Successful GPS Operations Contradict the Two Principles of Special Relativity and Imply a New Way for Inertial Navigation – Measuring Speed Directly

Ruyong Wang, *St. Cloud State University, St. Cloud, Minnesota, United States*

ABSTRACT

Successful GPS operations are based on a basic equation: the range measurement equation, $|\mathbf{r}_r(t_r) - \mathbf{r}_s(t_s)| = c(t_r - t_s)$, in an earth-centered inertial (ECI) frame, corrected for range biases. The calculations utilizing this equation show that (1) the speed of light is independent of the source's translational motion relative to the ECI frame if the receiver is stationary; (2) the speed of light is dependent on the receiver's tranlational motion relative to the ECI frame if the source is stationary; (3) for reference frames which are uniformly moving relative to the ECI frame, although the distances between the sources and the receivers are the same, their ranges in the ECI frame are different, so the propagation times are different and the speeds of light are different. Therefore, the ECI frame is a preferred frame near the earth.

To verify this experimentally, a practical and crucial experiment in which no clock synchronization is required (although simultaneity is the key of GPS operations and the relativity of simultaneity of Special Relativity disagrees with the basic operational principle of GPS) has been designed to check whether or not the propagation time changes in different frames. It can be predicted that the crucial experiment will give a result contradicting the two principles of Special Relativity. The crucial experiment can be further simplified by using GPS, and it can be simulated easily with GPS simulators.

Furthermore, the falsification of the two principles of Special Relativity and the calculations based on the GPS equation illustrate a new way for inertial navigation – measuring speed directly. A prototype of the new speedometer based on the crucial experiment is given.

INTRODUCTION

Special Relativity is based on two principles: the principle of relativity and the principle of the constancy of the speed of light. The most controversial part of Special Relativity involves the speed of light for an observer in motion. The principle of the constancy of the speed of light asserts that light in vacuum always has a definite speed of propagation that is independent of the state of the motion of the observer [1], and the principle of relativity states that the speed of light is a constant in all inertial frames moving relative to each other. In fact, this part of Special Relativity really has the least experimental support: up to now, all the experiments used to verify Special Relativity have been done with the earth as the reference frame [2]. No one has conducted an experiment which checks if the speed of light is still c in a reference frame moving relative to the earth. No one has conducted an experiment with a receiver (observer) moving relative to the earth to check the constancy of the speed of light. In the past, this is because the technology was not good enough and people only used 'Gedanken' experiments. But today, GPS has in fact provided a large 'laboratory' and 'instruments' for tests of the speed of light: moving sources and moving receivers; accurate atomic clocks in both the sources and (some) receivers; precise knowledge of the positions of the sources and receivers and long distances between the sources and the receivers; signals carrying the information of positions and times; etc., almost all the ingredients needed for tests of speed of light for moving observers.

GPS is a Timing-Ranging system. The operations of GPS are based on the range measurement equation in an earth-centered inertial (ECI) frame [3]:

$$| \mathbf{r}_r(t_r) - \mathbf{r}_s(t_s) | = c(t_r - t_s).$$

Here t_s is the instant of transmission of the signal from the source, and t_r is the instant of reception at the receiver; $\mathbf{r}_s(t_s)$ is the position of the source at the transmission time, and $\mathbf{r}_r(t_r)$ is the position of the receiver at the reception time. Besides, GPS considers some range biases: the receiver clock bias $\Delta\delta_r$, the satellite clock bias $\Delta\delta_s$, the satellite orbital error ΔD, the ionospheric refraction ΔI, and the tropospheric refraction ΔT [4].

Successful applications of GPS have shown that the range measurement equation corresponds well with experimental data, and therefore, is commonly accepted as being correct. The equation states that the traveling time of light multiplied by the speed of light gives the distance that light traveled between the position of the satellite at transmission time t_s and the position of the receiver's antenna at reception time t_r. But what does the correctness of this equation mean for the principle of the constancy of the speed of light, and therefore, for Special Relativity? Some people [1] think that the range measurement equation is based on the constancy of the speed of light. On the surface, this may appear to be true: c, the speed of light, is the only velocity term that appears within the equation. Expressions such as c-v and c+v, which are often seen in discussions of Special Relativity and classical physics, do not exist in the equation. Therefore, some people would conclude that if this equation is correct, Special Relativity is correct; if this equation has been proved with a high degree of accuracy, Special Relativity has been proved with a high degree of accuracy. For example, it has been concluded [5] that Special Relativity had been confirmed to the limit of $\delta c/c < 5\times10^{-9}$.

But we should not judge things by their appearance; we must try to grasp their essences. As we mentioned before, the notion that the speed of light is a constant in a reference frame, here the ECI frame, really is not a characteristic of Special Relativity. The characteristic of Special Relativity is that the speed of light is a constant in all reference frames moving relative to each other, or for all observers, moving or stationary. If we analyze the implication of the range measurement equation carefully, we will find that, contrary to what its appearance tells us and what some people think, the correctness of the GPS' range measurement equation actually leads to the incorrectness of the principle of the constancy of the speed of light, and furthermore, the principle of relativity. In fact, this is quite understandable if we compare GPS with Sonar systems. Recall that in underwater navigation, Sonar uses the same range measurement equation in a reference frame based on water to calculate the distance traveled by sound even though the sound receiver is moving relative to water. The difference there is that the speed of sound in water, a, is used instead of the speed of light in vacuum, c. However, no one would emphasize the constancy of the speed of sound, and contrarily, every one agrees the speed of sound is dependent on the motion of the sound receiver.

