

Proposed Experiment for Detection of Absolute Motion

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Abstract: According to special theory of relativity (SR) all motion is relative and existence of any privileged or absolute inertial frame of reference, which could be practically distinguished from all other inertial frames, is ruled out. However, we may define an absolute or universal reference frame as the one which is at rest with respect to the center of mass of the universe and assume the speed c of propagation of light to be an isotropic universal constant in that frame. Any motion with respect to such a reference frame will be called 'absolute motion'. The proposed experiment establishes the feasibility of detection of such an absolute motion by measuring the up-link and down-link signal propagation times between two fixed points on the surface of earth. With current technological advancements in pulsed lasers, detectors, precision atomic clocks and computers, feasibility of the proposed experiment has been confirmed. Successful conduct of the proposed experiment will initiate a paradigm shift in fundamental physics.

Résumé : Selon la théorie spéciale de relativité (RS), tout mouvement est relatif et l'existence de tout cadre d'inertie de référence, qu'il soit privilégié ou absolu, lequel pourrait pratiquement se distinguer de tous cadres d'inertie de référence, est éliminée. Cependant, nous pouvons définir comme cadre de référence, absolu ou universel, celui qui est en repos par rapport au centre de masse de l'univers et proposons la vitesse C de propagation de lumière comme une isotropie constante et universelle dans ce cadre. Tout mouvement par rapport à un tel cadre de référence sera appelé «le mouvement absolu». L'expérience que nous proposons établit la faisabilité de détection d'un tel mouvement absolu en mesurant la liaison montante et descendante des temps de propagation de signal lien entre les deux points fixes à la surface de la Terre. Avec les avancements technologiques en cours dans les pouds lasers, les instruments détecteurs, les montres à précision atomique, et les ordinateurs, la possibilité de réalisation de l'expérience proposée a été confirmée. La conduite avec succès de l'expérimentation proposée entraînera, initiera également un changement de paradigme dans la physique fondamentale.

Key Words: Relativity, isotropy, reference frame, clock synchronization, absolute motion, pulsed laser.

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I. MOTION UNDER NEWTONIAN NOTION OF ABSOLUTE TIME

Isaac Newton viewed ‘space’ as something distinct from material bodies and ‘time’ as something that passes uniformly without regard to whatever happens in the world. For this reason he spoke of absolute space and absolute time. Newton defined the absolute motion of a body to be its motion through absolute space. However, the second postulate of Special Theory of Relativity (SR) depicts an assumption that the speed of light in vacuum is the same isotropic constant c in all inertial reference frames (IRF) in relative uniform motion. This assumption has effectively ruled out the existence of any privileged or absolute inertial frame of reference which could be practically distinguished from all other inertial frames. According to SR, the time interval ‘ dt ’ of a standard atomic clock and a length segment ‘ dx ’ of a standard meter rod, will be *seen to be different* in each of the infinitely many inertial reference frames in relative uniform motion. Thus the Newtonian notion of time and length as absolute measures, has been replaced by the Einsteinian notion of relative time and length in SR.¹ However, as per the Newtonian notion of absolute time and length, we may define an absolute or universal reference frame as the one which is at rest with respect to the center of mass of the universe, is non-rotating with respect to the celestial background, and assume the speed ‘ c ’ of light propagation to be an isotropic constant in that frame. Any motion with respect to such a Universal Celestial Reference Frame (UCRF) will be called ‘absolute motion’.

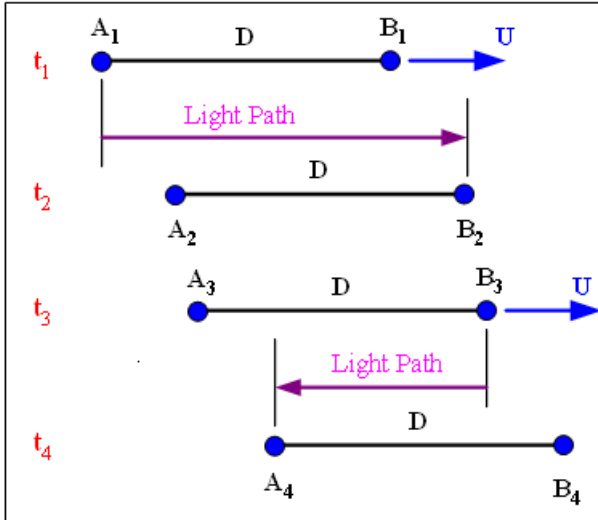


FIG. 1. Illustration of Light Path variation for up-link and down-link signal propagation.

Once we assume the isotropy of the speed of light propagation in the universal reference frame, it is possible

to detect absolute motion by monitoring the propagation times of light pulses between two co-moving points in absolute space. We shall first illustrate this approach through discussion of signal propagation times between two spacecraft, and later will give a detailed description of a feasible experiment that can be performed on the surface of earth. Let us assume that the points A and B in space represent two Pioneer type spacecraft in the outer region of our solar system. Let the separation distance AB, as measured in UCRF defined above, be D which remains constant over a period of time. Let us assume that the two spacecraft A and B are moving in the UCRF with a common uniform velocity U along AB. Since c is the isotropic constant speed of light propagation in UCRF, it can be shown that the ratio U/c depends on the ratio of the difference between the up-link (from A to B) and down-link (from B to A) signal propagation times, to the total round trip signal propagation time.

