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# MODERN APPROACH TO RELATIVITY THEORY (RADAR FORMULATION)

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INTRODUCTION

The special theory of relativity in its form generally accepted at present was in fact formulated at the beginning of our century. From the origin its building was based on the radar procedure used, for example, for the synchronization of distant clocks and what is more this procedure served for Einstein as a direct derivation of Lorentz transformations [1].

As is known, at first the transformations were obtained from the invariant condition of Maxwell's equations when passing to a moving (inertial) reference system.

Relativity theory made revolutionary changes in the representations of space and time going back to Newton. It opened new ways of trying to understand natural phenomena and served as the basis for relativization of many fields of physics including electrodynamics, mechanics, thermodynamics and so on. However, the process of origin and formation of new presentations cannot be completely separated from the previous notions at once. Because of their habitualness these old terms "being unnoticed" are going on to serve the theory which rejects them in essence. First of all, this concerns the notion of rigid rod. Indeed, such fundamental essence as reference system is thought to be in the form of a frame of rigid rods and a set of synchronized clocks placed at different points [2]. We would remind that the representation of a rigid (undeformed) rod was adopted from daily life in which we deal with very small (with respect to light) velocities. In essence undeformation means that perturbation propagates, e.g., from one end of the rod to the other one practically instantly. Otherwise, one can say that the rigid rod realizes an instant (simultaneous) length. In the nonrelativistic case this condition is actually fulfilled, and such a representation is quite justified. However, for motion velocities close to the light one, the velocity of deformation propagation is a small value. Nevertheless, we continue to hold our previous positions subconsciously, i.e., to use the representation of rigid bodies. One known elementary derivation of the relation $E = mc^2$ [3] can be a typical example here, where it is implicitly supposed that a rigid cylinder begins to move instantly due to the radiation of a light flash. Hitherto this derivation is often adduced when relativity theory is stated (see, e.g.,[4]).

Another radar formulation [5,6] operated with light or retarded distances directly observed in experiment and leans on the radar method of distance measurement[7].

Thereby in the frames of this formulation we get rid of a series of fictitious notions and, in the first place, such as rigid scales (rods). This approach is related to the asynchronous formulation purely mathematically[8]. One can conclude already on the basis of the foregoing that the main difference of the two approaches must be connected with the behaviour of space sizes of material bodies. Indeed, if in the first case we have the contraction of longitudinal sizes of moving objects, in the second one their elongation takes place.

The main aim of this paper is to state basic peculiarities of the radar formulation, its difference from the traditional (Einstein's) approach.

## THE TRADITIONAL (EINSTEIN'S) APPROACH

Just this approach is expounded in all text-books and monographs on relativity theory. The aspect of our interest concerns mainly a space part of the space-time picture (i.e., such notions as length, distance and quantities formed on their basis).

We would remind that according to Einstein the length of a moving rod is called the distance between simultaneous positions of its ends[1]. It is obvious that its definition includes any small velocities of rod motion, i.e., in the limit and the rod at rest. Thus, one can say that in the frames of the traditional approach we deal with simultaneous or instant distances. (Compare with the instant form of Dirac's relativistic dynamics[9]).

Here we would like to touch on the paper of Gamba[10] in which the generally accepted procedure of calculation of the electromagnetic field energy and momentum of a charge in different reference frames (S and S*) related to integration over space volumes for $t$ = const and $t^*$ = const, respectively, is subjected to criticism. Since integration is thus performed over different hypersurfaces, results of calculations should concern different sets of physical events as noted by the author (whereas the Lorentz transformations deal with the same set of events). Just this integration leads us to formulae for energy and momentum different from the corresponding known formulae of relativity theory.

Fermi paid attention to this contradiction earlier [11]. Moreover, he noted that the usual approach (based on the condition t = const) obviously contradicts the principle of relativity as it depends on reference system.

## RADAR FORMULATION OF RELATIVITY THEORY

As is already noted, the radar procedure was in fact used in relativity theory from its origin for synchronization of distant clocks. Later on a new method of statement, which basis became observers having identical clocks and radars, has been suggested [12]. Rigid scales were thereby excluded from the theory. However, this approach was, as a matter of fact, of a more formal character as all previous conclusions corresponding to Einstein's approach remained valid due to the following transition to instant distances.