To make the discussion complete, some of following paragraphs are similar to those in [6].

A SOURCE MOVING RELATIVE TO THE ECI FRAME

Most GPS sources move in circular motions, e.g., GPS satellites and DGPS sources moving with the rotation of the earth. But from the theoretical point of view, we will only investigate sources that are moving uniformly relative to the ECI frame.

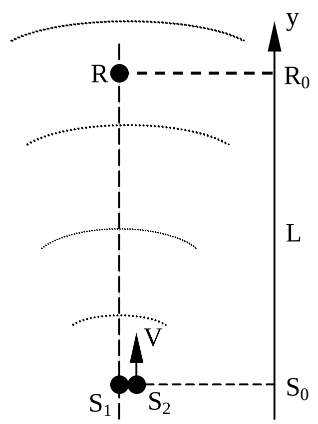

Fig. 1 Moving and stationary sources

Let us suppose that we have two sources, one stationary and one moving translationally with a speed of v, and a stationary receiver. The distance between the stationary source and the receiver is L and the moving source passes the stationary source at t_0 (fig. 1). When will the receiver receive the signals emitted at t_0 from the two sources according to the range measurement equation?

For the stationary source, S_1, and the receiver, R, we have (using one-dimensional expression)

$$\begin{cases} |y - y_1(t_0)| = c(t - t_0) \ (\text{range measurement equation}) \\ y = R_0 \ (\text{the equation of the position of the receiver}) \end{cases}$$

Hence, $t - t_0 = [R_0 - y_1(t_0)]/c = (R_0 - S_0)/c = L/c$.

For the moving source, S_2, and the receiver, R, we have

$$\begin{cases} |y - y_2(t_0)| = c(t - t_0) \\ y = R_0 \end{cases}$$

Hence, $t - t_0 = [R_0 - y_2(t_0)]/c = (R_0 - S_0)/c = L/c$.

That means, at the same time instant t, receiver R will receive the two signals emitted at t_0 from the two sources, one stationary and one moving, which are at the same distance from the receiver at t_0. Therefore, we can conclude that the speed of light is independent of the source's translational motion relative to the ECI frame.

A RECEIVER MOVING RELATIVE TO THE ECI FRAME

Most GPS receivers are moving relative to the ECI frame too. Some of them are in circular motion, e.g., the receivers on the ground stations and the receivers fixed on the earth; Some of them are in translational motion, e.g., on missiles, on airplanes and on cars.

Let us suppose that we have a stationary source and two receivers, one stationary and one moving translationally. The distance between the source and the stationary receiver is L. The moving receiver passes the stationary receiver at t_0 (fig. 2). When will the two receivers receive the signal emitted at t_0 from the source according to the range measurement equation?

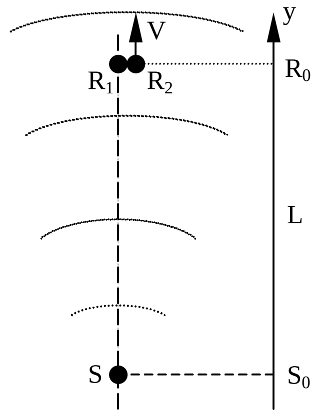

Fig. 2 Moving and stationary receivers

For the source, S, and the stationary receiver, R_1, we have

$$\begin{cases} |y - y_s(t_0)| = c(t - t_0) \\ y = R_0 \end{cases}$$

Hence, $t - t_0 = [R_0 - y_s(t_0)]/c = (R_0 - S_0)/c = L/c$.

For the source, S, and the moving receiver, R_2, we have

$$\begin{cases} |y - y_s(t_0)| = c(t - t_0) \\ y = R_0 + v(t - t_0) \end{cases}$$

Hence, $t - t_0 = [R_0 - y_s(t_0)]/(c - v) = (R_0 - S_0)/(c - v) = L/(c - v)$.

For a signal transmitted from the source at t_0, the two receivers, one stationary and one moving, will receive it at different instants, although the distances between them and the source at t_0 are the same. Therefore we can conclude that the speed of light is dependent on the translational motion of the receiver.

Contrary to the appearance of the range measurement equation that the speed of the receiver, v, does not appear explicitly, the speed of the receiver is implied in the definition of the position of the receiver, i.e., the position of the receiver at the reception time. Compared with the position of the stationary receiver at the reception time, the position of the moving receiver at the reception time is different, and the difference is proportional to the speed of the moving receiver, v.

FRAMES MOVING RELATIVE TO THE ECI FRAME

Most GPS applications involve moving sources and moving receivers, although the velocity of the source and the velocity of the receiver are not necessarily the same. Let us assume that they have the same velocity, therefore they constitute a frame with a constant distance between the source and the receiver. Discussing different frames in the ECI frame has a greater theoretical significance.

Let us suppose that both source S and receiver R move uniformly in a straight line and have the same velocity **v**. The distance between them is L, a constant. We can look at two different cases of signal transmission.

