Observation of Ether Drift in Experiments with Geostationary Satellites*

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The ether drift due to motion of the Earth has been discovered in the process of tracking of a geostationary satellite. The average annual velocity of the orbital component of the ether drift found to be 29.45km/s that almost coincides with the known value of orbital velocity of the Earth (29.765km/s). Parameters of galactic motion of the solar system were also measured, and the values for the Sun apex right ascension (270°) and declination (89.5°) are also in a close agreement with data accepted in observational astronomy. Such results are direct evidence that the velocity of a uniformly moving system can be measured with a device having the source of radiation (geostationary satellite) and detector (antenna of the telescope) fixed with respect to each other and the system itself. Evidently, this fact is reason for the hypotheses of light speed constancy **with respect to the observer** to be revised.

Introduction

In earlier, and unsuccessful, attempts to detect motion of the Earth, the issue of entrainment of the luminiferous medium (ether) by moving bodies was not properly taken into account. Ether was supposed to pass freely through any body, and through the Earth itself, and it was assumed that the velocity of ether drift is equal and opposite in direction to that of the Earth. However, in most cases tests performed at sea level gave negative results. That appears to confirm Stokes' hypothesis of ether drag by the moving Earth. Moreover, upon performing the tests at higher altitudes, increase of accuracy was usually achieved by protecting the light beams in the interferometer against external effects, *i.e*. by placing it in a metal container. But in doing so, experimenters did not take into account the possibility of screening of ether drift. Therefore, ether inside the container, for instance, a thermostat, a resonator, masers, a telescope filled water and so on, could be completely carried with the device, leading to negative result *at any accuracy* of measurement. It should be emphasized that in the experiments that, in the experimenter's opinion have given positive results (of about 6 to 10km/s in papers by Miller and Michelson, Pease, Pearson), the light beams were screened only by glass or cardboard, but not by metal.

Thus, a positive result might be obtained by carrying out the experiment beyond the layer of entrained ether, while avoiding light beam screening from the outer space by a container or other installation parts. That is why it would be desirable to perform such tests in free space (for example, on a satellite in orbit). These requirements have been satisfied in the present work, where during tracking a satellite we performed a first-order experiment based on the light aberration phenomenon. It was shown that the velocity of a uniformly moving system (the Earth) can really be measured with a device all components of which are at rest relative to this system.

Experimental Base

The device consists of a source of radiation (the satellite) and a receiver (the antenna of a radio-telescope). The choice of a geostationary satellite as a source gives us zero *relative* uniform velocity for both the source and the receiver, and the the satellite coordinates (geocentric longitude and latitude) remain practically the same with respect to Earth's frame during very long time intervals.

We used Intelsat704 satellite (USSPACECOM Catalog No. 23461) with a geocentric longitude of 66 deg.E and small inclination of 0.02deg. Diurnal observations were performed in Kazan (Russia) over three years (1997-2000), at different dates. To compare the experimental data obtained, we computed the satellite's position for the particular time of interest using the algorithm described in Intelsat Earth Station Standards (IESS-412). Instead of computing all the physical effects acting on a satellite, they describe the sum of all these effects in terms of three equations with approximation containing 11 parameters obtained with a least squares curve fitting. This set of parameters will, when used with a specified algorithm, approximate the same satellite location as predicted by the originating program. After these ephemeris for a specified satellite and time period had been generated by Intelsat, they always could be found on the site www.intelsat.com on a weekly basis.

From the satellite's predicted position and the Earth station known position, we calculated the geometric pointing angles (azimuth and elevation) using the Intelsat program POINT. We were operating in a program track mode, and care was used because our Earth station antenna position indicators and timing unit count scale have been pre-corrected by manufacturers with the aim to remove the offsets resulting from mechanical and electronic drift in their calibration or other anomalies. If part of these anomalies observed in tracking could be due to ether drift, then there would be no reason to remove it by these corrections. Therefore, in calculating we used the not-corrected station position (geodetic longitude of 49.228 deg. E, latitude of 55.765 deg. N, height above IAU-1976 Earth reference ellipsoid equal to 0.13 km) which was measured with a navigator GPS-38. To remove the corrections of the time scale of the telescope, we also controlled universal mean time (*GMT*) at each measurement.

