THE USING OF SPECIAL RELATIVITY IN NAVIGATION AND ATC

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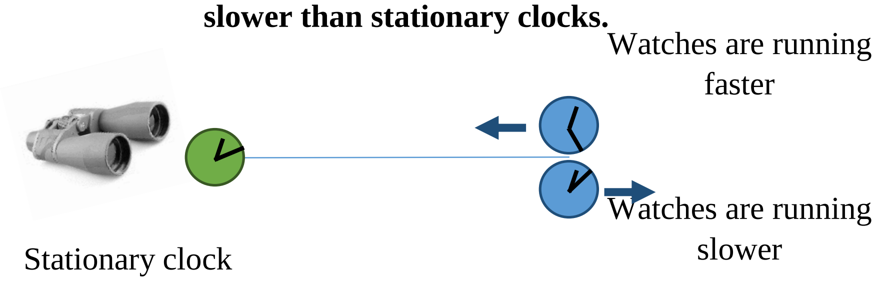
Abstract. *JSC All-Russian Research Institute of Radio Equipment (VNIIRA) conducted a practical experiment to measure the rate of the observed rate of moving clocks located on aircraft performing flights. It was experimentally confirmed that, according to observations, the clock moving towards the observer goes faster than its stationary clock, and the clock moving away from the observer, according to observations, goes slower than the stationary ones. It turned out that SRT contradicts this experimental fact: in accordance with SRT, moving clocks in all cases (regardless of the direction of movement) are observed to go slower than stationary ones. The relevance of the experiment is due to the fact that at present SRT formulas are widely used in works on satellite navigation systems. Meanwhile, it is well known that the use of erroneous formulas in the development of navigation and surveillance systems in the aviation and space industries can lead, at best, to a deterioration in the performance characteristics of these systems. In the worst case, this may affect the decrease in the level of safety of aviation and space flights, lead to accidents and catastrophes in aviation and astronautics, to significant economic losses and human casualties. The work consists of two parts. The first part presents the theoretical foundations of the experiment. The continuation (in the second part) presents the results of the experiment. The experiment was carried out using the Avrora-2 monopulse secondary surveillance radar manufactured by JSC VNIIRA, which provides high-precision measurement of the time intervals between the moments of transmitting a request and receiving response signals from aircraft transponders. The paper presents reliable formulas that should be used instead of the corresponding SRT formulas, which contradict the experimental data.*

Keywords: *law of aberration, inertial frame of reference, observer, special relativity, SRT, experiment, experimental refutation of SRT, criticism of SRT, mathematical statistics.*

Graphic annotation

It has been experimentally proved that, according to observations, clocks moving towards the observer go faster than stationary clocks; clocks moving away from the observer, according to observations, go slower than stationary clocks.



The results of the experiment contradict SR.

1. Introduction

The special relativity theory (SRT) appeared in 1905 [Einstein (b), 1965; With. 7-35; Einstein (v), 1965, p. 49-50; Einstein (g), 1965, p. 138-164; Einstein (d), 1965, p. 530-600; Feynman, 2019, pp. 264-295; Ugarov, 1977]. Many provisions of this theory, and, in particular, the position on slowing down the passage of time of a moving clock observed by a stationary observer (regardless of the direction of movement), despite the numerous criticisms of SRT by various authors that still exist, see, for example, [Artekha, 2004; Denisov, 2006; Plyasovskikh (a), 2021; Plyasovskikh (b), 2021; Plyasovskikh (c), 2021; Plyasovskikh (d), 2021; Smulsky, 1999; Einstein (a), 616-625], have not been subjected to experimental verification, although modern high-precision technical means of measuring time, as well as technologies available to modern researchers, allow them to be experimentally verified.

Despite the fact that the results of SRT have not been confirmed experimentally, it is widely used in theory, and primarily in the theory of satellite radio navigation systems GLONASS, GPS, GALILEO [Tyapkin, 2012; Understanding GPS, 1996; Global Positioning System, 1996].

The relevance and high significance of the experiment lies in the fact that SRT is widely used in works related to aviation and space navigation [Ashby, 2014; Fidalgo, 2021; Mudrak, 2015; Kouba, 2019] and, of course, the use of erroneous formulas in calculations can lead to errors in the development of aviation and space technology, and as a result, to a deterioration in the technical characteristics of navigation and surveillance systems. In the worst case, the use of erroneous formulas in space and aviation navigation and surveillance systems can lead to malfunctions and violation of the integrity of these systems, and ultimately to a decrease in flight safety, an increase in the risk of accidents and disasters in aviation and space technology. That is why the experimental verification of SRT formulas used in the theory of technical sciences and the determination of which of the formulas are reliable and which are not is of great scientific and applied importance.

This paper presents the results of an experimental study, the purpose of which is to confirm the reliability of the position of SRT on the slowing down of the passage of time by a moving clock observed by a stationary observer (regardless of the direction of movement). In accordance with the position being checked, the clock moving towards the observer, according to the observations, must go slower than the stationary ones.

Consider the following question. Let a clock move towards the observer (which is located, for example, on an aircraft), and the observer follows their readings using either optical means of observation (binoculars, for example), or the clock readings are broadcast to him using a frame-by-frame video camera and a data transmission channel over which frames are transmitted. In other words, the observer can see the video image of the watch on the monitor screen, which is transmitted to him online from the video camera that removes the watch and moves along with the watch.

The question arises: do the observed indications of a clock moving towards the observer count the passage of time at the same speed (tempo) as the observer's stationary clock? Or do moving clocks, according to observations, go faster than stationary ones? Or maybe they go slower than the stationary ones?

How much time passes on a moving clock when exactly one second passes on a stationary clock?

The main intrigue is as follows. If an online video report is conducted from a spacecraft moving at near-light speed, will the movements and speech of astronauts be observed accelerated or slowed down? Or the same as on Earth?

