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New Approaches to the Solution of the Problem of the Propagation of Electrical Energy Fluxes in the Material Media and the Long Lines

By F. F. Mende

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I. Introduction

If we as the direction of propagation of electromagnetic (EM) wave in the free space select axis Z, and the vector of electric field to direct along the axis x, the for this component of field wave equation, obtained from Maxwell's equations, will be written down:

$$\frac{\partial^2 E_x}{\partial x^2}=\frac{1}{c^2}\frac{\partial^2 E_x}{\partial t^2},$$

where $c=\frac{1}{\sqrt{\varepsilon_0\mu_0}}$ - speed of light. where ε_0 and μ_0 - dielectric and magnetic constant of vacuum.

The function satisfies this equation

$$E_x=E_{0x}\sin(\omega t-kz),$$

where $k=\frac{\omega}{c}$ - wave number.

Eletromagnitnaya wave with its propagation transfers energy. The quantity of energy, transferred by wave in one second, through the single area, normal to the direction of propagation, is determined by the Poynting's vector. This vector is formally introduced as follows for the free space in the system of SI:

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$$\mathbf{\Pi} = [\mathbf{E} \times \mathbf{H}].$$

The relation of the absolute values of electrical and magnetic field in EM to wave in the free space is determined by the wave drag of the free space Z_0

$$\frac{E}{H} = Z_0,$$

where

$$Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}}.$$

Consequently, the absolute value of the Poynting's vector is equal

$$\Pi = \frac{1}{Z_0} E^2 = \frac{1}{\sqrt{\frac{\mu_0}{\varepsilon_0}}} E^2.$$

The average value of the acting function $E_x = E_{0x} \sin(\omega t - kz)$ is equal $\frac{E_{0x}}{\sqrt{2}}$. The average value of the absolute value of the Poynting's vector will comprise for this case

$$\Pi = \frac{1}{Z_0} E^2 = \frac{1}{2Z_0} E_{0x}^2 = \frac{1}{2}\sqrt{\frac{\varepsilon_0}{\mu_0}}\ E_{0x}^2. \tag{1.1}$$

The transfer of energy EM by wave can be calculated by energy method.

The specific electric field energy, stored up per unit of volume, is determined by the relationship

$$W_0 = \frac{1}{2}\varepsilon_0 E_{0x}^2.$$

If EM wave moves with the speed of light c , that it will per unit time through the single area, located normal to the propagation of wave, transfer the energy

$$cW_0 = \frac{1}{2}\sqrt{\frac{\varepsilon_0}{\mu_0}}\ E_{0x}^2,$$

The obtained value coincides with the value of the absolute value of the Poynting's vector(1.1).

II. Electrodynamics Of Plasmo-Like Media

By plasma media we will understand such, in which the charges can move without the losses. To such media in the first approximation, can be related the superconductors, free electrons or ions in the vacuum (subsequently conductors). In the absence magnetic field in the media indicated equation of motion for the electrons takes the form:

$$m\frac{d\vec{v}}{dt} = e\vec{E}, \tag{2.1}$$

Notes

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

In the work [9] it is shown that this equation can be used also for describing the electron motion in the hot plasma. Therefore it can be disseminated also to this case. Using an expression for the current density

Notes

$$\vec{j} = ne\vec{v} \tag{2.2}$$

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

$$\vec{j}_L = \frac{ne^2}{m}\int \vec{E}\ dt \tag{2.3}$$

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

$$L_k = \frac{m}{ne^2} \tag{2.4}$$

we find

$$\vec{j}_L = \frac{1}{L_k}\int \vec{E}\ dt\ . \tag{2.5}$$

In this case the value L_k presents the specific kinetic inductance of charge carriers [2-6]. 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:

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

For the mathematical description of electro dynamic processes the trigonometric functions will be here and throughout, instead of the complex quantities, used so that would be well visible the phase relationships between the vectors, which represent electric fields and current densities.

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 [3-5]

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

or

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

If electrons are located in the material medium, then should be considered the presence of the positively charged ions. However, with the examination of the properties of such media in the rapidly changing fields, in connection with the fact that the mass of ions is considerably more than the mass of electrons, their presence usually is not considered.

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 the capacitive σ_C and by the inductive σ_L 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 $\omega_0=\sqrt{\frac{1}{L_k\varepsilon_0}}$ - plasma frequency.

And large temptation here appears to name the value

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

By the depending on the frequency dielectric constant of plasma, that also is made in all existing works on physics of plasma. But this is incorrect, since. this mathematical symbol is the composite parameter, into which simultaneously enters the dielectric constant of vacuum and the specific kinetic inductance of charges. It is clear from the previous examination that the parameter $\varepsilon^*(\omega)$ gives the possibility in one coefficient to combine derivative and the integral of harmonic function, since they are characterized by only signs and thus impression is created, that the dielectric constant of plasma depends on frequency. It should be noted that a similar error is perfected by such well-known physicists as Akhiezer, Tamm, Ginsburg [7-12].

