Comparing Spinning Mossbauer, GPS, and VLBI Experiments

Ronald R. Hatch
Global Positioning System Consultant
1142 Lakme Ave.
Wilmington, CA 90744
Pacific Division of AAAS, San Francisco State University, June 19-23, 1994

Abstract

Spinning Mossbauer experiments, with gamma ray source and detector on a spinning disk, are frequently cited as providing strong evidence in support of the special theory. However, as Hayden has shown, the claims are generally based upon two separate phenomena. Ruderfer suggested that one could detect the variation of the transit time across either the radius or diameter of the spinning disk if an ether wind were present. Turner and Hill looked for a change in the frequency of the gamma rays as a function of the source velocity. If an ether wind were present, then a modulation of the frequency with the spin would presumably appear. Ruderfer, in an erratum, pointed out that the two effects would cancel and render the experiment incapable of detecting an ether wind. In spite of this erratum, the claims are repeatedly found in the literature that the spinning Mossbauer experiments support the special theory. They do not. They are simply moot on the subject.

The Global Positioning System (GPS) constitutes a large scale near-equivalent to the spinning Mossbauer experiments. The transit time between the satellite and ground-based receivers is routinely measured. In addition, the atomic clocks on the satellite are carefully monitored; and high precision corrections are provided as part of the information transmitted from the satellites. Because the satellites and the receivers rotate at different rates (unlike the Mossbauer experiments), a correction for the motion of the receiver during the transit time is required. This correction is generally referred to as a Sagnac correction, since it adjusts for an anisotropy of the speed of light as far as the receiver is concerned. Why is there no requirement for a Sagnac correction due to the earth's orbital motion? Like the transit time in the spinning Mossbauer experiments, any such effect would be completely canceled by the orbital velocity.

The Very Long Baseline Interferometry (VLBI) experiments extend the phonomena of interest to aberration effects as well as the Sagnac effect.

Introduction

The spinning Mossbauer experiments are cited in a multitude of texts as supporting the special theory of relativity by showing that there is no detectable ether drift in the laboratory. But such claims are hollow. If it were possible to refute ether drift in such a simple fashion, it would be one of the simplest experimental contradictions to Poincare's principle that one could imagine. Indeed, Howard Hayden [1] has shown the fallacy of such claims, and his argument showing that the spinning Mossbauer experiments are moot about the presence (or absence) of ether drift is largely similar to the development of the next section below.

Analysis of the spinning Mossbauer experiments is a natural step toward analysis of the slightly more complex and much larger-scale Global Positioning System (GPS). There are two differences which must be considered when dealing with the GPS. First, instead of frequencies, the GPS deals with the integrated frequency or difference in transit time. Second, the satellite source and receiver do not rotate at the same rate. But these differences are easily analyzed; and we find that, just as with spinning Mossbauer experiments, the GPS system tells us nothing about the presence or absence of ether drift.

Finally, analysis of the Global Positioning System and its ranging measurements is a natural precursor toward the analysis of the more complicated Very Long Baseling Interferometry (VLBI) range difference measurements. To prevent the equations from becoming too complex, a simplified VLBI system, with the VLBI receivers located at the same latitude, is analyzed. All of the significant features of the more complicated general situation are exhibited by this simplified analysis. As with the prior systems, it is found that the VLBI experiments are moot about the existence or absence of any ether drift. However, there are some significant lessons to be learned in the analysis process.

The Spinning Mossbauer Experiments

Ruderfer [2] was among the first to suggest that the Mossbauer effect could be used to detect an ether drift. The Mossbauer effect allows one to detect very minute differences in the frequency of gamma rays. Ruderfer suggested that one could detect the variation in the transit time of gamma rays across a spinning disk because the time derivative of the transit time would appear as a frequency shift in the gamma ray as a function of path direction.

Ruderfer gave the transit time as:

$$\tau = \frac{\rho}{c - V_{frame}\, Cos\, \theta} \tag{1}$$

where: τ is the transit time

ρ is the distance between source and detector

c is the speed of light

V_{frame} is the local frame velocity through the ether

θ is the direction of the transit path relative to the local frame velocity

Note that the ether-drift velocity through the isotropic-light-speed frame is the negative of the local frame velocity. If the ether frame velocity is used rather than the local-frame velocity and the direction of θ changed to measure the transmission path relative to the ether-drift velocity, the sign of the equation is change.