In fact, this work is devoted to answering these interrelated questions. The authors experimentally proved that the hands of a clock moving towards the observer during their observation move faster than the hands of the observer's stationary clock. While one second passes according to the stationary clock, according to the observed readings of the clock moving towards the observer,

$\frac{1}{1-\frac{v}{c}}$ second (more than second),

where $v -$ is the speed of the clock movement towards the observer;

$c -$ is the speed of light.

When the clock moves away from the observer, while one second passes through the stationary clock, according to the observed readings of the moving clock,

$\frac{1}{1+\frac{v}{c}}$ second (less than second),

Thus, the experimentally proven fact (this paper describes the description and results of the experiment carried out by the authors using the Aurora-2 radar manufactured by JSC VNIIRA) is that the observed indications of clocks moving towards the observer go at a faster rate, that is, faster the progress of the stationary clock. This experimental fact is contradicted by SRT, which states: a moving clock (when observed by a stationary observer), regardless of the direction of movement, runs slower than stationary ones.

When observing the movements and speech of astronauts on a spacecraft moving towards the Earth at near-light speed using a frame-by-frame video camera, in accordance with the results of the experiment, we will see on the screen that the astronauts move and speak at an accelerated rate, as in a fast-paced video film. SRT, on the other hand, asserts quite the opposite: the movements and speech of the astronauts in this case will be observed slowed down, as in a slow-motion video film. Practice, experiment are the criterion of truth. Therefore, the main arbiter, whose name is Experiment, issues an unequivocal verdict: SRT is an erroneous theory, since the theoretical provisions of SRT contradict the experimentally established facts.

The experiment showed the erroneousness of the SRT formula, which describes the effect of slowing down the observed rate of clocks during their movement.

$$\Delta t_{\text{observ}} = \Delta t_{\text{resp}}\sqrt{1-\left(\frac{v}{c}\right)^2},$$

where Δt_{observ} и Δt_{resp} – respectively, the time intervals counted according to the observed readings of the moving clock and according to the observer's stationary clock.

The theoretical and experimental studies carried out have shown that when the clock moves relative to the observer, the time intervals Δt_{observ} and Δt_{resp}_ist are related by the relation $\Delta t_{\text{observ}} = \frac{\Delta t_{\text{resp}}}{1\pm\frac{v}{c}}$,

where the plus sign in the denominator is when the clock moves away from the observer, the minus sign is when it approaches the observer.

The essence of the experiment (briefly)

In SRT, it was concluded that if we observe a moving clock and compare its progress with that of a stationary clock, then it turns out that according to observations, the moving clock runs slower than the stationary ones. Einstein in [Einstein (e), 1965, p. 549] concluded that when observing a clock moving at a speed v in one second, according to the readings of these clocks on a stationary clock, “not a second passes, but $1/\sqrt{1-(v/c)^2}$ seconds, that is, somewhat more time. The clock, due to its movement, runs slower than at rest.

In order to confirm this conclusion of SRT, an experiment was carried out in which, using radar, clock measurements were made on twenty aircraft flying to and from the radar. Further, using the classical methods of mathematical statistics, calculations were performed in order to confirm or refute a number of hypotheses, among which was the hypothesis that, according to observations, moving clocks run slower than stationary ones.

With a high level of significance, the hypothesis of the observed course of a moving clock in accordance with SRT was discarded. In accordance with experimental data, it turned out that when observing a clock moving at a speed v, in one second, according to the readings of these clocks on a stationary clock, not a second passes, but $\left(1+\frac{v}{c}\right)$seconds (more than one second) - when the clock moves away from the observer, and $\left(1-\frac{v}{c}\right)$ seconds (less than one second) - when the clock approaches the observer.

In other words, if we take a stationary clock as a standard, in one second for this stationary clock, in accordance with SRT for moving clocks (regardless of the direction of movement), $\sqrt{1-(v/c)^2}$, that is, less than a second. In accordance with the experimental data, it turned out that in one second, according to a stationary clock, the readings of a moving clock will change by:

$\frac{1}{1+\frac{v}{c}}$ (less than second) – when the clock moves away from the observer;

$\frac{1}{1-\frac{v}{c}}$ (more than second) – when the clock moves towards the observer.

The observed readings of a moving clock go faster than the observed readings of a stationary clock if the clock is approaching the observer, and vice versa, the observed readings of a moving clock go slower than the observed readings of a stationary clock if the clock is moving away from him. In other words, the observed time course of the clock moving towards the observer is faster than the observed time course of the observer's stationary clock, and vice versa, the observed time course of the clock moving away from the observer is slower than the observed time course of the stationary clock.

The experiment showed that the above conclusion of SRT about the course of a moving clock is erroneous. A. Einstein was wrong.

Terms used in the work

The following terms will be used in this work.

Time. Clock readings.

The course of time (synonymous with the course of the clock). The progress of the clock.

The observed course of time of the clock (synonyms - the observed course of time, the observed course of the clock). Observed clock readings.

In all cases, when we talk about time, we mean that there is some device for measuring time, that is, a clock that shows the current time. A stationary observer, located in close proximity to the clock, always observes the true course of time of this clock. If the clock moves relative to the observer, the observer, when observing this clock, deals with the observed passage of time of the moving clock, with the observed readings of the moving clock.

Practical significance

The practical significance (value) of the results obtained in this work lies in the fact that they will help scientists in the field of technical sciences to avoid two common mistakes, one of which is the use of incorrect, erroneous SRT formulas. These formulas, being erroneous, can lead scientists engaged in theoretical and applied research to make mistakes in their theoretical work, in research and development. The second mistake is that under the influence of the delusion formed by SRT about the smallness of the "relativistic effects" described by this theory, they are ignored and not taken into account, which leads to a decrease in the accuracy of calculations and to incorrect results. In fact, the phenomena described by SRT manifest themselves and can be taken into account at terrestrial speeds, that is, not only in the space industry, but also in the aviation industry.