Let us further assume that the two spacecraft A and B are fitted with appropriate signal transmitters, receivers, computers and mutually synchronized identical atomic clocks. We shall discuss the practical aspects of mutual synchronization, along with possible synchronization errors of the two clocks, in section III. Let the time of transmission of a signal pulse from spacecraft A be t_1 and the time of reception of the signal pulse at the spacecraft B be t_2 . Let the time of return transmission of a signal pulse from spacecraft B be t_3 and the time of reception of the pulse back at the spacecraft A be t_4 as illustrated in figure 1. The up-link or outward signal propagation time T_u from A to B is given by,

$$T_u = t_2 - t_1 \quad (1)$$

During this up-link signal propagation time T_u the spacecraft B would have moved from its original position B_1 to B_2 such that the distance B_1B_2 in UCRF is given by,

$$B_1B_2 = U * (t_2 - t_1) = U * T_u \quad (2)$$

and the total distance traveled by the up-link signal pulse is,

$$D + U * T_u = c * T_u \quad (3)$$

Similarly, the down-link or inward signal propagation time T_d from B to A is given by,

$$T_d = t_4 - t_3 \quad (4)$$

During this down-link signal propagation time T_d the spacecraft A would have moved from its original position A_3 to A_4 such that the distance A_3A_4 in UCRF is given by,

$$A_3A_4 = U * (t_4 - t_3) = U * T_d \quad (5)$$

and the total distance traveled by the down-link signal pulse is,

$$D - U * T_d = c * T_d \quad (6)$$

Eliminating D from equations (3) and (6), we get,

$$U * (T_u + T_d) = c * (T_u - T_d)$$

$$\text{Or, } \frac{U}{c} = \left[\frac{T_u - T_d}{T_u + T_d} \right] \quad (7)$$

Putting it in words, equation (7) implies that the ratio U/c depends on the ratio of the difference between up-link and down-link signal propagation times to the total round trip propagation time. This shows that the common velocity U of two objects A and B , can be determined simply by measuring the outward and inward signal propagation times between them. However, in our attempt to detect absolute motion or the preferred reference frame, we are essentially attempting to invalidate the second postulate of SR regarding assumed isotropy of the speed of light propagation in all IRF. Any such attempt to invalidate the second postulate is logically not bound to make use of the consequent implications of that postulate, like length contraction and time dilation.

Since the digital time readouts t_1 , t_2 , t_3 , and t_4 from the atomic clocks constitute real physical data, it cannot change even if we refer the positions of the two spacecraft A and B to a local reference frame in which they appear to be at rest. We had assumed that both A and B are moving in the UCRF with a common velocity U along AB and that their separation distance D remains constant over the entire testing period. If however, we refer the positions and velocities of the same two spacecrafts A and B to the Galactic Reference Frame, the measure numbers depicting their positions and velocities will change. In particular, the common velocity of spacecrafts A and B along AB will now be a different value from U , say U_1 . Similarly, if we refer the positions and velocities of the same two spacecrafts A and B to the Barycentric Celestial Reference Frame (BCRF), the common velocity of spacecrafts A and B along AB will now be a different value say U_2 .

However, under Newtonian notion of absolute time, we have only one set of up-link and down-link signal propagation times (T_u and T_d) data recorded in the on-board computers, which cannot change with a change in reference frame. If we assume the same isotropic speed c of light propagation in all IRF as per second postulate of SR, it can be easily seen that equation (7) cannot be satisfied for different values of U , U_1 , U_2 corresponding to various reference frames considered above. This points to a significant conclusion that with ‘absolute time’, c cannot be the same isotropic universal constant in all reference frames in relative uniform motion. That is, the speed of signal propagation can be the isotropic value c only in one particular inertial reference frame which may be referred as the Universal Reference Frame. This isotropic value of the speed of signal propagation becomes the identifying characteristic feature of the Universal Reference Frame. The foregoing analysis suggests that we can detect the common velocity of two objects A and B (along AB), separated by a distance D , simply by measuring the up-link and down-link signal propagation times between them. This procedure can then be extended to a general technique for establishing the Universal Reference Frame,² just like BCRF.

II. MOTION UNDER EINSTEINIAN NOTION OF RELATIVE TIME

Quoting Albert Einstein, from his 1905 paper, “*If at the point A of space there is a clock, an observer at A can determine the time values of events in the immediate proximity of A . If there is at the point B of space another clock in all respects resembling the one at A , it is possible for an observer at B to determine the time values of events in the immediate neighborhood of B . But it is not possible without further assumption to compare, in respect of time, an event at A with an event at B . We have so far defined only an ‘ A time’ and a ‘ B time’. We have not defined a common ‘time’ for A and B , for the latter cannot be defined at all unless we establish by definition that the ‘time’ required by light to travel from A to B equals the ‘time’ it requires to travel from B to A .*” This arbitrary definition of ‘common time’ constitutes a fundamental departure from the Newtonian notion of absolute time, which has ultimately obscured the notion of absolute motion.

