flows along the internal conductor, energy accumulated in the linear inductance will compose

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

With the uniform distribution of current density over the section of internal conductor linear kinetic energy of charges will comprise

$$W_k = \frac{\pi d^2 nmv^2}{8}$$

where n, m, v are 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

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

From these relationships we obtain, that for the fulfillment of conditions

$$W_k \geq W_L$$

fulfilling of the inequality is required

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

From this relationship we obtain

$$n \leq \frac{8m}{d^2 e^2 \mu_0 \ln\left(\frac{D}{d}\right)}$$

The electronic flux we will consider kinetic when it is carried out the given condition.

We estimate the density of electrons in the stream for a specific example, when $d = 1мм$, $\ln\left(\frac{D}{d}\right) = 2$.

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

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.

For calculating the energy, transferred by electromagnetic fields, they use Poynting's vector, in this case the energy in the line is transferred by electromagnetic fields and it is separated on the effective resistance, which serves as the load of line. For calculating the energy, transferred by electron beams is used kinetic energy of 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. With this method of the energy transfer the energy is separated on that target, where the accelerated flow of charges falls.

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. Such limitations are not obvious for the purely kinetic beams.

5. Relaxation Properties of Conductors and Superconductive Channels

Let us examine the simplest case, when metal at room temperatures is placed into the electric field. Current rise in the environment of any point inside the metal is caused, in the first place, by the fact that the electrons are accelerated under the action of the electric field $\vec{E}$, and, in the second place, fact that as a result electron collisions with the lattice or the admixtures their way between two sequential collisions is limited by the mean free path of l. Mean free path depends also on temperature, with which an increase in the conductivity of normal metals with a decrease in their temperature is connected. During the formation of current must be considered the fields, which exist at the length l, with this at any point field $\vec{E}$ it is possible to consider it as constant. Current density in this case will be determined only by the value of field at the point in question, which indicate the local connection between the electric field and the current density.

For finding the connection between the current density of $\vec{j}$ and $\vec{E}$ it is possible to use the simple model of free electrons. On this model interaction of electron with the electric field and its collisions with the lattice are described by the equation of

$$\frac{d\vec{v}}{dt} = \frac{e\vec{E}}{m} - \frac{1}{\tau}\vec{v} \tag{5.1}$$

where e, m, $\vec{v}$ are charge, mass and the velocity of electron, n is electron density. The term $\frac{m}{\tau}$ is equivalent to the force of viscous friction of motion of particle in the viscous fluid. In the absence electric field conduction electrons in the state of equilibrium are uniform distributed along the metal. In the pulse space of their state (in view of the exclusion principle of Pauli) can be represented as those uniform distributed inside the sphere of a radius mv_F (v_F is Fermi's speed). At any temperature, different from absolute zero, the boundary of sphere (Fermi surface) will not be sharp because of the temperature excitations. However, smearing boundary is extremely small at all interesting us temperatures and it can be disregarded. Introducing the current density $\vec{j} = ne\vec{v}$, from (5.1) we obtain

$$\frac{d\vec{j}}{dt} = \frac{ne\vec{E}}{m} - \frac{1}{\tau}\vec{j} . \tag{5.2}$$

During the imposition of the dc field of $\vec{E}$ solution (5.2) with the initial condition of $\vec{j}(0) = 0$ takes the form

$$\vec{j}(t) = \sigma\vec{E}\left(1 - e^{-\frac{t}{\tau}}\right)$$

where

$$\sigma = \frac{ne^2\tau}{m} \tag{5.3}$$

Is conductivity with the direct current. Thus, current density is approached the equilibrium value $\vec{j} = \sigma\vec{E}$. This means that from the point of view of this semi-classical model all electrons in the pulse space move with one and the same with acceleration or, which is equivalent, the center of sphere is shifted to the value $m\vec{v}$, approaching the equilibrium value $e\tau\vec{E}$. Mean free path is determined by the relationship of $\tau = \frac{l}{v_F}$. In this treatment the mean free path represents the distance, passed electronic on the Fermi surface in the time τ.

In the conductor between the electron gas and the lattice there is a dynamic equilibrium. If we conductor place into the electric field, then electrons will begin to be accelerated, deriving additional energy in electric field. The model examined is represented in Fig. 3 assume that each electron, moving cyclically, in the time of τ derives energy in electric field, and then, colliding with the atoms of lattice, it returns to it the energy, obtained in field.

