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Induction and Parametric Properties of Radio-Technical Elements and Chains and Property of Charges and their Flows

By F. F. Mende

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Keywords: self-induction, reactive elements, field inductance, kinetic inductance, long line, wave equations.

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F. F. Mende

Abstract- 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. 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 cannot 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. 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. This opens the new technical possibility of designing of the analog converters, which connect displacement with the specific resistance of beam. 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.

Keywords: *self-induction, reactive elements, field inductance, kinetic inductance, long line, wave equations.*

I. Introduction

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 [1-4] 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 cannot 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. 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 electron beam depends on the distance between the electrodes and a potential difference between them, which opens the new technical capability of regulating this resistance by the way of changing the distance between the electrodes. This opens the new technical possibility of designing of the analog converters, which connect displacement with the specific resistance of beam.

a) Electrical and current 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. To such elements let us carry capacities, inductances, effective resistance and long lines.

By self-induction of reactive elements we will understand the reaction of such elements as capacity and inductance with the constant or changing parameters to the connection to them of the sources of voltage or current. Subsequently we will use these concepts: as current generator and the voltage generator. By ideal voltage generator we will understand

Author: *e-mail: fedormende@gmail.com*

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

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

When the discussion deals with a change in the charge, determined by relationship, 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 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:

$$I(U) = C_0\frac{\partial U}{\partial t} \quad (1.1)$$

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

$$I(C) = U_0\frac{\partial C}{\partial t} . \quad (1.2)$$

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 (1.1).

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

$$U(t) = \frac{I_0 t}{C_0} . \quad (1.3)$$

Using to this relationship Ohm's law

$$U = IR ,$$

We obtain the value of the effective resistance of the chain in question

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

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

$$P(t) = \frac{I_0^2 t}{C_0} \quad (1.4)$$

The energy, accumulated by capacity in the time t, we will obtain, after integrating relationship (1.4) with respect to the time:

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

Substituting here the value of current from relationship (1.3), we obtain the dependence of the value of the accumulated in the capacity energy from the instantaneous value of voltage on it:

$$W_C(U) = \frac{1}{2}C_0U^2 .$$

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 effective resistance R_C. 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:

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

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. From relationship (1.2) 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 and U - instantaneous values, and C_0 and U_0 - 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:

$$U = \frac{C_0 U_0}{C}, \qquad (1.5)$$

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

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.

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 L_0 is constant

$$U(I) = L_0 \frac{\partial I}{\partial t}. \qquad (1.6)$$

After integrating expression (1.6) on the time, we will obtain:

$$I(t) = \frac{Ut}{L_0}. \qquad (1.7)$$

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

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

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

$$P(t) = \frac{U^2 t}{L_0}. \qquad (1.8)$$

After integrating relationship (1.8) on the time, we will obtain the energy, accumulated in the inductance

$$W_L(t) = \frac{1}{2}\frac{U^2 t^2}{L_0}. \qquad (1.9)$$

After substituting into expression (1.9) the value of voltage from relationship (1.7), we obtain the value of the energy, accumulated in the inductance:

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

Now 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

$$U = I_0 \frac{\partial L}{\partial t}. \qquad (1.10)$$

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 and I_0 - 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 and L_1 - 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 of

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

where L - the instantaneous value of inductance.

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b) 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

$$\frac{\partial^2 U}{\partial z^2} = \frac{1}{v^2}\frac{\partial^2 U}{\partial t^2}$$

$$\frac{\partial^2 I}{\partial z^2} = \frac{1}{v^2}\frac{\partial^2 I}{\partial t^2},$$

which are obtained from the telegraphic equations

$$\frac{\partial U}{\partial z} = -L\frac{\partial I}{\partial t}$$

$$\frac{\partial I}{\partial z} = -C\frac{\partial U}{\partial t},$$

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 [1-4] 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]. Let us assume that the linear capacity and the inductance of line compose C_0 and L_0. If we to the line connect the dc voltage 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 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 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 (1.2) must leak the current:

$$I = U\frac{\partial C(t)}{\partial t} = UvC_0. \qquad (2.1)$$

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 (1.10), on it will be observed a voltage drop:

$$U_1 = I\frac{\partial L(t)}{\partial t} = IvL_0 = v^2UC_0L_0.$$

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 of is present, must compose

$$v = \frac{1}{\sqrt{L_0C_0}}. \qquad (2.2)$$

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 electric field 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 [elektrotokovoy]. It is interesting to note that the obtained result does not depend on the form of the function 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 result could be, until now, obtained only by the method of solution of wave equations. This process occurs in such a way that the wave front, being extended with the speed v, leaves after itself the line, charged to a potential difference 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 current strength in the line can be obtained, after substituting the values of the velocity of propagation of the wave front, determined by relationship (2.2), into relationship (2.1). After making this substitution, we will obtain

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

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

The regularities indicated apply to all forms of transmission lines.

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If we to the line with the length 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 elektrocurent spontaneous parametric self-induction. This name flow expansion they connected with the fact that occur spontaneously.

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 - inside diameter of the cylindrical part of the coaxial and the outer diameter of central core, and ε_0 and μ_0 - dielectric and magnetic constant of vacuum.

Exist coaxial lines with the variable section both the cylindrical part and the internal conductor. The sections of such coaxials are used as the soglasuyushchikh devices between the coaxials with different diameters of cylindrical part and central core. Propagation of signals in such prekhodnikakh has its specific character (Fig. 1).

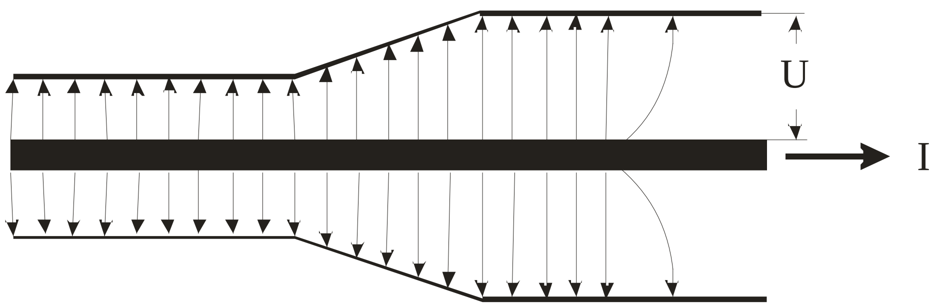

Fig. 1: Propagation of signal along the coaxial line with the variable section.

A change in the dimensions of coaxial leads to the fact that the linear parameters begin to depend on coordinate. Begins to depend on coordinate and the wave drag

$$Z = \sqrt{\frac{L}{C}} = \ln\left(\frac{D}{d}\right)\sqrt{\frac{\mu_0}{\varepsilon_0}},$$

At the same time velocity of propagation, both in the limits of the sections of coaxials and in the transition section it remains constant

$$v = \sqrt{\frac{1}{CL}} = \sqrt{\frac{1}{\varepsilon_0\mu_0}}$$

Penetrating this adapter, signal changes its parameters.

Since wave drag gives the relation between the voltage and the current in the line

$$Z = \frac{U}{I}$$

that changes the relationship between the voltage and the current in the initial and final section of coaxial. Consequently, such adapter is the current transformer and voltage. And this transformation occurs both with the propagation on the line of alternating voltage so and the constant. Thus this device is the configurative voltage transformer and currents. It is in the literature accepted to call such devices impedance transformers, but it is more correct them to call the voltage transformers and currents.

c) Properties of static charges and their flows

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

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

where ε_0, S and d - dielectric constant of vacuum, the area of plates and the distance between them respectively. Substituting in this relationship equality (1.5), we obtain

$$W_c = \frac{1}{2}\frac{d\left(C_0U_0\right)^2}{\varepsilon_0 S}, \tag{3.1}$$

is evident that with the constant charge, stored up in the capacitor, an increase in the distance between the

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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 electric field on. As this occurs, evidently from Fig. 2.

