The Accounting Possibilities for the Earth Rotation Speed in Satellite Coordinate Definitions

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\textbf{Abstract:} The article considers the influence of the Earth’s rotation speed on the satellite coordinates accuracy and lists the main factors affecting its movement unevenness.

\textbf{Introduction}

The satellite radio navigation systems application areas are currently quite expanded not only in the human life spheres, but also have acquired a great importance in the study of the figure and physical processes of the Earth. However, a number of factors affecting the satellite positioning accuracy remain poorly investigated.

\textbf{Goal, tasks, methods of study}

The factors affecting the satellite positioning accuracy among manufacturers are a “classified” part of the software, but in general, as it turns out, the declared coordinate definitions accuracy depends on the existing network accuracy of the points selected for the local coordinate definitions localization or the local geodetic constructions accuracy. One of the drawbacks is the correction determination for taking into account the Earth’s rotation speed, and the points coordinates determination at different geographical latitudes is ambiguous, as already at a latitude of 60° (e.g. St. Petersburg), the correction for the rotation linear speed is two times less than at the equator. At the equator, the rotation speed is 1674.369 km / h or ≈ 465 m / s. It follows that high-precision determination of coordinates is impossible without introducing into the calculations program the receiver’s standing point latitude.

During the signal propagation from the satellite to the receiver (≈ 0.07-0.08 sec), the Earth will rotate at an angle of 1.5°, and the receiver will move at the equator by l≈48 m, which can significantly affect the coordinates determining accuracy. The satellites coordinates are calculated at a certain point in time relative to the geocentric coordinate system. During the signal τ propagation from the satellite to the receiver due to the rotation of the Earth, the receiver will move a certain distance (Fig. 1).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{diagram.png}
\caption{Diagram of the receiver movement during the rotation of the Earth}
\end{figure}
In this regard, it becomes necessary to bring the satellite and receiver coordinates to a single point in time \cite{1}. If the receiver coordinates at the signal time from the satellite were \(X, Y, Z\), and at the time of receiving the signal became \(X', Y', Z'\), then the following relationships can be written:

\[
\begin{align*}
X' &= X \cos \alpha + Y \sin \alpha X \\
Y' &= X \cos \alpha + Y \sin \alpha X \\
Z' &= Z
\end{align*}
\]

where \(\alpha = \omega_0 \tau\) is the rotation angle of the Earth around the rotation axis during the signal propagation, \(\omega_0\) is the unperturbed angular rotation velocity.

Depending on the azimuthal location of the satellites located in the signal receiving zone, the determined ranges can be either much larger, or approximately the same, or significantly less \cite{1,2}.

But that’s not all, the Earth’s rotation speed is uneven and depends on many factors: such as ebbs and flows, compression and expansion of the atmosphere during changing seasons, solar activity, the Earth’s magnetic field, polar ice melting, the equatorial regions lowering, etc.

So, it is now firmly established that the Earth rotates around its axis with an unstable speed - it is increasing or decreasing.

In the practice of predicting the mechanical systems motion, the most accurate and stable results are usually obtained based on the use of physical and mathematical models based on the balance of forces acting on a certain system under study. Specifically, for the rotating Earth, due to the system complexity and the large number of factors affecting the rotation process, such models for the purpose of predicting the corrections for the Earth’s rotation (ERP) have not been fully used so far.

The Earth’s daily rotation features study has always been relevant for many Earth sciences. In space geodesy, the task of determining and predicting the parameters of the Earth’s rotation has gained particular relevance. This is due to the global navigation satellite systems appearance in the USA and Russia as well as in a number of other countries. The calculated ERP values are included in the initial conditions when solving the spacecraft differential motion equations. As a result, the coordinate-time determinations accuracy made with the help of GLONASS and GPS initially depends on the errors of the adopted model of the Earth’s rotation embedded in the spacecraft software. This implies the modern requirements for the ERP prediction accuracy for the space navigation systems ephemeris-temporal support purposes and, especially, for solving the problems of forecasting universal time (UT1).

The ERP set includes the parameter \(dUT1\) characterizing the uneven rotation of the Earth and the Earth’s pole current position coordinates \cite{5}:

\[
dUT1 = UT1 - UTC,
\]

where \(UTC\) is the coordinated time.

The leading position in the world in the quality of forecasts belongs to the International Earth Rotation Service (IERS) in Paris, the forecasting accuracy of which is 15 days (the term for laying on board the updated ERP satellite) is:

- according to the coordinates of the pole: 0.005 - 0.008 °;
- as amended by \(dUT1\): 1.5 - 2.5 ms.

For transmitting the satellite ephemeris with an accuracy of 6-7 m, the permissible error for 15 days is for the coordinates of the pole 0.01-0.02 °, and for the universal time correction \(dUT1\) - 1.5 ms. By increasing the GLONASS system electronic time support accuracy and predicting the ERP for a longer period, the State Service for Time and Frequency (SSTF) in Moscow and the FSUE "SNIIM" in Novosibirsk are currently engaged.

The presence of regular and irregular (daily, seasonal, secular) parameters of the Earth’s rotation speed confirms that it is in a highly stressed state and rotates with real forces that exceed the power...
of all braking forces acting on its surface as gravitation (e.g. gravity of celestial bodies), and repulsion (e.g. pressure from rays, meteorites and other extraterrestrial matter).

On the nature of the Earth’s constant forces rotating, there currently exists only one hypothesis of K.A. Kulikov [3], according to which the Earth is allegedly rotated by its own atmosphere, rotating at an angular speed exceeding the Earth’s rotation speed itself. And in confirming the hypothesis of K.A. Kulikov an uneven distribution of water and land on the Earth’s surface may serve. The northern hemisphere land area is larger than the southern one, taking into account Antarctica, more than 2 times, and in the southern hemisphere only 19% of the land. In this regard, the Earth’s rotation speed is affected not only by seasonal, but also by diurnal temperature fluctuations, as a result of uneven heating of the lithosphere and hydrosphere. In this regard, the Earth’s crust is stretched, therefore, its radius increases, increasing the inertial moment and decreasing the rotational moment. Atmospheric movement occurs relative to the Earth’s surface in low latitudes from the East to the West - and there the westerly winds blow, and in temperate and high latitudes - from the West to the East. In accordance with this, the eastern winds angular momentum is negative, and the western - positive. Seasonal unevenness consists in the angular momenta redistribution, and, the angular momentum of the eastern winds is several times smaller than the western angular momentum [4].

Summary

We can definitely say that the main source that rotates our planet is the Sun energy. And at the moment, with the current technology development level, it is not possible to calculate the exact correction for the uneven Earth rotation speed, not taking into account the measurement information distortions due to the Earth rotation which will obviously lead to the geodetic points coordination errors. We have to admit that most of the exact geodetic constructions at present are dependent on the state geodetic network created back in Soviet times.

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