High-accurate Doppler tracking combined with Very Long Baseline Interferometry (VLBI) phase-referencing techniques are used for determination of the state vectors of planetary and deep space spacecraft missions. Ultra-precise estimates of the position and velocity of spacecraft can address a wide range of research fields. The group has demonstrated successful detections on planetary fly-bys, landing of probes, drag acceleration measurements, and characterization of the interplanetary plasma.

2. VLBI and Doppler tracking of spacecraft

PRIDE has been adopted by a number of prospective planetary science missions as a part of their scientific suite. These missions include JAXA and ESA’s BepiColombo/MMO (Mercury Magnetospheric Orbiter), ESA’s international ExoMars rover, ESA’s MarcoPolo-R mission, ESA’s GAIA mission, and ESA’s Jupiter icy moons Explorers (JUICE). As a preparatory stage, PRIDE has been conducting test observations with the ESA Venus Express (VEX) spacecraft for the last three years (2009-2012). This campaign has focussed, among others, on characterizing the interplanetary scintillations (IPS) at different solar elongation and at various distances to the target.

In this paper, the analysis of the single-dish observations and the interplanetary plasma are presented, as well as the results of the VLBI and Doppler tracking session with several radio telescopes. This session (em081c) was conducted in 28.03.2011 using 10 different antennas located worldwide. The position of the VEX was estimated with high precision after 3 hours of intensive observations. The reconstructed image of the VEX spacecraft with an accuracy of 1 km x 100 m is shown in Figure 1.
3. Interplanetary scintillation

Phase scintillations of the spacecraft signal due to the propagation within the solar wind (interplanetary plasma) is one of the main factors limiting accuracy of VLBI observations of spacecraft. Regular monitoring of the phase scintillations of VEX signal at different stations and different solar elongations is helpful to optimization of detection technique and to debug possible problems at observing stations. On the other hand, the study of the phase fluctuations of the spacecraft carrier line is used to characterize the interplanetary plasma along the propagation path. During the two years of research more than 100 observations have been performed studying the propagation of the VEX spacecraft signal. In this exercise, the phase scintillation index and scintillation bandwidth were retrieved from the phase fluctuations.

The phase scintillations have shown direct dependency on the solar elongation, distance to the target, position of the source within the Solar System and solar activity index at the time of the observations. This work was focused on the technique of the measurements, data analysis and the interpretation of the physical consequences of the measurements. The analysis of the phase fluctuations on the spacecraft signal allows us to determine the best time frame for the approach, descent and landing operations for spacecraft to achieve precise estimation of the state vectors with VLBI spacecraft tracking.

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References


