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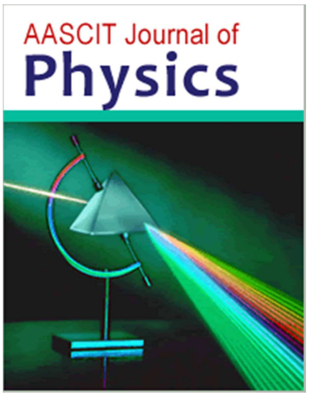

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What is Common and What Difference Between the Equations of Maxwell and the Kirgof Laws

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Abstract
In the article it is shown that Maxwell's equations can be represented in the symmetrical form and such equations describe entire spectrum of electrodynamic processes in the material media. Are represented the equivalent diagrams of plasma media, dielectrics and magnetic materials, placed between the planes of long line. Is introduced the new concept of kinetic capacity, which describes the energy processes, connected with the precessional motion of the magnetic moments of atoms in the magnetized media. The concepts of the electrokinetic and magnetopotential waves, which describe wave processes in the nonmagnetic and magnetized material media, are introduced.

1. Introduction

The laws of classical electrodynamics they reflect experimental facts they are phenomenological. The fundamental equations of contemporary classical electrodynamics are Maxwell's equations equation. They are written as follows for the vacuum:

$$rot\ \vec{E} = -\frac{\partial \vec{B}}{\partial t} \tag{1.1}$$

$$rot\ \vec{H} = \frac{\partial \vec{D}}{\partial t} \tag{1.2}$$

$$div\ \vec{D} = 0 \tag{1.3}$$

$$div\ \vec{B} = 0 \tag{1.4}$$

where $\vec{E}$, $\vec{H}$ are tension of electrical and magnetic field, $\vec{D} = \varepsilon_0 \vec{E}$, $\vec{B} = \mu_0 \vec{H}$ are electrical and magnetic induction, μ_0 and ε_0 are magnetic and dielectric constant of vacuum. From Maxwell's equations follow the wave equations

$$\nabla^2 \vec{E} = \mu_0 \varepsilon_0 \frac{\partial^2 \vec{E}}{\partial t^2}, \tag{1.5}$$

$$\nabla^2 \vec{H} = \mu_0 \varepsilon_0 \frac{\partial^2 \vec{H}}{\partial t^2}, \tag{1.6}$$

these equations show that in the vacuum can be extended the plane electromagnetic waves, the velocity of propagation of which is equal to the speed of light

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \quad (1.7)$$

For the material media of Maxwell's equation they take the following form:

$$rot\ \vec{E} = -\tilde{\mu}\mu_0 \frac{\partial \vec{H}}{\partial t} = -\frac{\partial \vec{B}}{\partial t} \quad (1.8)$$

$$rot\ \vec{H} = ne\vec{v} + \tilde{\varepsilon}\varepsilon_0 \frac{\partial \vec{E}}{\partial t} = ne\vec{v} + \frac{\partial \vec{D}}{\partial t} \quad (1.9)$$

$$div\ \vec{D} = ne \quad (1.10)$$

$$div\ \vec{B} = 0 \quad (1.11)$$

where $\tilde{\mu}$ and $\tilde{\varepsilon}$ are the relative magnetic and dielectric constants of the medium and n , e and $\vec{v}$ are density, charge and speed rate.

The Maxwell's equation describe processes in the material media with the distributed parameters. In these media occurs the three-dimensional dependence of electrical pour on and currents. Media with the distributed parameters are characterized by dielectric and magnetic constant, and also by conductivity. Material medium can be broken in the small sections, in which by three-dimensional change pour on and currents it is possible to disregard, considering it their not depending on the coordinates. Such sections present elements with the lumped parameters and can be characterized by such parameters as capacity, inductance and resistance. Electrodynamic processes in the elements with the lumped parameters are described by the Kirgof laws [1,2]. If we continuous material medium represent as a sequential set of elements with the lumped parameters and to examine the proceeding in them processes with the aid of theKirgof laws, then it is possible to combine ideas about the wave processes in the material media with the processes, proceeding in the elements with the lumped parameters. This approach is extended in radio engineering and is called the method of equivalent diagrams. This method is visual and is used during writing of telegraphic equations, and also with the propagation of electromagnetic waves in waveguides [3].

2. Plasmo-Like Media and Their Equivalent Diagrams

Let us examine the plasmo-like media, in which the ohmic losses can be disregarded. To such media in the first approximation, can be related the superconductors, free electrons or ions in the vacuum (subsequently conductors). In this case the equation of motion of electron takes the form:

$$m\frac{d\vec{v}}{dt} = e\vec{E} \quad (2.1)$$

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

In the work [4] it is shown that this equation can be used also for describing the electron motion in the hot plasma.

Using an expression for the current density

$$\vec{j} = ne\vec{v}, \quad (2.2)$$

from (2.1) we obtain the current density of the conductivity

$$\vec{j}_L = \frac{ne^2}{m}\int \vec{E}\,dt \quad (2.3)$$

In relationship (2.2) and (2.3) the value n represents electron density. After introducing the designation

$$L_k = \frac{m}{ne^2} \quad (2.4)$$

we find

$$\vec{j}_L = \frac{1}{L_k}\int \vec{E}\,dt\,. \quad (2.5)$$

In this case the value L_k presents the specific kinetic inductance of charge carriers [4-7]. Its existence connected with the fact that charge, having a mass, possesses inertia properties. Pour on $\vec{E} = \vec{E}_0 \sin\omega t$ relationship (2.5) it will be written down for the case of harmonics:

$$\vec{j}_L = -\frac{1}{\omega L_k}\vec{E}_0 \cos\omega t \quad (2.6)$$

from relationship (2.5) and (2.6) is evident that $\vec{j}_L$ presents inductive current, since its phase is late with respect to the tension of electric field to the angle $\frac{\pi}{2}$.