The results obtained in this work, in addition, may help to avoid accidents and disasters associated with errors in the operation of navigation and observation systems used in aviation and astronautics. In particular, the formulas whose validity is confirmed in this work can be used to reduce the risk of accidents and disasters associated with the deliberate distortion of ADS-B automatic dependent surveillance messages by intruders and terrorists. In other words, the results obtained in this work can be used in the development of methods and techniques for increasing the protection against terrorist impacts on navigation systems (GLONASS, GPS, GALILEO) and surveillance systems (for example, ADS-V) [Plyasovskikh (d), 2022].

2.1. Special relativity about the course of time of a moving clock

In accordance with SRT, when observing a moving clock by a stationary observer, the following theoretical results take place.

Let an observer located at the origin of coordinates of the inertial reference system (ISF) observe the passage of time of a moving clock, and compare the readings of these clocks he observes with the readings of his stationary clock located next to him.

Regardless of which direction the clock moves from the observer, that is, regardless of whether the clock approaches the observer or moves away from him, in accordance with SRT «Uniformly moving clocks from the point of view of a resting frame of reference go slower than from the point of view of an observer moving with them. If we denote by ν the number of clock ticks per unit time for an observer at rest, and by v_0 the corresponding number for an observer moving with them, then we have

$$\frac{\nu}{\nu_0} = \sqrt{1-(v/c)^2}»$$

[Einstain, 1965 p.49].

In the above formula, v and care, respectively, the speed of the clock and the speed of light.

The same SRT result is also formulated as follows: "If we observe a clock from a system in relation to which it moves uniformly with a speed v, then it turns out that they go to 1 :

$$\sqrt{1-(v/c)^2}$$

times slower than the same clock that is stationary with respect to this system" [Einstein (g), 1965, p. 156].

In a slightly different formulation, this result looks like this: "The clock reading (observed from the system at rest) lags per second by

$$\left(1-\sqrt{1-(v/c)^2}\right) \text{ sec}$$

[Einstain (b), 1965, p. 19].

Nobel laureate Richard Feynman expressed this result as follows: "If you watch from the side how an astronaut (of a moving interplanetary ship - ed.) lights a cigarette, it seems to you that he does it more slowly than usual, although he himself believes that everything going on at a normal pace. So ... instruments for measuring time ("clocks") must slow down. In other words, when the clock on the spacecraft counts down, according to the cosmonaut, 1 second, then, according to the opinion of an outside observer,

$$1/\sqrt{1-(v/c)^2} \text{ sec}$$

[Feiman, 2019, p 448].

Thus, in accordance with SRT, the observer, observing the readings of a clock moving towards him (let us pay attention to this particular case) or away from him, and comparing the readings of these moving clocks with the readings of his stationary clock, will fix that:

1. Clocks moving towards (or away from) the observer are observed to run slower than his stationary clocks.

While one second passes on the observer's stationary clock, the readings of the moving clock observed by him will change by $\sqrt{1-(v/c)^2}$ second (less than second).

1. While one second passes according to the indications of the moving clock, $1/\sqrt{1-(v/c)^2}$ second, (less than second).

If denote: Δt_{resp} – time interval counted by the clock of a stationary observer; Δt_{observ} – the corresponding time interval counted according to the readings of the observed moving clocks, then the ratio between these quantities, according to SRT, is expressed by the following formula

$$\Delta t_{\text{observ}} = \Delta t_{\text{resp}}\sqrt{1-\left(\frac{v}{c}\right)^2}.$$

1. Let's assume that a spacecraft is moving towards the Earth at near-light speed, the astronauts of which are making online video reporting using a frame-by-frame video camera and a radio data transmission channel, through which the captured frames are transmitted to Earth. On Earth, the receiver receives the transmitted frames and displays them on the screen immediately after reception. Watching the astronauts on the video screen, according to SRT, we will see that

the movements and speech of the astronauts are slowed down, as in a video film that is played back in slow motion.

2. It is obvious, therefore, that the hands of the clock on the screen of the video broadcast from the spacecraft must move more slowly than the hands of the earth's clock.

So it should be in accordance with SRT. This theoretical result of SRT has never been experimentally verified by directly measuring the readings of moving clocks during their movement.

One of the goals of the experimental study conducted by the authors was an experimental verification of the reliability of this theoretical result of SRT, the essence of which is expressed by the phrase "a moving clock (regardless of the direction of movement) according to observations (by a stationary observer) is slower than a stationary watch of the observer."

Modern technical means of high-precision time measurement and modern technologies make it possible to conduct a practical scientific experiment to verify the reliability of the stated SRT result regarding the observed time course of a moving clock.

2.2. Theoretical foundations of the experiment

Derivation of formulas for time intervals counted by moving clocks

The ratios presented below for time intervals counted by moving clocks were obtained in [Plyasovskikh (a), 2021; Plyasovskikh, 2021; Plyasovskikh (d), 2022; Plyasovskikh (e), 2022; Plyasovskikh (w), 2022]

Let us assume that the observed object is an aircraft moving towards the observer, which is observed in four ways at once.

Method 1 - transmission from an aircraft of an electromagnetic wave with a frequency of 100 Hz. The beginning of each hundredth wave corresponds to the beginning of the next second according to the aircraft clock. We will assume that every hundredth wave (one out of a hundred), which begins together with the beginning of each new second, has an increased amplitude in order to fix the moments of the transmitter clock seconds in the receiver.

Method 2 - watching the light bulb flashing on the plane. The light bulb flashes with a frequency of once per second, flashes occur at the moments of the beginning of seconds according to the aircraft clock.