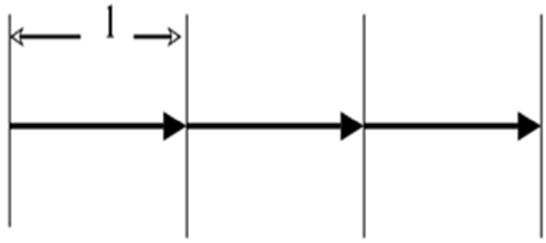

Fig 3. *Diagram of interaction of electrons with the atoms of lattice.*

It is possible to present the macroscopic situation, which reflects this process. Will arrange a sequential quantity of electrodes, located in the vacuum, as shown in Fig. 3, and let us connect to each the feather of electrodes the sources of voltage U. Let us ensure also the possibility of that so that after the acceleration between the electrodes, electronic flux would return the energy, obtained in field, to the subsequent electrode. In this case between each pair of electrodes there will be the leak current, and this pair will present effective resistance. Let us calculate this resistance.

The electron transit time between the electrodes (relaxation time) will comprise

$$\tau = l\sqrt{\frac{2m}{eU}} \tag{5.4}$$

This case is differed from that examined by the fact that mean free time depends on the voltage between the electrodes, while in the case of normal metal it it depends on the speed of Fermi and on temperature.

Since the processes, proceeding in the normal metal and depicted in Fig. 5, are similar, then for enumerating the conductivity of electronic flux, that is moved between the electrodes, it is possible to use relationship (5.3). Substituting (5.4) in (5.3), we obtain

$$\sigma = nl\sqrt{\frac{2}{mU}}.$$

Consequently as in the metal, conductivity is the greater, the greater the mean free path, but in the case examined it does not depend on magnitude of the charge. Knowing the conductivity of beam, it is possible to calculate its specific resistance

$$\rho = \frac{1}{\sigma} = \frac{1}{nl}\sqrt{\frac{mU}{2}}.$$

Knowing the specific resistance of beam, it is possible to calculate its resistance

$$R = \rho\frac{l}{S} = \frac{1}{nS}\sqrt{\frac{mU}{2}},$$

where S is the cross section of bundle.

It turned out that the resistance of beam does not depend on the distance between the electrodes, but the total resistance of the entire of the circuit of electrodes is multiple to a quantity of their pairs.

A similar case realizes in thin superconductive channels [10].

The superconductive channels, with reaching in them of critical current, convert to the normal state, which possesses resistance. This process has its special features. On the voltage-current characteristics of the thin and narrow superconductive films are observed steps (Fig. 4).

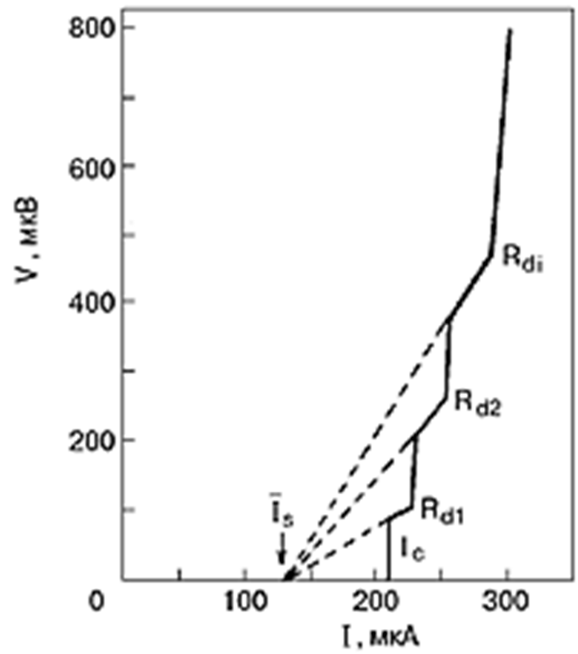

Fig 4. *Typical voltage-current characteristic of the intermediate state of the tape uniform superconductive channel.*

Voltage surges are the characteristic feature of the voltage-current characteristics of the superconductive channels, in this case the resistance of model changes with the multiple means

$$R = nR_{d1} \tag{5.5}$$

As follows from work [10] unity of opinion to physics of this behavior of the superconductive channels it is absent. In also the time the proposed model of the appearance of the resistance of electron beams makes it possible to give the phenomenological explanation of the behavior of the superconductive channels in the intermediate state. As it follows from the carried out examination in the diagram of interaction of electronic flux with the electrodes, given in Fig. 5, the flow resistance from the distance between the electrodes does not depend, but it depends only on a quantity of pairs of electrodes; therefore the total resistance of the totality of such pairs will be multiple to their quantity as in relationship (5.5).