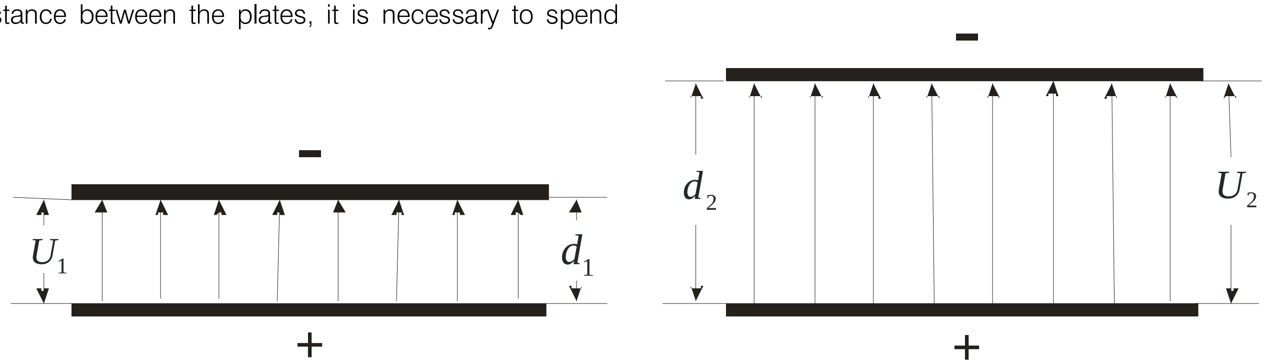

Fig. 2: The electric fields of parallel-plate capacitor with the different distance between its plates

Taking into account that the work of capacity and voltage is equal to charge, accumulated in the capacitor, relationship (1.9) can be rewritten

$$W_c = \frac{1}{2}\frac{d\left(Q_0\right)^2}{\varepsilon_0 S} = \frac{1}{2}\varepsilon_0 E^2 Sd \qquad (3.2)$$

where E - tension of electric field in the line.

From relationship (3.2) 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 they are superimposed, this energy can be as 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 electric field 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.

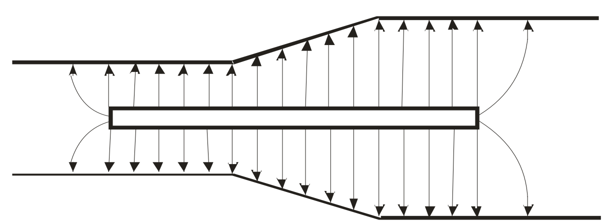

Fig. 3: Coaxial capacitor with the variable section

Let us load coaxial capacitor with the variable section, as shown in Fig. 3. If we move the charged rod from left to right, then the volume of electric field on it will be grow, and for this will have to expend energy. But if rod will be moved in the reverse direction, then volume pour on it will decrease, and rod will carry out external work. If we as the rod take the section of the moving electron beam, then picture not change. During the motion from left to right, kinetic energy of beam will pass into the energy of electric field on, and beam will slow down and vice versa.

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.

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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 - electronmass, e - the electron charge, $\vec{E}$ - the tension of electric field, $\vec{v}$ - 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

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

Kinetic inductance of charges.

Maxwell's equations for this case take the form:

$$rot\ \vec{E} = -\mu_0\frac{\partial \vec{H}}{\partial t},$$
$$rot\ \vec{H} = \varepsilon_0\frac{\partial \vec{E}}{\partial t} + \frac{1}{L_k}\int \vec{E}\,dt, \qquad (3.3)$$

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

System of equations (3.3) completely describes all properties of the conductors, in which be absent the ohmic losses. From relationship (3.3) we obtain

$$rot\ rot\ \vec{H} + \mu_0\varepsilon_0\frac{\partial^2 \vec{H}}{\partial t^2} + \frac{\mu_0}{L_k}\vec{H} = 0. \qquad (3.4)$$

For the case pour on, time-independent, equation (3.4) passes into the equation of London

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

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 (3.4), and do not consider bias currents. 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 electric field 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

$$\vec{j}_L = \frac{1}{L_k}\int \vec{E}\,dt. \qquad (3.5)$$

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. 4).