If charges are located in the vacuum, then during the presence of summed current it is necessary to consider bias current

$$\vec{j}_\varepsilon = \varepsilon_0 \frac{\partial \vec{E}}{\partial t} = \varepsilon_0 \vec{E}_0 \cos\omega t$$

is evident that this current bears capacitive nature, since. its phase anticipates the phase of the tension of electrical to the angle $\frac{\pi}{2}$. Thus, summary current density will compose [5-7]:

$$\vec{j}_\Sigma = \varepsilon_0 \frac{\partial \vec{E}}{\partial t} + \frac{1}{L_k}\int \vec{E}\,dt$$

or

$$\vec{j}_\Sigma = \left(\omega\varepsilon_0 - \frac{1}{\omega L_k} \right) \vec{E}_0 \cos \omega t \qquad (2.7)$$

In relationship (2.7) the value, which stands in the brackets, presents summary susceptance of this medium σ_Σ and it consists it, in turn, of the capacitive σ_C and by the inductive σ_L of the conductivity

$$\sigma_\Sigma = \sigma_C + \sigma_L = \omega\varepsilon_0 - \frac{1}{\omega L_k}$$

Relationship (2.7) can be rewritten and differently:

$$\vec{j}_\Sigma = \omega\varepsilon_0 \left(1 - \frac{\omega_0^2}{\omega^2} \right) \vec{E}_0 \cos \omega t$$

where $\omega_0 = \sqrt{\frac{1}{L_k \varepsilon_0}}$ is plasma frequency.

Value

$$\varepsilon^*(\omega) = \varepsilon_0 \left(1 - \frac{\omega_0^2}{\omega^2} \right) = \varepsilon_0 - \frac{1}{\omega^2 L_k}$$

is accepted to call the dielectric constant of conductors depending on the frequency, as is evident into it enter the not depending on the frequency parameters ε_0 and L_k.

With the examination of any media by our final task appears the presence of wave equation. In this case this problem is already practically solved.

Maxwell's equations for this case take the form:

$$rot\ \vec{E} = -\mu_0 \frac{\partial \vec{H}}{\partial t},$$
$$rot\ \vec{H} = \varepsilon_0 \frac{\partial \vec{E}}{\partial t} + \frac{1}{L_k} \int \vec{E}\, dt, \qquad (2.8)$$

System of equations (2.8) completely describes all properties of nondissipative conductors. From it we obtain

$$rot\ rot\ \vec{H} + \mu_0\varepsilon_0 \frac{\partial^2 \vec{H}}{\partial t^2} + \frac{\mu_0}{L_k} \vec{H} = 0 \qquad (2.9)$$

For the case fields on, time-independent, equation (2.9) passes into the London equation

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

where $\lambda_L{}^2 = \frac{L_k}{\mu_0}$ is London depth of penetration.

Thus, it is possible to conclude that the equations of London being a special case of equation (2.9), 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

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

The carried out examination showed that the dielectric constant of this medium was equal to the dielectric constant of vacuum and this permeability on frequency does not depend. The accumulation of potential energy is obliged to this parameter. Furthermore, this medium is characterized still and the kinetic inductance of charge carriers and this parameter determines the kinetic energy accumulated.

Thus, are obtained all necessary given, which characterize the process of the propagation of electromagnetic waves in conducting media examined. However, in contrast to the conventional procedure [8] with this examination nowhere was introduced polarization vector, but as the basis of examination assumed equation of motion and in this case in the second equation of Maxwell are extracted all components of current densities explicitly [9-10].

In radio engineering exists the simple method of the idea of radio-technical elements with the aid of the equivalent diagrams. This method is very visual and gives the possibility to present in the form such diagrams elements both with that concentrated and with the distributed parameters.

In order to show that the single volume of conductor or plasma according to its electrodynamic characteristics is equivalent to parallel resonant circuit with the lumped parameters, let us examine parallel resonant circuit. The connection between the voltage U, applied to the outline, and the summed current I_Σ, which flows through this chain, takes the form

$$I_\Sigma = I_C + I_L = C\frac{dU}{dt} + \frac{1}{L}\int U\, dt\ ,$$

where $I_C = C\frac{dU}{dt}$ is current, which flows through the capacity, and $I_L = \frac{1}{L}\int U\, dt$ is current, which flows through the inductance.

For the case of the harmonic voltage $U = U_0 \sin\omega t$ we obtain

$$I_\Sigma = \left(\omega C - \frac{1}{\omega L}\right) U_0 \cos\omega t \qquad (2.10)$$

In relationship (2.10) the value, which stands in the brackets, presents summary susceptance σ_Σ this medium and it consists by the capacitive σ_C and by the inductive σ_L the conductivity

$$\sigma_\Sigma = \sigma_C + \sigma_L = \omega C - \frac{1}{\omega L}.$$

In this case relationship (2.10) can be rewritten as follows:

$$I_\Sigma = \omega C\left(1 - \frac{\omega_0^2}{\omega^2}\right) U_0 \cos\omega t,$$

where $\omega_0^{\ 2} = \frac{1}{LC}$ is the resonance frequency of parallel circuit.

And here, just as in the case of conductor it is possible to introduce the parameter

$$C^*(\omega) = C\left(1 - \frac{\omega_0^2}{\omega^2}\right) = C - \frac{1}{\omega^2 L} \qquad (2.11)$$

From a mathematical point of view conducting this symbol it is permissible; however, not admitted to consider this parameter the capacity, which depends on the frequency.

If we compare the relationships(2.11), obtained for the parallel resonant circuit and for the conductors, then it is possible to see that they are identical, if we make $E_0 \to U_0$, $\varepsilon_0 \to C$ and $L_k \to L$. Thus, the single volume of conductor, with the uniform distribution of electrical pour on and current densities in it, it is equivalent to parallel resonant circuit with the lumped parameters indicated. In this case the capacity of this outline is numerically equal to the dielectric constant of vacuum, and inductance is equal to the specific kinetic inductance of charges.

Now let us show how the poor understanding of physics of processes in conducting media it led to the fact that proved to be unnoticed the interesting physical phenomenon transverse plasma resonance in the nonmagnetized plasma, which can have important technical appendices. This phenomenon can have important technical appendices [11].

Is known that the plasma resonance is longitudinal. But longitudinal resonance cannot emit transverse electromagnetic waves. However, with the explosions of nuclear charges, as a result of which is formed very hot plasma, occurs electromagnetic radiation in the very wide frequency band, up to the long-wave radio-frequency band. Today are not known those of the physical mechanisms, which could explain the appearance of this emission. On existence in the nonmagnetized plasma of any other resonances, except Langmuir, earlier known it was not, but it occurs that in the confined plasma the transverse resonance can exist, and the frequency of this resonance coincides with the frequency of Langmuir resonance, i.e., these resonance are degenerate. Specifically, this resonance can be the reason for the emission of electromagnetic waves with the explosions of nuclear charges.

