THE TRANSIENT RADIATION OF THE MAGNETIC MOMENT IN THE NON-STATIONARY MEDIUM

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The process of transient radiation of magnetic moment at the strong change of dielectric constant in time is considered. The formulae for eigen field and radiation field are obtained. It is established, that with the increase of energy the contribute of magnetic transient radiation with comparison of charge one increases essentially. In the case of magnetic medium at the strong change of physical properties isotropic radiation appears.

The transient radiation, appearing at the intersection of the boundary section of two mediums by the charge, firstly was considered by Ginzburg and Frank [1]. In our previous works the transient radiation of the magnetic moment on the strong boundary section of two mediums [2], and also the transient radiation of the magnetic moment on the scoured boundary of section of mediums, in a particular, the transient radiation in the plane-layered medium [3-6] were investigated.

One of the reason of the appearance of the transient radiation at the constant velocity of the source is the change of the physical properties of the medium in time. In the given task the transient radiation, appearing in the medium, physical properties of which strong change in time, is considered. The sharpness criterion of medium properties change is defined by the condition, when the time length of the change is much less, than time of the radiation forming. It is considered, that in the time moment $t=0$, the dielectric and magnetic constants change by the jump from the values ε_1 and μ_1 till the values ε_2 and μ_2 correspondingly.

On the base of Maxwell equations the differential equations for field vectors have been obtained:

$$\left(\vec{\nabla}^2-\frac{\varepsilon\,\mu}{c^2}\frac{\partial^2}{\partial t^2}\right)\vec{B}=-\frac{4\pi\mu}{c}\left[\vec{\nabla}\,\vec{j}\right], \qquad (1)$$

$$\left(\vec{\nabla}^2-\frac{\varepsilon\,\mu}{c^2}\frac{\partial^2}{\partial t^2}\right)\vec{E}=\frac{4\pi}{\varepsilon}\left[grad\,\rho+\frac{\varepsilon\,\mu}{c^2}\frac{\partial\,\vec{j}}{\partial t}\right]. \qquad (2).$$

Here the current density and charge density, created constantly by the moving magnetic moment are defined by the formulae

$$\vec{j}=c\,rot\vec{M}+\frac{\partial\vec{P}}{\partial t}\ , \qquad (3)$$

$$\rho=-div\vec{P}\ , \qquad (4)$$

where $\vec{M}(\vec{r},t)=\vec{m}\,\delta(\vec{r}-\vec{\upsilon}\,t)$ and $\vec{P}(\vec{r},t)=\left[\vec{\beta}\,\vec{m}\right]\delta(\vec{r}-\vec{\upsilon}\,t)$ are vectors of electric and magnetic polarization.

The considered task is completely homogeneous by the space that is why all values need to decomposition in Fourier integral on the space components. Moreover, we have Fourier-images of equations (1) and (2):

$$\left(k^2+\frac{\varepsilon\,\mu}{c^2}\frac{\partial^2}{\partial t^2}\right)\vec{B}_{\vec{k}}(t)=\frac{4\pi\,i\,\mu}{c}\left[\vec{k}\,\vec{j}_{\vec{k}}(t)\right], \qquad (5)$$

$$\left(k^2+\frac{\varepsilon\,\mu}{c^2}\frac{\partial^2}{\partial t^2}\right)\vec{E}_{\vec{k}}(t)=-\frac{4\pi}{\varepsilon}\left[i\,\vec{k}\,\rho_{\vec{k}}(t)+\frac{\varepsilon\,\mu}{c}\,\vec{\beta}\frac{\partial\rho_{\vec{k}}}{\partial t}\right]. \qquad (6)$$

In the equations (5) and (6) the Fourier-images of current density and charge density are correspondingly equal to:

$$\vec{j}_{\vec{k}}(t)=-\frac{i\,c}{(2\pi)^3}\left[\vec{m}\vec{K}\right]exp\left(-i\,\vec{k}\,\vec{\upsilon}\,t\right), \qquad (7)$$

$$\rho_{\vec{k}}(t)=-\frac{i\left(\vec{k}\left[\vec{\beta}\,\vec{m}\right]\right)}{(2\pi)^3}exp\left(-i\,\vec{k}\,\vec{\upsilon}\,t\right), \qquad (8)$$

where $\vec{K}=\vec{k}-\vec{\beta}\left(\vec{k}\vec{\beta}\right)$ and $\vec{\beta}=\vec{\upsilon}/c$.

