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IMPROVEMENTS IN BEPICOLOMBO AND JUICE RADIO SCIENCE EXPERIMENTS WITH A MULTI-STATION TRACKING CONFIGURATION FOR THE REDUCTION OF DOPPLER NOISE

Abstract

Radio science experiments for planetary geodesy mostly rely on measurements of the Doppler shift of microwave signals sent to a spacecraft by an Earth station, and retransmitted back coherently in phase to the same antenna (two-way link). The retransmitted signal can also be received by a different station in a listen-only configuration (three-way link). In state-of-the-art tracking systems, such as the ones will be used on the future ESA's missions JUICE and BepiColombo, the Doppler error budget is dominated by local noise sources arising at the ground-station, in particular tropospheric scintillation and unmodeled motions of the antenna's structure. In this work, a novel technique aimed at reducing these disturbances is analyzed, with particular emphasis on its benefits to BepiColombo's and JUICE's radio science experiments. The method, referred to as Time-Delay Mechanical-noise Cancellation (TDMC), relies on simultaneous two-way and three-way spacecraft tracking, the latter employing a stiffer listen-only antenna with better mechanical stability and located in a favorable dry region more immune to tropospheric noise. In fact, a proper linear combination of time-shifted observables from the two-way and three-way links can replace local noises of the two-way ground-station with those coming from the listen-only antenna, translating into increased accuracy of the final measurements, while preserving the original Doppler content. We show the results of covariance analyses performed with a multi-arc weighted least square estimator for the entire BepiColombo's hermean phase and JUICE's flybys of Callisto. We compare the two solutions obtained with and without the application of the TDMC technique. For BepiColombo and JUICE radio science experiments, the two-way links are baselined from the 35-m DSA-3 (Malargue, Argentina) and the 34-m DSS 25 (Goldstone, California). For the three-way link, we select the 12-m Atacama Pathfinder Experiment (APEX) antenna for three reasons: 1) its mechanical rigidity with respect to large beam-waveguide antennas , 2) its unique position in the extremely dry Chajnantor plateau, that assures low tropospheric noise, and 3) its limited longitudinal separation from the two other ground-stations, granting sufficient common visibility time to perform the requested combination of the observables. Besides its noise-reduction effect, enabling unprecedented levels of accuracy on Doppler measurements, TDMC provides also a back-up for unique events: a crucial satellite flyby or a specific passage over a site of particular geophysical interest. Indeed, measurements become virtually independent of unfavourable meteorological conditions at the transmitting station.