Theory and Experimental Results

With the aim to find out the motion of the Earth in space, we paid attention to the light aberration phenomenon in diurnal tracking of the geostationary satellite. Measurement of stellar aberration discovered by Bradley in 1728 is nowadays a routine operation in astronomical observation of celestial bodies. That is why there is no need to discuss this phenomenon in detail here (see, for instance, any textbook in optics). It should only be emphasized that this phenomenon is universal in nature:

i) The telescope needs to be tilted slightly toward the direction of the Earth's motion, and this angle is $(V_{orb} / c) \cdot \sin\chi$ radians for stars located in a direction χ, with V_{orb} being the value of the orbital speed of the Earth, and c being light speed in free vacuum. Light emitted by *any star* reveals the same aberration angle.

ii) No motion of stars has been established experimentally to have influence over the aberration angle and speed of light propagation.

iii) The aberration angle has no dependence on a source-observer distance.

All of these facts say that this phenomenon has universal nature being based on general conformities of natural lows for light propagation and motion of the observer in space. That is why we can conclude that an electromagnetic wave either emitted or scattered by *any body* (not solely by celestial objects) has to be subject to aberration with the angle depending **only on parameters of observer motion.** Thus, one can assume such aberration to occur in observation of satellites as well. If this is the case, then observers (or devices) do not see actual satellite positions, as it has calculated geometrically. They perceive apparent satellite coordinates that are strongly dependent on time because the aberration angles are changing during the day and year on account of the Earth rotating and orbiting around the Sun.

To determine the time behavior of all vectors of motion causing aberration alterations during the year, the ecliptic plane and the vernal equinoctial direction should be chosen as references. Here, the orbital velocity vector $\mathbf{V}_{orb}$ is directed along the orbital components of the Earth motion. To specify galactic velocity of the Sun's system, we have used the apex vector $\mathbf{V}_{apx}$ with declination angle δ referenced to the equatorial plane, and right ascension α_{apx} measured counterclockwise from the vernal equinoctial direction.

Besides gravity due to the Earth, the satellites are subject to many forces (the Sun, the Moon, planets), which slightly perturb the orbits during the day. For geostationary satellites with small inclination, the force of radiation pressure from the Sun becomes the main cause of small diurnal deviation of its geocentric longitude and latitude about the equilibrium point. The unit vector $\mathbf{s}$ specifying this is considered together with the velocity vectors in order to show time relation between actual (geometric) and apparent (due to aberration) contributions to satellite longitude and latitude. This force causes the real small displacement of the satellite.

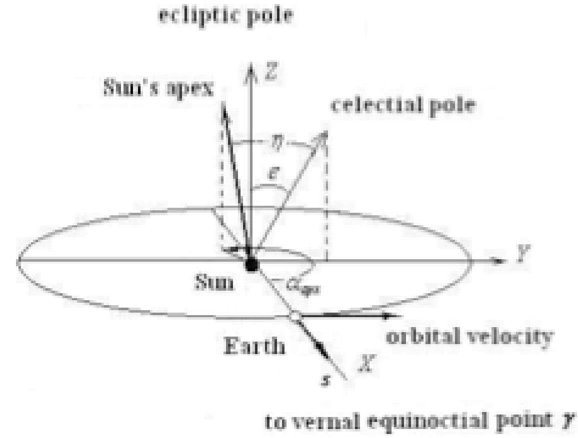

Figure 1. Positions of vectors of motion and unit vector of solar radiation pressure $\mathbf{s}$ in ecliptic reference frame at epoch 00:00:00 23 September (start of the new tropical year).

To find the time behavior of aberration contributions to actual position of a satellite during the day, we choose the equatorial plane as a reference one in the rotating frame of reference (the Earth) to consider a specific situation when the satellite is in the Greenwich meridian plane with zero inclination of its orbit (on the *X*-axis in Fig. 2).