Method 3 - transmission from the aircraft of messages of broadcasting automatic dependent surveillance (AZN-B, ADS-B). Each ADS-B message contains data on the position (latitude and longitude) of the aircraft, its absolute height, speed, identification index and other information received from on-board systems. Let all messages be transmitted from the aircraft at the moments of the beginning of seconds according to the aircraft clock (once per second) and contain information about the time the message was broadcast. We assume that from the message received by the observer, the time of transmission of information to the air is extracted, which is immediately displayed on the ADS-B electronic time display/ method - video surveillance of the cockpit and the clock located in the cockpit. The broadcast of the video image of the watch and the cockpit is carried out online using a time-lapse video camera and a radio data transmission channel. The transmitted frames are received by the receiver and immediately displayed on the video screen. The video image shows the clock of the aircraft, the readings of which are monitored by the observer. Let the video image be broadcast at a frequency of ν_ist = 100 frames per second. In other words, exactly 100 frames are transmitted every second, replacing each other every 1/100 of a second (according to the aircraft clock). Let the frames of the broadcast video image be transmitted simultaneously and synchronously with individual electromagnetic waves: one frame is transmitted simultaneously with one wave.

Thus, the observer will follow the course of time with the help of received electromagnetic waves (observing waves of increased amplitude corresponding to the beginning of the next second on the aircraft clock); watching the flashes of light, which, in fact, reflect the movement of the second hand on the clock of the aircraft; using an electronic time display ADS-B; as well as using the aircraft clock, the video image of which is broadcast frame-by-frame online and displayed on the screen (Fig. 1).

Observation of the passage of time moving towards the observer clock

Obviously, a stationary observer using a receiver will detect an increase in the frequency of electromagnetic waves in accordance with the Doppler effect. In this case, the frequency perceived by the receiver ν_{observ} equals:

$$\nu_{\text{observ}} = \frac{\nu_{\text{resp}}}{1-\frac{v}{c}},$$

where ν_{resp} – true (natural) frequency of the radiation source;

v – the speed of the transmitter to the receiver.Observation of the passage of time moving towards the observer clock

Obviously, a stationary observer using a receiver will detect an increase in the frequency of electromagnetic waves in accordance with the Doppler effect. In this case, the frequency ν_{observ} perceived by the receiver will be equal to:

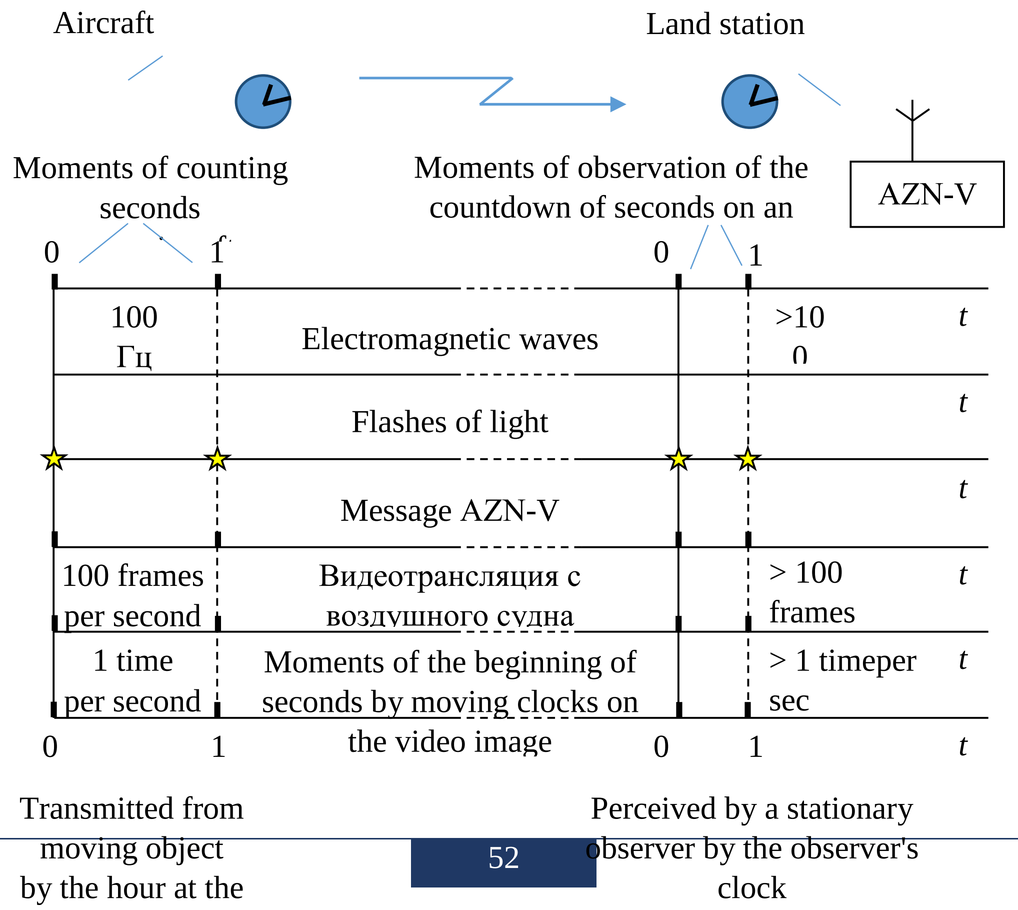
ν_obs=ν_source/(1-v/c),

where ν_source is the true (natural) frequency of the radiation source;

v is the speed of the transmitter to the receiver.

Figure 1

Observation of an approaching aircraft



Note that the transmitted waves were emitted into the ether with reference to time: the beginning of each hundredth of the transmitted wave with increased amplitude coincided with the beginning of each new second. In accordance with this, the observer will see not only an increase in the frequency of the received waves, but also an increase in the observed frequency of light flashes, synchronous with each hundredth wave received. In other words, flashes of light will be seen simultaneously with the beginning of the next hundredth received wave of increased amplitude. Flashes of light are observed to flash more than once per second.

Since flashes of light occur at the moments of the beginning of the next second, for the observer, flashes of light are visual messages about the change of seconds of the clock on a distant object.