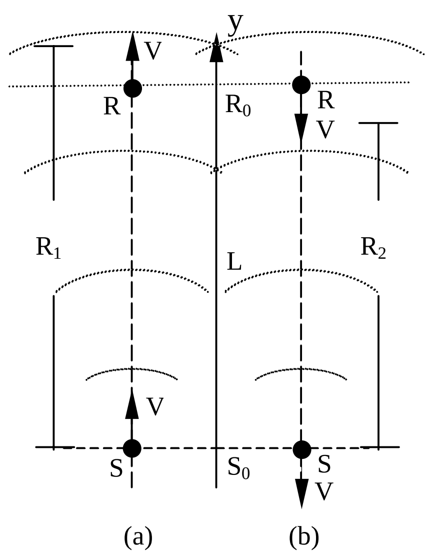

Fig. 3 Moving frames

In case 1, a signal is transmitted from source S at t_0 and the direction of the source and receiver motion is the same as the direction of the propagation of light (fig. 3a). In this case, we have

$$\begin{cases} |y - y_s(t_0)| = c(t - t_0) \\ y = R_0 + v(t - t_0) \end{cases}$$

Hence, $t - t_0 = [R_0 - y_s(t_0)]/(c - v) = (R_0 - S_0)/(c - v) = L/(c - v)$.

In case 2, a signal is transmitted from source S at t_0, but this time, the direction of the motion is opposite to the direction of the propagation of light (fig. 3b).

$$\begin{cases} | y - y_s(t_0) | = c(t - t_0) \\ y = R_0 - v(t - t_0) \end{cases}$$

Hence, $t - t_0 = [R_0 - y_s(t_0)]/(c + v) = (R_0 - S_0)/(c + v) = L/(c + v)$.

In these two cases, although the distance between the source and the receiver is always the same, the receiver will receive the signal at different instants, one later than the other, depending on whether the direction of the propagation of the signal is the same as, or opposite to, the direction of the translational motion.

The source and the receiver constitute a frame. In fact, the source and the receiver in these two cases can be viewed as two different frames uniformly moving relative to the ECI frame. In frame 1 (case 1), during the propagation time, the receiver moves away from the source, therefore, the range in the ECI frame is longer than L. $R_1 = |R_0 + vL/(c - v) - S_0| = Lc/(c-v)$. In frame 2 (case 2), during the propagation time, the receiver moves towards the source, and its range in the ECI frame is shorter than L. $R_2 = |R_0 - vL/(c + v) - S_0| = Lc/(c + v)$. Although the distances between the source and the receiver in these two frames are the same, their ranges in the ECI frame are different. Therefore, the propagation times are different, and the speeds of light are different.

GLOBAL SIMULTANEITY VS. THE RELATIVITY OF SIMULTANEITY

In any debate about the speed of light, the problem of simultaneity is always a focus. Special Relativity claims the relativity of simultaneity which states that two events occurring at two different places which are viewed as simultaneous for an observer in a frame, usually will not be simultaneous if viewed for an observer in another frame. But contrary to this, simultaneity is the key to GPS operations. GPS is a Timing–Ranging system: it does not directly measure the distance between two places where two events, i.e. signals transmitting and receiving, occur. It measures the difference of the two instants when these two events happen and then, the distance is calculated using the range measurement equation, therefore any ambiguity of simultaneity will cause big positioning errors. GPS, especially its space segment and control segment, make a huge effort to establish and maintain a GPS system time, or simply, GPS time [7]. In a scope where GPS is applied, roughly a scope with diameter of 50,000 km or bigger, if one is using GPS, one is using GPS time and therefore the concept of simultaneity of GPS: two events happened at two different places, (x_1, y_1, z_1, t_1) and (x_2, y_2, z_2, t_2), are simultaneous if $t_1 = t_2$. This is true no matter who the observer (receiver) is, where the receiver is, what its status is, or what its speed is. This is the basic operational principle of GPS. We can call it Global Simultaneity.

In the books about Special Relativity, the most commonly cited example about the relativity of simultaneity is the example about the railway platform and the moving train [8]. It says that two events (e.g., the two strokes of lightning A and B) which are simultaneous with reference to the platform are not simultaneous with respect to the moving train and vice versa. But now GPS receivers have been utilized extensively on railway platforms and moving trains, and lightning at two different places, A and B, conceptually is the same as the emissions of GPS signals from two satellites or two DGPS stations. In fact, if two signals are emitted from two satellites or two DGPS stations at the same GPS time, both the GPS receiver on the railway platform and the GPS receiver in the moving train would both acknowledge the two events, the emissions of the signals, to be simultaneous. Without this basic acknowledgement, the GPS receivers can not function at all.

THE CRUCIAL EXPERIMENT OF SPECIAL RELATIVITY

We have shown that the correctness of the range measurement equation contradicts the principle of the constancy of the speed of light and the principle of relativity. We have also indicated that the relativity of simultaneity disagrees with the purpose of GPS system time and the basic operational principle of GPS. Due to the popularity of Special Relativity, a lot of people still will not accept these assertions unless there is experimental support for them. Therefore, we would examine a crucial experiment, in which the result can be used to refute or verify Special Relativity from everybody's point of view. More importantly, in this experiment, simultaneity, or the synchronization of the clocks, is not a concern.

