EPSC Abstracts
Vol. 10, EPSC2015-212, 2015
European Planetary Science Congress 2015

Ground-based VLBI observations of orbiters and landers

G. Cimò (1), D.A. Duev (1), G. Molera Calvés (1,2), S. V. Pogrebenko (1), T. Bocanegra Bahamon (1,3,4) and L. I. Gurvits (1,3)

(1) Joint Institute for VLBI – European Research Infrastructure Consortium, The Netherlands (cimo@jive.nu / Fax: +31-521-596539), (2) Metsähovi Radio Observatory, Finland, (3) Delft University of Technology, The Netherlands, (4) Shanghai Astronomical Observatory, China

Abstract

Phase referencing near-field VLBI observations and radial Doppler measurements of spacecraft provide ultra-precise estimates of spacecraft state vectors. These measurements can be used for a variety of scientific applications, both fundamental and applied, including planetary science, improvement of ephemerides, ultra-precise celestial mechanics of planetary systems, gravimetry, spacecraft orbit determination, and fundamental physics.

Precise determination of the lateral position of spacecraft on the celestial sphere is the main deliverable of the Planetary Radio Interferometry and Doppler Experiment (PRIDE). This technique is complementary to radio science experiments and addresses those areas of spacecraft mission science objectives that require accurate estimation of spacecraft state vector.

Applications of Near field VLBI

The scientific applications of the Planetary Radio Interferometry and Doppler Experiment are based on two observable quantities: the radial range rate (Doppler shift of the service communication system carrier signal) and the lateral (transverse) celestial position of the spacecraft with respect to the International Celestial Reference Frame (ICRF). The measurements of the spacecraft differential lateral position relative to ICRF are performed by VLBI observations of spacecraft and background extragalactic radio sources with accuracy of tens of μas (1-σ RMS) over integration time of $60 - 1000\,$s[2]. The direct measurables of PRIDE are shown in Figure 1.

The PRIDE experiment is a direct descendant of legacy VLBI experiments with the VEGA [1], Huygens [5], IKAROS [7] and other planetary missions.

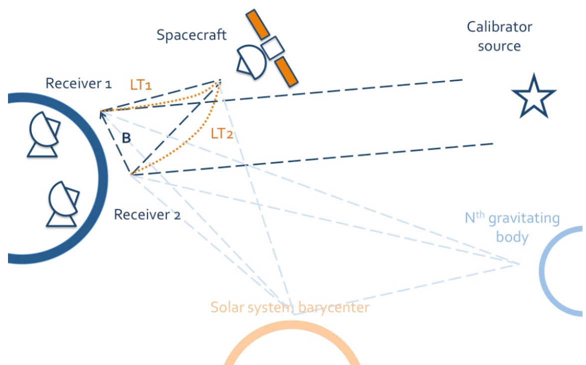

Figure 1: Geometry of a PRIDE experiment.

The use of the Very Long Baseline Interferometry for supporting of planetary missions was developed more than thirty years ago and has been used in missions requiring ultimate accuracy of a posteriori trajectory determination [8]. In the recent years, Jones [9] has observed the Cassini spacecraft using the Very Long Baseline Array (VLBA) to improve Saturn ephemeris.

The PRIDE team carried out a number of experiments to develop and improve VLBI and Doppler measurements of spacecraft and to study their scientific applications. ESA's Venus Express (VEX) and Mars Express (MEX) has been extensively targeted by PRIDE for studying the solar wind by observing the effects of intervening ionized plasmas on the spacecraft signal [3]. Radio occultation experiments of both Venus Express and Mars Express have performed to derive vertical density, pressure and temperature profiles of planetary atmospheres. In the case of MEX, a number of observations were carried out during the Phobos flyby on December 2013. Both Doppler and VLBI measurements can be used to improve the determination of the Phobos' gravity field derived so far from radioscience only [4]. The radioscience and VLBI data are complementary as the precise former data will be complemented by constraints from the VLBI measurements. Finally, we will present results of the VLBI tracking of the ESA's space astrometry mission, Gaia, which has been targeted by the PRIDE team as a test experiment to improve the VLBI algorithm and to explore the possibility to track Gaia in order to enhance significantly the mission science output, especially in the areas of parallaxes and identification of Solar System's small bodies where accuracy of the order of one milliarcsecond is required.

PRIDE is an experiment with zero impact on the science payload mass, and it offers a high degree of synergy with the typical on-board instrumentation. Near field VLBI can complement the scientific suite of any future missions with transmitting orbiters and/or landers. The flexibility of PRIDE and its many scientific outcomes for the minimal requirements have contributed to make PRIDE one of the selected experiments for JUICE (JUpiter ICy moons Explorer), the next ESA's L-class mission.

Acknowledgments

The authors acknowledge the EC FP7 project ESPaCE (grant agreement 263466). T. Bocanegra Bahamon acknowledges the NWO-ShAO agreement on collaboration in VLBI.

References

[1] Preston, R., et al. 1986, Science 231, 4744, 1414

[2] D. A. Duev, G. Molera Calvés, S. V. Pogrebenko, L. I. Gurvits, G. Cimò and T. Bocanegra Bahamon: Spacecraft VLBI and Doppler tracking: algorithms and implementation, Astronomy & Astrophysics, Vol. 541, 2012.

[3] Molera Calvés G., Cimò, G., Pogrebenko, S.V. & et al., 2014, A&A 564, A4

[4] Rosenblatt et al, in preparation.

[5] Jean-Pierre Lebreton et al: An overview of the descent and landing of the Huygens probe on Titan, Nature 438, 2005.

[6] Fridman P.A., L. Gurvits and S. Pogrebenko: The SKA as a Direct-to-Earth Data Acquisition Facility for Deep Space Science Missions, SKA2009 "Wide Field Astronomy & Technology for the Square Kilometre Array", 2009

[7] Takeuchi et al 2011, General Assembly and Scientific Symposium, 2011 XXXth URSI

[8] Thornton & Border, Radiometric Tracking Techniques for Deep Space Navigation, John Wiley & Sons, Hoboken, NJ 2003

[9] Jones D. L., Folkner W. M., Jacobson R. A. et al: Astrometry of Cassini With the Vlba to Improve the Saturn Ephemeris. AJ 149, 28 2015