Einstein introduced the notion of a ‘stationary system’ in his 1905 paper – “*Let us take a system of co-ordinates in which the equations of Newtonian mechanics hold good. In order to render our presentation more precise and to distinguish this system of co-ordinates verbally from others which will be introduced hereafter, we call it the ‘stationary system’.*” According to Relativity, all inertial reference frames in relative uniform motion, are equivalent and no particular IRF can be considered special, preferred or unique. Hence, while comparing two or more of this group of IRF in relative uniform motion, any one of them could be called the “stationary system” to distinguish it verbally from others. Further, as per Einstein, “*It is essential to have time defined by means of stationary clocks in the stationary system, and the time now defined being appropriate to the stationary system we call it ‘the time of the stationary system’.*”

This notion of ‘time of the stationary system’ implies the Einstein synchronization of identical stationary clocks in that reference system. Let us designate the ‘stationary system’ defined above as inertial reference frame K , with origin at O and coordinate axes X , Y , Z . Consider two objects, A and B , located on the X -axis with a separation distance D , co-moving along X -axis with a uniform velocity U as measured in K . Let us assume that two identical sets of test equipment, consisting of precision atomic clocks, pulsed lasers, detectors and networked computers, are positioned at A and B . Consider another (local) inertial frame K' with origin at O' and coordinate axes X' , Y' , Z' , which is co-moving with objects A and B . Assume that the reference frames K and K' are in standard configuration such that K' is moving along X -axis at uniform velocity U with X' -axis aligned with X -axis. Let us further assume that objects A

and B are located at x'_A and x'_B on the X' -axis in reference frame K' such that,

$$x'_B - x'_A = D' \quad (8)$$

$$\text{Let } \gamma = \frac{1}{\sqrt{1 - U^2/c^2}} \quad (9)$$

In the local frame K' , where the objects A and B are at 'rest', let us assume the atomic clocks A and B are synchronized as per Einstein synchronization convention. In the frame K' , let a short laser pulse be transmitted from point A(x'_A) towards point B, at time τ'_1 . Let this pulse be received at point B(x'_B) at time τ'_2 . The up-link signal propagation time in reference frame K' is, therefore given by,

$$T'_u = \tau'_2 - \tau'_1 \quad (10)$$

Let a return laser pulse be transmitted from point B(x'_B) at time τ'_3 , towards point A. Let this return pulse be received at point A(x'_A) at time τ'_4 . The down-link signal propagation time in reference frame K' is then given by,

$$T'_d = \tau'_4 - \tau'_3 \quad (11)$$

As per Einstein synchronization convention (e-synchronization) for two identical clocks A and B, which are stationary in reference frame K' , the up-link signal propagation time T'_u will be equal to the down-link signal propagation time T'_d .

$$T'_u = T'_d = \frac{D'}{c} \quad (12)$$

But for an observer in the stationary reference frame K , the moving clocks A and B will appear to be not synchronized. Hence, for this stationary observer, the up-link signal propagation time T_u will not be equal to the down-link signal propagation time T_d as measured in reference frame K . Using the Lorentz transformation between the reference frames K and K' , we can compute the values of T_u and T_d . For this we have to first transform the instantaneous timing values τ'_1 , τ'_2 , τ'_3 and τ'_4 in reference frame K' to the corresponding timing values t_1 , t_2 , t_3 and t_4 in reference frame K as follows,

$$t_1 = \gamma \left(\tau'_1 + \frac{U * x'_A}{c^2} \right) \quad (13)$$

$$t_2 = \gamma \left(\tau'_2 + \frac{U * x'_B}{c^2} \right) \quad (14)$$

$$t_3 = \gamma \left(\tau'_3 + \frac{U * x'_B}{c^2} \right) \quad (15)$$

$$t_4 = \gamma \left(\tau'_4 + \frac{U * x'_A}{c^2} \right) \quad (16)$$

$$\text{Therefore, } T_u = t_2 - t_1 = \gamma \left[(\tau'_2 - \tau'_1) + \frac{U * (x'_B - x'_A)}{c^2} \right]$$

$$= \gamma \left[T'_u + \frac{U * D'}{c^2} \right] \quad (17)$$

$$\text{And } T_d = t_4 - t_3 = \gamma \left[(\tau'_4 - \tau'_3) + \frac{U * (x'_A - x'_B)}{c^2} \right] \\ = \gamma \left[T'_d - \frac{U * D'}{c^2} \right] \quad (18)$$

Hence from equations (17), (18) and (12),

$$c * T_u = \gamma [c * T'_u + U * (D' / c)] \\ = \gamma [c * T'_u + U * T'_u] = \gamma (c + U) T'_u \quad (19)$$

$$\text{And } c * T_d = \gamma [c * T'_d - U * (D' / c)] \\ = \gamma [c * T'_d - U * T'_d] = \gamma (c - U) T'_d \quad (20)$$

Subtracting equation (20) from (19),

$$c(T_u - T_d) = \gamma c(T'_u - T'_d) + \gamma U(T'_u + T'_d) \\ = \gamma U(T'_u + T'_d) \quad (21)$$

Adding equations (19) and (20)

$$c(T_u + T_d) = \gamma c(T'_u + T'_d) + \gamma U(T'_u - T'_d) \\ = \gamma c(T'_u + T'_d) \quad (22)$$

Dividing equation (21) by equation (22) to eliminate $(T'_u + T'_d)$ we get,

$$\frac{U}{c} = \left[\frac{T_u - T_d}{T_u + T_d} \right] \quad (23)$$

That is, in an inertial reference frame K , the velocity of two co-moving objects A and B (along AB) is proportional to the difference between their up-link and down-link signal propagation times $(T_u - T_d)$ as measured in that frame.