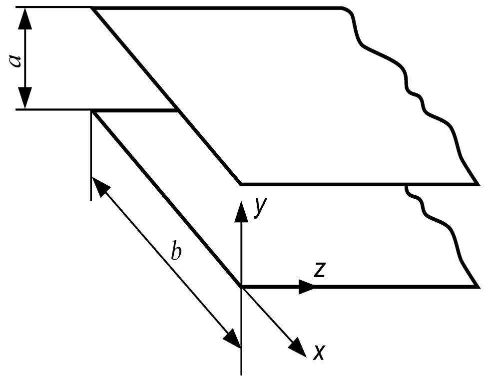

Fig 1. *The two-wire circuit, which consists of two ideally conducting planes.*

For explaining the conditions for the excitation of this resonance let us examine the long line, which consists of two ideally conducting planes, as shown in Fig.1

Linear (falling per unit of length) capacity and inductance of this line without taking into account edge effects they are determined by the relationships [9,10]:

$$C_0 = \varepsilon_0 \frac{b}{a}, \quad L_0 = \mu_0 \frac{a}{b}$$

Therefore with an increase in the length of line its total capacitance $C_\Sigma = \varepsilon_0 \frac{b}{a} z$ and summary inductance $L_\Sigma = \mu_0 \frac{a}{b} z$ increase proportional to its length.

If we into the extended line place the plasma, charge carriers in which can move without the losses, and in the transverse direction pass through the plasma the current I, then charges, moving with the definite speed, will accumulate kinetic energy.

Since the transverse current density in this line is determined by the relationship

$$j = \frac{I}{bz} = nev,$$

that summary kinetic energy of the moving charges can be written down

$$W_{k\Sigma} = \frac{1}{2}\frac{m}{ne^2}\, abzj^2 = \frac{1}{2}\frac{m}{ne^2}\frac{a}{bz} I^2 \qquad (2.12)$$

Relationship (2.12) connects the kinetic energy, accumulated in the line, with the square of current; therefore the coefficient, which stands in the right side of this relationship before the square of current, is the summary kinetic inductance of line.

$$L_{k\Sigma} = \frac{m}{ne^2} \cdot \frac{a}{bz} \tag{2.13}$$

Thus, the value

$$L_k = \frac{m}{ne^2} \tag{2.14}$$

presents the specific kinetic inductance of charges. This value was already previously introduced by another method (see relationship (2.4)). Relationship (2.14) is obtained for the case of the direct current, when current distribution is uniform.

Subsequently for the larger clarity of the obtained results, together with their mathematical idea, we will use the method of equivalent diagrams. The section, the lines examined, long dz can be represented in the form the equivalent diagram, shown in Fig. 2 (a).

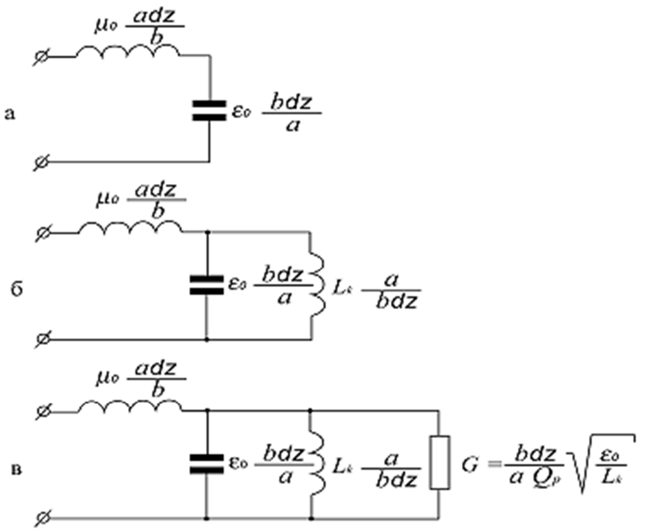

Fig 2. *a- the equivalent the schematic of the section of the two-wire circuit.*

б - the equivalent the schematic of the section of the two-wire circuit, filled nondissipative plasma;
в - the equivalent the schematic of the section of the two-wire circuit, filled dissipative plasma.

From relationship (2.13) is evident that in contrast to C_Σ and L_Σ the value $L_{k\Sigma}$ with an increase in z does not increase, but it decreases. Connected this with the fact that with an increase in z a quantity of parallel connected inductive elements grows.

The equivalent the schematic of the section of the line, filled with nondissipative plasma, it is shown in Fig. 2 (б). Line itself in this case will be equivalent to parallel circuit with the lumped parameters:

$$C = \frac{\varepsilon_0 bz}{a},$$

$$L = \frac{L_k a}{bz},$$

in series with which is connected the inductance

$$\mu_0 \frac{adz}{b}.$$

But if we calculate the resonance frequency of this outline, then it will seem that this frequency generally not on what sizes depends, actually:

$$\omega_\rho^2 = \frac{1}{CL} = \frac{1}{\varepsilon_0 L_k} = \frac{ne^2}{\varepsilon_0 m}.$$

Is obtained the very interesting result, which speaks, that the resonance frequency macroscopic of the resonator examined does not depend on its sizes. Impression can be created, that this is plasma resonance, since. the obtained value of resonance frequency exactly corresponds to the value of this resonance. But it is known that the plasma resonance characterizes longitudinal waves in the long line they, while occur transverse waves. In the case examined the value of the phase speed in the direction z is equal to infinity and the wave vector $\vec{k} = 0$.

This result corresponds to the solution of system of equations (2.8) for the line with the assigned configuration. In this case the wave number is determined by the relationship:

$$k_z^2 = \frac{\omega^2}{c^2}\left(1 - \frac{\omega_\rho^2}{\omega^2}\right) \tag{2.15}$$

and the group and phase speeds

$$v_g^2 = c^2\left(1 - \frac{\omega_\rho^2}{\omega^2}\right), \tag{2.16}$$

$$v_F^2 = \frac{c^2}{\left(1 - \frac{\omega_\rho^2}{\omega^2}\right)}, \tag{2.17}$$

where $c = \left(\frac{1}{\mu_0 \varepsilon_0}\right)^{1/2}$ is speed of light in the vacuum.

For the present instance the phase speed of electromagnetic wave is equal to infinity, which corresponds to transverse resonance at the plasma frequency. Consequently, at each moment of time pour on distribution and currents in this line uniform and it does not depend on the coordinate z, but current in the planes of line in the direction z is absent. This, from one side, it means that the inductance L_Σ will not have effects on electrodynamic processes in this line, but instead of the conducting planes can be used any planes or devices, which limit plasma on top and from below.