The essence of the "radar formulation" consists in that it deals just with distances directly observed in experiment (measured by the radar method). In electrodynamics, as is known, these distances are called retarded. Similar (light) distances were applied when determining the aberration angle of star light.

One can say that the transition to the radar formulation is connected with removal factually nonobserved (i.e., fictitious) instant distances. As a result, the space-time structure (basis of relativity theory) suffers a radical change. In particular, we have an increase of longitudinal sizes of relativistic objects (the elongation formula). We would remind that the elongation formula:

$$\ell_r = \ell^* \gamma, \tag{1}$$

where $\gamma$ is the Lorentz factor, is a direct consequence of the concept of relativistic length [7] based on the radar method of measuring distances, i.e., it deals just with retarded (light) distances [13].

In the framework of this conception the relativistic length is given as the half-sum of distances which a light signal passes along the rod from one of its ends to the other one and backward (in the direction of rod motion and against). In Minkowski's space the 4-vector of relativistic length $\ell_r^i$ is given as the half-difference of two light 4-vector $\ell_f^i$ and $\ell_b^i$ describing the corresponding processes of light propagation (in direct and opposite directions). Here the first quantity exactly corresponds to the 4-vector of retarded distance $\ell^i_{ret}$ , when the field propagates in the direction of source motion, and $\ell^i_b$ corresponds to $\ell^i_{adv}$ when the directions of field propagation and charge motion are opposite. In the rest system of the rod S* and in the S-system, where it moves along the x-axis with velocity v = $\beta$c, we have

$$\ell^{i*}_f(\ell^*/c, \ell^*, 0, 0), \quad \ell^{i*}_b(\ell^*/c, -\ell^*, 0, 0), \tag{2*}$$

$$\ell^i_f[\ell^*(1+\beta)\gamma/c, \ \ell^*(1+\beta)\gamma, 0, 0], \ \ell^i_b[\ell^*(1-\beta)\gamma/c, -\ell^*(1-\beta)\gamma, 0, 0] \tag{2}$$

whence for

$$\ell^i_r = \frac{1}{2}(\ell^i_f - \ell^i_b) \tag{3}$$

we obtain

$$\ell^{i*}_r(0, \ell^*, 0, 0), \tag{4*}$$

$$\ell^i_r(\beta\ell^*\gamma/c, \ell^*\gamma, 0, 0). \tag{4}$$

As is seen, the quantity $\ell^1_r(\equiv\ell_r)$ represents elongation formula (1). Owing to the new approach, not only the physical interpretation but also the qualitative explanation of a series of phenomena changes. Some known "paradoxes" are removed. Here, apparently in the first place, the "problem 4/3" should be pointed out (the definition of the electromagnetic field momentum and energy of a moving charge) (see, e.g., /14/ ). Another formula corresponding to (1) for the transformation of space volume instead of habitual Lorentz contraction has been proposed /15/ just to consider this problem. Then we mark the "paradox" of Lewis-Tolman's lever, the appearance of a charge in a moving (neutral) current-carrying conductor and so on. Its solution leads to removal of fictitious quantities such as Poincare pressure, von Laue flux and so on. Ott's formulation of relativistic thermodynamics /16/, which differed significantly from the Planck-Einstein original one, should be especially high-lighted. Its appearance was in no way related to the charge of the transformation of longitudinal sizes. However, as it was cleared up further /17/ Ott's formulae for the amount of heat and temperature are interspersed with the structure of radar formulation. We would like to note, too, that in the frame of radar formulation the character of the behaviour of the moving charge field changes substantially. In terms of retarded distances the equipotential surfaces of an electric field have the shape of rotating ellipsoids, stretched in the direction of motion.

Perhaps, it should be mentioned that the traditional treatment of the Michelson-Morley famous experiment, having played a great role for the formation of relativity theory, is also essentially based on the notion of instant length. The application of radar (i.e., relativistic) length leads to the elongation formula for the longitudinal arm of an interferometer /19/.