This happened still and because, beginning to examine this question, Landau introduced the determinations of dielectric constant only for the static pour on, but he did not introduce this lopredeleniya for the variables pour on. Let us introduce this determination.

If we examine any medium, including plasma, then current density (subsequently we will in abbreviated form speak simply current) it will be determined by three components, which depend on the electric field. The current of resistance losses there will be synchronizedto electric field. The permittance current, determined by first-order derivative of electric field from the time, will anticipate the tension of electric field on

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the phase to $\frac{\pi}{2}$. This current is called bias current. The conduction current, determined by integral of the electric field from the time, will lag behind the electric field on the phase to $\frac{\pi}{2}$. All three components of current indicated will enter into the second Maxwell's equation and others components of currents be it cannot. Moreover all these three components of currents will be present in any nonmagnetic regions, in which there are losses. Therefore it is completely natural, the dielectric constant of any medium to define as the coefficient, confronting that term, which is determined by the derivative of electric field by the time in the second Maxwell's equation. In this case one should consider that the dielectric constant cannot be negative value. This connected with the fact that through this parameter is determined energy of electrical pour on, which can be only positive.

Notes

Without having introduced this clear determination of dielectric constant, Landau begins the examination of the behavior of plasma in the ac fields. In this case is not separated separately the bias current and conduction current, one of which is defined by derivative, but by another integral, is written as united bias current. It makes this error for that reason, that in the case of harmonic oscillations the form of the function, which determine and derivative and integral, is identical, and they are characterized by only sign. Performing this operation, Landau does not understand, that in the case of harmonic electrical pour on in the plasma there exist two different currents, one of which is bias current, and it is determined by the dielectric constant of vacuum and derivative of electric field. Another current is conduction current and is determined by integral of the electric field. these two currents are antiphase. But since both currents depend on frequency, moreover one of them depends on frequency linearly, and another it is inversely proportional to frequency, between them competition occurs. The conduction current predominates with the low frequencies, the bias current, on the contrary, predominates with the high. However, in the case of the equality of these currents, which occurs at the plasma frequency, occurs current resonance.

Let us emphasize that from a mathematical point of view to reach in the manner that it entered to Landau, it is possible, but in this case is lost the integration constant, which is necessary to account for initial conditions during the solution of the equation, which determines current density in the material medium.

The obviousness of the committed error is visible based on other example.

Relationship (2.7) can be rewritten and differently:

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

and to introduce another mathematical symbol

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

In this case also appears temptation to name this bending coefficient on the frequency kinetic inductance.

Thus, it is possible to write down:

$$\vec{j}_\Sigma = \omega\varepsilon^*(\omega)\ \vec{E}_0 \cos\omega t,$$

or

$$\vec{j}_\Sigma = -\frac{1}{\omega L^*(\omega)}\ \vec{E}_0 \cos\omega t\ .$$

But this altogether only the symbolic mathematical record of one and the same relationship (2.7). Both equations are equivalent. But view neither $\varepsilon^*(\omega)$ nor $L^*(\omega)$ by dielectric constant or inductance are from a physical point. The physical sense of their names consists of the following:

$$\varepsilon^*(\omega) = \frac{\sigma_X}{\omega}\ ,$$

i.e. $\varepsilon^*(\omega)$ presents summary susceptance of medium, divided into the frequency, and

$$L_k{}^*(\omega) = \frac{1}{\omega\sigma_X}$$

it represents the reciprocal value of the work of frequency and susceptance of medium.

As it is necessary to enter, if at our disposal are values $\varepsilon^*(\omega)$ and $L^*(\omega)$, and we should calculate total specific energy. Natural to substitute these values in the formulas, which determine energy of electrical pour on

$$W_E = \frac{1}{2}\varepsilon_0 E_0^2$$

and kinetic energy of charge carriers

$$W_j = \frac{1}{2} L_k j_0^2. \tag{2.8}$$

Hence it follows that the summary specific energy, accumulated per unit of volume of plasma is equal

$$W_\Sigma = \frac{1}{2}\varepsilon_0 E_0^2 + \frac{1}{2} L_k j_0^2 .$$

It is not difficult to show that in this case the total specific energy can be obtained from the relationship of

$$W_\Sigma = \frac{1}{2}\cdot\frac{d\left(\omega\varepsilon^*(\omega)\right)}{d\omega} E_0^2\ , \tag{2.9}$$

from where we obtain

$$W_\Sigma = \frac{1}{2}\varepsilon_0 E_0^2 + \frac{1}{2}\ \frac{1}{\omega^2 L_k} E_0^2 = \frac{1}{2}\varepsilon_0 E_0^2 + \frac{1}{2} L_k j_0^2\ .$$

We will obtain the same result, after using the formula

$$W_\Sigma = \frac{1}{2}\ \frac{d\left[\dfrac{1}{\omega L_k{}^*(\omega)}\right]}{d\omega}\ E_0^2 .$$

Notes

The given relationships indicate, that the specific energy EM of wave consists not only of potential energy of electrical pour on, as we counted earlier, but into it it enters still and kinetic energy of charge carriers.