The equations (5) and (6) are nonhomogeneous common differential equations, the common solutions of which are presented in the sum form of the private solution of nonhomogeneous equation (eigen field) and common solution of homogeneous equation (radiation field):

$$B^s_{\vec{k}}(t)=\frac{4\pi\left[\vec{k}\left[\vec{m}\vec{K}\right]\right]\mu\,exp\left(-i\,\vec{k}\,\vec{\upsilon}\,t\right)}{(2\pi)^3\left[k^2-\varepsilon\,\mu\left(\vec{k}\vec{\beta}\right)^2\right]}, \qquad (9)$$

$$\vec{E}^s_{\vec{k}}(t)=\frac{4\pi}{(2\pi)^3\,\varepsilon}\,\frac{\varepsilon\,\mu\left(\vec{k}\vec{\beta}\right)\left[\vec{m}\vec{K}\right]-\vec{k}\left(\vec{k}\left[\vec{\beta}\vec{m}\right]\right)exp\left(-i\,\vec{k}\,\vec{\upsilon}\,t\right)}{k^2-\varepsilon\,\mu\left(\vec{k}\vec{\beta}\right)^2}. \qquad (10)$$

$$\vec{B}^r_{\vec{k}}(t) = \frac{4\pi\left[\vec{k}\left[\vec{m}\vec{K}\right]\right]}{(2\pi)^3 k^2}\left[b_+ e^{-i\left(kc/\sqrt{\varepsilon\mu}\right)t} + b_- e^{i\left(kc/\sqrt{\varepsilon\mu}\right)t}\right], \quad (11)$$

$$\vec{E}^r_{\vec{k}}(t) = -\frac{4\pi}{(2\pi)^3 k^3\sqrt{\varepsilon\mu}}\left[\vec{k}\left[\vec{k}\left[\vec{m}\vec{K}\right]\right]\right]\left[b_+ e^{-i\left(kc/\sqrt{\varepsilon\mu}\right)t} - b_- e^{i\left(kc/\sqrt{\varepsilon\mu}\right)t}\right], \quad (12)$$

In these formulae the *s* index corresponds to the eigen field, and *r* index corresponds to radiation field. In the formulae (11), (12) the complex coefficients b_+ and b_- describe the amplitudes of two waves, propagating in the opposite directions - on $\vec{k}$ and against $\vec{k}$ correspondingly.

At $t<0$, the radiation field is absent and at $t>0$ the two waves appear immediately. The amplitudes of the radiation field are defined from the condition of the linking of the solutions:

$$\vec{B}^{s(1)}_{\vec{k}}(0) = \vec{B}^{s(2)}_{\vec{k}}(0) + \vec{B}^{r(2)}_{\vec{k}}(0), \quad (13)$$

$$\varepsilon_1\vec{E}^{s(1)}_{\vec{k}}(0) = \varepsilon_2\left[\vec{E}^{s(2)}_{\vec{k}}(0) + \vec{E}^{r(2)}_{\vec{k}}(0)\right] \quad (14)$$

from which we obtain:

$$b_\pm(\vec{k},\vec{\beta}) = \frac{k^2}{2}\left[\frac{\mu_1}{k^2 - \varepsilon_1\mu_1(\vec{k}\vec{\beta})^2} - \frac{\mu_2}{k^2 - \varepsilon_2\mu_2(\vec{k}\vec{\beta})^{2\pm}} \pm \right.$$
$$\left. \pm k(\vec{k}\vec{\beta})\sqrt{\mu_2/\varepsilon_2}\,\frac{\varepsilon_1\mu_1 - \varepsilon_2\mu_2}{\left(k^2 - \varepsilon_1\mu_1(\vec{k}\vec{\beta})^2\right)\left(k^2 - \varepsilon_2\mu_2(\vec{k}\vec{\beta})^2\right)}\right] \quad (15)$$

From the condition of the field corporeality we have:

$$b^*_\pm(\vec{k},\vec{\beta}) = b_\mp(\vec{k},\vec{\beta}) \ . \quad (16)$$

Moreover, the formulae (15) it is followed, that

$$b_\pm(-\vec{k},-\vec{\beta}) = b_\pm(\vec{k},\vec{\beta}) \ . \quad (17).$$

From the formulae (15) it is followed, that module is $|b_+| > |b_-|$ at any source velocity, and in the ultrarelativistic case it is $|b_+| >> |b_-|$. It is need to note specially, that in the rest state of the magnetic moment at the strong change of the physical properties of magnetic medium

