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Inflight performance of the state-of-the-art BepiColombo MORE radio-tracking system

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The ESA/JAXA mission BepiColombo, launched on 20 October 2018 is in cruise towards Mercury and will arrive at Mercury in 2025 to investigate its surface, interior structure and magnetosphere. The Mercury Orbiter Radio-science Experiment (MORE) onboard the Mercury Planetary Orbiter (MPO) aims at determining the gravity field, the rotational state and librations of the planet, using precise tracking of the spacecraft during its orbital phase around Mercury. Range and range-rate measurements collected during the cruise phase will be used to test the theory of general relativity starting in March 2021. The MORE experiment exploits two-way multifrequency microwave links from ESA and NASA: two downlinks in X- and Ka-band coherent with the X-band uplink and one Ka-band downlink coherent with the Ka-band uplink. The range-rate and range measurements accurately BepiColombo's line-of-sight velocity and the round-trip light-time of the signal, respectively. The calibration of the dispersive plasma noise component through the combination of the X/X, X/Ka and Ka/Ka links and the use of water vapor radiometers to correct for the path delay due to Earth's troposphere will result in an accuracy of ~3 μm/sec (at 1000-s integration time) on the Doppler and centimeter-level range accuracies. We report on the analysis of dedicated tests executed on range and Doppler data collected by ESA and NASA stations at X and Ka-band. The comparison of the observed noise with the predictions shows results exceeding the expectations. In particular, the 24 Mcps pseudo-noise modulation of the Ka-band carrier, enabled by MORE's KaT transponder built by Thales Alenia Space Italia, provided two-way range measurements accurate to ~3 cm with just 4 s integration time, at a distance of 0.7 AU, September 2021, and 1.3 AU, November 2021. Under favorable weather conditions, the range rate has shown an accuracy of 25 μm/s at 10 s integration time, in line with the expected end-to-end performance. Under unfavorable weather conditions the performance was slightly over the requirements. We must remark that calibrations from water vapor radiometers were not available during these tests and only GNSS calibration were applied.