Model of Extended Space: Prediction and Test Experiment on Possible Transformation of Electromagnetic Field into Gravitational Field

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Abstract

A run of preliminary experiments was carried out to check the prediction of possible gravitational field generation process arising by stopping of charged massive particles in a substance.

Introduction

A model of extended (1+4)-dimensional space $G(T;\vec{X},S)$ with the interval S as the fifth coordinate has been recently developed [1,3]. Certainly, these five coordinates satisfy the relation $(ct)^2 - x^2 - y^2 - z^2 - s^2 = 0$. In addition to Lorentz transformations $(T;\vec{X})$ in (1+3)-dimensional Minkowski space, in the proposed (1+4)-dimensional Extended Space Model (ESM) two other transformations exist in planes $(T;S)$ and $(\vec{X},S)$. They convert massive particles into massless and vice verse. It was also considered energy-momentum-mass (1+4)D space $G'(E;\vec{P},M) = (E/c;\vec{p},mc)$ which is conjugated to time-coordinates-interval $(t;x,y,z,s)$ (1+4)D space, and thus a mass m in 5D space $G'(E;\vec{P},M)$ corresponds to interval s in 5D space $G(T;\vec{X},S)$. The coordinates in (1+4)D space $G'(E;\vec{P},M)$ satisfy the relation $E^2 - c^2p_x^2 - c^2p_y^2 - c^2p_z^2 - m^2c^4 = 0$.

Note, that this model differs from the analogous 5D theory developed in [6], in which mass is considered as the fifth coordinate in 5D time-coordinate-mass (matter) space. In such approach it is impossible to build the energy-momentum tensor due to mixing of mass coordinate with time and spatial coordinates.

Field transformations in the frame of ESM

In the proposed ESM the well known 4-vector of energy-momentum $\widetilde{P}(1+3) = (E/c;p_x,p_y,p_z) = (E/c;\vec{p})$ in the Minkowski $M(T;\vec{X})$ space is transformed to the 5-vector $\bar{P}(1+4) = (E/c;\vec{p},mc)$ in extended space $G(T;\vec{X},S)$ and becomes isotropic for 5-vectors of a massive particle $(mc;\vec{0},mc)$ as well as for a massless particle $(\hbar\omega/c;\hbar\omega\vec{k}/c,0)$ (here $\vec{k}$ is the unit propagation vector of the particle).

The basic predictions of general theory of relativity can be also obtained in ESM. For instance, the following gravitational effects are considered in [5]: the escape velocity, red shift and deflection of starlight, retardation of radar-echo from Mars. It has been shown that it is possible to obtain the same formula as those which are obtained in the general theory of relativity for calculation of the magnitudes of these effects completely in another way within the framework of ESM.

According to the concepts of ESM, any external action applied to any material object can be described as a change of appropriate index of refraction n in the location of this object (introduction of refraction index for gravitation field is well known, see, for example, [7]). A change of refraction index causes a reduction of energy, momentum or mass of the object. Formally, in the frame of ESM, such process is described by rotations in planes $(T;\vec{X})$, $(\vec{X},S)$ and $(T;S)$. We suppose that the weak gravitational field of central massive body generates in space refraction index $n(r) = 1 + \gamma M/rc^2$ (here γ is the gravitational constant). Refraction index $n(r)$ depends on the strength of gravitational field. This index of refraction determines the motion of both massless (photons) and massive particles in space. Taking into account the appearance of refraction index in space around of massive body, we then apply the technique of rotations in 5D extended space to calculate various interactions of external body with gravitational field.

For instance, let us briefly show the way in which we can obtain the escape velocity within ESM. Massive body at rest is described in our model by 5D vector $mc(1;\vec{0},1)$. The motion of a massive body in a gravitational field along the x-axes can be considered in the extended space $G(T;\vec{X},S)$ as the motion in the plane $(\vec{X},S)$. Consider the motion of this massive body from the point, where gravitational field is absent (this is the point with refraction index $n=1$) to the point with refractive index $n(r)$. This motion is described in EMS by Euclidean rotation of 5D vector in $(\vec{X},S)$ plane by an angle ψ:

$$mc(1;\vec{0},1) \quad \to \quad mc(1;-\sin\psi,\cos\psi) = mc(1;-\sqrt{n^2(r)-1}/n(r), 1/n(r)). \tag{1}$$