Here the signal propagation times T_u and T_d have not been physically 'measured' in the stationary reference frame K but only 'computed' through Lorentz transformation, from the T'_u and T'_d values physically measured in the local frame K' . In principle, the clocks at locations A and B can be simultaneously viewed as 'in motion' in many inertial reference frames K , K_1 , K_2 ...etc. in relative uniform motion. But the physical measurements or the digital time readouts of their proper time, like τ'_1 , τ'_2 , τ'_3 , τ'_4 will correspond to only one reference frame in which the two clocks had been at 'rest' and e-synchronized. This means that equation (23) cannot be used for detecting the motion of two co-moving clocks A and B in stationary reference frame K , because T_u and T_d values cannot be computed from the physically measured values T'_u and T'_d without knowing the relative velocity between K and K' beforehand. The inability to directly measure the signal propagation times T_u and T_d in the stationary reference frame K , is not due to any technological limitations, but is a logical consequence of the relativity of time and the corresponding clock synchronization constraints, induced by the second postulate of SR. Therefore, if we begin by assuming the

validity of the second postulate of SR, we cannot detect absolute motion because successful detection of such absolute motion will itself invalidate the second postulate of SR.

III. DETECTION OF ABSOLUTE MOTION IN THE UNIVERSAL REFERENCE FRAME

From the foregoing discussion, we can develop a simple experimental technique to measure the ‘absolute’ velocity of two objects A and B, fixed on the surface of earth, on the basis of Newtonian notion of absolute time. Even though the objects A and B under consideration are fixed on the surface of earth, we can imagine their motion through space in our solar system or in our galaxy. Let us assume the speed of light propagation to be an isotropic constant c in a particular inertial reference frame K. Let U_{ab} be the common velocity of A and B along the direction AB as measured in K. The magnitude of U_{ab}/c will be given by the ratio of the difference between the up-link and down-link signal propagation times to the total round trip propagation time (equation 7), as measured with two mutually synchronized identical precision atomic clocks at A and B.

A. Selection of Test Equipment

For planning **part I** of this experiment, we need to select two microwave communication towers (or two hill features or two tall buildings), separated by a distance of about 30 km along **west to east** direction, as the two objects A and B mentioned above. Exact distance between A and B is not required to be measured. Since the determination of up-link and down-link signal propagation times between A and B will require line of sight communication, we need to position identical sets of test equipment at about 20 m height, on each of the two towers (or buildings). For **part II** of this experiment, we need to select two objects A and B as above but separated by a distance of about 30 km along **south to north** direction. Each set of the test equipment required at both ends, consists of:

- (a) Diode-Pumped Solid State Pulsed Laser – with 1064 nm wavelength, about one mJ pulse energy, one ns pulse width, collimated beam and single shot pulse option. Some commercially available Lasers in this category are:
 - PULSELAS-P-1064-100-HE ³
 - picoREGEN : SC-1053-3000 HE ⁴
- (b) Laser Detector with focusing optics – Solid State, Silicon Photomultiplier detector. The detector consists of an array of Geiger Mode Avalanche Photo diodes (APDs), each individually coupled to integrated quench electronics. A typical commercially available APD in this category is:
 - SPMMicro: Low Cost High Gain APD ⁵
- (c) Precision Timing System – Cesium Atomic Clock with a precision Rubidium Oscillator. Such a

Cesium Atomic Clock - 5071A, is commercially available from Symmetricom, ⁶ which delivers unsurpassed accuracy, stability and reliability for demanding laboratory and field applications. In addition a patented SRO-100 (Synchronized Rubidium Oscillator) with Auto-Adaptive SmarTiming+ technology at 1ns resolution, is available from SpectraTime. ⁷

- (d) High Precision Event Timer – Measures instant times when events occur. One such Event Timer that is commercially available, is: RIGA Event Timer A032-ET ⁸
- (e) Data Acquisition Computer

As per the Sixteenth International Workshop on Laser Ranging, ⁹ held in October 2008, significant advancements have been made in laser technology, especially in the field of Satellite Laser Ranging. As such, many options are available for selection of a suitable Laser System for the proposed experiment. Of these, a sub-nanosecond Passively Q-Switched Microchip Solid-State Laser, with suitable collimation optics, from ALPHALAS appears to be most suited for the proposed experiment. The Cesium Primary Frequency Standard - 5071A from Symmetricom, with Rubidium Oscillator from SpectraTime is the crucial technology input for the conduct of this experiment on the surface of earth. As per SpectraTime, “*The patented SRO-100 is the industry’s first smart Rubidium clock, integrating complex synchronization functionality all in one low-cost, super-small package. The SRO intelligently synchronizes, disciplines, and controls any Stratum-1 reference such as GPS, Cesium and Hydrogen Maser, at cutting-edge 1 ns resolution*”. The cutting-edge technology has now advanced into the picosecond range as claimed in an article “Space clocks and fundamental tests: The ACES experiment”. ¹⁰ Since there is no requirement to handle the scattered laser pulses or to develop an image from the returned pulses in the proposed experiment, it should be possible to optimize the size, weight and cost of the assembly.