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:

Notes

$$rot\ \vec{E} = -\mu_0 \frac{\partial\ \vec{H}}{\partial\ t},$$
$$rot\ \vec{H} = \varepsilon_0 \frac{\partial\ \vec{E}}{\partial\ t} + \frac{1}{L_k}\int \vec{E}\ dt, \quad (2.10)$$

system of equations (2.10) completely describes all properties of nondissipative conductors. From it we obtain

$$rot\ rot\ \vec{H} + \mu_0\varepsilon_0 \frac{\partial^2 \vec{H}}{\partial\ t^2} + \frac{\mu_0}{L_k}\vec{H} = 0 \quad (2.11)$$

For the case pour on, time-independent, equation (2.11) passes into the London equation

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

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

Thus, it is possible to conclude that the equations of London being a special case of equation (2.11), 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.

The wave equation in this case it appears as follows for the electrical field:

$$rot\ rot\ \vec{E} + \mu_0\varepsilon_0 \frac{\partial^2 \vec{E}}{\partial\ t^2} + \frac{\mu_0}{L_k}\vec{E} = 0 \quad (2.12)$$

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 on Wednesday.

Taking into account the fact that $div\vec{E} = 0$ from (2.12) we obtain wave equation with the right side

$$\frac{\partial^2 \vec{E}}{\partial x^2} - \frac{1}{c^2}\frac{\partial^2 \vec{E}}{\partial t^2} = \frac{\mu_0}{L_k}\vec{E}\,.$$

Solution of this equation will give the value of the unknown function.

III. Physical Processes in the Parallel Resonant Circuit

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 of

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

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

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

$$\text{of } I_{\Sigma}=\left(\omega C-\frac{1}{\omega L}\right)U_0\cos\omega t\,, \qquad (3.1)$$

In relationship (3.1) the value, which stands in the brackets, presents summary susceptance σ_{Σ} this medium and it consists it, in turn, of 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 (3.1) can be rewritten as follows:

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

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

And here, just as in the case of conductors, appears temptation, to name the value

$$C^*(\omega)=C\left(1-\frac{\omega_0^2}{\omega^2}\right)=C-\frac{1}{\omega^2 L} \qquad (3.2)$$

by the depending on the frequency capacity. Conducting this symbol it is permissible from a mathematical point of view; however, inadmissible is awarding to it the proposed name, since. this parameter of no relation to the true capacity has and includes in itself simultaneously and capacity and the inductance of outline, which do not depend on frequency.

is accurate another point of view. Relationship (3.1) can be rewritten and differently:

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

Notes

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and to consider that the chain in question not at all has capacities, and consists only of the inductance depending on the frequency

$$L^*(\omega)=\frac{L}{\left(\frac{\omega^2}{\omega_0^2}-1\right)}=\frac{L}{\omega^2 LC-1} \quad . \tag{3.3}$$

But, just as $C^*(\omega)$, the value of $L^*(\omega)$ cannot be called inductance, since this is the also composite parameter, which includes simultaneously capacity and inductance, which do not depend on frequency.

Using expressions (3.2) and (3.3), let us write down:

$$I_\Sigma=\omega C^*(\omega)\ U_0 \cos\omega t\,, \tag{3.4}$$

or

$$I_\Sigma=-\frac{1}{\omega L^*(\omega)}\ U_0 \cos\omega t\,. \tag{3.5}$$

The relationship (3.4) and (3.5) are equivalent, and separately mathematically completely is characterized the chain examined. But view neither $C^*(\omega)$ nor $L^*(\omega)$ by capacity and inductance are from a physical point, although they have the same dimensionality. The physical sense of their names consists of the following:

$$C^*(\omega)=\frac{\sigma_X}{\omega}\,,$$

i.e. $C^*(\omega)$ presents the relation of susceptance of this chain and frequency, and

$$L^*(\omega)=\frac{1}{\omega\sigma_X}\,,$$

it is the reciprocal value of the work of summary susceptance and frequency.