The behaviour of a series of typical quantities, illustrating the difference of the two approaches, is presented in our table.

Table

| Generally accepted approach | Radar formulation |
|---|---|
| **Transformation of longitudinal sizes** | |
| $\ell = \ell^* \gamma^{-1}$ | $\ell = \ell^* \gamma$ |
| **Torque of a system in equilibrium** | |
| $N_z^* = 0 (F_x^*, F_y^* \neq 0), N_z \neq 0$ | $N_z = N_z^* = 0$ |
| **Momentum and energy of electromagnetic field** | |
| $G^1 = \frac{4\beta}{3c} E^* \gamma, E = (1 + \frac{1}{3}\beta^2) E^* \gamma$ | $G^1 = \frac{\beta}{c} E^*, E = E^* \gamma$ |
| **Equation of equipotentials** | |
| $R = \frac{e}{\phi}(1 - \beta^2 \sin^2\theta)^{-1/2}$ | $R = \frac{e}{\phi}(1 - \beta\cos\theta)^{-1}$ |
| **Electric charge of current-carrying conductor** | |
| $q \neq q^*$ | $q = q^*$ |
| **Transformation of heat and temperature** | |
| $Q = Q^* \gamma^{-1}, T = T^* \gamma^{-1}$ | $Q = Q^* \gamma, T = T^* \gamma$ |

Table (continued)

| | |
|---|---|
| Addition theorem for 4-velocities [20] | |
| – | $U^o = u^i u_i$, $U^a = u^a + u^a \frac{u^o + U^o}{u^o + 1}$ |

But, apparently, high energy physics should be considered as the most direct field of application of the radar formulation and, in particular, the conception of relativistic length [21]. The known growth of the scales of longitudinal distances at high energies is conditioned by increasing formation length what is in fact described by formula (1). It is notable that the radiation angle is given just by the light distance in Cherenkov counters widely applied in high energy physics [6]. It should be also remarked that the introduction of fundamental length, which, as one supposes, must play an important role in elementary particle physics, contradicts the generally accepted representation of contraction of longitudinal sizes whereas in the framework of the radar formulation this difficulty does not arise.

## CONCLUSION

The contours different from the traditional (Einstein's) formulation of relativity theory called asynchronous appeared in the sixties. Its main peculiarity consisted in the use of another transformation formula for longitudinal sizes of relativistic objects. Instead of habitual contraction, the longitudinal sizes must increase with increasing velocity. However, the formulation was not recognized since it had no physical grounds. Only the introduction of the concept of relativistic length based on the radar method of distance measurement gave such foundation. The new radar formulation (including asynchronous one) operates with light or retarded, i.e. nonsimultaneous (asynchronous), distances whereas in the generally accepted approach we in fact deal with instant (simultaneous) distances.

## EPILOGUE

More than eight decades were required to come to the radar formulation of relativity theory although its construction and development proper took place during the last three decades. If the origin of relativity theory were connected with the treatment of the Michelson-Morley experiment, this period would exceed the whole century. Just on the basis of this treatment Lorentz contraction was introduced which is hitherto considered to be one of the main results of relativity theory.

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Стрельцов В.Н. Д2-91-436

Современный подход к теории относительности (Локационная формулировка)

Излагаются основные особенности локационной формулировки теории относительности. Эта формулировка оперирует с запаздывающими (световыми) расстояниями и введенной на их основе релятивистской или локационной длиной. Дается ее сравнение с традиционным (эйнштейновским) подходом. Как известно, в его рамках мы фактически имеем дело с мгновенными или одновременными расстояниями.

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Modern Approach to the Relativity Theory (Radar Formulation)

The main peculiarities of the radar formulation of the relativity theory are presented. This formulation operates with the retarded (light) distances and relativistic or radar length introduced on their basis. Its comparison with the traditional (Einstein's) approach is given. As it is known, we deal in fact with instant or simultaneous distances in this approach.

The investigation has been performed at the Laboratory of High Energies, JINR.

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