Here we took into account that for massless particles (photons) the same rotation in the plane $(\vec{X},S)$ has the form

$$\frac{\hbar\omega}{c}(1;\vec{1},0) \to \frac{\hbar\omega}{c}(1;\vec{k}\cdot\cos\psi,\sin\psi). \tag{2}$$

Since the velocity of this particle is $v = c\cdot\cos\psi$, the refractive index equals $n = c/v = 1/\cos\psi$ [1]. Thus, we obtain a relation between refractive index and an angle ψ that was used in (1). Thus, in the case $n(r) \simeq 1$ a velocity gain of a massive particle equals

$$v = pc^2/E = c\sqrt{n^2(r)-1}/n(r) \simeq \sqrt{2\gamma M/r}. \tag{3}$$

This value coincides with the escape velocity, if we substitute to this formula the radius of the Earth, instead of r.

In the frame of ESM the 5-current

$$\bar{\rho} = (\rho,\vec{j},j_s) = (\rho_0 c/\sqrt{1-\beta^2}, \rho_0\vec{v}/\sqrt{1-\beta^2}, \rho_0 c), \quad \beta^2 = v^2/c^2 \tag{4}$$

has been built instead of 4-current $\tilde{\rho} = (\rho,\vec{j})$ as well as 5-vector potential $(\varphi,\vec{A},A_s) = (A_t,A_x,A_y,A_z,A_s)$ instead of $(\varphi,\vec{A})$. Potential and current are connected by the equations [1,8]

$$\Diamond A_t = -4\pi\rho, \tag{5}$$

$$\Diamond \vec{A} = -\frac{4\pi}{c}\vec{j}, \tag{6}$$

$$\Diamond A_s = -\frac{4\pi}{c} j_s. \qquad (7)$$

$$\text{Here} \qquad \Diamond = \frac{\partial^2}{\partial s^2} + \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}. \qquad (8)$$

With 5-vector potential it is possible to build the tensor of tensions $||F_{ik}||$ which components are calculated in the usual way as

$$F_{ik} = \frac{\partial A_i}{\partial x_k} - \frac{\partial A_k}{\partial x_i}; \quad i,k = 0,1,2,3,4. \qquad (9)$$

$$||F_{ik}|| = \begin{pmatrix} 0 & -E_x & -E_y & -E_z & -Q \\ E_x & 0 & -H_z & H_y & -G_x \\ E_y & H_z & 0 & -H_x & -G_y \\ E_z & -H_y & H_x & 0 & -G_z \\ Q & G_x & G_y & G_z & 0 \end{pmatrix} \qquad (10)$$

In new 5×5 tensor we have not only usual electromagnetic components $E_x = F_{10},\ E_y = F_{20},\ E_z = F_{30},\ H_x = F_{32},\ H_y = F_{13},\ H_z = F_{21}$ but also new components:

$$Q = F_{40} = \frac{\partial A_4}{\partial x_0} - \frac{\partial A_0}{\partial x_4} = \frac{\partial A_s}{c\partial t} - \frac{\partial \varphi}{\partial s}. \qquad (11)$$

$$G_x = F_{41} = \frac{\partial A_4}{\partial x_1} - \frac{\partial A_1}{\partial x_4} = \frac{\partial A_s}{\partial x} - \frac{\partial A_x}{\partial s}, \qquad (12)$$

$$G_y = F_{42} = \frac{\partial A_4}{\partial x_2} - \frac{\partial A_2}{\partial x_4} = \frac{\partial A_s}{\partial y} - \frac{\partial A_y}{\partial s},$$

$$G_z = F_{43} = \frac{\partial A_4}{\partial x_3} - \frac{\partial A_3}{\partial x_4} = \frac{\partial A_s}{\partial z} - \frac{\partial A_z}{\partial s}.$$

We relate the vector $\vec{G}$ to the gravitational field.

In the empty Minkowski (1+3) space $M(T;\vec{X})$ $(S = 0)$, electromagnetic fields are independent of the new fields $(\vec{G}, Q)$. But when we deal with material medium, that means that parameter S becomes nonzero, the fields form a unified field, and their components can interact each with other in the ESM model.