Accumulated in the capacity and the inductance energy, is determined from the relationships

$$W_C=\frac{1}{2}CU_0^{\ 2}\,, \tag{3.6}$$

$$W_L=\frac{1}{2}LI_0^{\ 2}\,. \tag{3.7}$$

How one should enter for enumerating the energy, which was accumulated in the outline, if at our disposal are $C^*(\omega)$ and $L^*(\omega)$? Certainly, to put these relationships in formulas (3.6) and (3.7) cannot for that reason, that these values can be both the positive and negative, and the energy, accumulated in the capacity and the inductance, is always positive. But if we for these purposes use ourselves the parameters indicated, then it is not difficult to show that the summary energy, accumulated in the outline, is determined by the expressions:

$$W_\Sigma=\frac{1}{2}\ \frac{d\sigma_X}{d\omega}\ U_0^{\ 2}\,, \tag{3.8}$$

$$W_{\Sigma}=\frac{1}{2}\ \frac{d\sigma_X}{d\omega}\ U_0^{\ 2}, \qquad (3.8)$$

or

$$W_{\Sigma}=\frac{1}{2}\ \frac{d\left[\omega C^*(\omega)\right]}{d\omega}\ U_0^{\ 2}, \qquad (3.9)$$

or

$$W_{\Sigma}=\frac{1}{2}\ \frac{d\left(\frac{1}{\omega L^*(\omega)}\right)}{d\omega}\ U_0^{\ 2}. \qquad (3.10)$$

If we paint equations (3.8) or (3.9) and (3.10), then we will obtain identical result, namely:

$$W_{\Sigma}=\frac{1}{2}CU_0^{\ 2}+\frac{1}{2}LI_0^{\ 2}$$

where U_0 - amplitude of stress on the capacity, and I_0- amplitude of the current, which flows through the inductance.

If we compare the relationships, obtained for the parallel resonant circuit and for the conductors, then it is possible to see that they are identical, if we make of $E_0 \to U_0$, $j_0 \to I_0$, $\varepsilon_0 \to C$ 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.

A now let us visualize this situation. In the audience, where are located specialists, who know radio engineering and of mathematics, comes instructor and he begins to prove, that there are in nature of no capacities and inductances, and there is only depending on the frequency capacity and that just she presents parallel resonant circuit. Or, on the contrary, that parallel resonant circuit this is the depending on the frequency inductance. View of mathematics will agree from this point. However, radio engineering they will calculate lecturer by man with the very limited knowledge. Specifically, in this position proved to be now those scientists and the specialists, who introduced into physics the frequency dispersion of dielectric constant.

IV. Transverse Plasma Resonance

Longitudinal mechanical Langmuir resonance is observed during the imposition on the plasma of ac field in it. Physical understanding of the processes, proceeding in the plasma made possible to open the previously unknown phenomenon, which taught name transverse plasma resonance, for the first time described in the article [14].
Let us examine in more detail this phenomenon.

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

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14. Никольский В. В., Никольская Т. И. Электродинамика и распространение радиоволн М: Наука, 1989.- 543 с.

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 razonansy are degenerate. Specifically, this resonance can be the reason for the emission of electromagnetic waves with the explosions of nuclear charges.

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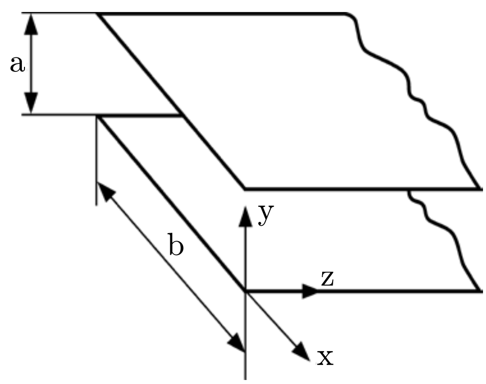

Fig. 1: The two-wire circuit, which consists of two ideally conducting planes

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:

$$C_0=\varepsilon_0\frac{b}{a}$$

$$L_0=\mu_0\frac{a}{b}.$$

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. Let us note that here are not examined technical questions, as and it is possible confined plasma between the planes of line how. In this case only fundamental questions, which are concerned transverse plasma resonance in the nonmagnetic plasma, are examined. 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

$$W_{k\Sigma}=\frac{1}{2}\ \frac{m}{ne^2}\ abzj^2=\frac{1}{2}\ \frac{m}{ne^2}\ \frac{a}{bz}I^2. \tag{4.1}$$

Relationship (4.1) 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.

$$L_{k\Sigma} = \frac{m}{ne^2} \cdot \frac{a}{bz} \,. \tag{4.2}$$

Thus, The value

$$L_k = \frac{m}{ne^2} \tag{4.3}$$

presents the specific kinetic inductance of charges. Relationship (4.3) is obtained for the case of the direct current, when current distribution is uniform.

