# A Local-Ether Model of Wave Propagation Complying with the Sagnac Correction in the Global Positioning System

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**Abstract** — To comply with the Sagnac pseudorange correction in the GPS (global positioning system), the local-ether model of wave propagation is proposed. In this model, it is postulated that electromagnetic wave propagates via ether. However, the ether is not universal. It is supposed that the region under substantial influence of the gravity due to the Earth or another celestial body forms a local ether. Each individual local ether tends to move with the associated celestial body. And the earth local ether is stationary in the ECI frame. Within each local ether, electromagnetic wave propagates at the speed of light $c$ with respect to the respective local-ether frame, independent of the motion of the source and the receiver. It is pointed out that this new classical model is in accord with various propagation phenomena of electromagnetic wave, including the GPS pseudorange correction, the interplanetary radar echo delay, and the earthbound and the interplanetary Doppler shift. One exception is that the proposed local-ether model predicts a quite small but nonnull effect of earth's rotation in the Michelson-Morley experiment.

## I. Introduction

The NAVSTAR GPS (global positioning system) employs about 24 non-geostationary (half-synchronous) satellites carrying highly precise and synchronized atomic clocks around six nearly circular orbits of radius of about 26600 km [1]. Each GPS satellite repeatedly broadcasts microwave carrying a sequence of its own unique codes which can be used to determine the time of signal emission. At the user site, the receiver generates a synchronous replica of the codes and uses it to compare with the received one. Then, the time shift between the two sequences of codes corresponds to the measured propagation time which when multiplied with $c$ is called the pseudorange corresponding to the propagation range in the ideal case. The propagation range in GPS is based on the ECI (earth-centered inertial) system. That is, the propagation range is the distance between the transmitter at the instant of emission to the receiver at the instant of reception in the ECI frame [2], [3]. Accordingly, in calculating the propagation range, the displacement of the receiver due to earth's rotation and to the movement of the receiver with respect to the ground during the wave propagation is corrected (from the separation distance between the transmitter and receiver at the instant of emission). This Sagnac pseudorange correction depend on the positions of the transmitters and the receiver and a typical value is 30 m. While, a further examination shows that the displacement of the receiver due to the orbital motion of the Earth around the Sun or whatever is not corrected. It is noted that the orbital motion has a linear speed about 100 times that of earth's rotation. The GPS provides an accuracy of about 15 m or better in positioning. Thus, the precision of GPS will be degraded significantly, if the correction due to earth's rotation is not considered. On the other hand, the present high-precision GPS would be entirely impossible if the omitted correction due to orbital motion is really necessary. To bridge this disparity in the GPS pseudorange correction, we propose a local-ether model of wave propagation and point out that this new classical model is in accord with various phenomena associated with wave propagation.

## II. The Proposed Local-Ether Model of Propagation

To comply with the pseudorange correction in GPS, the local-ether model of wave propagation is proposed. It is supposed that, as in an obsolete theory, electromagnetic wave propagates via a medium called ether. However, the ether is not universal at all. It is supposed that the region under substantial influence of the gravity due to the Earth, the Sun, or another celestial body forms a local ether. Each individual local ether is finite in extent and may be wholly immersed in another local ether of larger extent. Thus, the local ethers may form a multiple-level hierarchy. Each local ether tends to move with the respective celestial body. And the earth local ether is stationary in a geocentric inertial frame. Within each local ether, it is supposed that electromagnetic wave propagates at the speed of light $c$ with respect to that local ether, independent of the motion of the source and the receiver. For the case where both the source and the receiver are bounded to the Earth, the speed of light $c$ is then referred to a geocentric frame. Moreover, the earthbound propagation is entirely independent of the motion of the Earth with respect to upper-level local ethers.