Obviously, the observed flash frequency will be equal to:

$$f_{\text{observ}} = \frac{f_{\text{resp}}}{1-\frac{v}{c}} = \frac{1}{1-\frac{v}{c}}, \qquad (1)$$

где f_{resp} – the true (natural) frequency of flashes on an aircraft, equal to one flash per second (1 Hz).

It is also obvious that, synchronously with the received waves of increased amplitude and the observed flashes of light, the observer will receive ADS-B messages, according to which the readings of seconds on the electronic time display ADS-B will change simultaneously with the beginning of each hundredth of the received wave of increased amplitude and simultaneously with observations flashes of light.

In other words, the indication of seconds on the ADS-B time display will change in strict accordance with formula (1), which means that when the aircraft moves towards the observer, the second hand on the ADS-B time display will move faster than the second hand of the stationary clock located next to the observer. In Δt_ist seconds, according to the observer's fixed clock on the ADS-B electronic time display,

$$\Delta t_{\text{observ}} = \frac{\Delta t_{resp}}{1-\frac{v}{c}} \text{ second (more than second).}$$

The passage of time on the ADS-B board will accelerate in $\mu = \frac{1}{1-\frac{v}{c}}$ times compared to the time course of the observer's stationary clock.

Since video frames were transmitted at a frequency of 100 frames per second, or one frame per wave, the device receiving the broadcast video will receive one frame while the receiver will receive one wave. But since the frequency of the received waves will increase compared to the transmission frequency, then the frequency of receiving video frames will also increase proportionally. In a second, the receiving device will receive$100\mu = 100\frac{1}{1-\frac{v}{c}}$ frames, that is, more than 100 frames per second. And this means that on the video image of the watch transmitted from the aircraft, the observer will see that the second hand of this watch moves synchronously with the observed flashes of light, and with the second hand on the ADS-B electronic time display.

Let's assume that we are watching astronauts on a spacecraft using video broadcasting, which is rapidly approaching the Earth at a speed comparable to the speed of light. 100 frames that were recorded and transmitted over the air in one second will be received and played back in less than a second. Therefore, watching the video broadcast of the astronauts on the video screen, we will see that the movements and speech of the astronauts are accelerated in $\mu = \frac{1}{1-\frac{v}{c}}$ раз.

Thus, the acceleration of the observed course of time of the clock moving towards the observer is an inevitable consequence of the Doppler effect, according to which the frequency of oscillations perceived by the receiver increases - which means that the perceived (observed) course of time of the clock approaching the observer, by which the frequency is measured, increases with the same proportionality factor.

Derivation of a formula for measuring the observed course of time of a clock moving towards the observer

Consider the movement of an aircraft with a clock towards the observer. We will assume that the aircraft clock and the observer clock are synchronized, that is, the aircraft clock readings, observed, for example, using the ADS-B technology, in the immediate vicinity of the observer's clock, lag behind the observer's clock readings by $\Delta t = \frac{r}{c}$,
Where r – the distance between these clocks at the moment of synchronization.

Let the aircraft clock readings be transmitted to the observer once a second at the beginning of the next second using ADS-B messages, and the observer sees the readings of these clocks on the ADS-B electronic display.

Consider two ADS-B messages that are transmitted from an aircraft at times t_1.and t_2, the time interval between these messages is equal to $\Delta t = t_2 - t_1$. At the time of transmission of the first message, the distance to the aircraft was r_1, therefore, according to the observer's clock, the first message was observed by him at the time $t_1^{'} = t_1 + \frac{r_1}{c}$. During the time interval between messages Δt, an aircraft with a speed v will cover the distance $\Delta r = v\Delta t$, and at the time of transmission of the second message, it will be at a distance $r_2 = r_1 - \Delta r = r_1 - v\Delta t$. Therefore, the second message will be observed by the observer at time $t_2^{'} = t_2 + \frac{r_2}{c} = t_2 + \frac{r_1 - v\Delta t}{c}$.

Find the time interval between message observations
$\Delta t^{'} = t_2^{'} - t_1^{'} = t_2 + \frac{r_1 - v\Delta t}{c} - t_1 - \frac{r_1}{c} = t_2 - t_1 - \frac{v\Delta t}{c} = \Delta t\left(1 - \frac{v}{c}\right)$.

Let's rewrite this ratio as:

$$\Delta t_{\text{resp}} = \Delta t_{\text{observ}}\left(1 - \frac{v}{c}\right)$$

Or:

$$\Delta t_{\text{observ}} = \frac{\Delta t_{\text{resp}}}{1-\frac{v}{c}}.$$

In this case $\Delta t_{\text{resp}} = t_2^{'} - t_1^{'}$ – time interval elapsed between the moments of observation of ADS-B messages according to the observer's clock; Δt_{observ}– the time interval between messages, which was observed on the ADS-B electronic scoreboard. In other words, while the time interval passes by the observer's clock Δt_{resp}, on the electronic scoreboard ADS-B passes the time interval Δt_obs. The clock on the ADS-B electronic scoreboard is running faster than the observer's clock. In 1 second, according to the observer's clock on the ADS-B electronic scoreboard, $\frac{1}{1-\frac{v}{c}}$ second (more than aecond).

Similar calculations made for the case of the movement of the observed clock from the observer lead to the derivation of the formula

$$\Delta t_{\text{observ}} = \frac{\Delta t_{\text{resp}}}{1+\frac{v}{c}}.$$

In one second, according to the observer's stationary clock, the observed readings of the clock moving away from the observer will change by

$\frac{1}{1+\frac{v}{c}}$ second less than second).

В общем случае соотношение между наблюдаемым Δt_{observ} and true Δt_{resp} time intervals has the form

$$\Delta t_{\text{observ}} = \frac{\Delta t_{\text{resp}}}{1\pm\frac{v}{c}}, \tag{2}$$

where the plus sign in the denominator is when the clock moves away from the observer, the minus sign is when it approaches the observer.