$$b_\pm(\vec{k},0) = \frac{\mu_1 - \mu_2}{2} \neq 0,$$

that proves about the fact, that radiation takes place that can't be said about rest charge, amplitudes of radiation field of which is such case $a_\pm(\vec{k},0) = 0$, i.e. the radiation doesn't take place. This effect is interest by the fact that the rest particle is the nonstationary medium, having magnetic moment, then because of the magnetic moment the transient radiation will be exactly, that has the real value for fixation of particles. For the nonmagnetic medium $(\mu_1=\mu_2=1)$ the amplitudes of transient radiation, charge and magnetic moment are proportional to the jump of the dielectric constant, $|\varepsilon_1 - \varepsilon_2|$, i.e. the more bigger the jump of the dielectric constant, the more stronger the radiation is. For the nonmagnetic medium the ratio of module quadrate is equal to:

$$\frac{|b_+|^2}{|b_-|^2} = \frac{\left|1 + \beta\sqrt{\varepsilon_2}\cos\theta\right|^2}{\left|1 - \beta\sqrt{\varepsilon_2}\cos\theta\right|^2}.$$

The dependence of the ratio (18) on the energy at the fixed angle θ is given on the fig.1. As it is seen from the plots, the ratio $|b_+|^2/|b_-|^2$ strongly increase with the increase of energy, that shows, that the main pert of the radiation energy is on the radiation part forward.

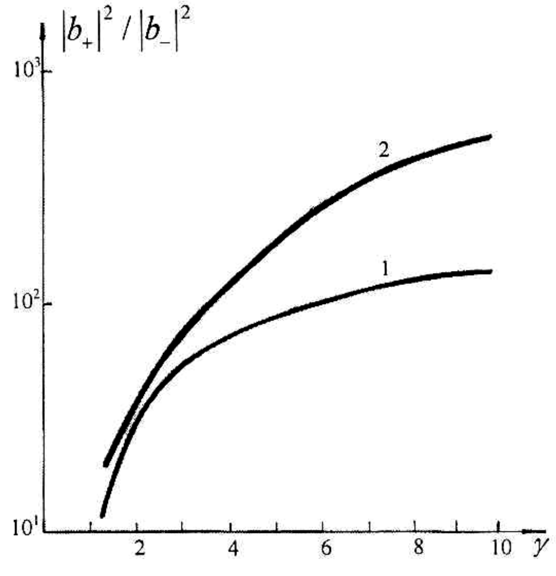

Fig.1. The energy distribution of the ratio of quadrate module amplitudes. Here curve 1 corresponds to the value θ=15°, but curve 2 corresponds to the value θ=5°.

The plot of the dependence of the ratio (18) on the angle θ at the fixed energy value is given on the fig.2. From the fig.2 it is seen, that in the region of small angles the forward radiation becomes stronger, i.e. the radiation is along the source velocity.

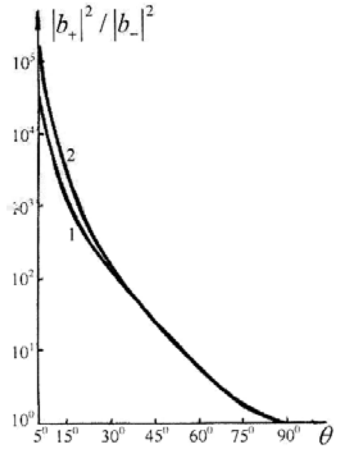

Fig.2. The angular distribution of the ratio of quadrate module amplitudes. Here curve 1corresponds to the value γ=10, but curve 2 corresponds to the value γ=25.

In the work the influence of the electron magnetic moment on its transient radiation is also considered. The expression for the ratio of the intensity module quadrate of the transient forward radiation of the magnetic moment and charge:

$$\Delta = \frac{\left|\vec{E}^{\,r1}_{\vec{k},m}\right|^2}{\left|\vec{E}^{\,r1}_{\vec{k},q}\right|^2} = \frac{1}{4}\left(\frac{\varepsilon_\gamma}{Mc^2}\right)^2 f(\beta,\theta) \ , \quad (19)$$

where

$$f(\beta,\theta) = \frac{1}{\beta^2}\left(2-\beta^2-3\beta^2\cos^2\theta+\beta^4\left(\cos^2\theta+\cos^4\theta\right)\right) \ , \quad (20)$$

and m_0 is the electron magnetic moment in the eigen reference system.