From relationships (2.15), (2.16) and (2.17) is evident that at the point $\omega = \omega_p$ occurs the transverse resonance with the infinite quality. With the presence of losses in the resonator will occur the damping, and in the long line in this case $k_z \neq 0$, and in the line will be extended the damped transverse wave, the direction of propagation of which will be normal to the direction of the motion of charges. It should be noted that the fact of existence of this resonance is not described by other authors.

Before to pass to the more detailed study of this problem, let us pause at the energy processes, which occur in the line in the case of the absence of losses examined.

The characteristic impedance of plasma, which gives the relation of the transverse components of electrical and magnetic, let us determine from the relationship

$$Z = \frac{E_y}{H_x} = \frac{\mu_0 \omega}{k_z} = Z_0 \left(1 - \frac{\omega_\rho^2}{\omega^2}\right)^{-1/2},$$

where $Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}}$ is characteristic impedance of vacuum.

The obtained value Z is characteristic for the transverse electrical waves in the waveguides. It is evident that when $\omega \to \omega_p$, then $Z \to \infty$, and $H_x \to 0$. When $\omega > \omega_p$ in the plasma there is electrical and magnetic component of field. The specific energy of these pour on it will be written down:

$$W_{E,H} = \frac{1}{2}\varepsilon_0 E_{0y}^2 + \frac{1}{2}\mu_0 H_{0x}^2 .$$

Thus, the energy, concluded in the magnetic field, in $\left(1 - \frac{\omega_\rho^2}{\omega^2}\right)$ of times is less than the energy, concluded in the electric field. Let us note that this examination, which is traditional in the electrodynamics, is not complete, since. in this case is not taken into account one additional form of energy, namely kinetic energy of charge carriers. Occurs that pour on besides the waves of electrical and magnetic, that carry electrical and magnetic energy, in the plasma there exists even and the third - kinetic wave, which carries kinetic energy of current carriers. The specific energy of this wave is written:

$$W_k = \frac{1}{2} L_k j_0^2 = \frac{1}{2} \cdot \frac{1}{\omega^2 L_k} E_0^2 = \frac{1}{2}\varepsilon_0 \frac{\omega_\rho^2}{\omega^2} E_0^2 .$$

Thus, total specific energy is written as

$$W_{E,H,j} = \frac{1}{2}\varepsilon_0 E_{0y}^2 + \frac{1}{2}\mu_0 H_{0x}^2 + \frac{1}{2} L_k j_0^2$$

thus, for finding the total energy, by the prisoner per unit of volume of plasma, calculation only pour on E and H it is insufficient.

At the point $\omega = \omega_p$ are carried out the relationship:

$$W_H = 0$$
$$W_E = W_k,$$

i.e. magnetic field in the plasma is absent, and plasma presents macroscopic electromechanical resonator with the infinite quality, ω_p resounding at the frequency.

Since with the frequencies $\omega > \omega_p$ the wave, which is extended in the plasma, it bears on itself three forms of the energy: electrical, magnetic and kinetic, then this wave can be named the electrokinetic wave. Kinetic wave is the wave of the current density $\vec{j} = \frac{1}{L_k}\int \vec{E}\, dt$. This wave is moved with respect to the electrical wave the angle $\frac{\pi}{2}$.

If losses in plasma are located, moreover completely it does not have value, by what physical processes such losses are caused, then the quality of plasma resonator will be finite quantity. For this case Maxwell's equation they will take the form:

$$rot\ \vec{E} = -\mu_0 \frac{\partial \vec{H}}{\partial t},$$
$$rot\ \vec{H} = \sigma_{p.ef}\ \vec{E} + \varepsilon_0 \frac{\partial \vec{E}}{\partial t} + \frac{1}{L_k}\int \vec{E}\, dt. \quad (2.18)$$

The presence of losses is considered by the term $\sigma_{p.ef}\vec{E}$, and, using near the conductivity of the index ef, it is thus emphasized that us does not interest very mechanism of losses, but only very fact of their existence interests. The value σ_{ef} determines the quality of plasma resonator. For measuring σ_{ef} should be selected the section of line by the length z_0, whose value is considerably lower than the wavelength in the plasma. This section will be equivalent to outline with the lumped parameters:

$$C = \varepsilon_0 \frac{bz_0}{a}, \quad (2.19)$$

$$L = L_k \frac{a}{bz_0}, \quad (2.20)$$

$$G = \sigma_{\rho.ef} \frac{bz_0}{a}, \quad (2.21)$$

where G is conductivity, connected in parallel C and L.

Conductivity and quality in this outline enter into the relationship:

$$G = \frac{1}{Q_\rho}\sqrt{\frac{C}{L}}\,.$$

Taking into account (2.19-2.21), we obtain

$$\sigma_{\rho.ef} = \frac{1}{Q_\rho}\sqrt{\frac{\varepsilon_0}{L_k}}\,. \qquad (2.22)$$

Thus, measuring its own quality plasma of the resonator examined, it is possible to determine $\sigma_{p.ef}$. Using (2.18) and (2.22) we will obtain:

$$rot\ \vec{E} = -\mu_0 \frac{\partial \vec{H}}{\partial t},$$
$$rot\ \vec{H} = \frac{1}{Q_\rho}\sqrt{\frac{\varepsilon_0}{L_k}}\ \vec{E} + \varepsilon_0 \frac{\partial \vec{E}}{\partial t} + \frac{1}{L_k}\int \vec{E}\ dt. \qquad (2.23)$$

The equivalent the schematic of this line, filled with dissipative plasma, is represented in Fig. 2(в).

Let us examine the solution of system of equations (2.21) at the point $\omega = \omega_p$, in this case, since

$$\varepsilon_0 \frac{\partial \vec{E}}{\partial t} + \frac{1}{L_k}\int \vec{E}\ dt = 0\,,$$

We obtain

$$rot\ \vec{E} = -\mu_0 \frac{\partial \vec{H}}{\partial t},$$
$$rot\ \vec{H} = \frac{1}{Q_P}\sqrt{\frac{\varepsilon_0}{L_k}}\ \vec{E}.$$

These relationships determine wave processes at the point of resonance.