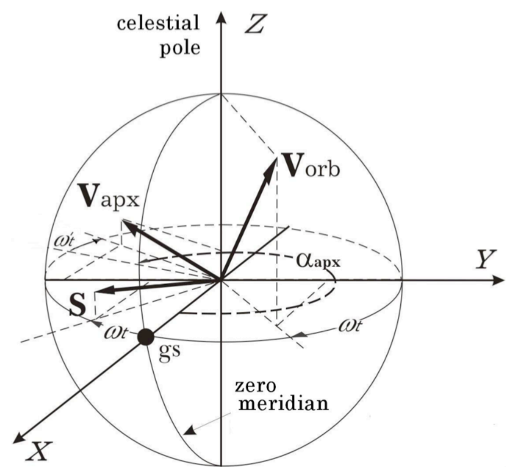

Figure 2. Positions of the velocity vectors and unit one $\mathbf{s}$ in the geo-centered rotating equatorial frame of reference at the moment t after the start of a new tropical year. The geostationary satellite position is gs, and the frequency of Earth rotation is ω

The contributions to the satellite coordinates consist of aberration angles (V_{orb}^{proj} / c) radians for ether drift caused by orbital motion of the Earth and (V_{apx}^{proj} / c) caused by galactic motion. Here, c is light speed in free vacuum and V_{orb}^{proj} and V_{apx}^{proj} are magnitudes of projections of $\mathbf{V}_{orb}$ and $\mathbf{V}_{apx}$ on the plane which is orthogonal to the source-observer line.

In the Earth frame of reference, all of the vectors are revolving about the polar axis, while the positions of the satellite and Earth station are invariant during all times. In Fig. 1 and Fig. 2 where X -axes are coincident in direction at time 00:00:00 *GMT* 23 September (the initial position-autumnal equinox), the solar vector $\mathbf{s}$ is directed along X and located in both the ecliptic and equatorial planes. The vector $\mathbf{V}_{\rm orb}$ is orthogonal to $\mathbf{s}$ any time and inclined to Y-axis by the angle ε between the equatorial and ecliptic planes at the start time. In the left-hand frame (Fig. 2) both of these vectors are rotating clockwise with angular frequency ω. Moreover, because of orbiting of the Earth around the Sun, their angles with the Z-axis are slowly varying during the year. On the contrary, the angle between $\mathbf{V}_{\rm apx}$ and the polar axis remains constant, but the frequency of $\mathbf{V}_{\rm apx}$ rotation ω' is slightly higher because of orbital motion of the Earth. This can be written as follows: $\omega' = \omega + \Omega$, where $\Omega = 2\pi / T_{\rm ty}$ and $T_{\rm ty}$ is the duration of the tropical year at our epoch.

Following the geometrical calculation of the projections of the vectors $\mathbf{V}_{\rm orb}$ and $\mathbf{V}_{\rm apx}$ on the Y and Z-axes, which are orthogonal to the source-observer line, we obtain the aberration angles for the geo-centered observer as additions to the actual geocentric longitude ξ and latitude φ of the satellite in the form

$$\begin{gathered}\Delta\xi_{\rm orb}(t) = \beta_{\rm orb}\sqrt{1-(\sin\varepsilon\cos\gamma)^2}\cos\omega t \\ \Delta\xi_{\rm apx}(t) = -\beta_{\rm apx}\cos\delta\cdot\sin(\omega t+\gamma-\alpha_{\rm apx}) \\ \Delta\varphi_{\rm orb}(t) = \beta_{\rm orb}\sin\varepsilon\cdot\cos\gamma\ ,\ \Delta\varphi_{\rm apx} = \beta_{\rm apx}\sin\delta\end{gathered} \qquad (1)$$

where $\beta_{\rm orb} = (V_{\rm orb}/c)$, $\beta_{\rm apx} = (V_{\rm apx}/c)$ and slowly varying angle $\gamma = \Omega\tau$, τ – the number of days taken from 00:00:00 *GMT* 23 September (the start of the new tropical year).