Equation (1) can be approximated to second order in the inverse speed of light as:

$$\tau = \frac{\rho}{c} + \frac{\rho}{c^2} V_{frame}\, Cos\, \theta \tag{2}$$

The negative of the time derivative of equation (2) gives the apparent change in frequency of the source when it reaches the detector.

$$\left(\frac{\Delta f}{f}\right)_{drift} = \frac{\rho\, \dot{\theta}\, V_{frame}\, Sin\, \theta}{c^2} \tag{3}$$

Equation (3) gives the difference in the expected frequency at the detector compared to the source. But $\rho\dot{\theta}$ is simply the spin velocity of the source (and the detector). If we define θ' as the direction of the spin velocity relative to the drift velocity, then - $Cos\theta'$ is equal to $Sin\theta$ and equation (3) becomes:

$$\left(\frac{\Delta f}{f}\right)_{drift} = -\frac{V_{spin}\, V_{frame}\, Cos\, \theta'}{c^2} \tag{4}$$

Note that equation (3) applies no matter whether the transit path is across the radius or the diameter of the spinning disk. But equation (4) only applies when either the source of the detector is at the center of the spinning disk. If the path is across the diameter of the disk, equation (4) would be doubled.

Several groups have implemented the experiment suggested by Ruderfer (e.g. Hay et al. [3] and Champeney et al. [4]). The ether-drift effect predicted by equation (4) was not detected. Unfortunately, each of the experimenters ignored Ruderfer's erratum [5] in which he stated that a counteracting clock-frequency effect would lead to a null result even in the presence of an ether drift.

Ironically, Turner and Hill [6] ran a similar spinning Mossbauer experiment and claimed a null result. However, they were looking for the clock-frequency effect and ignored the counteracting transit-time effect.

The clock-frequency effect is easily computed, assuming that the velocity through the ether affects the frequency by the amount Lorentz suggested and by the amount Einstein ascribed to the effect of the relative velocity of two observers.

$$f' = f\left(1 - \frac{\left(V_{frame} + V_{spin}\right)^2}{c^2}\right)^{1/2} \tag{5}$$

Equation (5) approximated to second order gives:

$$\left(\frac{\Delta f}{f}\right)_{clock} = -\frac{1}{2}\frac{V_{frame}^2}{c^2} - \frac{V_{spin}\, V_{frame}\, Cos\,\theta'}{c^2} - \frac{1}{2}\frac{V_{spin}^2}{c^2} \tag{6}$$

Clearly, as indicated by Ruderfer, the middle term of equation (6) will cancel the transit-time effect given by equation (4). Note that, as Ruderfer correctly derived, the effects cancel when they are of the same sign and magnitude. When the transit-time effect causes the source frequency to be high, the clock effect causes the absorber to look for a frequency that is high, etc. Thus, the cancellation occurs when the two effects are equal.

The third term of equation (6), due entirely to the spin velocity, is present no matter what drift velocity is present. If the path is across the entire diameter of the disk, the contribution of the third term from the source and detector will always cancel in the spinning Mossbauer experiments.

In conclusion, the spinning Mossbauer experiments do not indicate the absence of any ether drift. They simply indicate that, if an ether drift is present, clocks are slowed as a function of their velocity through the ether. Thus, the results of the Mossbauer experiments are in complete accord with the Lorentz ether theory and with Poincare's principle. They do not contradict the special theory of relativity, but they certainly do not support it to the exclusion of an ether theory.

GPS One-Way Range Measurements

The effect of an ether drift on the GPS one-way range measurements is exactly counteracted by the effect of the ether drift on the receiver clocks. This result is quite similar to the cancellation effects which occur in the Mossbauer spin experiments and implies that GPS range measurements provide no information at all about the isotropy of the speed of light.

#insert figure 1 here

Let us illustrate the canceling effect with some simple geometry. Let a source signal be generated by object A (see Figure 1), which, for the moment, is treated as a GPS satellite. Let the receiver, object B, lie on the earth's surface. Now let the path between A and B (designated by ρ) and the ether-drift velocity through the receiver (object B) define a plane. Assume the ether drift is caused by the earth's orbital motion. The plane defined above will intersect the earth in a small circle. Let the vector r be defined by the earth-radius vector of B projected onto the plane defined above. When measurements are made, assuming a non-rotating earth-centered frame and no ether drift, the transit time, τ, is given by:

$$\tau = \frac{\rho}{c} \tag{7}$$

where: ρ is the range from the source at time of transmission to the receiver at time of reception
c is the speed of light

The computed range is then:

$$R_{ab} = c\tau = \rho \tag{8}$$

Now, when an ether drift is allowed as in Figure 1, the transit time will become:

$$\tau_{ab} = \frac{\rho}{c - v_o \, Cos\,\theta} \approx \tau + \frac{\rho v_o \, Cos\,\theta}{c^2} \tag{9}$$

where: v_o is the velocity of movement through the ether (minus ether-drift velocity)
θ is the angle which the ray makes with respect to movement through the ether

But ρ Cos θ is simply the component of ρ in the up-wind direction. Thus:

$$\tau_{ab} \approx \tau + \frac{\rho \cdot v_o}{c^2} \tag{10}$$

The last term in equation (10) indicates that the range will be measured as a larger value in the presence of an ether drift—unless there is some offsetting factor. But the change in clock rates in an ether-drift field contribute just such an offsetting factor.