To some extent a similar experiment was proposed by A. I. Kozynchenko in his article “*The terrestrial one-way experiment on measuring the absolute velocity of the Earth using two atomic clocks*” ¹¹. That experiment involved the use of two non-synchronized clocks, separated by distance D on the same latitude. Short light pulses emitted at equal time intervals from one clock site were measured at the second clock site during twenty-four hours to retrieve the pair wise differences in the one way light propagation times (ΔT_u). Analysis of this timing data was expected to yield quantitative information on the equatorial component of the absolute velocity of earth. However, accurate discrimination between the pair wise differences in one way propagation times (ΔT_u) required much better time resolutions than currently available in atomic clocks. Further, being a one-way experiment on

the surface of earth, its accuracy could be severely hampered by the variations in one way light propagation time delays due to atmospheric pressure, temperature, humidity and wind effects.

B. Layout Configuration

Before commencement of the main experiment, the two sets of test equipment will be positioned close by, say at a separation distance of about one meter, to mutually synchronize and calibrate their clocks and to monitor their system delays. In this close by position, the synchronization and calibration checks may be continued for at least 24 hours to eliminate any systematic errors. At any instant when the time on one clock is t_1 , if the second clock reads t_1 with about one ns accuracy, the two clocks can be regarded as mutually synchronized for the purpose of this experiment. Thereafter, one set of test equipment will be positioned on each of the two towers (or buildings) at about 20 m height from the ground. The system will be aligned with a telescope, in such a way that the laser beam from point A is focused on the photo detector at point B (Figure 2.) and the laser beam from point B is focused on the photo detector at point A.

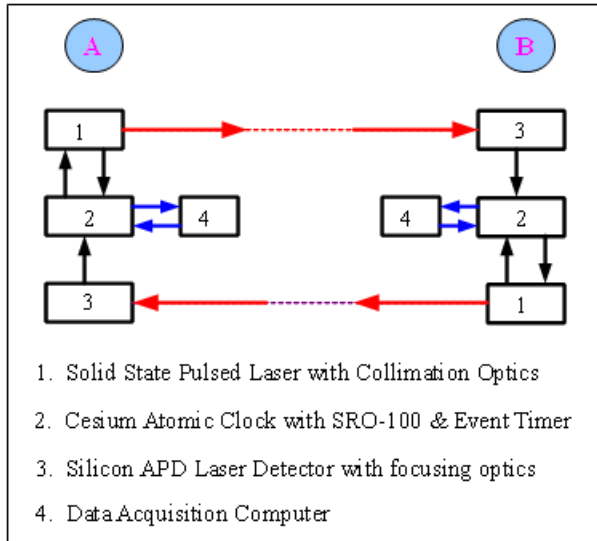


FIG. 2. Schematic layout of test equipment for detection of absolute motion

An important part of this experiment consists of mutual synchronization of the two clocks. Keeping in view various theoretical and practical problems associated with mutual synchronization of two precision atomic clocks, we may not be able to achieve a ‘perfect’ synchronization between them. Hence we shall take into account some finite but constant synchronization error or time offset that may persist, in spite of our best efforts to achieve perfect synchronization between the two clocks. To elaborate, let us assume that at a certain instant of time $t_1(\text{UTC})$, clock A reads T_{a1} and clock B reads T_{b1} such

that the reading of clock B is offset or lags behind clock A by an amount T_{SE} due to the synchronization error. Therefore,

$$T_{a1} - T_{b1} = T_{SE} \quad (24A)$$

Similarly, at certain other instants of time t_2 , t_3 and t_4 , clock A readings (T_{a2} , T_{a3} , T_{a4}) and clock B readings (T_{b2} , T_{b3} , T_{b4}) will be mutually offset by the synchronization error as,

$$T_{a2} - T_{b2} = T_{SE} \quad (24B)$$

$$T_{a3} - T_{b3} = T_{SE} \quad (24C)$$

$$T_{a4} - T_{b4} = T_{SE} \quad (24D)$$

Since we are going to account for the synchronization error T_{SE} in the result, we shall use two high precision, ultra-stable, Cesium atomic clocks as independent primary time standards, synchronize and calibrate them in the close by position and then separate them to the selected locations. After synchronizing the clocks in close by position, the synchronization error T_{SE} introduced by the process of shifting them to their respective positions is not expected to be more than one ns. Even if the synchronization error happens to be considerably more than expected, in part I of the experiment (west to east orientation) it will get segregated in the data set mean value over a 24 hour period, as a constant shift from zero (fig. 3).

However, it may be emphasized here that any synchronization offset T_{SE} , induced by the process of separation of the two clocks, will remain constant during the actual conduct of the experiment. That is because mutual synchronization of two clocks fixed or moving at common uniform speed with respect to ECI frame, will hold good provided they are located at same gravitational potential. Since the two clocks A and B are fixed on the ground at same gravitational potential and have no relative velocity in the ECI frame their mutual synchronization, with constant offset, will be maintained during the conduct of the experiment. Further, all constant hardware delays and atmospheric signal propagation delays will get cancelled out in the computation of $(T_u - T_d)$ in equation (7). All other errors, including random hardware delays, earth rotation effects and wind effects are expected to remain within one ns and are considered negligible.