These additions due to the orbital and galactic motion of the Earth were taken into account in calculating the pointing angles (azimuth and elevation). An astronomical azimuth observed in tracking the satellite can be written as sum of the actual term calculated geometrically and the contribution

$$Az^{\rm observed}(\xi^{\rm obs},\varphi^{\rm obs}) = Az^{\rm actual}(\xi,\varphi) + \Delta Az + OF_{\rm az} \qquad (2)$$

where $\xi^{\rm obs} = \xi + \Delta\xi$, $\varphi^{\rm obs} = \varphi + \Delta\varphi$, and $\Delta\xi = \Delta\xi_{\rm orb} + \Delta\xi_{\rm apx}$, $\Delta\varphi = \Delta\varphi_{\rm orb} + \Delta\varphi_{\rm apx}$. The last term is an offset of azimuth due to mechanical and electronic drift in calibration.

To find ΔAz, we will expand this function in Taylor's series and, since usually $V << c$, we neglect the terms above the first-order:

$$\begin{aligned}&Az^{\rm observed}(\xi+\Delta\xi,\varphi+\Delta\varphi) = \\ &\qquad Az^{\rm actual}(\xi,\varphi) + \frac{\partial Az}{\partial\xi}\Delta\xi + \frac{\partial Az}{\partial\varphi}\Delta\varphi + OF_{az}\end{aligned} \qquad (3)$$

The first term in (3) can be found by routine operation used in celestial mechanics at transition from the equatorial frame to the horizontal one aligned with the Earth station meridian. We simply give it without derivation here

$$Az(\xi,\varphi) = \arctan\left(\frac{\sin\Xi}{\cos\Xi\cdot\sin\Phi - \cos\Phi\cdot\tan\varphi}\right) \qquad (4)$$

where $\Xi = \xi - \xi_{\rm telescope}$, $\xi_{\rm telescope}$ and Φ are the geodetic longitude and latitude of the specific Earth station (the telescope). This function was used later for obtaining the derivatives in (3).

The calculation of the first term in (2) with the POINT40 program (Intelsat), using 11 parameter ephemeris information, shows that predicted geodetic azimuth ($\pi - Az^{\rm actual}$) oscillates as $Az^{\rm actual}_{\rm geodetic}(t) = \alpha^{\rm actual}_{\rm o} + \alpha_{\rm cal}\sin\omega t$, in phase with variation of $\mathbf{s}$ direction. This is clearly seen in Fig. 3, where the example of such a three-day behavior of both the actual behavior (*predicted*-lower plot) and apparent behavior (*observed*-upper plot) are shown in the time frame of *LMT*. Maximum values for azimuth are achieved at a time of about 6 hours morning (on sunrise) when the light pressure force is almost orthogonal to line of observation and East longitude of the satellite reaches its minimum.

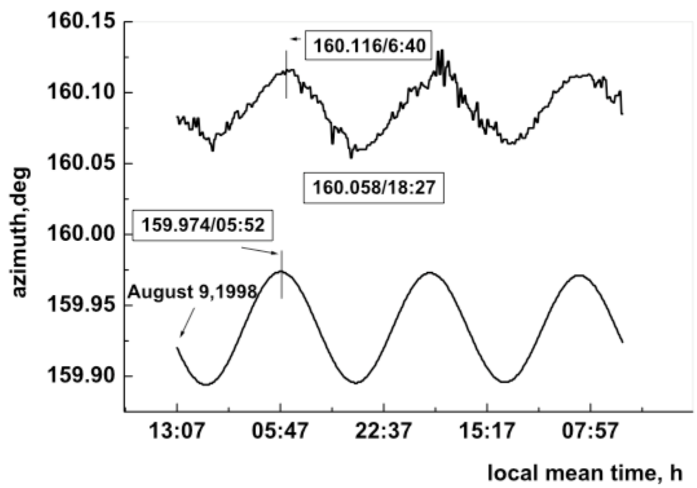

Figure 3. Observed and predicted geodetic azimuth for Intelsat704 satellite during 9-12August 1998