Explanation of the effect of acceleration of the observed course of time of a clock moving towards the observer

The effect of acceleration of the observed course of time of a clock moving towards the observer is explained quite simply as follows.

Consider, for example, ADS-B messages, which contain information about the broadcast time. Based on this information, the ADS-B ground station monitors the progress of the clock on the observed object moving towards the observer.

We will assume that messages are transmitted on the air at the beginning of each next second by a moving clock.

Since the observed object with the clock is moving towards the ground station (observer), each subsequent message is transmitted on the air at the moment when the object is closer to the ground station (than at the time of the previous message). This means that each subsequent message takes less time to "get" to the ground station. And this, in turn, means that messages will arrive at the ground station more often than if the object were stationary. The frequency of arrival of messages about the moments of the onset of the next second according to the clock of the object will be more than once per second. In other words, the reported seconds will change more frequently than the seconds of the ground station's stationary clock. An observer on the ground will observe that the time on the clock of an object moving towards him will run faster than the time on his own clock.

It is also obvious that when the object with the clock moves away from the ground station, due to the fact that at the moment of transmission of each next message the observed object will be farther than at the moment of transmission of the previous message, messages will arrive at the ground station less often than once per second. In other words, when the observed clock moves away, the observer will notice that the course of the observed time has slowed down, the hands of the moving clock will move more slowly than the hands of his stationary clock.

We also note that a reasonable explanation of the effect of slowing down a moving clock in SRT from the point of view of the laws of physics for more than a century of history of this theory has not been found. Why time slows down on moving objects, none of the physicists can clearly and consistently explain. And the existing explanations, upon their careful consideration, turn out to be untenable and contradictory [Plyasovskikh (v), 2021; Plyasovskikh (d), 2021].

A simple illustration of the effect of acceleration of the observed passage of time of a clock moving towards the observer

We have seen that when an aircraft with a clock on it approaches an observer, there is an effect of accelerating the observed course of time of this clock. Why and how does this happen? Let's explain this "on the fingers."

Imagine that in outer space at a distance of 4 light hours (that is, at a distance that a ray of light travels in 4 hours) there is a spacecraft, the clock of which runs synchronously with the earth's clock. The spacecraft clock readings are transmitted to Earth via online video communication, in real time.

At 12 noon Earth time, the video image of the ship's clock, broadcast and observed on Earth, will show 8 hours. Obviously, the difference between the readings of the earth clock and the readings of the ship's clock broadcast on Earth will be 4 hours - this time is required to bring the video signal with the image of the ship's clock to Earth (Fig. 2).

Suppose now that the spacecraft began to move towards the Earth, and after a month (year) approached the Earth at a distance of 3 light hours. At the same time, at 12 o'clock in the afternoon according to the earth clock, the video image of the ship's clock will show 9 o'clock readings. The difference between the readings of the earth and the ship's clocks (the readings of the ship's clocks broadcast on Earth) will be 3 hours.

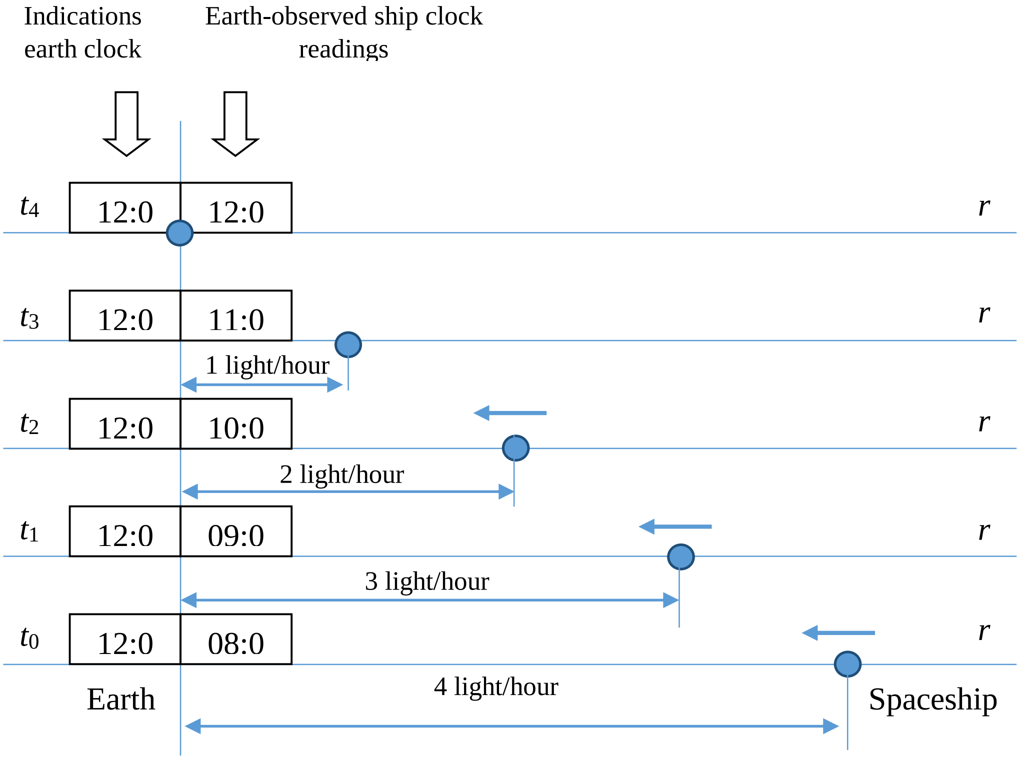


Figure 2 - As the spacecraft moves towards the Earth, the readings of the ship's clocks observed on Earth lag behind the readings of the earth's clock less and less. This means that the observed rate of the clock approaching the Earth is higher than the rate of the Earth clock.