3. Dielectrics

In the existing literature there are no indications that the kinetic inductance of charge carriers plays some role in the electrodynamic processes in the dielectrics. This not thus. This parameter in the electrodynamics of dielectrics plays not less important role, than in the electrodynamics of conductors. Let us examine the simplest case, when oscillating processes in atoms or molecules of dielectric obey the law of mechanical oscillator [10].

$$\left(\frac{\beta}{m} - \omega^2\right)\vec{r}_m = \frac{e}{m}\vec{E}, \qquad (3.1)$$

where $\vec{r}_m$ is deviation of charges from the position of equilibrium, β is coefficient of elasticity, which characterizes the elastic electrical binding forces of charges in the atoms and the molecules. Introducing the resonance frequency of the bound charges

$$\omega_0 = \frac{\beta}{m}\,,$$

we obtain from (3.1):

$$r_m = -\frac{e\ E}{m(\omega^2 - \omega_o^2)}. \qquad (3.2)$$

Is evident that in relationship (3.2) as the parameter is present the natural vibration frequency, into which enters the mass of charge. This speaks, that the inertia properties of the being varied charges will influence oscillating processes in the atoms and the molecules.

Since the general current density on medium consists of the bias current and conduction current

$$rot\vec{H} = \vec{j}_\Sigma = \varepsilon_0 \frac{\partial \vec{E}}{\partial t} + ne\vec{v}\,,$$

that, finding the speed of charge carriers in the dielectric as the derivative of their displacement through the coordinate

$$\vec{v} = \frac{\partial r_m}{\partial t} = -\frac{e}{m(\omega^2 - \omega_o^2)}\frac{\partial \vec{E}}{\partial t}\,,$$

from relationship (3.2) we find

$$rot\vec{H} = \vec{j}_\Sigma = \varepsilon_0 \frac{\partial \vec{E}}{\partial t} - \frac{1}{L_{kd}(\omega^2 - \omega_0{}^2)}\frac{\partial \vec{E}}{\partial t} \qquad (3.3)$$

But the value

$$L_{kd} = \frac{m}{ne^2}$$

presents the kinetic inductance of the charges, entering the constitution of atom or molecules of dielectrics, when to consider charges free. Therefore relationship (3.3) it is possible to rewrite

$$rot\vec{H} = \vec{j}_\Sigma = \varepsilon_0\left(1 - \frac{1}{\varepsilon_0 L_{kd}(\omega^2 - \omega_0{}^2)}\right)\frac{\partial \vec{E}}{\partial t} \qquad (3.4)$$

Since the value

$$\frac{1}{\varepsilon_0 L_{kd}} = \omega_{pd}{}^2$$

it represents the plasma frequency of charges in atoms and molecules of dielectric, if we consider these charges free, then relationship (3.4) takes the form:

$$rot\vec{H} = \vec{j}_\Sigma = \varepsilon_0\left(1 - \frac{\omega^2{}_{pd}}{(\omega^2 - \omega_0{}^2)}\right)\frac{\partial \vec{E}}{\partial t} \qquad (3.5)$$

Value

$$\varepsilon^*(\omega)=\varepsilon_0\left(1-\frac{\omega^2{}_{pd}}{(\omega^2-\omega_0{}^2)}\right) \quad (3.6)$$

It is accepted to call the dielectric constant of dielectric depending on the frequency.

Let us examine two limiting cases:

If $\omega << \omega_0$ then from (3.5) we obtain

$$rot\vec{H}=\vec{j}_\Sigma=\varepsilon_0\left(1+\frac{\omega_{pd}{}^2}{\omega_0^2}\right)\frac{\partial\vec{E}}{\partial t}. \quad (3.7)$$

In this case the coefficient, confronting the derivative, does not depend on frequency, and it presents the static dielectric constant of dielectric. As we see, it depends on the natural frequency of oscillation of atoms or molecules and on plasma frequency. This result is intelligible. Frequency in this case proves to be such low that the charges manage to follow the field and their inertia properties do not influence electrodynamic processes. In this case the bracketed expression in the right side of relationship (3.7) presents the static dielectric constant of dielectric. As we see, it depends on the natural frequency of oscillation of atoms or molecules and on plasma frequency. Hence immediately we have a prescription for creating the dielectrics with the high dielectric constant. In order to reach this, should be in the assigned volume of space packed a maximum quantity of molecules with maximally soft connections between the charges inside molecule itself.

If $\omega >> \omega_0$ thenwe obtain

$$rot\vec{H}=\vec{j}_\Sigma=\varepsilon_0\left(1-\frac{\omega_{pd}^2}{\omega^2}\right)\frac{\partial\vec{E}}{\partial t}$$

and dielectric became conductor (plasma) since. the obtained relationship exactly coincides with the equation, which describes plasma.

One cannot fail to note the circumstance that in this case again nowhere was used this concept as polarization vector, but examination is carried out by the way of finding the real currents in the dielectrics on the basis of the equation of motion of charges in these media. In this case as the parameters are used the electrical characteristics of the media, which do not depend on frequency.

From relationship (3.5) is evident that in the case of fulfilling the equality $\omega=\omega_0$, the amplitude of fluctuations is equal to infinity. This indicates the presence of resonance at this point. The infinite amplitude of fluctuations occurs because of the fact that they were not considered losses in the resonance system, in this case its quality was equal to infinity. In a certain approximation it is possible to consider that lower than the point indicated we deal concerning the dielectric, whose dielectric constant is equal to its static value. Higher than this point we deal already actually concerning the metal, whose density of current carriers is equal to the density of atoms or molecules in the dielectric.

Now it is possible to examine the question of why dielectric prism decomposes polychromatic light into monochromatic components or why rainbow is formed. So that this phenomenon would occur, it is necessary to have the frequency dispersion of the phase speed of electromagnetic waves in the medium in question. If we to relationship (3.5) add the Maxwell first equation, then we will obtain:

$$rot\vec{E}=-\mu_0\frac{\partial\vec{H}}{\partial t}$$

$$rot\vec{H}=\varepsilon_0\left(1-\frac{\omega^2{}_{pd}}{(\omega^2-\omega_0^2)}\right)\frac{\partial\vec{E}}{\partial t},$$

from where we immediately find the wave equation:

$$\nabla^2\vec{E}=\mu_0\varepsilon_0\left(1-\frac{\omega_{pd}^2}{\omega^2-\omega_0^2}\right)\frac{\partial^2\vec{E}}{\partial t^2}.$$

If one considers that

$$\mu_0\varepsilon_0=\frac{1}{c^2}$$

where C is speed of light, then no longer will remain doubts about the fact that with the propagation of electromagnetic waves in the dielectrics the frequency dispersion of phase speed will be observed.