In addition, the 5×5 second rank energy-momentum-mass tensor $||T^{ik}||$ has been built in the ESM [8] in the same way as the 4×4 energy-momentum tensor is built in the usual $(1+3)$D field theory. The $||T^{ik}||$ components can be found from $||F_{ik}||$ components by the well known formula:

$$T^{ik} = \frac{1}{4\pi}\left(-F^{il}F^k_l + \frac{1}{4}g^{ik}F_{lm}F^{lm}\right), \ i,k,l,m = 0,1,2,3,4. \qquad (13)$$

If we rotate 5D vectors, which correspond to 5D-particles in ESM, in the plane $(T;\vec{X})$, this rotation leads to mixing of momentum with mass of a particle. On the other hand, rotation in the plane $(T;S)$ leads to a mixing of mass with energy, and in the plane $(\vec{X}, S)$ — to a mixing of a momentum with mass.

Going further, we can apply such rotations to 5D vector-potential $(\varphi, \vec{A}, A_s)$, tension tensor $||F_{ik}||$, and the fields $\vec{E}, \vec{H}, \vec{G}, Q$. The fields $\vec{E}, \vec{H}, \vec{G}, Q$ formally can be converted into each other under the same transformations in the planes $(T; \vec{X})$, $(T; S)$ and $(\vec{X}, S)$ [1,2]. The transformation formulas are described with introduction of parameters $(\vec{v}, v_s, \vec{u})$. These parameters determine transition from one reference system to another [1,2,9]:

1) rotation in the $(T; \vec{X})$-plane, that is characterized by a velocity $\vec{v}$, leads to:

$$\vec{E}' = \vec{E} + (1/c)[\vec{v}, \vec{H}],\ \vec{G}' = \vec{G} - (1/c)\vec{v}Q,\ \vec{H}' = \vec{H} - (1/c)[v, \vec{E}],\ Q' = Q - (1/c)(\vec{v}, \vec{G}); \quad (14)$$

2) rotations in the plane (TS) are characterized by the velocity v_s along a coordinate S, field transformations are:

$$\vec{E}' = \vec{E} + (v_s/c)\vec{G}, \quad \vec{G}' = \vec{G} + (v_s/c)\vec{E}, \quad \vec{H}' = \vec{H}, \quad Q' = Q; \quad (15)$$

3) rotations in the plane $(S, \vec{X})$ are characterized by a parameter $\vec{u}$, this vector parameter describes reduction of the refraction index n as a result of a motion in direction of $\vec{u}$. The fields are transformed in accordance with the following relations:

$$\vec{E}' = \vec{E} - \vec{u}Q, \quad \vec{G}' = \vec{G} + [\vec{u}, \vec{H}], \quad \vec{H}' = \vec{H} + [\vec{u}, \vec{G}], \quad Q' = Q + (\vec{u}, \vec{E}). \quad (16)$$

Thus, we see that electromagnetic and gravitational fields can be converted to each other by a corresponding transformation in the planes $(T; \vec{X}), (\vec{X}, S), (T; S)$.

In particular, when a moving massive charged particle is decelerated, falling into an external field or substance, it can lead to processes that cause generation of a gravitational field. Such transformation of fields could, in principle, also take place during various nuclear processes such as gamma- or neutron de-excitation, pair annihilation or formation and so on.

Experimental

To check this qualitative prediction, the following experimental setup has been proposed and recently realized. A relativistic 30 MeV electron beam of an average power 450 W from a microtron is stopped in condensed material (e.g. a tungsten plate). The accelerator setup gives a very useful for such type of experiment possibility to stop electron beam in two different targets (left or right). A massive torsion pendulum with two massive left and right weights 4 kg each and a rather long transverse rod (120 cm) is used to measure gravitational field originated. One of the pendulum shoulders is set very close to the left stopping target — a possible source of the gravitational field created during deceleration of electrons, and another shoulder is located elsewhere. As usual, reflection of laser beam (He-Ne laser wavelength 632.8 nm) from a mirror mounted on a shoulder is used to detect a possible pendulum deflection caused by electron deceleration. The light spot from the mirror is observed on a screen located at 5 m from the mirror and is registered by video-recording system with 15-fold optical gain for increasing the measurement accuracy. The experimental setup offers a possibility to shift the accelerated electron beam from one (left) stopping target to another (right) target, thus the change of a stopping target (i.e. the change of the spatial location of a possible source of gravitational field) could bring rotation of the pendulum into opposite directions. Detailed description of the experiment can be found in [2,4].