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Consider the case where both the source and the receiver are located within the same local ether and are moving at velocities $\mathbf{v}_s$ and $\mathbf{v}_e$ with respect to the associated local-ether frame, respectively. According to the classical ether notion, the propagation time $\tau$ is the propagation range $R$ divided by the speed of light $c$. The propagation range in turn is the distance from the position of the source at the instant of emission to that of the receiver at the instant of reception in the local-ether frame. It is noted that these two positions are specifically referred to the local-ether frame, since the distance between them is generally different in different frames. After the instant of emission, the propagation range is no longer dependent on the motion of the source. However, the actual propagation range and hence the propagation time depend on the movement of the receiver with respect to the local ether. Quantitatively, as the source and the receiver are located within the same local ether, the propagation range $R$ is given implicitly as

$$R = |\mathbf{R}_t + \mathbf{v}_e R/c| \tag{1}$$

and the propagation time $\tau$ $(= R/c)$ can be given implicitly as $\tau = |\mathbf{R}_t + \mathbf{v}_e\tau|/c$, where $\mathbf{R}_t$ is the directed separation distance from the source to the receiver both at the instant of emission, $\mathbf{v}_e\tau$ is a correction term representing the displacement of the receiver with respect to the local ether during the propagation period of $\tau$, and $\mathbf{v}_e$ is supposed to be a constant. It can be shown that the propagation range $R$ in formula (1) can be given explicitly as

$$R = R_t \frac{u_e/c + \sqrt{1 - v_e^2/c^2 + u_e^2/c^2}}{1 - v_e^2/c^2}. \tag{2}$$

In this investigation, the radial speed $u = \mathbf{v}\cdot\hat{R}_t$ is the component of velocity $\mathbf{v}$ along $\mathbf{R}_t$. To the second order of normalized speed, the propagation range can be given in terms of the separation distance $R_t$ as

$$R = R_t \left\{1 + u_e/c + (u_e^2 + v_e^2)/2c^2\right\}. \tag{3}$$

Consider the case where the source is emitting wave periodically and the source and/or the receiver are moving with respect to the local-ether frame. Due to the movement of the source and the receiver, the rate of reception tends to be different from that of emission. This difference between the rates of wave transmission and reception is known as the Doppler effect. The received time difference $\Delta t_r$ between two signals transmitted with a differential time difference $\Delta t_t$ is given in terms of the difference in the propagation range as

$$\Delta t_r = \Delta t_t + [R(t_t + \Delta t_t) - R(t_t)]/c, \tag{4}$$

where $R(t)$ denotes the propagation range for the wave emitted at the instant $t$. By expressing the propagation range $R$ in terms of the separation distance $R_t$ and by using the expansion $R_t(t_t + \Delta t_t) = R_t(t_t) + u_{es}\Delta t_t$, the differential received time difference $\Delta t_r$ can be given in terms of the difference $\Delta t_t$. Thereby, to the third order of normalized speed, the received and the transmitted frequencies are related to each other as

$$\frac{f_t}{f_r} = \frac{\Delta t_r}{\Delta t_t} = 1 + \frac{1}{c}u_{es}\left\{1 + \frac{1}{c}u_e + \frac{1}{2c^2}(u_e^2 + v_e^2)\right\}, \tag{5}$$

where $u_{es}$ $(= u_e - u_s = \mathbf{v}_{es}\cdot\hat{R})$ is the radial speed of the receiver with respect to the source and $\mathbf{v}_{es} = \mathbf{v}_e - \mathbf{v}_s$ is the Newtonian relative velocity between the receiver and the source.

In the preceding formulas of propagation range and time, both the source and the receiver are supposed to be located within the same local ether frame. When the signal is originated from a different local ether, the calculation of the propagation time is somewhat more complicated. However, when an overwhelming majority of the propagation path is located in a particular local ether, the preceding formulas remain valid, if the receiver velocity $\mathbf{v}_e$ is referred to the main local ether.