After another month (year), the ship approached the Earth at a distance of 2 light hours. At 12 o'clock in the afternoon, the ship's clock will show 10 o'clock. 2 hour difference.

In another month (year) the ship will be at a distance of 1 light hour from the Earth. At 12 noon, the ship's clock will show 11 o'clock. The difference will be 1 hour.

And finally, in another month (year) the spacecraft will land on Earth. At 12 noon on Earth, the ship's clock will show the same time.

Let us now note that as the ship moved towards the Earth, the difference between the indications of the earth clock and the indications of the ship's clock broadcast to the Earth decreased from 4 hours to zero. This means that the clock hands in the image of the ship's clock broadcast on Earth were moving faster than the hands of the earth's clock. In other words, the observed rate of time of the clock approaching the Earth in the process of movement was higher than the true rate of time of the earth clock, which was to be proved.

If we similarly consider the movement of a spacecraft from the Earth, then it is easy to see that the observed rate of time of the departing clocks is less than the rate of time of the Earth's clocks.

One of the conclusions: the observed rate of movement of a moving clock is directly proportional to the perceived frequency of electromagnetic waves.

Below in this work, we will call the observed rate of time of a moving clock the number of seconds μ that have passed according to the observed readings of the moving clock during the time that exactly one second passes through the observer's stationary clock (Fig. 3).

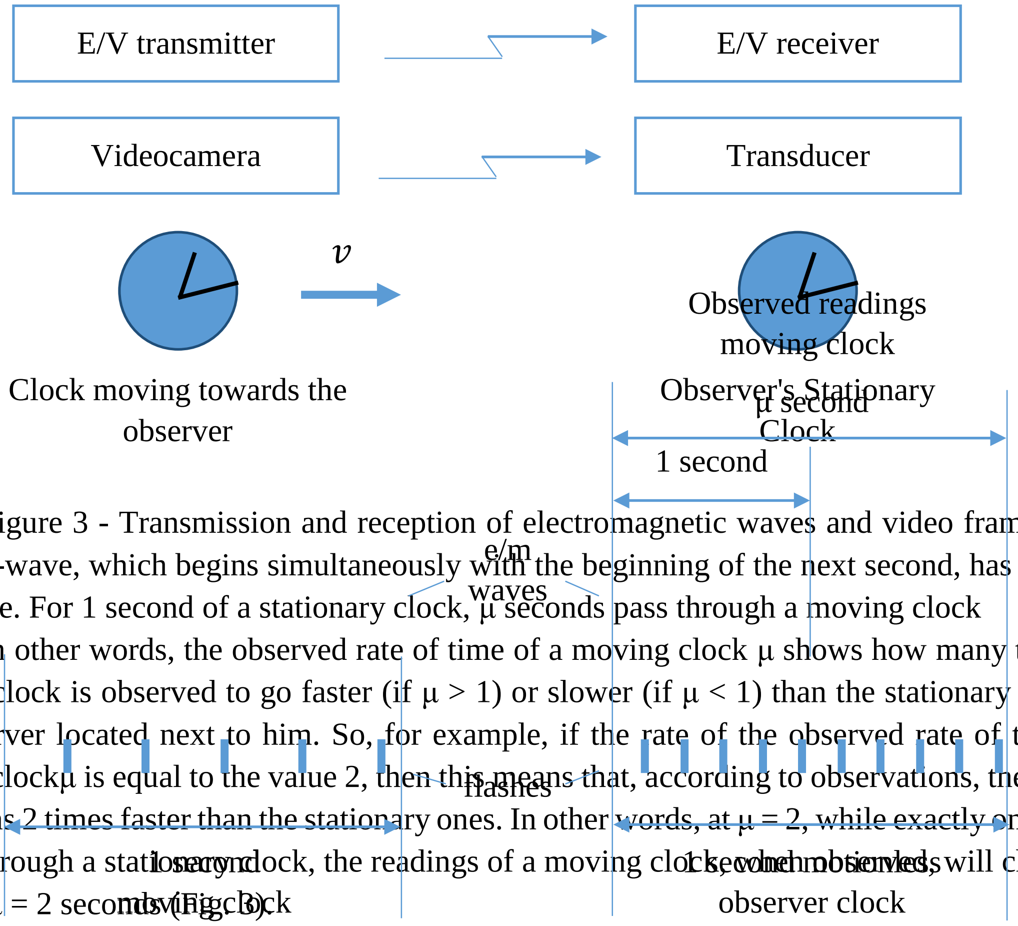


Figure 3 - Transmission and reception of electromagnetic waves and video frames. Each first half-wave, which begins simultaneously with the beginning of the next second, has a greater amplitude. For 1 second of a stationary clock, μ seconds pass through a moving clock

In other words, the observed rate of time of a moving clock μ shows how many times the moving clock is observed to go faster (if μ > 1) or slower (if μ < 1) than the stationary watch of the observer located next to him. So, for example, if the rate of the observed rate of time of a moving clockμ is equal to the value 2, then this means that, according to observations, the moving clock runs 2 times faster than the stationary ones. In other words, at μ = 2, while exactly one second passes through a stationary clock, the readings of a moving clock, when observed, will change by exactly μ = 2 seconds (Fig. 3).

Each first half-wave, which begins together with the beginning of each new second, has an increased amplitude in order to fix the moments of the transmitter's clock seconds in the receiver.