Calibration measurements

For realization of measurements it was necessary to optimize the parameters of the pendulum (masses of the weights, rigidity of the pendulum, the magnitude of a damping of oscillations). First, it is desirable that the amplitude of oscillations and the frequency of the pendulum are as large as possible. As to the ray reflected from the mirror, it should not fall outside the limit of observations, restricted by the diameter of the narrow observed channel in the radiation shielding around the accelerator. Besides, the characteristic operation time of the accelerator under a load usually was 10-15 minutes. A necessity to accumulate during this time sufficient statistical data poses restriction on the period of the oscillations and the time of taking a new position of equilibrium of a pendulum in the case of exterior action. All these requirements were, whenever possible, taken into account under the choice of final parameters of the unit.

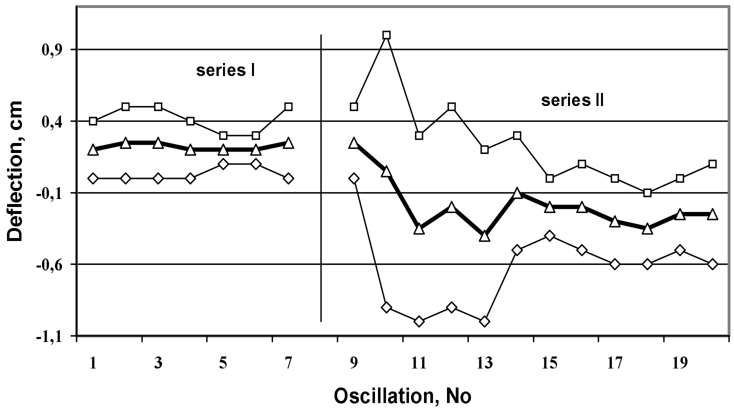

Figure 1: Calibration measurements.

The example of free oscillations of the pendulum in the case of availability of small mechanical vibrations from working vacuum pumps is shown in Fig.1 — series I (the experiment was carried out 31.05.2001). The graph shows the amplitude of oscillations on a screen of a laser ray (upper and lower series of values) that was reflected from the mirror attached to the pendulum, in dependence on the number of oscillations and a position of the equilibrium (which was calculated from these amplitudes). The accuracy of the determination of the position of the center of the light spot was 0,1 mm.

The measurements in this case were performed with one liquid damper and enlarged rigidity of the pendant (by restriction of the effectively working pendant length). In this series the period of free oscillations was 29 seconds. Undamped oscillations of the pendulum around of the average value of equilibrium of 2,2 mm were established. The average amplitude of these oscillations was about 0,2 mm. For the study of the response of a pendulum on a small constant exterior force, the ventilation of one of massive cargoes by very weak constant stream of air was carried out. In this case (Fig.1, series II) the noticeable variation of oscillations of the pendulum happened already through 3-4 periods. Full establishing of a new position of equilibrium happened after 7-8 oscillations.

Both liquid dampers were involved in the other series of calibration measurements (07.06.2001), when in addition the pendants rigidity was reduced. The period of free oscillations of the pendulum in this case was about 40 seconds.

Adding the second damper and the diminution of pendant rigidity leads to diminishing of oscillation frequency of the pendulum under the action of an exterior force. On the other hand, noticeable modification of the position of equilibrium of a pendulum happened already after 1-2 oscillations. Also periodical checking of independence of an initial average position of equilibrium of the pendulum during the time was made. For example, in a series of measurements 07.06.2001 not only the measurement of the position of the equilibrium prior to beginning of principal series of measurements was performed, but also 2 hours after the termination of principal series.

Experimental results and discussion

During the period from 17.05.2001 to 07.06.2001 7 series of measurements under various operational modes of the accelerator and different parameters of the pendulum were performed. Before switching on and after switching off of the electronic bundle, the control of the position of equilibrium of the pendulum was carried out, the same as in the case of calibration measurements. In this case the electric and mechanical noises remained constant during all phase of measurements. This was achieved with the help of preliminary switching on of all devices which were used during the measurements (water and vacuum pumps, magnetron, deflecting magnets etc.) and their cut-off only after a full termination of measurements.