Next, we consider the round-trip propagation time in the ranging case composed of a transceiver and a target, where an electromagnetic wave is emitted from the transceiver, reaches and reflected back from the target, and then received by transceiver. Suppose that the target and the transceiver move at constant velocities $\mathbf{v}_a$ and $\mathbf{v}_b$ with respect to the main propagation medium. To the second order of normalized speed, the round-trip propagation time $\tau$ can be shown to be

$$\tau = \frac{2R_t}{c}\left\{1 + \frac{1}{c}u_{ab} + \frac{1}{2c^2}\left(v_{ab}^2 + u_a^2 + v_b^2\right)\right\}, \tag{6}$$

where $R_t$ is the separation distance between the transceiver and the target at the instant of signal emission.

## III. Local-Ether Interpretation of Various Propagation Phenomena

It is noted that various terms in the preceding formulas of propagation time and the Doppler effect depend on the velocities of the source and the receiver. Further, the velocity is either a Newtonian relative velocity or the individual velocity referred specifically to the associated local-ether frame. Those terms involving the individual velocity will in general lead to different values if the reference frame chosen in an analysis is different from the associated local-ether frame. Therefore, by examining the reference frame adopted to analyze the propagation experiments in the literature, we present some evidences for the proposed local-ether model.

### A. Pseudorange correction in GPS

According to the local-ether model, the associated propagation medium in GPS is the earth local ether which in turn is stationary in the ECI frame. Thereby, GPS in entirely independent of the orbital motion of the Earth. While, earth's rotation and the movement of the receiver with respect to the ground have effect on propagation delay. The pseudorange correction term in GPS is the difference between the propagation range in the ECI frame and the source-receiver separation distance at the instant of emission. According to the propagation-range formula (3), the GPS pseudorange correction for a receiver on or close to the ground can be given to the first order of normalized speed as

$$R - R_t = \mathbf{R}_t \cdot (\bar{\omega}_E \times \mathbf{r} + \mathbf{v}_f)/c, \tag{7}$$

where $\bar{\omega}_E$ is the directed earth's rotation rate, $\mathbf{r}$ is a vector from earth's center to the receiver at the instant of emission, and $\mathbf{v}_f$ is the velocity of the receiver with respect to the ground. This correction term has been put in practical use in GPS. Therefore, the high-precision GPS supports the statement that **an earthbound wave propagates via a classical medium which in turn is stationary in the ECI frame.**

### B. Interplanetary radar echo delay

Consider the propagation experiment which is extended in such a way that the source is placed in an extraterrestrial spacecraft or planet and the receiver remains on the ground. Thus, the main propagation medium becomes the solar local ether. Thereby, the linear velocity due to earth's rotational and orbital motion should have effect on the interplanetary propagation time. This effect has been demonstrated in the earth-Venus radar echo delay [4]. An examination of the adopted propagation model shows that the propagation time for the forward or the backward path is obtained by solving the implicit propagation-range formula (1) iteratively. Further, the propagation range is based just on a heliocentric inertial frame [4]. Therefore, the interplanetary radar echo delay supports the statement that **an interplanetary wave propagates mainly via a classical medium which in turn is stationary in a heliocentric frame.** Comparing GPS with the interplanetary radar, it is evident that in calculating the propagation time, whether earth's orbital motion should be incorporated in the velocity of a geostationary receiver depends on which local ether that encloses the main propagation medium and hence the source.

### C. Earthbound Doppler shift

To the second order of normalized speed, the frequency relation (5) can be written as

$$\frac{f_r}{f_t} = 1 - \frac{1}{c}u_{es} - \frac{1}{c^2}u_{es}u_s = \frac{1 - u_e/c}{1 - u_s/c}, \tag{8}$$

which is in accord with the classical Doppler formula derived in an alternative way. It is noted that the classical second-order Doppler shift involves the source or the receiver radial speed with respect to the local-ether frame. The frequency shift to the second order of normalized speed has been demonstrated in the earthbound gravitational redshift experiment, where a microwave was transmitted from a spacecraft launched to the apogee at an altitude of 10,000 km and was received by ground stations [5]. In the computation of the frequency shift, **the classical Doppler formula (8) is actually adopted. Further, the speeds are referred just to the ECI frame** [5]. Therefore, the earthbound Doppler shift as well as GPS is entirely independent of earth's orbital motion.