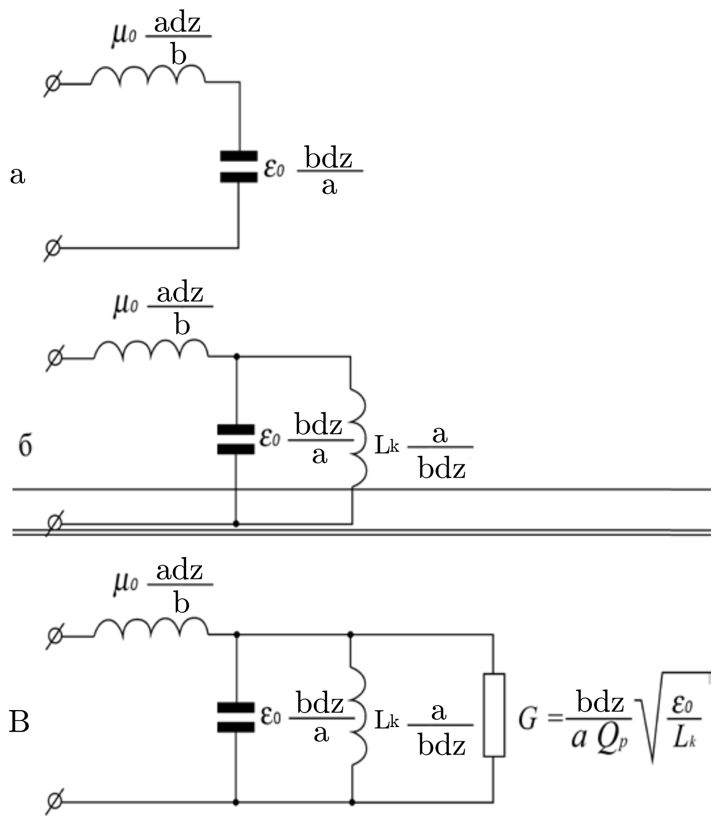

Fig. 2: a - the equivalent the schematic of the section of the two-wire circuit

б - the equivalent the schematic of the section of the two-wire circuit, filled with nondissipative plasma;

в - the equivalent the schematic of the section of the two-wire circuit, filled with dissipative plasma.

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).

From relationship (4.2) 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 non dissipative plasma, it is shown in Fig. 2(б). Line itself in this case will be equivalent to parallel circuit with the lumped parameters:

Notes

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

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

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 $\vec{k}=0$.

In this case the wave number is determined by the relationship:

$$k_z^2=\frac{\omega^2}{c^2}\left(1-\frac{\omega_\rho^2}{\omega^2}\right) \tag{4.4}$$

and the group and phase speeds

$$v_g^2=c^2\left(1-\frac{\omega_\rho^2}{\omega^2}\right) \tag{4.5}$$

$$v_F^2=\frac{c^2}{\left(1-\frac{\omega_\rho^2}{\omega^2}\right)} \tag{4.6}$$

where $c=\left(\frac{1}{\mu_0\varepsilon_0}\right)^{1/2}$ - 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 (4.4), (4.5) and (4.6) 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.

Pour on 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 $Z_0=\sqrt{\frac{\mu_0}{\varepsilon_0}}$ - characteristic (wave) resistance 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 ω ¿ ω_p of 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.

Notes

At the point of $\omega = \omega_p$ 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, resounding at the frequency ω_p.

Notes

Since with the frequencies of ¿ of 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 [elektromagnitokineticheskoy]. 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 $\frac{\pi}{2}$.

Until now, the physically unrealizable case has been considered, when there are no losses in the plasma, which corresponds to an infinite Q-factor of the plasma resonator.If losses 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:

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

$$rot\ \vec{H} = \sigma_{p.ef}\ \vec{E} + \varepsilon_0 \frac{\partial\ \vec{E}}{\partial\ t} + \frac{1}{L_k}\int \vec{E}\ dt \qquad (4.7)$$

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:

$$C = \varepsilon_0 \frac{bz_0}{a} \qquad (4.8)$$

$$L = L_k \frac{a}{bz_0} \qquad (4.9)$$

$$G = \sigma_{\rho.ef} \frac{bz_0}{a} \qquad (4.10)$$

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

Conductivity and quality in this outline enter into the relationship:

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

from where, taking into account (4.8 - 4.10), we obtain

$$\sigma_{\rho.ef} = \frac{1}{Q_\rho}\sqrt{\frac{\varepsilon_0}{L_k}} \tag{4.11}$$

Thus, measuring its own quality plasma of the resonator examined, it is possible to determine $\sigma_{p.ef}$. Using (4.2) and (4.11) we will obtain

$$\begin{aligned} rot\ \vec{E} &= -\mu_0 \frac{\partial\ \vec{H}}{\partial\ t} \\ rot\ \vec{H} &= \frac{1}{Q_\rho}\sqrt{\frac{\varepsilon_0}{L_k}}\ \vec{E} + \varepsilon_0 \frac{\partial\ \vec{E}}{\partial\ t} + \frac{1}{L_k}\int \vec{E}\ dt \end{aligned} \tag{4.12}$$

The equivalent the schematic of this line, filled with dissipative plasma, is represented in 3 (в).