Let us show that the equivalent the schematic of dielectric presents the sequential resonant circuit, whose inductance is the kinetic inductance L_{kd}, and capacity is equal to the static dielectric constant of dielectric minus the capacity of the equal dielectric constant of vacuum. In this case outline itself proves to be that shunted by the capacity, equal to the specific dielectric constant of vacuum. For the proof of this let us examine the sequential oscillatory circuit, when the inductance L and the capacity C are connected in series.

The connection between the current I_C, which flows through the capacity C, and the voltage U_C, applied to it, is determined by the relationships:

$$U_C=\frac{1}{C}\int I_C dt$$

and

$$I_C=C\frac{dU_C}{dt} \quad (3.8)$$

This connection will be written down for the inductance:

$$I_L=\frac{1}{L}\int U_L dt$$

and

$$U_L=L\frac{dI_L}{dt}.$$

If the current, which flows through the series circuit, changes according to the law $I = I_0 \sin \omega t$, then a voltage drop across inductance and capacity they are determined by the relationships

$$U_L = \omega L I_0 \cos \omega t$$

and

$$U_C = -\frac{1}{\omega C} I_0 \cos \omega t ,$$

and total stress applied to the outline is equal

$$U_\Sigma = \left(\omega L - \frac{1}{\omega C} \right) I_0 \cos \omega t .$$

In this relationship the value, which stands in the brackets, presents the reactance of sequential resonant circuit, which depends on frequency. The stresses, generated on the capacity and the inductance, are located in the reversed phase, and, depending on frequency, outline can have the inductive, the whether capacitive reactance. At the point of resonance the summary reactance of outline is equal to zero.

It is obvious that the connection between the total voltage applied to the outline and the current, which flows through the outline, will be determined by the relationship

$$I = -\frac{1}{\omega \left(\omega L - \frac{1}{\omega C} \right)} \frac{\partial U_\Sigma}{\partial t} \tag{3.9}$$

Taking into account that the resonance frequency of the outline

$$\omega_0 = \frac{1}{\sqrt{LC}} ,$$

let us write down

$$I = \frac{C}{\left(1 - \frac{\omega^2}{\omega_0{}^2} \right)} \frac{\partial U_\Sigma}{\partial t} \tag{3.10}$$

Comparing this expression with relationship (3.8) it is not difficult to see that the sequential resonant circuit, which consists of the inductance L and capacity C, it is possible to present to the capacity in the form dependent on the frequency

$$C(\omega) = \frac{C}{\left(1 - \frac{\omega^2}{\omega_0{}^2} \right)} . \tag{3.11}$$

This idea does not completely mean that the inductance is somewhere lost. Simply it enters into the resonance frequency of the outline ω_0. Relationship (3.10) this altogether only the mathematical form of the record of relationship (3.9). Consequently, this is $C(\omega)$ the certain composite mathematical parameter, which is not the capacity of outline.

Relationship (3.9) can be rewritten and differently:

$$I = -\frac{1}{L\left(\omega^2 - \omega_0{}^2 \right)} \frac{\partial U_\Sigma}{\partial t}$$

and to consider that

$$C(\omega) = -\frac{1}{L\left(\omega^2 - \omega_0{}^2 \right)} . \tag{3.12}$$

Is certain, the parameter $C(\omega)$, introduced in accordance with relationships (3.11) and (3.12) is not the depending on the frequency capacity.

Let us examine relationship (3.10) for two limiting cases:

1. For the case, when $\omega << \omega_0$, we have

$$I = C \frac{\partial U_\Sigma}{\partial t} .$$

This result is intelligible, since. at the low frequencies the reactance of the inductance, connected in series with the capacity, is considerably lower than the capacitive and it is possible not to consider it.

2. For the case, when $\omega >> \omega_0$, we have

$$I = -\frac{1}{\omega^2 L} \frac{\partial U_\Sigma}{\partial t} . \tag{3.13}$$

Taking into account that for the harmonic signal

$$\frac{\partial U_\Sigma}{\partial t} = -\omega^2 \int U_\Sigma dt ,$$

we obtain from (3.13):

$$I_L = \frac{1}{L} \int U_\Sigma dt .$$

In this case the reactance of capacity is considerably less than in inductance and chain has inductive reactance.

The carried out analysis speaks, that is in practice very difficult to distinguish the behavior of resonant circuits of the inductance or of the capacity. In order to understand the true composition of the chain being investigated it is necessary to remove the amplitude and phase response of this chain in the range of frequencies. In the case of resonant circuit this dependence will have the typical resonance nature, when on both sides resonance the nature of reactance is different. However, this does not mean that real circuit elements: capacity or inductance depend on frequency.

The equivalent the schematic of the dielectric, located between the planes of long line is shown in Fig. (3)

