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EnVision Radio Science Experiment

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Abstract

EnVision is a one of the three candidate missions selected for the competitive phase-A studies of the M5 call of the ESA's Cosmic Vision program. EnVision aims to unravel the Venus activity and evolution by probing its interior (from the core to the shallow sub-surface), by monitoring its atmosphere, by mapping its surface and detecting present geological activity [1]. To reach the mission goals three instruments and an experiment are foreseen: VenSAR, VenSpec, VenSRS and VenRSE, the latter being the radio-science experiment. These instruments will be carried in a spacecraft orbiting the planet at relatively low-altitude (220-470 km) and on a near-polar orbit (88° of inclination), allowing for local high-resolution and global mapping. This abstract focuses on the specific goals of the VenRSE experiment and how its future data will allow reaching those goals.

1. The Radio-Science Experiment

1.1 Goals

The primary goals of the radio-science experiment of EnVision are to improve our knowledge of the internal structure of Venus and to contribute to the understanding of the atmospheric sulfur cycle. The former will be reached with an improved solution of the gravity field and its tidal contribution (k2 tidal potential Love number) [2], and the latter with radio-sounding when the spacecraft is occulted by Venus as viewed from the Earth [3, 4]. Additional goals are to improve the ephemeris of Venus in order to perform tests of General Relativity [5] as well as to get new Total Electron Content (TEC) profiles of the ionosphere [6].

1.2 Doppler and ranging measurements

The principle of radio-science measurements is to establish a radio-link between the spacecraft orbiting the targeted body and deep space stations on the Earth. For EnVision, this radio-link is provided by the telemetry and commands communication link. The Doppler shift of the carrier frequency of the radio-link and the ranging (station-spacecraft round-trip light time) measurements are then performed by these Earth-based antennas. For EnVision the ESA's ESTRACK stations will be used and possibly the NASA's DSN stations. The baseline is a two-way link (uplink from stations to spacecraft and downlink from spacecraft to stations). The stability in the frequency generated at Earth-based stations is provided by atomic clocks and a radio-transponder onboard the spacecraft. A one-way link (downlink only), using an Ultra-Stable Oscillator (USO) onboard the spacecraft, is under study in the EnVision radio-science design, especially for radio-occultations in order to increase the spatial coverage and precision of atmospheric radio-soundings. The frequency bands that will be used are the X-band (uplink and downlink) and the Ka band (only downlink). The latter is mandatory for downloading the huge amount of data generated by the VenSAR instrument. The X/Ka dual-frequency downlink allows for correcting the effect of dispersive media (essentially the interplanetary plasma) along the propagation path of the downlink, therefore allowing for better Doppler noise (0.03 mm/s at 10 seconds Doppler count time instead of 0.05 mm/s at 10 seconds time count for single X-band radio-links). Ranging can be performed using the X-band up and down links with a precision of around 0.5-1 meter.

Hereafter, we describe how the radio-science measurements are used to recover the gravity field of the planet and improvement of the Venus ephemeris. The radio-occultations (atmospheric sounding) are described in a companion abstract submitted to the same session of this meeting [8].

2. The gravity field recovery

The Doppler measurements are used as tracking data of the spacecraft orbital motion. This motion is accurately reconstructed from these tracking data to extract the gravity field of the planet from the perturbations it generates on this motion (methods of perturbations). The spatial resolution and the accuracy of the gravity solution depends on both orbital altitude, Doppler tracking noise and coverage, a priori knowledge of the gravity field itself, and inaccuracy of the non-gravitational forces due to the atmospheric drag, radiation pressure (cloud top-layer albedo and infra-red emission) as well as residual accelerations generated by attitude maneuvers [9, 10]. The elliptical orbits of the Magellan spacecraft have indeed provided a gravity solution with a spatial resolution of about 300 km on average but including large areas with 500 km spatial resolution in the northern and southern hemisphere at mid-latitudes [10, 11]. The EnVision gravity solution will improve the current Magellan solution by providing a gravity solution with a spatial resolution of 200 km on average. Better and coarse resolution are expected in the southern and northern hemisphere, respectively, due to the slightly elliptical orbit presently planned for the EnVision scientific nominal phase (220-470 km altitude). The accuracy of the gravity solution is also expected to be improved thanks to better Doppler tracking data noise and coverage (at least 3-4 hours of tracking per day) than for Magellan tracking data. The EnVision k2 tidal potential Love number precision will be at around 3% (against 22% for the Magellan solution [12]), allowing to better constrain the state and the size of the core [2].

3. Improving the Venus ephemeris

The precise ephemeris of a planet of the solar system is provided by several observations including the radio-ranging tracking data of spacecraft orbiting those planets. These observations are used in a global inversion procedure to derive the position and velocity of the planet, providing its ephemeris [5]. This inversion procedure is based on a physical model of the planetary motion described in a general relativistic context but also using alternative models of gravity if desired. In turn, the knowledge of the values of the General Relativity parameters (PPN) and tests of alternative theories could be improved. Furthermore, the EnVision mission (launch foreseen in 2032) will happen after the Bepi-Colombo mission (in route to Mercury), providing a good complement to its gravity measurements (MORE experiment), in particular if the EnVision ranging data are obtained with enough accuracy and occurrence.

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