The effect on time, which the special theory claims is caused by relative velocity, is ascribed by most anti-relativists to an effect on clocks caused by the velocity of the clock relative to the isotropic light-speed frame. Now, if we make this assumption, the clock rate for any clock moving with respect to the earth's center (assuming a sun-centered frame and an ether drift from the orbital velocity) is:

$$f' = f\sqrt{1 - \frac{(v_o + v_s)^2}{c^2}} \tag{11}$$

where: v_o is the earth's orbital velocity
v_s is the velocity with respect to the earth's center

Thus:

$$\frac{\Delta f}{f} \approx -\frac{(v_o + v_s)^2}{2c^2} \tag{12}$$

Expanding:

$$\frac{\Delta f}{f} \approx -\frac{v_o^2}{2c^2} - \frac{v_s^2}{2c^2} - \frac{v_o \cdot v_s}{c^2}$$

The first term is a simple constant clock-rate term that affects all of the clocks equally since they all are moving with the earth's orbital speed. Thus, it can be ascribed to clock design and the rate adjusted appropriately. The second term can also be ascribed to clock design if the moving clock is always moving at a constant speed (such as clocks at a fixed location on the earth and clocks in circular orbit around the earth). If a clock is moved at a variable speed and used to synchronize other clocks via slow transport, the second term can be made arbitrarily small. But the last term does contribute to a clock bias term as a function of the clock position. The clock bias is given by the integral of the last term in equation (13). If the orbital velocity is assigned the direction of the X axis, then the component of v_s in the direction of the orbital velocity is given by dx/dt and the clock-bias term is given by:

$$\Delta clock = -\frac{v_o}{c^2}\int \frac{dx}{dt}\,dt = -\frac{v_o\,x}{c^2} \tag{14}$$

This means that the clock bias due to the ether drift at the receiver will be:

$$\Delta clock(B) = -\frac{r \cdot v_o}{c^2} \tag{15}$$

and the clock bias at the source:

$$\Delta clock(A) = -\frac{r \cdot v_o}{c^2} + \frac{\rho \cdot v_o}{c^2} \tag{16}$$

These clock biases will affect the measured transit time of the signal. To get the new transit time, the transit time in equation (10) must be modified by adding the clock bias at the receiver (B) and subtracting the clock bias at the source (A). This gives:

$$\tau_{ab} \approx \tau + \frac{\rho \cdot v_o}{c^2} - \frac{p \cdot v_o}{c^2} \approx \tau \tag{17}$$

Is it proper to conclude that there is no way to tell whether the local gravitational region determines the speed of light? For GPS satellites in orbit around the earth, the answer is yes. One-way range measurements cannot determine the absence or presence of ether drift.

VLBI and One-Way Speed-of-Light Range Differences

The first step in extending the GPS analysis in the above section to the VLBI situation is to add a second receiver and consider only the time difference in the two transit times. The use of a nearby source will help to clarify the phenomena involved. If the geometry is simplified a bit by assuming the second receiver is in the same plane defined above, it is easy to see from equation (10) that the measured time difference in the presence of an ether drift (motion through an isotropic light-speed frame) is just:

#insert figure 2 here

$$\tau = \frac{\rho_1}{c} - \frac{\rho_2}{c} + \frac{\rho_1 \cdot v}{c^2} - \frac{\rho_2 \cdot v}{c^2} = \frac{\Delta\rho}{c} + \frac{b \cdot v}{c^2} \qquad (18)$$

where: ρ_1 is the range to the up-wind receiver
ρ_2 is the range to the down-wind receiver
b is the baseline vector between the two receivers
v is the velocity through the isotropic frame
$\Delta\rho$ is the difference in the two ranges

But it is also clear from equation (15) that the clock biases induced by their motion through the isotropic frame will contribute an effect which will cancel the last term. Thus:

#insert equation 19 here

Any effect of the source clock is canceled in the range-differencing process. The last term in equation (18) is composed of two physical effects. This becomes more obvious if equation (18) is derived in another fashion.

Using the angles defined in Figure 2, the transit time from the source to receiver 1 is:

#insert equation 20 here

In like manner the transit time to the second receiver is:

#insert equation 21 here

Expanding the sine of the sum of two angles in each case and taking the difference of these two equations gives:

#insert equation 22 here

Since the angle, δ, defines the path from the source to the midpoint of the baseline in Figure 2, it is possible to make a geometric substitution into equation (22) to get:

#insert equation 23 here

The second and third terms of equation (23) can be interpreted as separate physical effects. The second term is just the decrease in the differential transit time which arises due to the receiver motion after a wave-front reaches one receiver and before it reaches the other receiver. This effect is often referred to as the Sagnac effect. The third term is due to the differential light speed along the two paths. It causes the wave-front to be bent as if it is encountering a negative stellar aberration effect. These two terms will be addressed again later; but, first, the derivation is completed to show the result agrees with that obtained in equation (18).