Let us examine the solution of system of equations (4.12) 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.

If losses in the plasma, which fills line are small, and strange current source is connected to the line, then it is possible to assume:

$$\begin{aligned} & rot\ \vec{E} = 0 \\ & \frac{1}{Q_p}\sqrt{\frac{\varepsilon_0}{L_k}}\ \vec{E} + \varepsilon_0 \frac{\partial\ \vec{E}}{\partial\ t} + \frac{1}{L_k}\int \vec{E}\ dt = \vec{j}_{CT} \end{aligned} \tag{4.13}$$

where $\vec{j}_{CT}$ - density of strange currents.

After integrating (7.13) with respect to the time and after dividing both parts to, we will obtain

$$\omega_p^2\ \vec{E} + \frac{\omega_p}{Q_p}\cdot\frac{\partial\ \vec{E}}{\partial\ t} + \frac{\partial^2 \vec{E}}{\partial\ t^2} = \frac{1}{\varepsilon_0}\cdot\frac{\partial\ \vec{j}_{CT}}{\partial\ t} \tag{4.14}$$

if we (4.2) integrate over the surface of normal to the vector of and to designate

Notes

$$\omega_p^2 P_E + \frac{\omega_p}{Q_p} \cdot \frac{\partial P_E}{\partial t} + \frac{\partial^2 P_E}{\partial t^2} = \frac{1}{\varepsilon_0} \cdot \frac{\partial I_{CT}}{\partial t} \quad (4.15)$$

where I_{CT} - strange current.

Equation (4.15) is the equation of harmonic oscillator with the right side, characteristic for the two-level lasers, which opens the possibility of designing of the lasers of large power.

Notes

V. Electrodynamics Of The Dielectrics

Let us examine the simplest case, when oscillating processes in atoms or molecules of dielectric obey the law of mechanical oscillator [15].

$$\left(\frac{\beta}{m} - \omega^2\right)\mathbf{r}_m = \frac{e}{m}\mathbf{E}, \quad (5.1)$$

where $\mathbf{r}_m$ - deviation of charges from the position of equilibrium, β - 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 (5.1):

$$\mathbf{r}_m = -\frac{e\,\mathbf{E}}{m(\omega^2 - \omega_o^2)}. \quad (5.2)$$

Is evident that in relationship (5.2) 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

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

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

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

from relationship (5.2) we find

$$\mathrm{rot}\,\mathbf{H} = \mathbf{j}_\Sigma = \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} - \frac{1}{L_{kd}(\omega^2 - \omega_0^2)} \frac{\partial \mathbf{E}}{\partial t}. \quad (5.3)$$

Let us note that 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 (5.3) let us rewrite in the form:

$$\text{rot}\,\mathbf{H} = \mathbf{j}_\Sigma = \varepsilon_0 \left(1 - \frac{1}{\varepsilon_0 L_{kd} (\omega^2 - \omega_0{}^2)} \right) \frac{\partial \mathbf{E}}{\partial t}. \quad (5.4)$$

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 (9.4) takes the form:

$$\text{rot}\,\mathbf{H} = \mathbf{j}_\Sigma = \varepsilon_0 \left(1 - \frac{\omega^2{}_{pd}}{(\omega^2 - \omega_0{}^2)} \right) \frac{\partial \mathbf{E}}{\partial t}. \quad (5.5)$$

It is possible to name the value

$$\varepsilon^*(\omega) = \varepsilon_0 \left(1 - \frac{\omega^2{}_{pd}}{(\omega^2 - \omega_0{}^2)} \right) \quad (5.6)$$

by the effective dielectric constant of dielectric and it depends on frequency. But this mathematical parameter is not the physical dielectric constant of dielectric, but has composite nature. It includes three those not depending on the frequency of the value: electrical constant, natural frequency of atoms or molecules and plasma frequency for the charge carriers, entering their composition, if we consider charges free.
Let us examine two limiting cases:

a) If $\omega << \omega_0$ then from (5.6) we obtain

$$\text{rot}\,\mathbf{H} = \mathbf{j}_\Sigma = \varepsilon_0 \left(1 + \frac{\omega_{pd}{}^2}{\omega_0{}^2} \right) \frac{\partial \mathbf{E}}{\partial t}. \quad (5.7)$$

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

Notes

relationship (5.7) 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.