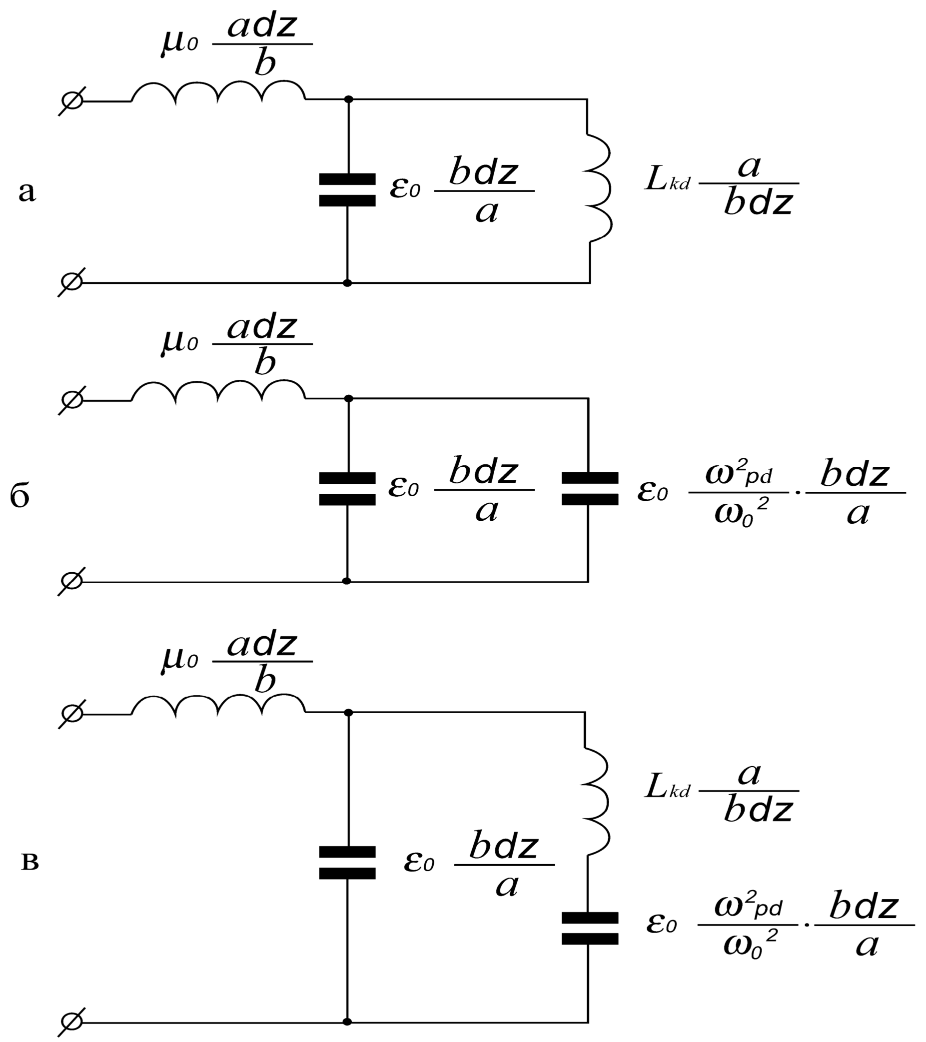

Fig 3. *a- equivalent the schematic of the section of the line, filled with dielectric, for the case* $\omega >> \omega_0$.

б - the equivalent the schematic of the section of line for the case $\omega << \omega_0$;

в- the equivalent the schematic of the section of line for entire frequency band.

In Fig. 3 (a) and 3 (б) are shown two limiting cases. In the first case, when $\omega >> \omega_0$, dielectric according to its properties corresponds to conductor, in the second case, when $\omega << \omega_0$, it corresponds to the dielectric, which possesses the static dielectric constant

$$\varepsilon = \varepsilon_0 \left(1 + \frac{\omega_{pd}^2}{\omega_0^2} \right).$$

Thus, it is possible to make the conclusion that the introduction, the depending on the frequency dielectric constants of dielectrics, are physical and terminological error. If the discussion deals with the dielectric constant of dielectrics, with which the accumulation of potential energy is connected, then the discussion can deal only with the static permeability. And precisely this parameter as the constant, which does not depend on the frequency, enters into all relationships, which characterize the electrodynamic characteristics of dielectrics.

The most interesting results of applying such new approaches occur precisely for the dielectrics. In this case each connected pair of charges presents the separate unitary unit with its individual characteristics and its participation in the processes of interaction with the electromagnetic field (if we do not consider the connection between the separate pairs) strictly individually. Certainly, in the dielectrics not all dipoles have different characteristics, but there are different groups with similar characteristics, and each group of bound charges with the identical characteristics will resound at its frequency. Moreover the intensity of absorption, and in the excited state and emission, at this frequency will depend on a relative quantity of pairs of this type. Therefore the partial coefficients, which consider their statistical weight in this process, can be introduced. Furthermore, these processes will influence the anisotropy of the dielectric properties of molecules themselves, which have the specific electrical orientation in crystal lattice. By these circumstances is determined the variety of resonances and their intensities, which is observed in the dielectric media. The lines of absorption or emission, when there is a electric coupling between the separate groups of emitters, acquire even more complex structure. In this case the lines can be converted into the strips. Such individual approach to each separate type of the connected pairs of charges could not be realized within the framework earlier than the existing approaches.

4. Processes in the Gyromagnetic Media, Kinetic Capacity

If we consider all components of current density in the conductor, then the Maxwell second equation can be written down:

$$rot\vec{H} = \sigma_E \vec{E} + \varepsilon \frac{\partial \vec{E}}{\partial t} + \frac{1}{L_k}\int \vec{E}dt \tag{4.1}$$

where σ_E is conductivity of metal.

At the same time, the Maxwell first equation can be written down as follows:

$$rot\vec{E} = -\mu \frac{\partial \vec{H}}{\partial t} \tag{4.2}$$

where μ is magnetic permeability of medium. It is evident that equations (4.1) and (4.2) are asymmetrical.

To somewhat improve the symmetry of these equations are possible, introducing into equation (4.2) term linear for the magnetic field, that considers heat losses in the magnetic materials in the variable fields:

$$rot\vec{E} = -\sigma_H \vec{H} - \mu \frac{\partial \vec{H}}{\partial t} \tag{4.3}$$

Where σ_H is conductivity of magnetic currents. But here there is no integral of such type, which is located in the right side of equation (4.1), in this equation. At the same time to us it is known that the atom, which possesses the magnetic moment $\vec{m}$, placed into the magnetic field, and which accomplishes in it precessional motion, has potential energy $U_m = -\mu\vec{m}\vec{H}$. Therefore potential energy can be accumulated not only in the electric fields, but also in the precessional motion of magnetic moments, which does not possess inertia. Similar case is located also in the mechanics, when the gyroscope, which precesses in the field of external gravitational forces, accumulates potential energy. Regarding mechanical precessional motion is also noninertial and immediately ceases after the removal of external forces. For example, if we from under the precessing gyroscope, which revolves in the field of the earth's gravity, rapidly remove support, thus it will begin to fall, preserving in the space the direction of its axis, which was at the moment, when support was removed. The same situation occurs also for the case of the precessing magnetic moment. Its precession is noninertial and ceases at the moment of removing the magnetic field.

Therefore it is possible to expect that with the description of the precessional motion of magnetic moment in the external magnetic field in the right side of relationship (4.3) can appear a term of the same type as in relationship (4.1). It will only stand L_k, i.e., instead C_k the kinetic capacity, which characterizes that potential energy, which has the precessing magnetic moment in the magnetic field:

$$rot\vec{E} = -\sigma_H \vec{H} - \mu \frac{\partial \vec{H}}{\partial t} - \frac{1}{C_k}\int \vec{H}dt \tag{4.4}$$

For the first time this idea of the Maxwell first equation taking into account kinetic capacity was given in the work [13].