Expanding the sine and cosine of the angle difference above gives:

#insert equation 24 here

The second and fourth terms combine, and the third and fifth terms cancel. The result is the same as equation (18). And, as was already shown in equation (19), this ether-drift effect cancels the clock-bias term.

Now let's return to the physical explanation for the terms in equation (23). If the directional dependence of the relative light speed gives rise to an orbital Sagnac effect, together with a negative aberrational wave-front bending effect, then the clock-bias effect, which was shown to cancel it in the GPS section above, must be equivalent to a negative of an orbital Sagnac effect, together with an aberrational wave-front bending effect.

The quasar source plays no fundamental role in the analysis of effects. As stated earlier, any source-clock effects cancel out in the differencing process. Therefore, it is not significant which frame is ascribed to the source. Furthermore, from the geometry it becomes clear that the ether-drift effects are not a function of the distance to the quasar. Only the separation distance between the two receivers affects the ether-drift results.

At this point it is appropriate simply to report what the experimenters have done in order to get agreement between the earth-centered isotropic frame results and the sun-centered isotropic frame results. The relativists do apply the Sagnac effect to receivers which are moving with respect to the chosen frame of reference. In the sun-centered frame, an adjustment is made for the orbital and spin motion of the second receiver after the signal is received at the first receiver. In the earth-centered frame, no orbital Sagnac effect is applied; but a spin Sagnac effect is. A second adjustment which the practitioners make is to apply aberrational effects if the chosen frame is moving with respect to the source. (They assume the quasar source is in the sun's frame.) But they do not apply aberration when it is the receiver rather than the frame which is moving, since this rain-drop aberration (receiver moving with respect to the isotropic-light-speed frame) is unknown in special relativity and, in any case, the VLBI dish antennas would not be affected by this ray-bending-only type of aberration.

With these adjustments, the special theory advocates get the same VLBI results in the earth-centered frame as thy get in the sun-centered frame. The orbital Sagnac effect goes away; but, in its place, an abberational bending effect is added. Note that this difference can be blamed on the clock bias between the two isotropic-light-speed frames. As shown above, the clock bias causes a wave-front bending aberrational effect and the negative of an orbital Sagnac effect. Thus when the bias is added to the results in the sun-centered frame it cancels the orbital Sagnac effect and induces the wave-front bending aberrational effect.

Note the options which are available: (1) the VLBI data does give valid solutions in the absolute simultaneity sun-centered frame; (2) the VLBI data does fit an earth-centered absolute simultaneity frame if aberrational bending can be explained; and, (3) the VLBI data does give valid solutions using the frame of the cosmic background radiation if clocks are slowed by their velocity through that frame. Since the sun-centered frame is essentially moving at a constant velocity relative to the cosmic background frame, it is very difficult to detect the differences between options (1) and (3). The aberration of the quasar sources would be different in the two frames; but, since the aberration changes so very slowly, it would be hard to detect. Option (2) is the option which was proposed in *Escape from Einstein*, [7] but I have been forced to abandon that choice since I cannot find any mechanism by which the required aberrational bending can be generated. I now believe that option (3) is the correct option.

References

1. Hayden, Howard C. (1992) "Rotating Mossbauer Experiments and the Speed of Light," *Galilean Electrodynamics*, Vol. 3, No. 6, Nov.

2. Ruderfer, Martin, (1960) "First-Order Terrestrial Ether Drift Experiment Using the Mossbauer Radiation," *Physical Review Letters*, Vol. 5, No. 5, Sept. 1, pp 191-192.

3. Hay, H.J., et al., (1960) "Measurement of the Red Shift in an Accelerated System Using the Mossbauer Effect in Fe^{56}," *Physical Review Letters*, Vol. 4, No. 4, Feb. 15, pp 165-166.

4. Champeny, C.G., G.R. Isaak, A.M. Khan, (1963) "An Aether Drift Experiment Based on the Mossbauer Effect," *Physics Letters*, Vol. 7, No. 9, 1 Nov., p 361.

5. Ruderfer, Martin, (1961) "Errata—First-Order Terrestrial Ether Drift Experiment Using the Mossbauer Radiation," *Physical Review Letters*, Vol. 7, No. 9, 1 Nov., p 361.

6. Turner, K.C., and H.A. Hill, (1964) "New Experimental Limit on Velocity-Dependent Interactions of Clocks and Distant Matter," *Physical Review*, Vol. 134, No. 1B, 13 April, pp B252-B256.

7. Hatch, Ronald, (1992) *Escape from Einstein*, Kneat Kompany, Wilmington, CA.