Colocation of high-precision geodetic observation methods for time synchronization in context of the ACES-Mission: a simulation study

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Abstract

The future Atomic Clock Ensemble in Space (ACES) mission of the European Space Agency (ESA) will address the development of a time transfer concepts for tomorrow's technologies. The ACES configuration includes a new generation of high-precision atomic clocks, a microwave link terminal (MWL) on the ground and on the satellite, and an optical detector and reflector also on the satellite. The satellite-based instruments and clocks will be installed on the ISS Columbus module in 2025. The two clocks generate a long and short-term stable time signal, the ACES time. With the uplink and downlink measurements of the MWL terminal alone, time transfer between a ground clock and the ACES clock can be performed with an accuracy of 0.3 ps per ISS pass and absolute accuracy of 100 ps. The comparison of two ground clocks can be performed with an uncertainty of 1 ps in the common view and with an uncertainty of 2 ps in the non-common view. Experiments in fundamental physics, such as the determination of the gravitational redshift or the drift of fundamental constants, can be performed prospectively with accuracies of 2x10ˆ-6 and 10ˆ-17. However, MWL measurements are not error-free, leading to problems in evaluating the measurements. The task is to decompose these measurements into their error components. However, this becomes difficult due to the high correlations, especially of the propagation time variations of the microwave signal in the atmosphere, orbit errors, delays in the receiving and transmitting electronics of the MWL terminal, and the clock signal. In order to design a suitable concept to minimize such error effects in advance, a full-scale simulator has been implemented. This simulator was used to generate a data set of 100 passes during July 2021. Investigations based on this data set showed that the co-location of the high-precision geodetic observation techniques of the ACES mission could better separate the individual error contributions of a measurement. In addition to the optical and microwave-based geodetic methods, the errors to be estimated can also be collocated. In particular, estimating a common orbit and a common troposphere for all measurement techniques increases the accuracy of the calibration of the electronic delays. Thus, it was shown that the offset between ground and ACES clocks could be determined with even higher accuracy. Our further investigations focus on the common troposphere estimation of multi-color optical observations, together with microwave-based observations and the effects of different weighting methods. An extension to a network of ground stations will demonstrate the advantages of the ACES mission for synchronizing multiple ground clocks. The co-location of different high-precision geodetic observation methods and estimating common parameters will benefit timing and ranging applications and fundamental physics studies.

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