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b) The case is exponential $\omega >> \omega_0$, *in this case*

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

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 in this mathematical model as the initial electrical characteristics of medium are used the values, which do not depend on frequency.

From relationship (5.5) is evident that in the case of fulfilling the equality of $\omega = \omega_0$, 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. For this the phase speed of electromagnetic waves on Medium must depend on frequency (frequency wave dispersion). Let us add to (5.5) the first Maxwell equation:

$$\operatorname{rot} \mathbf{E} = -\mu_0 \frac{\partial \mathbf{H}}{\partial t}; \quad \operatorname{rot} \mathbf{H} = \varepsilon_0 \left(1 - \frac{\omega^2{}_{pd}}{(\omega^2 - \omega_0{}^2)}\right) \frac{\partial \mathbf{E}}{\partial t},$$

from where we immediately find the wave equation:

$$\nabla^2 \mathbf{E} = \mu_0 \varepsilon_0 \left(1 - \frac{\omega_{pd}{}^2}{\omega^2 - \omega_0{}^2}\right) \frac{\partial^2 \mathbf{E}}{\partial t^2}. \qquad (5.8)$$

If one considers that

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

where c - the speed of light, then is easy to see the presence in dielectrics of frequency dispersion. But the dependence of phase speed on the frequency is connected not with the dependence on it of physical dielectric constant. In the formation of this dispersion it will participate immediately three, which do not depend on the frequency, physical quantities: the self-resonant frequency of atoms themselves or molecules, the plasma frequency of charges, if we consider it their free, and the dielectric constant of vacuum.

Let us accept that $div\mathbf{E} = 0$, then from (5.8) we obtain

$$\frac{\partial^2 \mathbf{E}}{\partial z^2} = \frac{1}{c^2}\left(1 - \frac{\omega_{pd}{}^2}{\omega^2 - \omega_0{}^2}\right)\frac{\partial^2 \mathbf{E}}{\partial t^2}.$$

This equation is reduced to the standard form

$$\frac{\partial^2 \mathbf{E}}{\partial z^2} = \frac{1}{v_d{}^2}\frac{\partial^2 \mathbf{E}}{\partial t^2}$$

if we place the velocity of propagation EM of wave in the dielectric

$$v_d = \frac{c}{\sqrt{\left(1 - \frac{\omega_{pd}{}^2}{\omega^2 - \omega_0{}^2}\right)}}.$$

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 of U_C, applied to it, is determined by the relationships:

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

$$I_C = C\frac{dU_C}{dt}. \qquad (5.10)$$

This connection will be written down for the inductance:

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

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

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

Notes

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

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

Notes

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

$$I = -\frac{1}{\omega\left(\omega L - \dfrac{1}{\omega C} \right)} \frac{\partial U_\Sigma}{\partial t} \,. \qquad (5.11)$$

The resonance frequency of outline is determined by the relationship

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

therefore let us write down

$$I = \frac{C}{\left(1 - \dfrac{\omega^2}{\omega_0{}^2} \right)} \frac{\partial U_\Sigma}{\partial t} \,. \qquad (5.12)$$

Comparing this expression with relationship (5.12) and (5.10) 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 of in the form dependent on the frequency

$$C(\omega) = \frac{C}{1 - \dfrac{\omega^2}{\omega_0{}^2}} \qquad (5.13)$$

The inductance is not lost with this idea, since it enters into the resonance frequency of the outline ω_0. Relationships (5.12) and (5.11) are equivalent. Consequently, value $C(\omega)$ is not the physical capacitance value of outline, being the certain composite mathematical parameter.

Relationship (5.11) 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

$$C(\omega) = -\frac{1}{L\left(\omega^2 - \omega_0{}^2\right)}. \qquad (5.14)$$

Is certain, the parameter $C(\omega)$, introduced in accordance with relationships (5.13) and (5.14) no to capacity refers.

Let us examine relationship (9.12) for two limiting cases:

c) 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.