Figure 2 presents results of a measurement of an average position of a pendulum in the case of stopping of electron beam at the left target with the left weight located close to this target. Series I and III correspond to control measurements immediately before switching on and some minutes after switching off of the electron beam. Series II-A and II-B reflect total oscillations of the pendulum during the moment of operation of the accelerator (about 10 minutes) and some time after switching off of the electron beam. A line of a trend (average over 3 data points) is additionally plotted.

Figure 3 presents results of a measurement of an average position of a pendulum in the case of stopping of electron beam at the right target with the right weight located close to this target. A line of a trend (averaged over 3 data points) is also added.

From a qualitative comparison of the lines of a trend on Fig.2 and Fig.3 it is possible to conclude, that there is correlation between the switch on of the electronic bundle and the mean deviation of the pendulum from a position of equilibrium in a comparison with a control series before and after switching. Also it was found that the direction of a deviation varies in dependence of near to which of the cargoes of the pendulum the stopping target was.

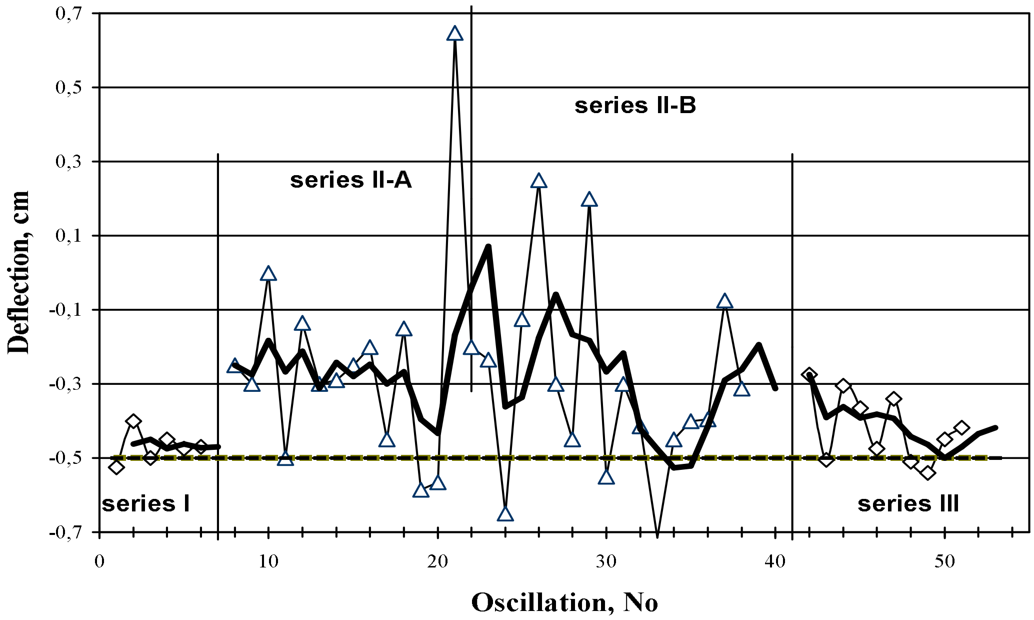

Figure 2: Stopping of electrons in the left target near the left weight.

Thus, the first preliminary experimental results show that there is a correlation between switching of the electronic bundle and mean deviation of the pendulum from the equilibrium position as compared with the control series before and after inclusion. It was also found that the direction of the deviation varies depending on which of the pendulum loads was near the stopping target. An additional evaluation was made by various methods of statistics to prove that deviations detected are statistically authentic. Thus, by the Pirson criterion, the probability of an authentic statistical distinction between the outcomes of control measurements of pendulum oscillations as compared with the phases of exposure of a stopping target by relativistic electrons exceeds 99%.

Evaluation of the magnitude of a force that can cause such a displacement of the equilibrium position of the pendulum was also made. In the performed experiments this deviation did not exceed 1-2 mm (value of a light spot deflection on the screen). The force that could cause a displacement of the equilibrium position of the pendulum was also evaluated. The calibration of the pendulum gives an upper limit of this force, and thus we can estimate that the deflecting force was between 10^{-8}N and 10^{-6}N.