Let us explain, can realize this case in practice, and that such in this case kinetic capacity. Resonance processes in the plasma and the dielectrics are characterized by the fact that in the process of fluctuations occurs the alternating conversion of electrostatic energy into the kinetic kinetic energy of charges and vice versa. This process can be named electrokinetic and all devices: lasers, masers, filters, etc, which use this process, can be named electrokinetic devices. At the same time there is another type of resonance - magnetic. If we use ourselves the existing ideas about the dependence of magnetic permeability on the frequency, then it is not difficult to show that this dependence is connected with the presence of magnetic resonance. In order to show this, let us examine the concrete example of ferromagnetic resonance. If we magnetize ferrite, after applying the stationary field H_0 in parallel to the axis Z, the like to relation to the external variable field medium will come out as anisotropic magnetic material with the complex permeability in the form of tensor [12]

$$\mu = \begin{pmatrix} \mu_T*(\omega) & -i\alpha & 0 \\ i\alpha & \mu_T*(\omega) & 0 \\ 0 & 0 & \mu_L \end{pmatrix},$$

where

$$\mu_T*(\omega) = 1 - \frac{\Omega\ |\gamma|\ M_0}{\mu_0(\omega^2 - \Omega^2)}, \quad \alpha = \frac{\omega\ |\gamma|\ M_0}{\mu_0(\omega^2 - \Omega^2)}, \quad \mu_L = 1, \tag{4.5}$$

Moreover is natural frequency of precession, and

$$M_0 = \mu_0(\mu - 1)H_0 \tag{4.6}$$

is a magnetization of medium. Taking into account (4.4) and (4.5) for $\mu_T*(\omega)$, it is possible to write down

$$\mu_T*(\omega) = 1 - \frac{\Omega^2(\mu - 1)}{\omega^2 - \Omega^2} \tag{4.7}$$

If we consider that the electromagnetic wave is propagated along the axis x and there are components pour on H_y and H_z, then in this case the Maxwell first equation will be written down:

$$rot\ \vec{E} = \frac{\partial \vec{E}_Z}{\partial x} = \mu_0 \mu_T \frac{\partial \vec{H}_y}{\partial t}$$

Taking into account (4.6), we will obtain

$$rot\ \vec{E} = \mu_0 \left[1 - \frac{\Omega^2(\mu-1)}{\omega^2 - \Omega^2} \right] \frac{\partial \vec{H}_y}{\partial t}$$

for the case $\omega >> \Omega$ we have

$$rot\ \vec{E} = \mu_0 \left[1 - \frac{\Omega^2(\mu-1)}{\omega^2} \right] \frac{\partial \vec{H}_y}{\partial t} \qquad (4.8)$$

assuming $H_y = H_{y0} \sin \omega t$ and taking into account that in this case

$$\frac{\partial \vec{H}_y}{\partial t} = -\omega^2 \int \vec{H}_y\, d\, t$$

we obtain from (4.1)

$$rot\ \vec{E} = \mu_0 \frac{\partial \vec{H}_y}{\partial t} + \mu_0\, \Omega^2 (\mu - 1) \int \vec{H}_y\, d\, t$$

or

$$rot\ \vec{E} = \mu_0 \frac{\partial \vec{H}_y}{\partial t} + \frac{1}{C_k} \int \vec{H}_y\, d\, t \qquad (4.9)$$

for the case $\omega << \Omega$ we find

$$rot\ \vec{E} = \mu_0 \mu \frac{\partial \vec{H}_y}{\partial t}$$

Value

$$C_k = \frac{1}{\mu_0\, \Omega^2 (\mu - 1)}$$

which is introduced in relationship (4.9), let us name kinetic capacity.

With which is connected existence of this parameter, and its what physical sense? If the direction of magnetic moment does not coincide with the direction of external magnetic field, then the vector of this moment begins to precess around the vector of magnetic field with the frequency Ω. The magnetic moment $\vec{m}$ possesses in this case potential energy $U_m = -\vec{m} \cdot \vec{B}$. This energy similar to energy of the charged capacitor is potential, because precessional motion, although is mechanical, however, it not inertia and instantly it does cease during the removal of magnetic field. However, with the presence of magnetic field precessional motion continues until the accumulated potential energy is spent, and the vector of magnetic moment will not become parallel to the vector of magnetic field.

The equivalent diagram of the case examined is given in Fig. 4. At the point $\omega = \Omega$ occurs magnetic resonance, in this case $\mu_T^* \to -\infty$ The resonance frequency of macroscopic magnetic resonator, as can easily be seen of the equivalent diagram, also does not depend on the dimensions of line and is equal Ω. Thus, the parameter

$$\mu_T * (\omega) = \mu_0 \left[1 - \frac{\Omega^2 (\mu - 1)}{\omega^2 - \Omega^2} \right]$$

is not the frequency dependent magnetic permeability, but it is the combined parameter, including μ_0, μ and C_k which are included on in accordance with the equivalent diagram, depicted in Fig. 4.

Is not difficult to show that in this case there are three waves: electrical, magnetic and the wave, which carries potential energy, which is connected with the precession of magnetic moments around the vector H_0.

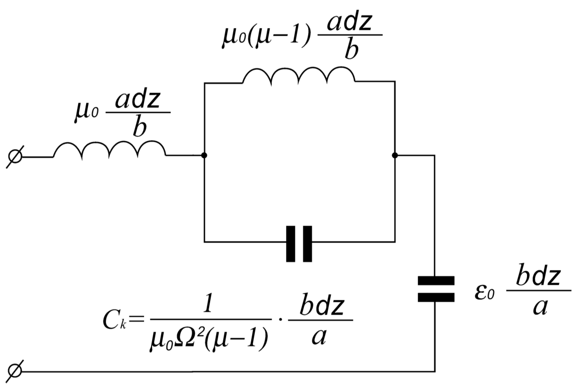

Fig 4. Equivalent the schematic of the two-wire circuit of that filled with magnetic material.

For this reason such waves can be named magnetopotential.

Before the appearance of a work [13] in the electrodynamics this concept, as kinetic capacity it was not used, although this the real parameter has very intelligible physical interpretation.

5. Conclusion

In the article it is shown that Maxwell's equations can be represented in the symmetrical form and such equations describe entire spectrum of electrodynamic processes in the material media. Are represented the equivalent diagrams of plasma, dielectrics and magnetic materials, placed between the planes of long line. Is introduced the new concept of kinetic capacity, which describes the energy processes, connected with the precessional motion of the magnetic moments of atoms in the magnetized media.

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