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

Notes

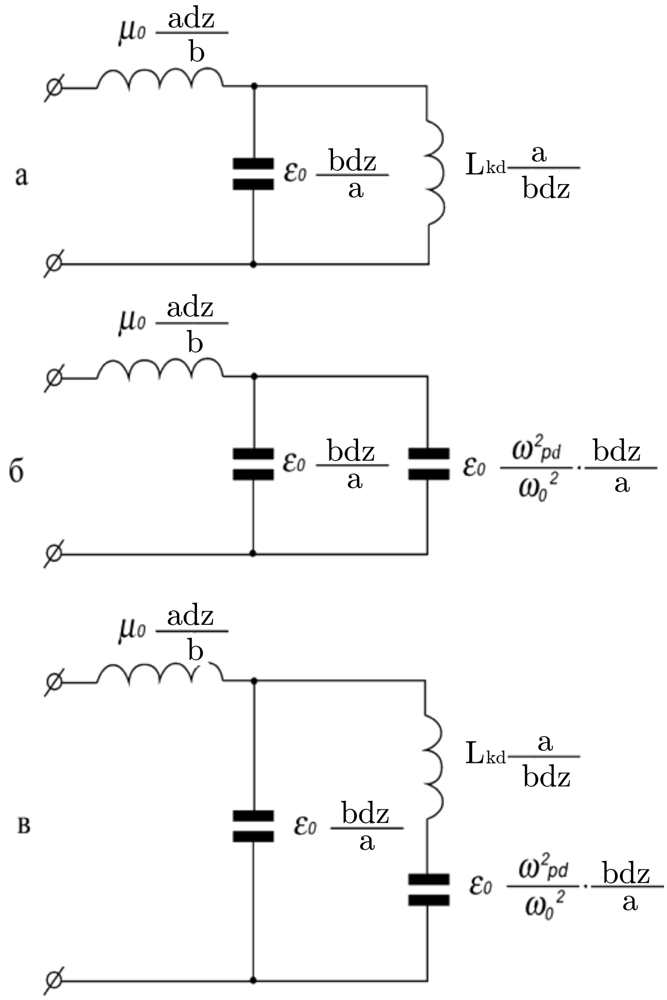

Fig. 3: a - equivalent the schematic of the section of the line, filled with dielectric, for the case ω ¿¿ ω_0;

б - equivalent the schematic of the section of line for the case ω ¡¡ ω_0;

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

d) When $\omega >> \omega_0$, we have

$$I = -\frac{1}{\omega^2 L}\frac{\partial U_\Sigma}{\partial t} \tag{5.15}$$

Taking into account that for the harmonic signal

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

we obtain from (5.2):

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

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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. For understanding of true design of circuits it is necessary to remove its amplitude and phase response 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.

In Fig. 3 a and 5 б are shown two limiting cases. ω ¿¿ ω_0, when the properties of dielectric correspond to conductor; ω ¡¡ ω_0 , when - to dielectric with the static dielectric constant

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

Thus, the use of a term “dielectric constant of dielectrics” in the context of its dependence on the frequency is not completely correct. If the discussion deals with the dielectric constant of dielectrics, with which the accumulation of potential energy is connected, then correctly examine only static permeability, which is been the constant, which does not depend on the frequency. Specifically, it enters into all relationships, which characterize the electrodynamic characteristics of dielectrics.

Application of such new approaches most interestingly precisely for the dielectrics. Then each connected pair of charges is a separate unitary unit with its individual characteristics, and its interaction with the electromagnetic field (without taking into account the connections between the pairs) is strictly individual. 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 it is possible to introduce the appropriate partial coefficients. 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. With the electric coupling between the separate groups of emitters the lines of absorption or emission can be converted into the strips. Such individual approach to the types of the connected pairs of charges is absent from the available theories.

Let us emphasize the important circumstance, which did not receive thus far proper estimation. In all relationships for any material media (conductors and dielectrics) together with the dielectric and magnetic constant figures the kinetic inductance of the charges, which indicates not less important role of this parameter.

In the works [3-6] the role of the kinetic inductance of charges in the electrodynamic processes, which occur in the conductors and the plasmo-like media is in sufficient detail opened, but the role of this parameter in the electrodynamics of dielectrics is not opened. This parameter in the electrodynamics of dielectrics plays not less important role, than in the electrodynamics of conductors. In this division the electrodynamics of dielectrics taking into account the kinetic inductance of the charges, which form part of their atoms or molecules is examined. This most important question fell out from the field of the sight of scientists, and this article completes this deficiency. Let us emphasize this important circumstance, which did not receive thus far proper estimation. In all relationships for any material media (conductors and dielectrics) together with the dielectric and magnetic constant figures the kinetic inductance of the charges, which indicates not less important role of this parameter.

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VI. Conclusion

In the article are examinednew approaches to the solution of the problem of the propagation of electrical energy fluxes in the material media and the long lines it is examined the electrodynamics of plasma and shown that the absolute value of the vector Of poytinga can be obtained with the examination of the motion of specific electric field energy and kinetic kinetic energy of the charges, concentrated in the single volumes of plasma. Is obtained wave of equation for the plasma. The electrodynamics of dielectrics is examined and is obtained wave equation for them. Are examined processes occurring in the long lines, filled with plasma or dielectrics and predicted new phenomenon transverse plasma resonance in the limited nonmagnetized plasma. The use of transverse plasma resonance opens the possibility of designing of the lasers of large power.

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