An alternative approach of synchronizing the two clocks A and B to the common UTC time through GPS service, is not considered suitable for the proposed experiment. The path lengths of the communication links from GPS satellite to the two clocks are expected to get differentially affected by the Sagnac effect associated with their absolute motion, thereby producing an absolute velocity dependent synchronization offset between the two clocks. A continuous or repeated synchronization of the two clocks with the GPS time will have the effect of repeatedly adjusting their synchronization offsets and thus

obscure the detection of up-link (T_u) and down-link (T_d) timing differentials.

C. Conduct of the Experiment

For conducting this experiment, the Solid State Pulsed Laser is to be operated in a single shot mode. In this mode the electrical pulse from the controller or Event Timer will trigger the Laser at point A to send out a short laser pulse towards point B. The emission of laser pulse at point A will trigger the clock time readout (T_{a1}) at A. This time readout, will get recorded in the data acquisition computer at A. When the laser pulse transmitted from point A, reaches the photo detector at B, it will be captured by the detector to produce a trigger pulse for the time readout (T_{b2}) at point B. This time readout, will get recorded in the data acquisition computer at B. The two computers located at points A and B, may be interconnected through a computer network. The difference between these two time readouts will provide the 'measured' pulse propagation time ($T_u = T_{b2} - T_{a1}$) from points A to B. But the true pulse propagation time ($T_{a2} - T_{a1}$) is different from this measured propagation time due to the synchronization error offset as,

$$T_{a2} - T_{a1} = T_{b2} + T_{SE} - T_{a1} = T_u + T_{SE} \quad (25)$$

Therefore, the distance traveled by the up-link laser pulse given by equation (3), will get modified to,

$$\begin{aligned} D + U_{ab}(T_{a2} - T_{a1}) &= c(T_{a2} - T_{a1}) \quad \text{or,} \\ D + U_{ab}(T_u + T_{SE}) &= c(T_u + T_{SE}) \end{aligned} \quad (26)$$

After a preset time delay from T_{b2} , say one second, an electrical pulse from the Event Timer at B will trigger the Laser at point B to send out a short laser pulse towards point A. The emission of a laser pulse at B will trigger the clock time readout (T_{b3}) at B. This time readout, will get recorded in the data acquisition computer at B. When the laser pulse transmitted from B reaches the photo detector at A, it will be captured by the detector to produce a trigger pulse for the clock time readout (T_{a4}) at point A. This time will get recorded in the data acquisition computer at A. The difference between these two time readouts will provide the 'measured' pulse propagation time ($T_d = T_{a4} - T_{b3}$) from points B to A. But the true pulse propagation time ($T_{a4} - T_{a3}$) is different from this measured propagation time due to the synchronization error offset as,

$$T_{a4} - T_{a3} = T_{a4} - (T_{b3} + T_{SE}) = T_d - T_{SE} \quad (27)$$

The distance traveled by the down-link laser pulse, as given by equation (6), will get modified to,

$$\begin{aligned} D - U_{ab}(T_{a4} - T_{a3}) &= c(T_{a4} - T_{a3}) \quad \text{or,} \\ D - U_{ab}(T_d - T_{SE}) &= c(T_d - T_{SE}) \end{aligned} \quad (28)$$

Eliminating D from equations (26) and (28), we get:

$$U_{ab}(T_u + T_d) = c(T_u - T_d + 2T_{SE}) \quad (29)$$

$$\text{Or,} \quad \frac{U_{ab}}{c} = \frac{T_u - T_d + 2T_{SE}}{T_u + T_d} \quad (30)$$

Similarly, after a preset time delay from T_{a4} , say one second, an electrical pulse from the Event Timer at A will trigger the Laser at point A to send out a short laser pulse towards B. The emission of a laser pulse at A will trigger the clock time readout (T_{a5}) at A. This up-link and down-link pulse propagation process could go on repeating automatically with the corresponding timing data getting stored in the two data acquisition computers at points A and B. As discussed above, the magnitude of U_{ab}/c will be given by the ratio of the difference between the up-link and down-link signal propagation times to the total round trip signal propagation time as per equation (30).

Apart from constant time offset T_{SE} , if the two atomic clocks at points A and B experience some extraneous but common influence that affects their clock rates, it will not influence the final result of the experiment. Assuming that the clock rate of the two clocks A and B used in the experiment does somehow get affected, then it is understandable that while measuring a standard time interval t_1 with the affected clocks, we may get that time interval as $k.t_1$ in place of t_1 . Here the rate factor k is assumed to be different from unity (say 0.999 or 1.001). Accordingly the value of measured up-link and down-link signal propagation times T_u and T_d given by equations (1) and (4), will now change to $k.T_u$ and $k.T_d$ respectively. But in the final result given by equation (7), the rate factor k will get cancelled out and hence the outcome of this experiment will be immune to such clock rate variations.

D. Data Analysis

For a separation distance D of about 30 km, the pulse return propagation time ($T_u + T_d$) will be of the order of 200,000 nanoseconds. The orbital velocity of earth is about 30 km/s and the orbital velocity of our solar system around the Galactic center is about 220 km/s. Further, our milky way galaxy is estimated to be in motion with respect to the CMBR frame at about 500 km/s. Therefore, the absolute velocity U of the earth in the Universal reference frame, will be a vector sum of all these velocities and may be in the range of 300 to 600 km/s. Since the rotational velocity of earth (about 0.46 km/s) will not make any significant difference on the absolute velocity U (say 450 km/s) in the Universal Reference Frame, the velocity vector U can be treated as a constant vector in space. The expected value of ($T_u - T_d$) in equation (30) can be in the range of 100 ns to 200 ns. With the selected test equipment, as described above, we can surely detect the up-link and down-link timing differences of the order of 100 to 200 nanoseconds.