It is obvious that (this is clearly seen from Figure 3) the ratio of the frequency of electromagnetic waves perceived by the receiver ν_obs to the transmission frequency ν_tr is exactly equal to the ratio of the frequency of frames received (and then reproduced) by the receiver of the video image $\nu_{\text{набл}}^{kadr}$ to the frequency of shots and broadcast frames $\nu_{\text{ист}}^{kadr}$ and is equal to the observed rate of time of the moving clock μ:

$$\frac{\nu_{\text{набл}}}{\nu_{\text{ист}}} = \frac{\nu_{\text{набл}}^{kadr}}{\nu_{\text{ист}}^{kadr}} = \mu.$$

Therefore, as it follows from (1), the following relation holds:

$$\mu = \frac{1}{1-\frac{v}{c}}.$$

and

$$\frac{\Delta t_{\text{набл}}}{\Delta t_{\text{ист}}} = \mu = \frac{1}{1-\frac{v}{c}}.$$

Thus, we have proved theoretically that the fundamental relations take place

$$\frac{\nu_{\text{набл}}^{kadr}}{\nu_{\text{ист}}^{kadr}} = \frac{\nu_{\text{набл}}}{\nu_{\text{ист}}} = \frac{\Delta t_{\text{набл}}}{\Delta t_{\text{ист}}} = \frac{1}{1-\frac{v}{c}} = \mu. \qquad (3),$$

When the observed clock moves away from the observer, instead of the minus sign in the denominator, the ratio v⁄c is preceded by a plus sign, while the observed rate of time of the moving clock μ is less than one.

One of the interesting results that follows from the obtained relation (3) is that the observed rate of time of a moving clock is directly proportional to the perceived frequency of electromagnetic waves:

$$\mu = \frac{\nu_{\text{набл}}^{kadr}}{\nu_{\text{ист}}^{kadr}} = \frac{\nu_{\text{набл}}}{\nu_{\text{ист}}}.$$

The value of μ, which is the direct proportionality factor in the Doppler effect,

$$\mu = \frac{1}{1-\frac{v}{c}},$$

has the physical meaning of the observed rate of time of a moving clock.

In the present work, relations (2) and (3) obtained theoretically, despite their obviousness, are confirmed experimentally. The need for experimental confirmation of the relationship

$$\frac{\Delta t_{\text{набл}}}{\Delta t_{\text{ист}}} = \frac{1}{1-\frac{v}{c}} = \mu$$

due to the fact that it is contradicted by a similar SRT relation

$$\frac{\Delta t_{\text{набл}}}{\Delta t_{\text{ист}}} = \sqrt{1-\left(\frac{v}{c}\right)^2},$$

according to which, according to observations, moving clocks in all cases go slower than stationary ones (that is, the observed rate of time of a moving clock is always less than unity).

3. Results and discussion

Thus, the following theoretical results were obtained in the work.

When the clock moves towards the observer, the observed rate of movement of this clock increases. In one second, according to the observer's stationary clock, the readings of the moving clock according to the observation will change by

$\frac{1}{1-\frac{v}{c}}$ second (more than second).

When the clock moves away from the observer, the observed rate of movement of this clock decreases. In one second, according to the observer's stationary clock, the readings of the moving clock according to the observation will change by

$\frac{1}{1+\frac{v}{c}}$ second (less than second).

This result contradicts SRT, according to which, in one second counted by a stationary clock, by a moving clock (including when moving towards the observer) during their observation,

$$\sqrt{1-\left(\frac{v}{c}\right)^2} \text{ second,}$$

that is, less than one second.

SRT contradicts the experimentally established facts not only quantitatively, but also qualitatively.

The physical meaning of the results obtained in this work is as follows.

If there is an online video broadcast from a spacecraft moving towards the Earth at a significant speed, in which 100 frames are transmitted within one second, and at the same time the transmitter on the spacecraft transmits electromagnetic waves with a frequency of 100 Hz, so that one wave is transmitted synchronously with one frame , then on Earth it will be fixed that, in accordance with the Doppler effect, the frequency of received electromagnetic waves will be $\frac{100}{1-\frac{v}{c}}$ Hz that is more 100 Hz. In this case, the video broadcast receiver will receive not 100 frames in one second, a $\frac{100}{1-\frac{v}{c}}$ frames (according to the number of electromagnetic waves received in one second). Accordingly, the reproduction of this number of frames per second will be в $\frac{1}{1-\frac{v}{c}}$ times accelerated (compared to the transmitted) video image. All movements and speech of the astronauts on the video broadcast will look in $\frac{1}{1-\frac{v}{c}}$ times accelerated. Accordingly, the movement of the clock hands on the video image broadcast from the spacecraft will be accelerated with the same proportionality factor.

It is interesting to note that the proportionality factor

$$\beta = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}},$$

which appears in the SRT formulas, is the geometric mean of the proportionality coefficients connecting the observed and true time intervals when the clock approaches the observer

$$\frac{1}{1-\frac{v}{c}},$$

and when the clock moves away from the observer

$$\frac{1}{1+\frac{v}{c}}.$$

By definition, the geometric mean of a and b is defined as the square root of the product of these quantities

$$g = \sqrt{ab}.$$

Can be seen:

$$\sqrt{\frac{1}{1-\frac{v}{c}} \times \frac{1}{1+\frac{v}{c}}} = \frac{1}{\sqrt{\left(1-\frac{v}{c}\right)\left(1+\frac{v}{c}\right)}} = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}} = \beta.$$

Thus, the values of relativistic effects in the SRT formulas are the geometric mean of the acceleration and deceleration of the observed clock rate, moving towards the observer on the one hand, and moving away from the observer on the other hand.

It turns out that the so-called relativistic effects of SRT, derived mathematically, are the average of those effects that actually exist (which is confirmed experimentally).

4. Conclusion

The material presented above is the first part of the experimental study, which outlines the theoretical foundations of the experiment. In this part, formulas are theoretically obtained, the reliability of which is verified experimentally.

In the second part of the work, the results of the experiment will be presented. It will be concluded that SRT cannot be used for calculations in technical sciences, in particular in navigation and surveillance systems used in the aviation and space industries, since the experiment has shown that SRT formulas are erroneous. The use of erroneous formulas in navigation and surveillance systems can lead to a deterioration in the performance characteristics of these systems (including a decrease in the accuracy of navigation and surveillance) and lead to accidents, disasters in aviation and astronautics, and, as a result, to significant economic losses.

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