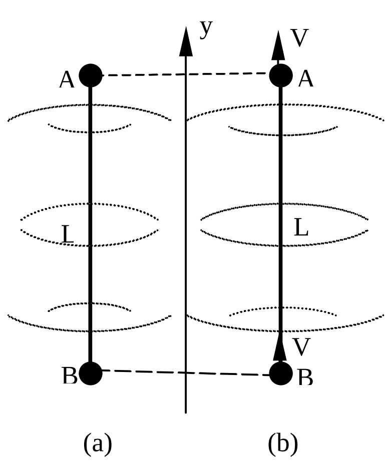

Fig. 4 Crucial experiment

We mount two atomic clocks with the same construction, signal transmitter, reflector, and receivers on the two ends, points A and B, of a vehicle, with distance L between A and B. First (fig. 4a), the vehicle is stationary relative to the earth (facing due South or due North, so when the vehicle moves, the direction of the velocity is due South or due North, eliminating the effect of the rotation of the earth.) The two clocks are not synchronized with each other. A signal is transmitted from A at $t_1(A)$ (according to clock A) to B (arriving at $t_1(B)$ according to clock B) and reflected back to A (arriving at $t'_1(A)$ according to clock A). By the readings of clocks, we can calculate the difference of the nominal travelling times for two directions, $\Delta t_1 = [t'_1(A) - t_1(B)] - [t_1(B) - t_1(A)]$. (We say that the travelling times $t_1(B) - t_1(A)$ and $t'_1(A) - t_1(B)$ are nominal because the two clocks are not synchronized. For example, $t_1(B) - t_1(A)$ could be negative if clock B is too much behind clock A.) Then let the vehicle move. First let it move due South, stop, then due North. We repeat the same measurement when the vehicle moves back to its original position with a constant speed of v (fig. 4b). We will obtain $\Delta t_2 = [t'_2(A) - t_2(B)] - [t_2(B) - t_2(A)]$. If the readings of the clocks show that Δt_1 is different from Δt_2, we think everybody would agree that the experiment refutes the principle of the constancy of the speed of light, and the principle of relativity (because we now find a difference between two uniform motion states), especially noting that the relativity of simultaneity is not a problem here, because the synchronization of clocks is not required. If Δt_1 is equal to Δt_2, then the experiment verifies Special Relativity. Notice that, because the two clocks are not synchronized, we can not measure the value of the speed of light. But we can check whether or not the propagation time changes, i.e., whether or not the speed of light changes when the distance does not change.

Let us calculate Δt_1 and Δt_2 according to the range measurement equation. First, we assume that both clocks have GPS time for convenience. Later we will show that the source clock bias, the receiver clock bias and other range biases will not affect the conclusion here.

In case 1, when the vehicle is stationary, for the signal transmitted from A to B, we have

$$\begin{cases} |y_B - y_A[t_1(A)]| = c[t_1(B) - t_1(A)] \\ y_B = y_B[t_1(A)] \end{cases}$$

Hence, $[t_1(B) - t_1(A)] = \{y_A[t_1(A)] - y_B[t_1(A)]\}/c = L/c$.

For the signal reflected back from B to A, we have

$$\begin{cases} |y_A - y_B[t_1(B)]| = c[t'_1(A) - t_1(B)] \\ y_A = y_A[t_1(B)] \end{cases}$$

Hence, $[t'_1(A) - t_1(B)] = \{y_A[t_1(B)] - y_B[t_1(B)]\}/c = L/c$.

In this case, we have $\Delta t_1 = [t'_1(A) - t_1(B)] - [t_1(B) - t_1(A)] = 0$.

In case 2, when the vehicle is uniformly moving North with a speed of v, for the signal emitted from A to B, we have

$$\begin{cases} |y_B - y_A[t_2(A)]| = c[t_2(B) - t_2(A)] \\ y_B = y_B[t_2(A)] + v[t_2(B) - t_2(A)] \end{cases}$$

Hence, $[t_2(B) - t_2(A)] = \{y_A[t_2(A)] - y_B[t_2(A)]\}/(c + v) = L/(c + v)$. (1)

For the signal reflected back from B to A, we have

$$\begin{cases} |y_A - y_B[t_2(B)]| = c[t'_2(A) - t_2(B)] \\ y_A = y_A[t_2(B)] + v[t'_2(A) - t_2(B)] \end{cases}$$

Hence, $[t'_2(A) - t_2(B)] = \{y_A[t_2(B)] - y_B[t_2(B)]\}/(c - v) = L/(c - v)$. (2)

Therefore, we have $\Delta t_2 = [t'_2(A) - t_2(B)] - [t_2(B) - t_2(A)] = L/(c - v) - L/(c + v) \approx 2vL/c^2$, neglecting the quantities of the second and higher order of v/c.

Now let us consider the range biases involved in GPS calculation, first, the source clock bias and the receiver clock bias. Let us eliminate the assumption of having GPS time in both clocks and find the result. Suppose that neither clock A nor clock B uses GPS time, and the two clocks are not synchronized with each other: clock A would be δt_A ahead of GPS time and clock B would be δt_B ahead of GPS time, Then, in case 1, where the vehicle is stationary, we will record a $\Delta t_1 = 2\delta t_A - 2\delta t_B$, in stead of recording $\Delta t_1 = 0$. In case 2, when the vehicle is moving, we will record a $\Delta t_2 = 2vL/c^2 + 2\delta t_A - 2\delta t_B$. Therefore, when we calculate the time difference between two cases, we will find the same $\Delta t = \Delta t_2 - \Delta t_1 = 2vL/c^2$, whether clock B is synchronized with clock A or not, and whether the clocks are synchronized with GPS time or not. As for the other range biases, the source position error is irrelevant here, and the ionospheric delay and tropospheric delay are the same for these two cases, therefore, there is no net effect caused by them.