Let us assume that at the commencement of part I of the proposed experiment, when the two clocks A and B are aligned along west to east direction at latitude L , the line segment AB makes an angle θ_E with the absolute velocity vector U . Then the component of U along AB will be given by,

$$U_{ab} = U \cdot \cos(\theta_E) \quad (31)$$

To be more specific, let us consider an XYZ coordinate system with a north pointing Z-axis located on the earth's axis and the XY plane, containing the line segment AB, passing through the latitude circle with center O. Let us assume that the absolute velocity vector U makes an angle δ with the positive Z-axis and we choose the direction of X-axis such that vector U is contained in XZ plane. Further, let us assume that at any instant t , with line segment AB pointing towards east on the latitude circle, the position vector OA of clock A makes an angle ϕ with the X-axis. In this configuration the direction cosines of vector U are $[\sin(\delta), 0, \cos(\delta)]$ and the direction cosines of the line segment AB are given by $[-\sin(\phi), \cos(\phi), 0]$. From these direction cosines, $\cos(\theta_E)$ will be given by,

$$\cos(\theta_E) = -\sin(\delta)\sin(\phi) \quad (32)$$

From equations (30), (31) and (32) we get,

$$T_u - T_d = -\frac{U}{c}(T_u + T_d)\sin(\delta)\sin(\phi) - 2T_{SE} \quad (33)$$

As the line segment AB turns around the Z-axis during the rotational motion of the earth, $\cos(\theta_E)$ will oscillate between $-\sin(\delta)$ and $+\sin(\delta)$ during a 24 hour cycle. The rotational angle ϕ can be expressed in terms of sidereal time t in seconds as,

$$\phi = \frac{2\pi t}{86164} \quad (34)$$

With this value of ϕ , equation (33) can be rewritten as,

$$T_u - T_d = -\frac{U}{c}(T_u + T_d)\sin(\delta)\sin\left(\frac{2\pi t}{86164}\right) - 2T_{SE} \quad (35)$$

From a 48 hour recorded data of T_u and T_d pairs, a typical diurnal variation of $(T_u - T_d)$, as indicated by equation (35), is illustrated at figure 3. Maximum amplitude of the sinusoidal variation of $(T_u - T_d)$ curve, marked A_e in figure 3, can be actually measured from the data plot. This measured value A_e of the sinusoidal amplitude, represents a significant term from equation (35) as,

$$A_e = (U/c)(T_u + T_d)\sin(\delta)$$

$$\text{Or, } U \cdot \sin(\delta) = \frac{c \cdot A_e}{(T_u + T_d)} \quad (36)$$

This is an important result derived from a minimum of 24 hour recorded data of up-link (T_u) and down-link (T_d) signal propagation times measured during part I of the experiment. The mean value of the sinusoidal plot, marked 'Sync. Offset' in figure 3 represents $(-2T_{SE})$ in

equation (35) and effectively segregates the synchronization error offset T_{SE} .

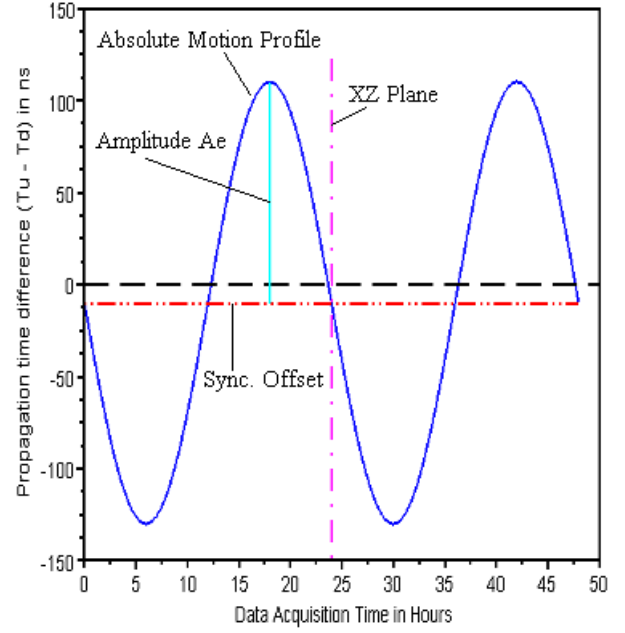


FIG. 3. Diurnal variation of 'to and fro' signal timing difference $(T_u - T_d)$ in East-West orientation.