We carefully checked experimentally various possible sources which could cause deviation of pendulum — mechanical vibrations due to operation of water and air pumps, magnetic and electric dc and ac fields, all these sources could not cause such magnitude of rotation of the pendulum.

Certainly, these first experimental results on checking the qualitative predictions from ESM, are of preliminary nature and require a much more substantial check, which will be a subject of future experiments.

References

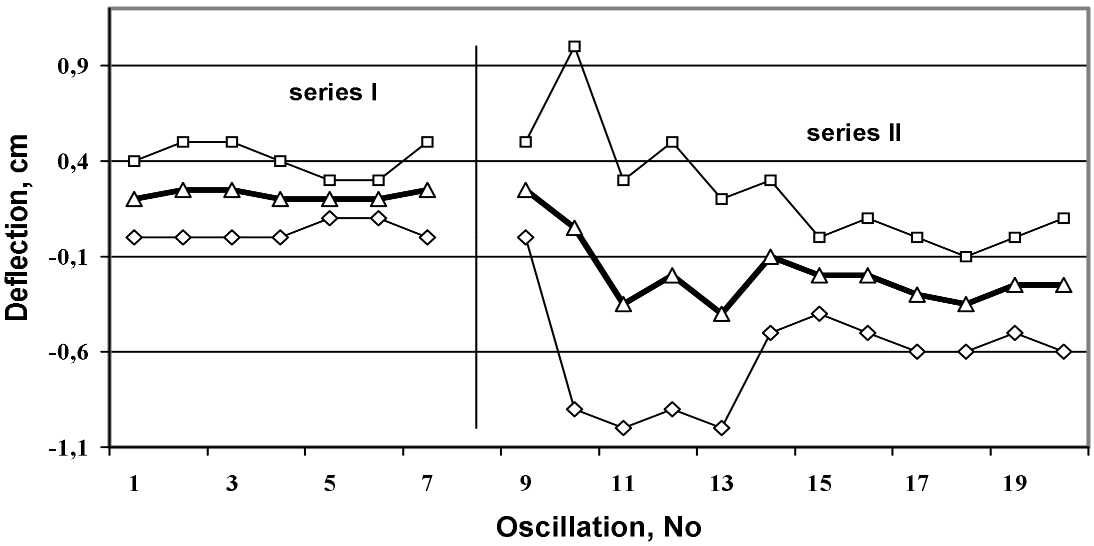

Figure 3: Stopping of electrons in the right target near the right weight.

[1] D.Yu.Tsipenyuk and V.A.Andreev, *Kratkie Soobstcheniya po Fizike* 6 (2000) 23 (*Lebedev Physics Institute Bulletin (Russian Academy of Sciences)*, No 6, pp. 18-29, Allerton Press, Inc., NY, 2001); http://www.arxiv.org/abs/gr-qc/0106093

[2] D.Yu.Tsipenyuk, *Kratkie Soobstcheniya po Fizike* 7 (2001) 39 (*Lebedev Physics Institute Bulletin (Russian Academy of Sciences)*, Allerton Press, Inc., NY); http://www.arxiv.org/abs/physics/0107007

[3] D.Yu.Tsipenyuk and V.A.Andreev, *Issledovano v Rossii* (Russian Electronic Journal), 60 (1999); http://zhurnal.mipt.rssi.ru/articles/1999/060.pdf

[4] D.Yu.Tsipenyuk, *Issledovano v Rossii* (Russian Electronic Journal), 81 (2001) 907; http://zhurnal.ape.relarn.ru/articles/2001/081.pdf

[5] D.Yu.Tsipenyuk and V.A.Andreev, "Gravitational effects in extended space", *preprint* IOFAN (General Physics Institute), No. 4, Moscow,2001.

[6] "Space,time,matter:Modern Kalutza-Klein theory", Ed. by P.S.Wesson. Singapore, World Scientific, 1999.

[7] L.B.Okun, Mod. Phys. Lett., A15 (2000) 1941; eXprint:hep-ph/0010120.

[8] D.Yu.Tsipenyuk and V.A.Andreev, "Electrodynamics in Extended Space", *preprint* IOFAN (General Physics Institute), No.9, Moscow, 2000.

[9] D.Yu.Tsipenyuk and V.A.Andreev, "Lienard-Wiechert potentials in Extended Space", *preprint* IOFAN (General Physics Institute), No.1, Moscow, 2001.