Hence, according to the range measurement equation corrected for range biases, when we conduct this experiment, we will find a time difference of $\Delta t = \Delta t_2 - \Delta t_1 = 2vL/c^2$ between the two cases. It is a first-order effect pertaining to the direction of motion. The Lorentz contraction, which is a second-order effect and does not pertain to the direction of motion, is irrelevant here. Time dilation, and hence, the effect of moving clocks are relevant here. However, since both clocks move in exactly the same way, there will be no net effect on the time difference from the two moving clocks. Therefore, the range measurement equation's correctness has lead to the prediction that the crucial experiment will refute the two principles of Special Relativity.

It is suggested in [9] that this experiment can be implemented by mounting the two clocks not in one moving object, but in two separate objects that move in a straight line, one after another, with the same velocity. This way, L, the distance between the two clocks can be increased substantially, and hence, the predicted time difference can reach up to 1 nanosecond, a value that is relatively easy to detect with current technology. Also, the effect of moving clocks, including time dilation, and the effect resulting from the fact that L is not strictly constant are discussed there in detail, and it has been indicated that these effects will not prevail over the time difference we are trying to detect. In fact, $\Delta t = 2vL/c^2$ is the time difference of light propagation between two directions and between two cases. Therefore, if the light paths of the two directions are slightly different, as long as the difference is the same for both cases, or if the light paths of the two cases are slightly different, as long as the difference is the same for both directions, the time difference, $2vL/c^2$, will exist.

THE MICHELSON-MORLEY EXPERIMENT

The Michelson-Morley experiment [10] is a second-order experiment because the light rays travel round-trips. The possible time difference there, $\Delta t = (2L/c)(v/c)^2$, is too small for even the most advanced atomic clocks. But we can still calculate the possible time difference in the Michelson-Morley experiment using the range measurement equation.

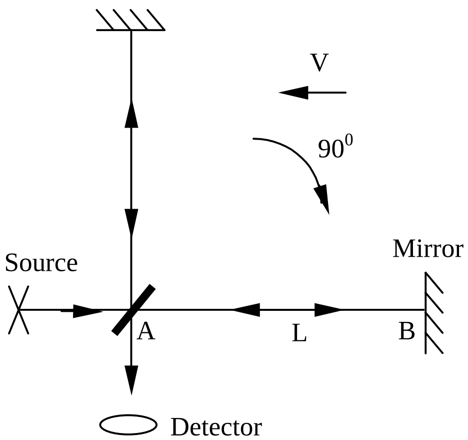

Fig. 5 Michelson-Morley experiment

Let us calculate the time elapsed for the horizontal arm (fig. 5) only. How much time is needed for a light ray travelling from A to B and back to A? Obviously, it is similar to the calculation in the previous paragraph and the difference is that we now want to have the summation of two travelling times in stead of the subtraction of two travelling times. According to (1) and (2), we have $t = [t'_2(A) - t_2(B)] + [t_2(B) - t_2(A)] = L/(c - v) + L/(c + v)$. In fact, this is the result we can find in any physics textbooks when the Michelson-Morley experiment is discussed. It seems that the range measurement equation tells us that in the Michelson-Morley experiment, a time difference, therefore, a non-null result would be found. So far, the Michelson-Morley experiment has been repeated many times, but no concrete fringe shift has been found. Why? One possible reason would be that the range measurement equation is correct in the ECI frame. Therefore, the motion should be in this frame too. We should conduct the Michelson-Morley experiment in a platform translationally moving relative to the ECI frame and its speed should be fast enough to produce a detectable fringe shift. One example would be conducting the Michelson-Morley experiment in a space shuttle [2].

Another example would be using fiber-optic Michelson interferometer for a fiber-optic Michelson-Morley experiment (fig. 6). Like in fiber-optic gyroscopes, the optical paths in fiber-optic Michelson interferometers can be few kilometers long, therefore the expected time difference can be much longer and the required speed can be lower.

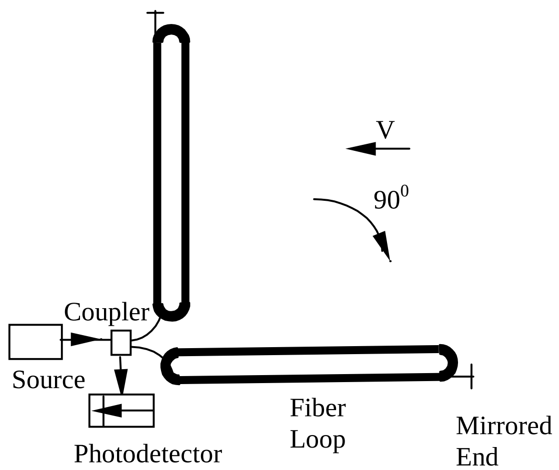

Fig. 6 Fiberoptic Michelson-Morley experiment

THE ECI FRAME IS A PREFERRED FRAME NEAR THE EARTH

It is well known that the purpose of Michelson-Morley experiment was to detect the ether, or a preferred frame for light propagation. If the crucial experiment does show the time difference between the two cases, we can conclude that the speed of light is c only in the ECI frame and the speed of light is not c in the frames moving relative to the ECI frame. Therefore, we do indeed find a preferred frame, that is the ECI frame.