Taking (3) into consideration, we can write down the azimuth observed (upper plot) as follows

$$Az^{\rm observed}_{\rm geodetic}(t) = \alpha^{\rm actual}_{\rm o} + \alpha_{\rm cal}\sin\omega t - q_1\Delta\xi - q_2\Delta\varphi + OF_{\rm az} \qquad (5)$$

where the coefficients q_1, q_2 are the first derivatives from (4) with respect to ξ and φ. The last term is almost constant and together with the previous one, which is also very slowly varying function, makes a baseline $D_{az} = -q_2\Delta\varphi + OF_{az}$ for azimuth observed. At first, we consider in (5) only two terms (second and third ones) oscillating with frequency of the Earth rotation ω. After using the contributions (2) and (5) we obtain for the oscillating terms

$$Az_{\text{geodetic}}^{\text{observed}}(t) = \alpha_{\text{cal}} \sin \omega t - m\beta_{\text{orb}} \cos \omega t + q_1 p \cdot \sin(\omega t + \gamma - \alpha_{\text{apx}}) \quad (6)$$

where $m = q_1 \sqrt{1-(\sin\varepsilon \cos\gamma)^2}$, and $p = \beta_{\text{apx}} \cos\delta$ is the ratio of projection of V_{apx} on equatorial plane to free space velocity of light. Following the simple trigonometric transformations this takes a form

$$Az_{\text{geodetic}}^{\text{observed}}(t) = \alpha_{\text{obs}} \sin(\omega t - \vartheta) \quad (7)$$

where the amplitude α_{obs} and phase ϑ of the observed curve obey

$$\alpha_{\text{obs}} \sin\vartheta = q_1 \left[\beta_{\text{orb}} \sqrt{1-(\sin\varepsilon\cos\gamma)^2} - p \sin(\gamma - \alpha_{\text{apx}}) \right] \quad (8)$$

where $$q_1 = \frac{\sin\Phi - \cos\Xi \cdot \tan\varphi \cdot \cos\Phi}{\left(\cos\Xi \cdot \sin\Phi - \tan\varphi \cdot \cos\Phi\right)^2 + \sin^2\Xi} .$$

From Eq. (7) we take the conclusion that the experimental oscillating plot should be shifted by the angle θ to later times relative to the actual one. Such a shift has really been observed in all our measurements. We can see such a behavior, for example, in Fig. 3 where the experimental plot is delayed by 48 min ($\theta = 12^\circ$) with respect to one predicted.

Eq. (8) is the principle point in this paper, since together with experimental data (α_{obs} and ϑ) measured at different dates, it allows us to find the orbital and galactic ether drift velocities, apex of the solar system, and then to compare that with values of orbital velocity of the Earth and the Sun's system apex right ascension, well-known in astronomy.

We have found these parameters following the treatment of experimental data that had been accumulated during a long period of time (1998 - 1999). Calculations were performed numerically (with Mathcad7) on the basis of a set of three Eqs. (8) taken for three different dates. The dates were chosen so that the Earth orbital velocities could be equal as far as possible on these days of the year. The calculations were performed with the following parameters: geodetic latitude $\Phi = 55.765^\circ$N and longitude $\xi_{\text{telescope}} = 49.228^\circ$E of the telescope, ecliptic-celestial pole angle $\varepsilon = 23.45^\circ$, duration of the tropical year at our epoch $T_{\text{ty}} = 365.2422$ days, $\tau =$ number of days from the start of new tropical year (00:00:00 GMT 23 September) till the specified date. In Fig. 4 we present the results obtained. Each point for specified date, here, is a result of averaging over all of the sets in which this date have been used.

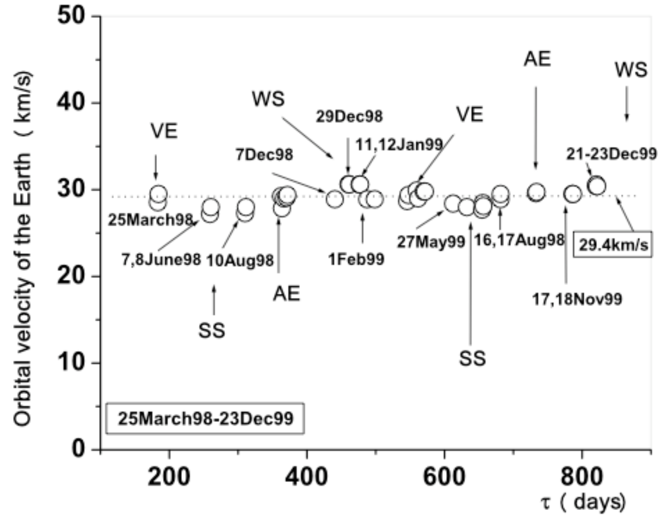

Figure 4. Behavior of ether drift velocity due to orbital motion of the Earth during March 1998-December 1999