### D. Interplanetary Doppler shift

As a spacecraft flies far away from the Earth, the main propagation medium for sending wave back to earth stations becomes the sun local ether. Therefore, it is expected that the velocity of the receiver or the spacecraft that determines the interplanetary second-order Doppler shift should be referred to a heliocentric inertial frame. The interplanetary Doppler frequency shift to the second order of normalized speed has been demonstrated in the extraterrestrial gravitational redshift experiment, where a transmitting spacecraft ventured on an interplanetary trajectory with a flyby of Venus [6]. In the computation of the Doppler effect, the same classical Doppler formula (8) is actually adopted. Further, the speeds are referred just to a **heliocentric** frame [6]. Comparing the earthbound with the interplanetary case, it is evident that in calculating the second-order Doppler shift, whether earth's orbital motion should be incorporated in the velocity of a geostationary receiver also depends on which local ether that encloses the transmitting spacecraft.

### E. Michelson-Morley experiment

Consider the Michelson-Morley experiment of the interference between two light beams in two orthogonal optical arms composed of beam splitter and mirror. It is noted that since the mirror moves with the beam splitter, the round-trip propagation time to the second-order of normalized speed is then given from (6) as

$$\tau = \frac{2R_t}{c}\left\{1 + \frac{v^2}{2c^2}(1+\cos^2\theta)\right\}, \tag{9}$$

where $\mathbf{v}$ is the velocity of the interferometer, $R_t$ is the length between the beam splitter and the mirror in each optical arm, and $\theta$ is the angle between $\mathbf{v}$ and $\mathbf{R}_t$. The difference between the round-trip propagation times through the two orthogonal optical arms corresponds to a phase difference, which in turn depends on the angle $\theta$. According to the local-ether model, the propagation for such an earthbound experiment is referred to the ECI frame. Thereby, the propagation is entirely independent of the orbital motion of the Earth around the Sun. If $v$ were the linear speed due to the orbital motion of the Earth around the Sun, then $v \simeq 30$ km/s and $v^2/c^2 \simeq 10^{-8}$. Thus, as the interferometer is rotating, the two propagation times will vary and hence result in a periodic variation in the phase difference. The amplitude of this phase-difference variation can be as sufficiently large as $\pi/3$, as wavelength $\lambda = 0.6$ $\mu$m and arm length $R_t = 10$ m. However, in the proposed local-ether model, $v$ is the linear speed due to earth's rotation rather than that due to the orbital motion around the Sun or whatever. Thus, the second-order correction is as small as $v^2/c^2 \sim 10^{-12}$. Thereby, according to the local-ether model, **the variations in the propagation times are not exactly zero, but are practically too small to cause a detectable interference fringe shift.** This is our local-ether interpretation of the Michelson-Morley experiment, which is fundamentally different from that based on the special relativity.

## IV. Conclusion

Inspired by the disparity in the pseudorange correction in GPS, the local-ether model is proposed for the propagation of electromagnetic wave. It is supposed that each local ether moves with the associated celestial body. And the earth local ether is stationary with respect to the ECI frame. Within each local ether, electromagnetic wave propagates at the speed of light $c$ with respect to the respective local-ether frame. This new classical propagation model has been used to account for the GPS pseudorange correction, the interplanetary radar echo delay, and the earthbound and the interplanetary Doppler shift. Moreover, the proposed model can be shown to be in accord with the constancy of speed of light, the spatial isotropy in the one-way fiber link and in the Kennedy-Thorndike experiment, the Sagnac effect in a rotating interferometer, Roemer's observations, the radar Doppler shift, and with the gravitational effect on the light deflection and on the increment in the interplanetary radar echo delay predicted from the general relativity. However, the proposed local-ether model predicts a nonnull effect of earth's rotation on the Michelson-Morley experiment. This prediction then provides a means to test the proposed propagation model.

## References


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