The hierarchy of structure in the universe proceeds from satellites to planets, to stars, to galaxies, to clusters of galaxies, etc. The earth is a relatively small part of the solar system. It is unconceivable that the ECI frame is a preferred frame for the whole solar system, or for the whole universe. Reasonably, the ECI frame is only a terrestrial preferred frame, a preferred frame near the earth.

SIMPLIFYING THE CRUCIAL EXPERIMENT FURTHER USING GPS

When we say that the correctness of the range measurement equation leads to the incorrectness of the two principles of Special Relativity, we mean it not only qualitatively as we mentioned before, but also quantitatively. The difference between what Special Relativity predicts and what the range measurement equation calculates is an item of vL/c (for length) or vL/c^2 (for time). This item is 'big' in GPS applications because L is about 20,000km. Therefore, vL/c reaches 200m when v = 3 km/s (speed of missiles), it reaches 20m when v = 300 m/s (speed of airplanes), and it reaches 2 m when v = 30 m/s (speed of cars). GPS has reached unprecedented precision of positioning up to the order of millimeters which is much smaller than the values listed above. Therefore, quantitatively, GPS practices have proved the correctness of the range measurement equation and the incorrectness of the two principles of Special Relativity.

The crucial experiment we proposed before is a practical one. But we can simplify it further using GPS: assume that two satellites, S_1 and S_2, are located on the extension of line AB (fig. 7), then it is not necessary to have a signal transmitter at A and a reflector at B. What we need are only GPS receivers at A and B, and we can calculate the times needed as $t(A \to B) = t(S_1 \to B) - t(S_1 \to A)$ and $t(B \to A) = t(S_2 \to A) - t(S_2 \to B)$. We can conduct the experiment in two parts. In part 1, A and B move South (to eliminate the effect caused by the rotation of the earth) with a speed of v and in part 2, A and B move North with a speed of v. Special Relativity predicts that there is no time difference between the two parts, but the calculation of the range measurement equation tells us that we will find a time difference in the experiment, $\Delta t =$

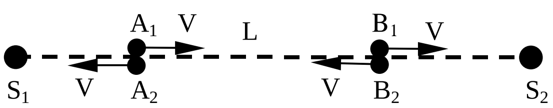

Fig. 7 Simplifying the crucial experiment (ideal case)

$4vL/c^2$ (the time difference is doubled because in both two parts, A and B move South or North and all the discussions about clock synchronization of the crucial experiment can be applied here too). It reaches 4 ns when L = 3,000 km and v = 30 m/s (speed of cars).

Realistically, the assumption that GPS satellites are exactly located on the extension of line AB is unpractical and almost unachievable. Any small shift of the positions of satellites from the extension of line AB will cause big errors because the distances between satellites and A or B are much longer than the distance between A and B. Then, is it still possible to find a way to simplify the crucial experiment? It is possible if we recall how Galileo overcame the seemly inevitable difficulty that a perfectly frictionless and perfectly horizontal track did not exist when he conducted the experiment that led him to his Law of Inertia. He used two inclined planes set end-to-end and changed the tilt of the second track. The ball always reached a vertical height that was almost the same as it started from. Then Galileo argued that if the second track were perfectly frictionless and perfectly horizontal, the

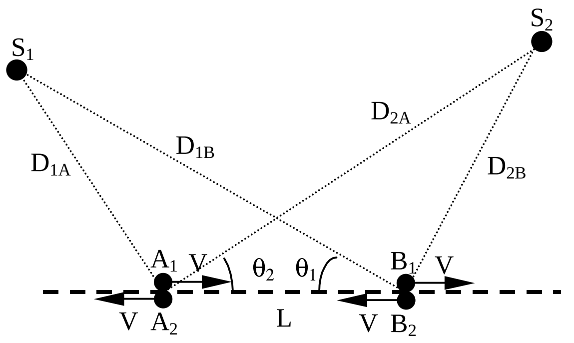

Fig. 8 Simplifying the crucial experiment (real case)

ball would roll forever. We can gain a good deal of enlightenment from this famous experiment. We can conduct the experiment with different positions of the satellites, then, different inclinations to line AB (fig. 8). According to the range measurement equation, we will have the result as
$[(t_{S1B1} - t_{S1A1}) - (t_{S2A1} - t_{S2B1})] - [(t_{S1B2} - t_{S1A2}) - (t_{S2A2} - t_{S2B2})] = 2v(D_{1B} - D_{1A})\cos\theta_1/c^2 + 2v(D_{2A} - D_{2B})\cos\theta_2/c^2$.

If we can find, from the results of the experiments, that this is true for different $\theta_1$and θ_2, then we can conclude that it will be true for $\theta_1 = 0$ and $\theta_2= 0$ also. It means $(t_{A1B1} - t_{B1A1}) - (t_{A2B2} - t_{B2A2}) = 4vL/c^2$, and therefore, the two principles of Special Relativity will be falsified.

SIMULATION OF THE CRUCIAL EXPERIMENT WITH A GPS SIMULATOR

A GPS simulator is a good tool for GPS applications. Since it can produce GPS signals and simulate the motion of the receiver, a user in the lab can utilize the GPS simulator and receivers to simulate real GPS applications, e.g., airplane landing, ship steering, and spacecraft rendezvous. The GPS simulator is particularly useful for simulating the crucial experiment here since the motion of the receiver which is the most difficult part of the experiment can be easily achieved using the simulator. Also the simulator can easily place the GPS satellites at the exact locations on the extension of line AB as mentioned before.

