Venus Express spacecraft observations with EVN radio telescopes

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ABSTRACT

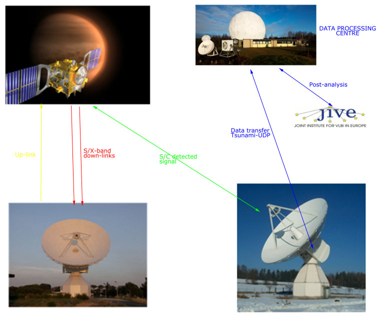
The ESA Venus Express spacecraft was observed at X-band with several European radio telescopes during a 2008-2010 observational campaign in a framework of the assessment study of the possible contribution of the European VLBI Network (EVN) to the upcoming ESA deep space missions. The first goal of these observations was to develop and test the scheduling, data capture, transfer, processing and analysis pipeline. Observed data recorded in a VLBI compatible mode were transferred from the radio telescopes to Metsähovi Radio Observatory (MRO) where they were processed with an ultra-high spectral resolution software spectrometer-correlator and then analysed at Joint Institute for VLBI in Europe (JIVE). The high dynamic range of the detections allowed us to achieve a milli-Hertz level of spectral resolution accuracy and to extract the phase of the spacecraft signal carrier line. Several physical parameters can be retrieved from these observations.

Here we report the technology aspects of our research and preliminary scientific results obtained during several multi-station VLBI phase referencing observations of the Venus Express.

Fig 1: European VLBI Network radio telescopes and partners. These antennae can be used for our purpose of VLBI spacecraft tracking.

INTRODUCTION

Planetary spacecraft (S/C) signal has been used as targets of radio astronomy observations. They offer a new tool for studying a broad variety of physical processes: dynamics of extraterrestrial atmospheres, geodynamical diagnostics of planetary interiors or physics effects of spacecraft motion. Many of these applications require an extremely high angular resolution achievable only with VLBI, coupled with very high spectral resolution. The latest development called Planetary Radio Interferometry and Doppler Experiment (PRIDE) is adopted by a number of prospective planetary science missions as a part of their scientific suite, such as Phobos-Mars mission, the BepiColombo/MMO, ExoMars mission and prospective studies of the Europa Jupiter System Mission (EJSM) and Titan Saturn System Mission (TSSM) [1,2].



In 2008 a campaign including a number of European VLBI Network telescopes (see Fig. 1) started with trial observations of Venus Express focused on spacecraft observations, S/C signal detection, data processing and analysis. The experiments were performed with Metsähovi (Aalto University, Finland), Wettzell (BKG, Germany), Yebes (OANIGN, Spain), Medicina (INAF-RA, Italy), Matera (ASI, Italy), Noto (INAF-IRA, Italy) and Puschino (ASCLPI, Russia) radio telescopes in coordination with ESA Space Astronomy Centre (ESAC). Table 1 describes the main characteristics of the antennae. The typical SNR achieved in the observations is of several thousands in 1 Hz accuracy or several millions in 1 mHz. We demonstrate how the phase-time of the S/C signals was applied to detect interplanetary plasma scintillation on a novel frequency band (X-band) and present the results of this two-year work.

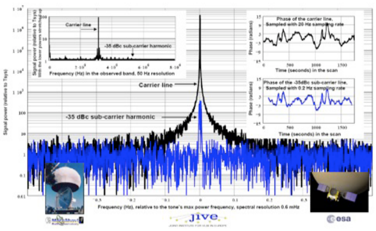
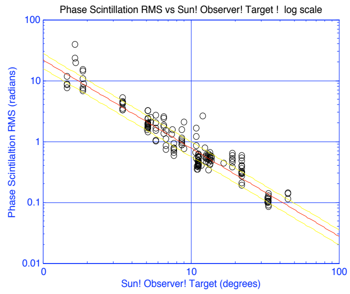


Fig 2: left image, standard VEX observations set-up. Observations are done with any EVN radio telescope, data is transferred to Metsähovi for the analysis.

Fig 5: Below, a comparison between the phase scintillation RMS of the observations samples versus the Sun-Observer-Target (SOT) angle in logarithmic scale.



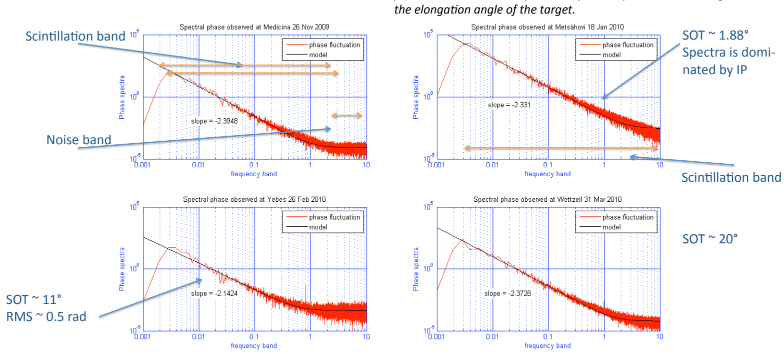
METHODOLOGY

Standard procedure used on our standards VEX or MEX observations:

- Observations at 8400-8450 MHz, (X-band downlink)
- Sampling bandwidth (BW) ≤ 16MHz and 2-bit encoding.
- Data recorded with VLBI equipment (Mark5A/B/C, PCEVN or K5 systems).
- Each session provides several GB's of data.
- High-resolution spectrometer with the SWSpec [3] for first tone detection.
- Construction of the fitting model to compensate the Doppler effect due to the spacecraft motion.
- Spacecraft tone tracking software with the SCTracker [3], tone tracking, filtering and the phase detection.
- Post-analysis of the extracted phases.

Fig 3: left image, First detection of the VEX carrier signal and the respective multi-tones.

Fig 4: Below, several phase fluctuation spectra observed during last year's campaign with the EVN radio telescopes. Note, the different phase variation caused by the Interplanetary Plasma according to the elongation angle of the target.



	Lon (E)	Lat (N)	Elevation (m)	Dish (m)	SEFD	Epochs	Hours	Scans
Metsähovi	24°23'35''	60°13'04''	75	14	3200	13	31	72
Wettzell	12°52'38''	49°08'42''	67	20	750	9	18	41
Yebes	356°54'38''	40°31'27''	543	40	200	6	14	21
Medicina	11°38'49''	44°31'13''	143	32	320	4	7	21
Matera	16°42'14''	40°38'58''	669	20	3000	2	4	11
Noto	14°59'20''	36°52'33''	998	32	770	1	2	6
Puschino	?	?	?	22	?	3	4	6
Total	-	-	-	-	-	***38***	***80***	***187***

CONCLUSIONS

Single- and multi-station observations of the spacecraft signal phase scintillations can assess the characterisation of the achievable accuracy of the phase-referencing VLBI tracking of the spacecraft during critical phases of the mission. Parameterisation of the phase scintillation dependence on the solar elongation and solar activity index will help to better determine the timing of entry events for planetary probes.

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