Determining and Predicting UT1-UTC to Support China's Interplanetary Spacecraft Navigation

Lue Chen [1,2], Geshi Tang [1,2], Songjie Hu[1,2], Jing Sun[1,2], Mei Wang[1,2]

1. Beijing Aerospace Control Center, Beijing 100094, China

2. National Key Laboratory of Science and Technology on Aerospace Flight Dynamic, Beijing 100094, China

ABSTRACT: Earth orientation parameters (EOP), consists of polar motion, UT1-UTC, precession, nutation, is essential for the transformation of the international terrestrial reference system (ITRS) and the international celestial reference system (ICRS), being necessary for interplanetary spacecraft navigation missions. EOP affects the transformations, with UT1-UTC being the most important contributor. Since UT1-UTC is the fastest varied parameter in EOP, which is also the most difficult parameter for determination and prediction, thus, the accuracy of UT1-UTC determination and prediction directly affects the accuracy of the spacecrafts' orbit measurement and determination. For example, Error in UT1-UTC of 0.1 ms produces an error of 7 nrad in spacecraft right ascension, corresponding to a position error at Mars of 1.6 km. Error in UT1-UTC of 10 ms produces a position error at LEO of 6m, GEO of 31m. Meanwhile, high precision determination and prediction of UT1-UTC plays a very important role in real-time or near real-time navigation. In addition, Very Long Baseline Interferometry (VLBI) is the only technique able to provide long-period variations in UT1-UTC, by mean of observing quasars, correlating the received quasar signals, and estimating UT1-UTC observations.

Beijing Aerospace Control Center (BACC) is the leading China's flight control center for interplanetary exploration of the solar system, which is responsible for researching and applying interplanetary spacecrafts' orbit measurement, determination, control techniques. On the one hand, this paper introduces BACC determining UT1-UTC based on VLBI observations, using Vievs VLBI software, which is developed by Vienna University of Technology. From the obtained results, it can be shown that, the accuracy of UT1-UTC determination is better than 10us. In addition, the determined results are compared with the EOP 08 C04 series, provided by mean of combining with GPS, VLBI, SLR etc observations by International Earth Rotation and Reference

Systems Service (IERS). The deviation of BACC UT1-UTC results and EOP 08 C04 UT1-UTC results is about 12us, which is logical， thus， this validates the capability of UT1-UTC determination in BACC.

On the other hand, this paper introduces BACC UT1-UTC prediction situation, and proposes a prediction method of UT1-UTC by dual differential least-squares (DDLS) and autoregressive (AR) model (DDLS+AR). Firstly, leap seconds are removed in UT1-UTC observations, and Earth zonal harmonic tidal is corrected. Then, the corrected UT1-UTC is processed by dual differential method. In doing so, the stationary of UT1-UTC is improved. Then, least-squares and AR methods are utilized to analyze the dual differential UT1-UTC to obtain the preliminary prediction results. Finally, the preliminary prediction results are processed by inverse dual differential method, and tidal correction are extrapolated and leap seconds are recovered to obtain high precision UT1-UTC prediction results. The UT1-UTC prediction results are compared with IERS Bulletin A from 2011 to 2014, shown that the short-term (30 days) UT1-UTC prediction errors are at the same level of IERS Bulletin A, with prediction error less than 2.5ms for 30 days prediction. Especially, 1 day prediction accuracy of UT1-UTC is less than 0.03ms, which is better than IERS Bulletin A 1 day UT1-UTC prediction accuracy.

Currently, BACC could provide the determination and prediction products of EOP, including UT1-UTC, by Vievs software and self-developed prediction software called EOP Prediction Software (EOPS). The UT1-UTC results are daily and automatically compared with IERS and United States Naval Observatory (USNO) results. In addition, UT1-UTC determination prediction products are successfully applied in China’s first reentry test of lunar exploration (CE-5T1) mission, to support CE-5T1 high precision orbit determination. In short, now, BACC can provide high precision UT-UTC products to support for China’s future deep space exploration missions.