Let us utilize a GPS simulator and two receivers, A and B. The two receivers need not necessarily be high grade receivers, since in simulation, we can make the distance between A and B big enough, so that the expected time difference reaches microseconds. Receiver A has a clock bias δt_A, and receiver B has a clock bias δt_B, and generally, δt_A and δt_B are not the same. This means that the two receivers are not synchronized, therefore, the relativity of simultaneity is not an issue in the simulation of the crucial experiment. We simulate four cases respectively: (1) satellite S_1 and receiver A; (2) satellite S_1 and receiver B; (3) satellite S_2 and receiver B; (4) satellite S_2 and receiver A (fig. 9). In these cases, S_1 and S_2 are stationary satellites and the distance between S_1 and S_2 is 40,000 km and receivers A and B are always on the straight line S_1S_2. The starting position of receiver A at t = 0 is at a distance of 5,000 km from S_1. At first, receiver A is stationary relative to the ECI frame for 2 seconds (A1), then it moves back (towards S_2), stops, and moves forward (towards S_1). At the instant of t = 10 seconds, it reaches the original position with a constant speed of 3 km/s (A2). The motions of receiver B are exactly the same as those of receiver A, the only difference is that the starting position of receiver B at t = 0 is at a distance of 5,000 km from S_2. this means that the distance between the two receivers is always 30,000 km.

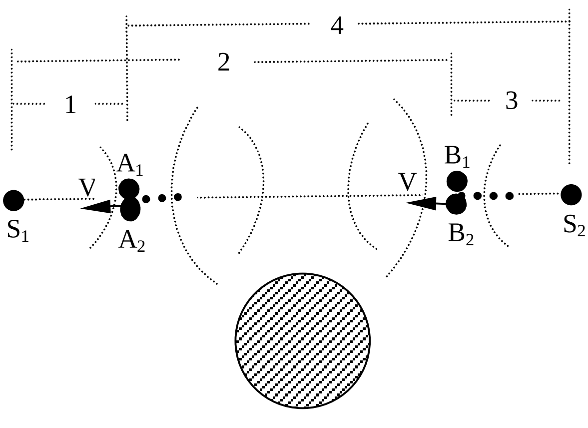

Fig. 9 Simulation of the crucial experiment using a GPS simulator

In case 1, we can find the propagation time $t(S_1 \rightarrow A_1)$ and $t(S_1 \rightarrow A_2)$, and in other cases, we can find, respectively, $t(S_1 \rightarrow B_1)$ and $t(S_1 \rightarrow B_2)$, $t(S_2 \rightarrow B_1)$ and $t(S_2 \rightarrow B_2)$, and finally, $t(S_2 \rightarrow A_1)$ and $t(S_2 \rightarrow A_2)$. Therefore, we can find
$[(t_{S2A2} - t_{S2B2}) - (t_{S1B2} - t_{S1A2})] - [(t_{S2A1} - t_{S2B1}) - (t_{S1B1} - t_{S1A1})]$.
Since A and B are located on the straight line S_1S_2, it becomes $(t_{B2A2} - t_{A2B2}) - (t_{B1A1} - t_{A1B1}) \equiv \Delta t_2 - \Delta t_1$ in the crucial experiment.

Utilizing the GPS equation and correcting for all the range biases, we can conclude that we will get $[(t_{S2A2} - t_{S2B2}) - (t_{S1B2} - t_{S1A2})] - [(t_{S2A1} - t_{S2B1}) - (t_{S1B1} - t_{S1A1})] = 2vL/c^2 = 2 \text{ x3km/sx30,000km}/c^2 = 2\mu s$.

As we mentioned before, Lorentz contraction is a second order effect and it is not an issue here. In fact, the Lorentz contraction in this case ($v^2L/2c^2$) is only 1.5 mm, and it will cause a time difference of 5 ps (<< 2μs). The only effect we can not simulate is that the clocks in the receivers become slower because of the motion of the receivers. But this should not affect the conclusion here. First, the movements of both receivers are the same, and clock rate changes in both receivers are the same. Therefore, there is no net effect on the time difference detected. Second, according to the calculation (rate change of $v^2/2c^2$), the changes of clocks in 8 seconds should be a small amount compared to the time difference detected.

The GPS simulators have been utilized extensively and successfully in a lot of applications. That means the results of simulations match with the real world. Therefore, we could conduct the simulation of the crucial experiment on a GPS simulator and conclude that the crucial experiment in the real world should show the same result, i.e., a result refuting the two principles of Special Relativity.

A NEW WAY FOR INERTIAL NAVIGATION – MEASURING SPEED DIRECTLY

It is well known that inertial navigation utilizes an accelerometer for linear acceleration and a gyroscope for rotation. Linear speed is determined by integrating the accelerometer output and cannot be measured directly. Why? Because the principle of relativity claims that motion is purely relative, and therefore, it is impossible, using instruments within inertial frame itself, to distinguish any one such frame from any other. But from the calculations given before, we understand the principle of relativity could not true. If the crucial experiment shows a result refuting the principle of relativity, naturally, it also tells us that it is possible to distinguish one inertial frame from other inertial frames, hence the speed relative to the ECI frame can be measured directly. In fact, we can design a prototype of a new speedometer immediately from the crucial experiment, because the crucial experiment shows a time difference $\Delta t = 2vL/c^2$, and therefore, the speed $v = \Delta t\, c^2/2L$.