For the part II of the proposed experiment, when the two clocks A and B are aligned along south to north direction at latitude L , let us assume the line segment AB makes an angle θ_N with the absolute velocity vector U . Then the component of U along AB will be given by,

$$U_{ab} = U \cdot \cos(\theta_N) \quad (37)$$

In the XYZ coordinate system considered above, direction cosines of the velocity vector U remain same $[\sin(\delta), 0, \cos(\delta)]$ as in part I of the experiment. However, the direction cosines of the line segment AB, aligned along south to north direction, will be $[-\sin(L)\cos(\phi), -\sin(L)\sin(\phi), \cos(L)]$. From these direction cosines of U and the line segment AB, cosine of their included angle θ_N will be given by,

$$\cos(\theta_N) = -\sin(\delta)\sin(L)\cos(\phi) + \cos(\delta)\cos(L) \quad (38)$$

From equations (30), (37) and (38) we get,

$$T_u - T_d = \frac{U}{c}(T_u + T_d)\{\cos(\delta)\cos(L)\} - 2T_{SE} - \frac{U}{c}(T_u + T_d)\{\sin(\delta)\sin(L)\cos(\phi)\} \quad (39)$$

Substituting the value of ϕ from equation (34) in equation (39) we get,

$$T_u - T_d = \frac{U}{c}(T_u + T_d)\{\cos(\delta)\cos(L)\} - 2T_{SE} - \frac{U}{c}(T_u + T_d)\left\{\sin(\delta)\sin(L)\cos\left(\frac{2\pi t}{86164}\right)\right\} \quad (40)$$

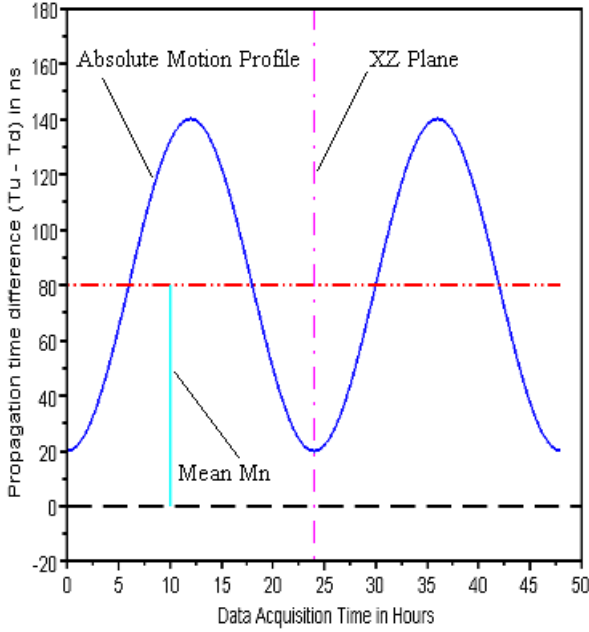


FIG. 4. Diurnal variation of ‘to and fro’ signal timing difference ($T_u - T_d$) in North-South orientation.

From a 48 hour recorded data of T_u and T_d pairs, a typical diurnal variation of $(T_u - T_d)$, as indicated by equation (40), is illustrated at figure 4. Mean value of the sinusoidal variation of $(T_u - T_d)$ curve, marked M_n in figure 4, can be actually measured from the data plot. This measured value M_n of the mean value represents a significant term from equation (40) as,

$$M_n = \frac{U}{c} (T_u + T_d) \{ \cos(\delta) \cos(L) \} - 2T_{SE} \quad (41)$$

Making use of the estimated value of synchronization offset T_{SE} from part I of the experiment, known value of the latitude L of the test site and the measured mean M_n derived from a minimum of 24 hour recorded data of signal propagation times measured during part II of the experiment, we get,

$$U \cos(\delta) = \frac{c(M_n + 2T_{SE})}{(T_u + T_d) \cos(L)} \quad (42)$$

From equations (36) and (42) we can separate the magnitude of absolute velocity U and its spatial direction δ as,

$$\tan(\delta) = \frac{A_e \cos(L)}{M_n + 2T_{SE}} \quad (43)$$

And

$$U = \frac{c}{(T_u + T_d) \cos(L)} \sqrt{(M_n + 2T_{SE})^2 + (A_e \cos(L))^2} \quad (44)$$

From equations (33) and (39) we can locate the XZ plane represented by $\phi=0$, which represents the polar plane containing the absolute velocity vector U . In figures 3 and 4, this plane is identified from the corresponding phase change in the diurnal variation plots and is marked by vertical dotted lines labeled XZ plane in these figures. The corresponding Right Ascension angle can be determined from the test site longitude and date, time (sidereal) parameters associated with the location of these dotted lines representing polar plane of the absolute velocity vector. The Declination angle of the vector U can be obtained from the angle δ computed above. The unique absolute velocity vector U thus determined, will establish a preferred or Universal Reference Frame K in which the speed of light propagation c is an isotropic universal constant.

The simplified experimental test described above can be conducted by any space agency, research center or academic institution provided they have the technical competence and necessary resources for undertaking this challenging task. The proposed method of detecting absolute motion in space is considered unique, the like of which has not been conducted by anyone as yet. It is unique in the following respects.

- (a) There is no attempt to measure the one-way or two-way speed of light.
- (b) There is no need to measure the distance between two points A and B.
- (c) There is no dependence on the wave properties of light for measuring any interference effects or fringe shifts. It does not involve any reflection of waves from moving mirrors.
- (d) For detecting absolute motion in space, we only need to measure the up-link (T_u) and down-link (T_d) signal propagation times between two locations A and B.
- (e) The result depends on the difference between T_u and T_d , due to which the hardware delays and atmospheric signal propagation delays get canceled out and do not influence the result.

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