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Kinetic Capacity

By F. F. Mende

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I. Introduction

If in the existing scientific literature occurs only of the irregular reference about the fact that such is the kinetic inductance of charge carriers [1-4], that there was no work known about the kinetic [5] capacity before the appearance.

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

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

where σ_E - the conductivity is metal, ε_0 - the dielectric constant of vacuum, L_k - the kinetic inductance of charge carriers.

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

$$rot\vec{E} = -\mu \frac{\partial \vec{H}}{\partial t}, \qquad (2)$$

where μ - magnetic permeability of medium. It is evident that equations (1) and (2) are asymmetrical.

To somewhat improve the symmetry of these equations are possible, introducing into equation (2) term linear for the magnetic field, that considers heat losses in the magnetic materials in the variable fields:

$$rot\vec{E} = -\sigma_H \vec{H} - \mu \frac{\partial \vec{H}}{\partial t}, \qquad (3)$$

where σ_H - conductivity of magnetic currents. But here there is no integral of such type, which is located in the right side of equation (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 (3) can appear a term of the same type as in relationship (1). It will only stand L_k, i.e. instead of C_k the kinetic capacity, which characterizes that potential energy, which has the precessing magnetic moment in the magnetic field:

$$rot\vec{E} = -\sigma_H \vec{H} - \mu_0 \frac{\partial \vec{H}}{\partial t} - \frac{1}{C_k}\int \vec{H}dt. \qquad (4)$$

For the first time this idea of the first equation of Maxwell taking into account kinetic capacity was given in the work [3].

II. Kinetic Capacity Of The Magnetic Moments

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. At the same time there is another type of resonance -

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

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 of in parallel to the axis of, 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 [7]

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

where

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

moreover

$$\Omega=|\gamma|\,H_0 \tag{5}$$

is natural frequency of precession, and

$$M_0=\mu_0(\mu-1)H_0 \tag{6}$$

is a magnetization of medium. Taking into account (4) and (5) for, it is possible to write down

$$\mu_T{}^*(\omega)=1-\frac{\Omega^2(\mu-1)}{\omega^2-\Omega^2} \tag{7}$$

That magnetic permeability of magnetic material depends on frequency, and can arise suspicions, that, as in the case with the plasma, here is some misunderstanding.

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 first Maxwell 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 (7), 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

$$rot\ \vec{E}=\mu_0\left[1-\frac{\Omega^2(\mu-1)}{\omega^2}\right]\frac{\partial\ \vec{H}_y}{\partial\ t}, \tag{8}$$

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 will obtain from (8)

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

or

$$rot\ \vec{E}=\mu_0\frac{\partial\ \vec{H}_y}{\partial\ t}+\frac{1}{C_k}\int\vec{H}_y\ d\ t. \tag{9}$$

Value

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

which is introduced in relationship (8), let us name kinetic capacity.

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

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

we have the first equation of Maxwell.

With which is connected existence of kinetic capacity, and its which 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 Figure 1. At point $\omega=\Omega$ occurs magnetic resonance, in this case $\mu_T^*(\omega)=-\infty$. 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

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

is not the frequency dependent magnetic permeability, but it is the combined parameter, including μ, μ_0 and C_k, which are included on in accordance with the equivalent diagram, depicted in Figure 1.

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

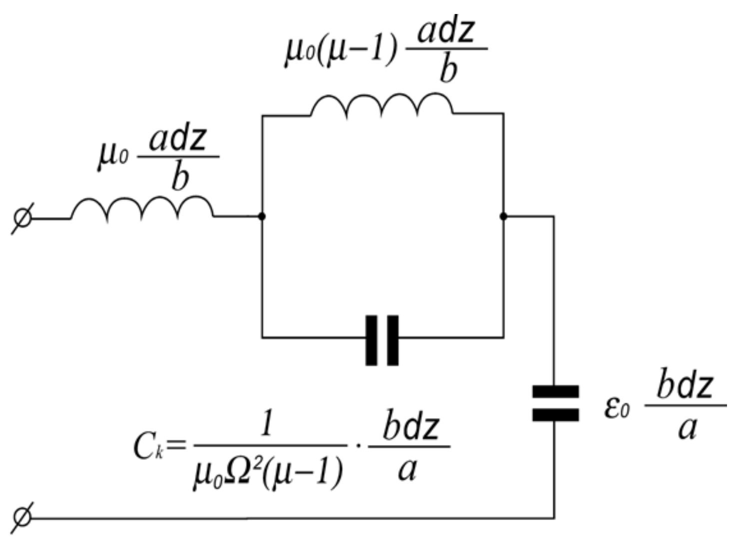

Figure 1: The equivalent the schematic of the two-wire circuit of that filled with the magnetic material, to which is superimposed magnetostatic field.

III. Conclusion

Before the appearance of a work [5] in the electrodynamics this concept, as kinetic capacity it was not used, although this the real parameter has very intelligible physical interpretation. if the vector of magnetic moment does not coincide with the direction of the magnetic field, then this moment accomplishes precessional motion. This motion does not have a inertia. since. it instantly ceases at the moment of removing the magnetic field. At the same time to us it is known that the atom, which possesses the magnetic moment, placed into the magnetic field, and which accomplishes in it precessional motion, has potential energy of. 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.

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