During the imposition on the film of electric field the current in it must grow in accordance with relationship (4.5). However, for the narrow film, connected to the massive contacts, this process has its special features. Into the beginning of the superconductive channel the superconductive electrons (Cooper pairs) enter with the zero speed, and their acceleration begins after this. If during the motion for the elongation of entire channel the speed of Cooper pair does not reach critical value (as can be seen from Fig. 5 this the currents of below 200 μA) that film remains superconductive. But, as soon as Cooper pair, after passing almost entire film, near its end will reach critical speed, will occur its disintegration and the normal electrons, which were being formed as a result of this disintegration will return the energy obtained by them, to lattice. In this case on the voltage-current characteristic the first step will appear. The further decomposed electrons again form Cooper pair and will continue their way, but will be accelerated to the critical speeds they will not have time and they will leave the film into the massive opposite contact in the form of Cooper pair. With further increase in the speed of Cooper pairs, the place of reaching critical speed begins to be shifted to the middle of film, but during the intersection of its middle in the end of the film the following Cooper pairs will reach their critical speed and the second step will appear on the voltage-current characteristic. Further increase in the current will lead to appearance third of step, then by the fourth, etc that also is observed during the experiment.

In Fig. 5 is shown the process of the development of the jumps of the resistance of the superconductive film in the intermediate state.

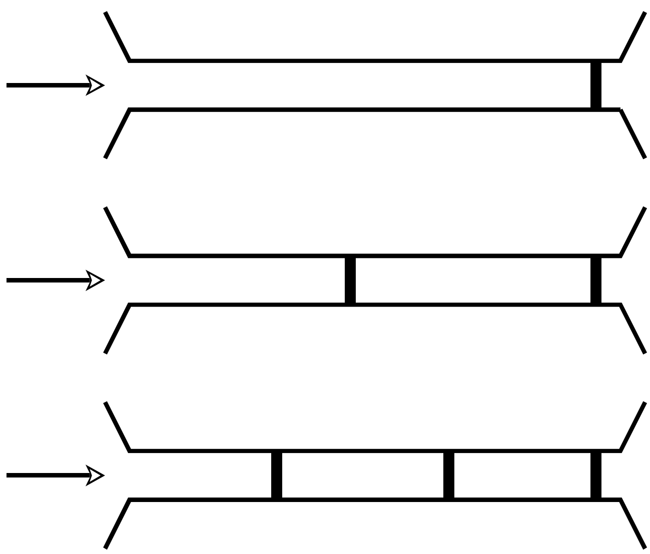

Fig 5. Process of the development of the jumps of resistance in the superconductive film.

By black vertical line in the figures are designated the place of the disintegration of the Cooper pairs (them accepted to call the places of the slippage of the superconductive phase), pointers is to the right indicated the place of entry into the film of Cooper pairs. Upper figure corresponds to the first jump of resistance, average - corresponds to two jumps, lower - three. In the same sequence appear the subsequent jumps.

6. Conclusions

In the theory of electrical chains is customary to assume that the capacities and inductances are the reactive elements, which cannot accumulate energy. However, this point of view is not accurate, since under specific conditions both the capacity and inductance can accumulate energy. In addition to this, it occurs that the capacity and inductance can play the role of effective resistance, which depends on time. Such properties of these elements before the appearance of publications [1-6] were not known. At present wave equations for the long lines require the knowledge second derivative voltages and currents, which are extended in such lines. However, there are such cases, when such derivatives cannot be determined. This is the case, when dc power supply is connected to the line, or when this voltage changes according to the linear law. Answer to a question, as one should enter in this case, give in the proposed article. The properties of long lines are characterized by such parameters as linear capacity and inductance, which do not consider the kinetic properties of charges. This connected with the fact that linear field inductance in the long lines considerably exceeds linear kinetic inductance. This condition can not be observed when as the conductors of line it serves electronic or ionic flux. In the article carried out the study also of this problem are given the conditions for the separation of the flows of charges into the field flows and kinetic.

In the article the new law, which determines the dependence of the specific resistance of electron beam on a potential difference between the electrodes and the distances between them, is obtained. It follows from this law that the specific resistance of electronic flux depends on the distance between the electrodes, between which moves electronic flux. It is shown that the stepped voltage-current characteristic of the superconductive thin narrow superconductive channels, which are been in an intermediate state, is connected with the presence to resistance in electron beams.

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