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ASTRA: INTERDISCIPLINARY STUDY ON ENHANCEMENT OF THE END-TO-END ACCURACY FOR SPACECRAFT TRACKING TECHNIQUES

Abstract

Navigation of deep-space probes is accomplished through a variety of different radio observables, namely Doppler, ranging and Delta Differential One-way Ranging (Delta-DOR). The particular mix of observations used for navigation mainly depends on the available on-board radio system, the mission phase and orbit determination requirements. The accuracy of current ESA and NASA tracking systems is at level of 0.1 mm/s at 60 s integration time for Doppler, 1 to 5 m for ranging and 6 to 15 nrad for Delta-DOR measurements in a wide range of operational conditions.

The ASTRA study, funded under ESA's General Studies Programme (GSP), addresses the ways to improve the end-to-end accuracy of Doppler, ranging and Delta-DOR systems by roughly a factor of 10. The target accuracies were set to 0.01 mm/s at 60 s integration time for Doppler, 20 cm for ranging and 1 nrad for Delta-DOR. The companies and universities that took part in the study were the University of Rome Sapienza, ALMASpace (a spin-off company of the University of Bologna), BAE Systems and Thales Alenia Space.

The analysis of an extensive data set of radio-metric observables and dedicated tests of the ground station allowed to consolidate the error budget for each measurement technique. The radio-metric data set is built using X/X, X/Ka and Ka/Ka range and Doppler observables from the Cassini and Rosetta missions. It is complemented by AMCS (Advanced Media Calibration System) measurements obtained from the new class of microwave water vapour radiometers, developed by JPL for the radio science experiments of the Cassini mission.

The first phase of the study was devoted to the consolidation of the error budget. By comparing the statistical properties of the data set with the expected error models we have been able to confirm the contribution from some error sources, but also to identify some discrepancies. The outcome of the analysis provides adequate information for building guidelines and strategies to effectively improve the navigation accuracies of future deep space missions.We report both on updated error budget for radio-metric observables and the system configurations proposed for the upgrade of the current ESA tracking and orbit determination systems.