Mount two atomic clocks with the same construction, a light source and two reflectors on the two ends, points A and B, of a rod with length of L (fig. 10). A light pulse is reflected from A at $t_1(A)$ (according to clock A) to B (arriving at $t_1(B)$ according to clock B) and reflected back to A (arriving at $t'_1(A)$ according to clock A). By the

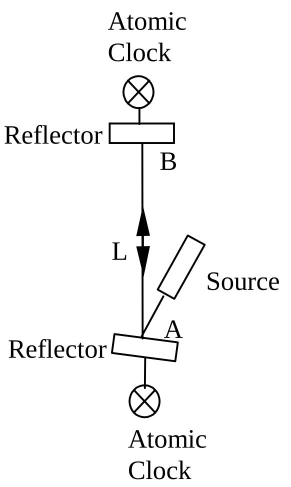

Fig. 10 A prototype of new speedometer

readings of clocks, we can calculate the difference of the nominal travelling times for two directions, $\Delta t_1 = [t'_1(A) - t_1(B)] - [t_1(B) - t_1(A)]$. We can get a Δt_0 when the rod is

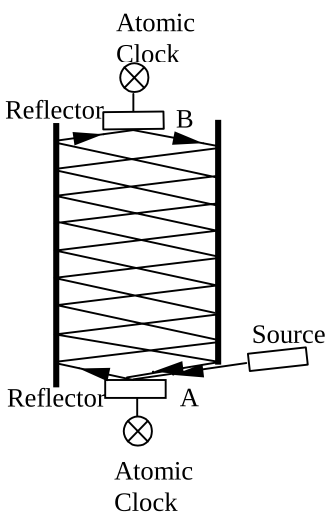

Fig. 11 An improved prototype of new speedometer

stationary in ECI frame. According to the calculations mentioned before and if confirmed by the crucial experiment, for any speed of the rod relative to ECI frame, v, $\Delta t = \Delta t_1 - \Delta t_0 = 2vL/c^2$. There, v is positive if the direction of the speed is from B to A and v is negative if the direction of the speed is from A to B. As we mentioned before, utilizing the time difference between the propagation times of two opposite directions will eliminate the possible error caused by the change of the length of the rod.

If we mount the speedometer on a missile, (the typical speed of a missile is 3 km/s and the typical length of a missile is 30 m) the expected time difference will be $(v/c)(2L/c) = 2$ ps comparing with the total propagation time between A and B of 0.2 μs (2L/c). This time difference is measurable using modern technology.

With the possibility of measuring speed directly, new and better speedometers will be invented. For example, we can improve the prototype of the speedometer by letting the light pulse reflect many times between two mirrors before it arrives at the other end (fig. 11). Then the propagation time is much longer than 2L/c. Therefore, the possible time difference will be much longer than (v/c)(2L/c). Besides, if the fiber-optic Michelson-Morley experiment in a frame relative to the ECI frame shows a time difference, the fiber-optic Michelson interferometer can be utilized as a new speedometer also, although it only detects a second-order effect.

RE-EXAMINE AND RE-CONSTRUCT SPECIAL RELATIVITY

When we state that the GPS operations contradict the two principles of Special Relativity, we do not mean that every thing in Special Relativity is incorrect. Some deductions in Special Relativity, like the relation between mass and speed, have strong experimental support. We should re-examine Special Relativity: for the parts that have experimental support, we should keep them; for the parts that lack experimental support, we have to re-think them; for the parts that contradict experimental results, we must reject them.

If the crucial experiment shows a time difference as we calculated and therefore, refutes the two principles of Special Relativity, then we must re-construct Special Relativity from its foundations. From the calculations given before, we find that the speed of light in a reference frame moving relative to the ECI frame is $c - v$ or $c + v$. Therefore, the Galilean transformation has its place in the new theory. We also know that the relation between mass and speed is based on the Lorentz transformation. Therefore, the Lorentz transformation also has its place in the new theory. In Special Relativity, the Galilean transformation is replaced by the Lorentz transformation and these two do not co-exist. Can we reconcile these two so that both transformations can co-exist in the new theory? It is possible, and the answer lies in the preferred frame. Let us recall the history of physics one hundred years ago. Before Einstein's first paper of Special Relativity was published in 1905, it had been known that the mass of an electron increased with its speed relative to the laboratory [11]. In fact, it immediately brought a serious problem for the viewpoint that motion is purely relative. If motion really is purely relative, then speed is also purely relative, and therefore, mass must be purely relative. A heuristic answer for this problem is that the preferred frame, the ECI frame, is not only preferred for the propagation of photons with zero rest mass near the earth, but also is preferred for the motion of other particles or bodies with finite rest mass near the earth, e.g., electrons Because there is a preferred frame near the earth, we can identify two different kinds of motion. The motion relative to the preferred frame is a true motion, and the motion relative to the other reference frames is an apparent motion. For example, an airplane moving eastward with a speed of v relative to the ECI frame is in a true motion. If in the airplane, there is an electron moving westward with a speed of v relative to the airplane, its motion relative to the airplane is an apparent motion, its true motion, in fact, is stationary in the preferred frame. In this case, the mass of the electron will not increase. Because now we have two different kinds of motion, we could have two different transformations. The Lorentz transformation is suitable for the transformation between two true motion states, like a stationary electron and a moving electron. Otherwise, the Galilean transformation is suitable, for example, for measuring the speed of light in a moving airplane.

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