The plot clearly shows that the behavior of the orbital component of the ether drift velocity is the same as for the orbital velocity of the Earth accepted in observational astronomy: the average annual values (29.45 km/s and 29.765 km/s, respectively) are practically equal, the velocities are slightly higher at the perihelion of Earth's orbit (winter on the plot) and lower at the aphelion (summer on the plot). From such a coincidence of the velocities, one can conclude that full aberration takes place, *i.e.* the aberration angle for satellites is $\beta_{\text{orb}} = 10^{-4}$ rad, as well as for any star (20.5").

As for the apex right ascension α_{apx}, we have obtained $\cos\alpha_{\text{apx}} \cong 0$ for the solution of evey set of Eqs. (8); i.e, its value is close to 269.99º or 90º. One of them almost coincides with hour angle of Sun's apex of $17^{\text{h}}59^{\text{min}}$, *i.e.* 269,75º taken from astronomic literature. In the geometry of our experiment the projection of the ether drift velocity on the equatorial plane due to galactic motion turned out to be very small (average annual value of $p = 1.6 \times 10^{-5}$ rad; *i.e.* this projection is about 5km/s). It could be explained if the apex declination is higher than for generally accepted one in astronomy (51º30′ $\gamma - Draconis$). In order to evaluate the declination of the apex and velocity of galactic motion, we made use of the ratio $\tan\delta = \Delta\varphi_{\text{apx}} / p$. The experimental aberration contribution $\Delta\varphi_{\text{apx}}$ was found here from the relation

$$\Delta\varphi_{\text{apx}} = \frac{1}{Q_2}\left[-Q_1 + \sqrt{Q_1^2 + 2Q_2(D - \Delta_{\text{refraction}})} \right] \quad (9)$$

where Q_1 and Q_2 are the first and second derivatives of the actual elevation ($\psi^{\text{geometric}}$) with respect to latitude of the satellite φ , D is the constant difference between the actual and observed elevation angles, and $\Delta_{\text{refraction}}$ is the refraction correction at our elevation $\psi^{\text{geometric}} = 24.75^\circ$, which is usually accepted in the form $\Delta_{refraction} = 0.01617^o \times \mathrm{cotan}\psi^{geometric}$ at angles $\psi^{geometric} \le 10^o$. In view of rather cumbersome intermediate calculations, Eq. (9) is given here without derivation. To derive it one needs the following steps. First, we use POINT to predict the elevation, compare it with the experimental one, and obtain the value of the pedestal D. Afterwards, in the expression for elevation, obtained as (3) by expanding in Taylor series and keeping the second derivative with respect to latitude, take all of the terms independent of time and put them equal to $(D - \Delta_{refraction})$. By solving the quadratic equation obtained we arrive at Eq. (9).

By using the average annual experimental value of $D = 0.16^o$ in (9), we have obtained the aberration angle due to the galactic motion $\Delta\varphi_{apx} = 0.117^o$. This gives us the respective estimates for the apex declination $\delta = 89.5^o$ and, after applying the last term in (2), the upper limit for the solar system velocity of approximately 600 km/s.

Thus, the results obtained in this experiment lead us to conclude that velocity of the uniformly moving laboratory system can really be measured with a device with *the source of radiation and detector fixed to each other and the system itself*. This fact is reason for the hypotheses of light-speed *constancywith respect to the observer* to be revised.

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$$\Delta\xi_s^{\text{actual}} = -\sqrt{1-(\sin\varepsilon\sin\gamma)^2}\,\sin\omega t\ ,\ \ \Delta\varphi_s^{\text{actual}} = \sin\varepsilon\cdot\sin\gamma$$