MODELING OF THE EARTH ROTATION AND HIGH PRECISION ASTROMETRY OBSERVATION TECHNIQUES

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ABSTRACT. Earth Orientation Parameters (EOP) are needed to locate an object in the celestial or terrestrial reference systems. IERS provides EOP series at 1-day interval and standard numerical models for some variations of the EOP. High precision EOP are requested in many research and application domains, i.e. geodesy, satellite orbitography, astronomical observations. Several techniques contribute to estimate the EOP: VLBI, GPS, SLR, LLR, and DORIS. Their contributions vary while their precisions evolve. It is interesting to investigate their potentiality to determine the various components of the Earth's rotation and especially precession-nutation. The purpose of this work is to investigate the potentiality of VLBI and GPS techniques to determine the various components of precession-nutation, and to compare the performance and precision of their results, for long term components and short term components respectively. This paper recalls the IERS modeling of Earth rotation and the method used for estimating the EOP by VLBI and GPS; it also presents a new option to estimate short-period nutations.

1. MODELING EARTH ROTATION

Earth's rotation is described as the sum of following components (see Fig. 1, left):

1. The celestial motion of the Celestial intermediate Pole (CIP), noted (X, Y) in rectangular coordinates in the GCRS; its main component results from the rotation of the Earth's axis around a moving axis perpendicular to the ecliptic plane. It has a polynomial part (precession) and a periodic part (nutation).

2. The terrestrial motion of the CIP (polar motion), noted (x_p, y_p) in rectangular coordinates in the ITRS. Its main components are the Chandler oscillation (period of about 430 days and amplitude lower than 150 mas), annual term (amplitude of about 100 mas), secular motion (4 mas/year towards Canada).

3. Earth's rotation velocity ω, or rotation angle ERA, or length of day (LOD), or UT1.

The IAU 2006/2000A expressions for X, Y (Capitaine et al. 2003, Hilton et al. 2006) and ERA, as well as models for some other variations of the EOP, are available in the IERS Conventions (2003).

The rectangular coordinates in the International Terrestrial Reference System [ITRS] can be transformed into rectangular coordinates in the Geocentric Celestial Reference System [GCRS] by the following equation: [GCRS]= $Q(t) * R(t) * W(t)*$[ITRS], where Q(t) is a matrix determined by (X, Y), R(t) is a matrix determined by the rotation angle ERA, and W(t) is a matrix determined by (x_p, y_p).

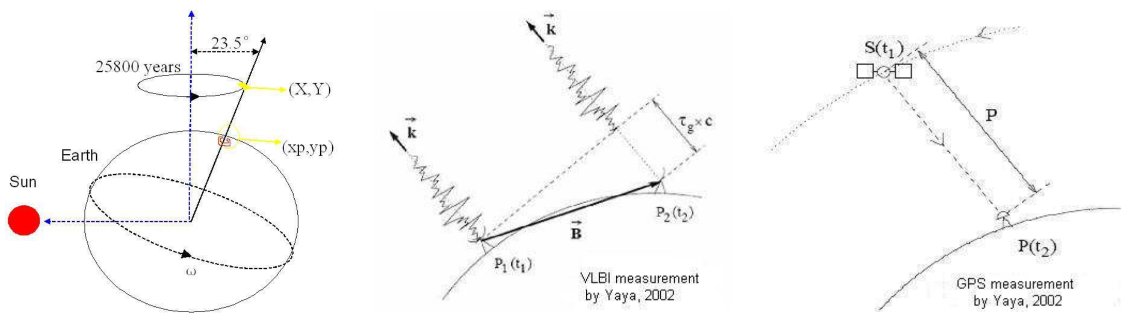

Figure 1: The Earth orientation parameters (left). Techniques for EOP estimation (right): VLBI and GPS

2. EOP DETERMIMATION BY VLBI and GPS

The EOP have been estimated by various techniques, i.e. VLBI, GPS (see Fig. 1), LLR, SLR, DORIS and optical astronomy. VLBI is currently the most important technique to estimate (X, Y) and LOD, while GPS is the most important one to estimate (x_p, y_p).

a) VLBI: the simplified geometric delay function is (see Fig. 1, middle): $\tau_g = ((P_2(t_2) - P_1(t_1)) \cdot \vec{k})/c$. The EOP information are contained in the GCRS stations positions: $P_1(t_1)$ and $P_2(t_2)$. But the troposphere, ionosphere, clock variation contribute to the VLBI delay: $\tau = \tau_g + \tau_{trop} + \tau_{ion} + \tau_{clock}$. These contributions need to be corrected.

Generally, the EOP are estimated by a weighted least squares method based on the normal equations, with a priori values: $\tau_{measured} - \tau_{theoretical} = \sum_i (d\tau_{theoretical}/dp_i) * \Delta p_i$.

The advantage of using VLBI is the accurate realization of the GCRS.

b) GPS: the simplified geometric delay function is (see Fig. 1, right): $\tau_g = t_2 - t_1 = |\vec{S}(t_1) - \vec{P}(t_2)|/c$. The EOP information are contained in the ITRS satellite position $\vec{S}(t_1)$. As it the case of VLBI, corrections for troposphere, ionosphere, clock variation, relativity are needed, as well as linearization, to get a weighted least squares estimation of the EOP. The advantage of using GPS is the accurate realization of the ITRS.

By investigating the satellite position in ITRS, we can obtain the following relation between the rates of the EOP (X, Y, ERA) and those of the satellite orbit parameters (Ω: ascending node, i: inclination, u_0: argument of latitude at the osculation epoch) (see Rothacher & Butler 1999):

$$\dot{ERA} = -\dot{\Omega} - \cos i \cdot \dot{u}_0, \quad \dot{X} = -\sin\Omega \cdot \dot{i} + \sin i \cos\Omega \cdot \dot{u}_0, \quad \dot{Y} = \cos\Omega \cdot \dot{i} + \sin i \sin\Omega \cdot \dot{u}_0.$$

The rates of (X, Y) can thus be derived from the rates of the orbital elements of the satellite and compared with the semi-analytical series for the time derivatives of the IAU 2006/2000 model (see Table 1). This would be a new method to estimate nutation corrections with minimizing the systematic (long-period) errors coming from the correlations between the EOP and the satellite orbit parameters. The estimated values of the rates of (X, Y) can also be combined with VLBI EOP result to get a better estimation of the short term nutations.

	sine coefficient (uas/d)	cosine coefficient (uas/d)	frequency l l' F D Ω	period (days)
1	-51.16	-41648.80	0 0 2 0 2	13.66
2	-22.33	-8249.95	1 0 2 0 2	9.13
3	-6.97	-7100.50	0 0 2 0 1	13.63
4	3.90	-1559.86	1 0 -2 -2 -2	9.56
5	-3.54	-1414.41	1 0 2 0 1	9.12
6	-5.57	-1358.41	0 0 2 2 2	7.10
7	-4.77	-1311.22	2 0 2 0 2	6.86
8	2.54	1072.81	0 0 0 2 0	14.77
9	1.34	530.49	2 0 0 0 0	13.78
10	1.21	475.51	0 0 2 0 0	13.61

Table 1: Series for the development of the time derivative of X (periods less than 23 d)

3. REFERENCES

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