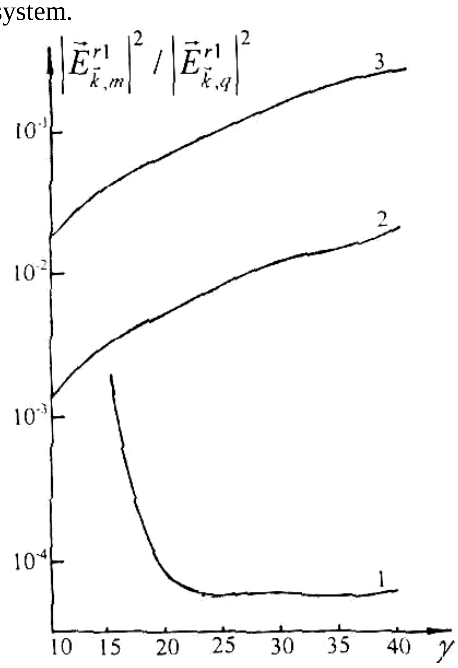

Fig.3. The energy dependence of the ratio of quadrate of module intensities of transient radiation of magnetic moment and charge. Here curve 1 corresponds to the value θ=5°., but curve 2 corresponds to the value θ=15°., curve 3 corresponds to the value θ=30°.

The plot of the dependence of the ratio (19) on the γ energy at the fixed values of angle θ is given on the fig.3. From the figure it is seen, that at small angles and velocity increase, this ratio strongly decreases. This is connected with the fact, that charge transient radiation with the velocity increase more increases, than transient radiation of the magnetic moment. At the transition to the big angles (θ=15°, 30°) with γ energy increase, to ratio (19) increases, i.e. deposit of the magnetic transient radiation becomes more significant, than charge one.

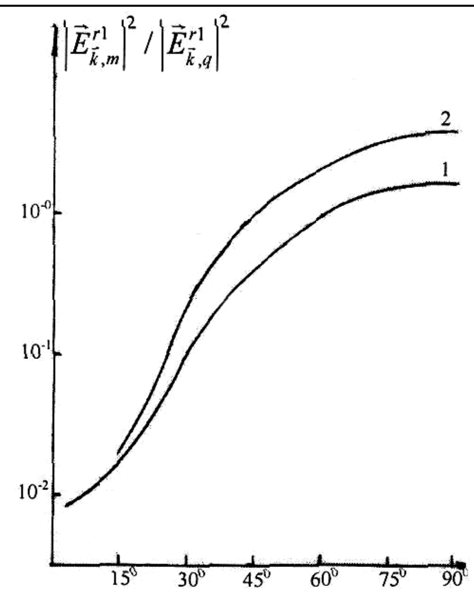

Fig.4. The angular dependence of quadrate of the module of intensities of transient radiation of magnetic moment and charge. Here curve 1 corresponds to the value γ=25, but curve 2 corresponds to the value γ=40.

The angular distribution of the ratio (19) at the fixed values of γ energy is represented on the fig.4. As it is seen from the plots, the deposit of the magnetic transient radiation significantly increases with the angle increase, so for example at the angle θ=45° (γ=40) and θ=60°(γ=25) the charge and magnetic transient radiation become almost equal. The energy of the radiated transient photon is chosen by $\varepsilon_\gamma = 0{,}1\gamma Mc^2$, where $Mc^2=0.51MeV$ is electron rest energy at the construction of the curves on the figures 3 and 4.

These results can be applied in the one of the important tasks of the modern physics of high energies.

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MAQNİT MOMENTİNİN QEYRİ-STASİONAR MÜHİTDƏ KEÇİD ŞÜALANMASI

Dielektrik nüfuzluğun zamana görə kəskin dəyişməsində maqnit momentinin keçid şüalanmasına baxılmışdır. Məxsusi və şüalanma sahələri üçün ifadələr alınmışdır. Müəyyən edilmişdir ki, enerjinin artması ilə maqnit keçid şüalanmasının payı yük şüalanmasına nisbətən kifayət qədər artır. Maqnit mühitlər üçün fiziki xassələrin kəskin dəyişməsində izotrop şüalanma baş verir.

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ПЕРЕХОДНОЕ ИЗЛУЧЕНИЕ МАГНИТНОГО МОМЕНТА В НЕСТАЦИОНАРНОЙ СРЕДЕ

Рассмотрен процесс переходного излучения магнитного момента при резком изменении диэлектрической проницаемости во времени. Получены формулы для собственного поля и поля излучения. Установлено, что с ростом энергии вклад магнитного переходного излучения относительно зарядового значительно увеличивается. В случае магнитной среды при резком изменении физических свойств возникает изотропное излучение.