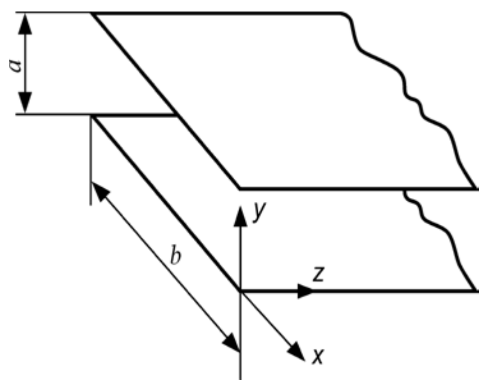

Fig. 4: The two-wire circuit, which consists of two ideally conducting planes

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 - density, charge and the velocity of the superconductive electrons, and $\lambda = \sqrt{\frac{L_k}{\mu}}$ - 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:

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

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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 pour on. 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. 4, as l, that the volume of skin-layer in the superconductive planes of line will comprise $2lb\lambda$. 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 pour 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 $\frac{a}{2\lambda}$ 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 - 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

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

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

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

Electronic flux we will consider kinetic when the linear field inductance of less than the linear kinetic inductance, which is carried out with the observance of the given condition.

Let us estimate, what electron density in the flow corresponds to the case examined.

Let us examine the concrete example $d = 1\,мм$, $\ln\left(\frac{D}{d}\right) = 2$, then we obtain

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

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.

Therefore for calculating the energy, transferred by electromagnetic fields they use Poynting's 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.

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d) Electronic flux as the effective resistance

Electronic flux can be represented as the effective resistance, which absorbs energy. If electron is accelerated for the action of electric field and it moves between two electrodes with a potential difference U, it acquires energy eU , which is equal to its kinetic energy

$$eU = \frac{mv^2}{2}$$

With braking of electron with the impact about the target this energy is converted in the heat-. Consequently, the chain, in which occurs this process, is the effective resistance, which has specific resistance and specific conductivity.

The specific conductivity of metal is determined by the relationship

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

The electron transit time between two electrodes, the distance between which is equal d , and a potential difference between them is equal U, it is determined from the relationship

$$\tau = d\sqrt{\frac{2m}{eU}},$$

This is a relaxation time for the electrons in the electron beam; therefore the conductivity of beam will be determined by the relationship

$$\sigma = \frac{d}{L_k}\sqrt{\frac{2m}{eU}}.$$

Since specific resistance ρ early

$$\rho = \frac{1}{\sigma},$$

We obtain

$$\rho = \frac{L_k}{d}\sqrt{\frac{eU}{2m}} = \frac{1}{dn}\sqrt{\frac{mU}{2}} \qquad (3.5)$$

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. Interesting circumstance is the fact that the specific resistance of beam does not depend on electron charge, but it depends only on its mass. The obtained dependence opens the new technical capabilities of the resistance control of beam by the way of changing the distance between the electrodes. This opens the new technical possibility of designing of the analog converters, which connect displacement with the specific resistance of beam.

their resistance. Control of lamp resistance is accomplished with the aid of control grid, which regulates electron density.

From relationship (3.5) it follows that the specific resistance of beam depends that the mass of charge carriers. This circumstance it is possible to use for purposes spectroscopies. For this into the camera with the rarefied gas should be placed two electrodes, to which should be connected the dc power supply. To one of the electrodes should be given the radio-frequency voltage for the ionization of gas. Measuring the flow resistance of the charges between the electrodes, and controlling current in the circuit of the voltage source it is possible to measure the mass of atoms or molecules of gas.

II. Conclusion

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 [1-4] 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, daN 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 electron beam depends on the distance between the electrodes and a potential difference between them, which opens the new technical capability of regulating this resistance by the way of changing the distance between the electrodes. This opens the new technical possibility of designing of the analog converters, which connect displacement with

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way of changing the distance between the electrodes. This opens the new technical possibility of designing of the analog converters, which connect displacement with the specific resistance of beam. 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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