
# Single baseline GLONASS observations with VLBI: preliminary results

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## Abstract

**We used the VLBI technique, in geodetic mode, to observe signals transmitted by GLONASS (GLObal NAvigation Satellite System) satellites. The radio telescopes involved in observations are Medicina (32 m) and Onsala85 (25 m) both equipped with L-band receiver. Several preparational tests were necessary in order to obtain data that could be processed. During these tests several problems had to be faced, among them the pointing of the satellite by VLBI antennas, the high signal strength of the satellite, etc. In this work we present preliminary results of two successful experiments.**

**The method applied considers the artificial radio signals transmitted by satellites in a similar way as natural radio signal that are emitted by natural radio sources. The signal strength of satellite signals is of course much stronger than the signal strength of natural radio signals, therefore in order to avoid overload of the telescope frontends, corresponding signal attenuation had to be applied. The observations at the stations were performed using the standard Mark4 VLBI data acquisition rack and Mark5A disk-based recorders. The goals of the observations were to develop and test the scheduling, signal acquisition and processing routines to verify the full tracking pipeline, foreseeing the cross-correlation of the recorded data on the baseline Onsala–Medicina. The natural radio source 3c286 was used as a calibrator.**

**It is worth to note that classical astronomical tools can contribute to Space Science, too, in fact VLBI determination of GNSS state vector could also impact the GNSS field leading to improve present models and methods for orbitography especially for those constellations not yet completed (like Galileo and Compass).**

## The two VLBI GLONASS experiments

**Two experiments were carried out on June 28 and August 16, 2010 on the baseline Onsala-Medicina and several GLONASS satellites were observed one by one (see Fig. 1). During both experiments the radio source 3C286 was observed as a calibrator for 2 minutes before the starting of the satellite sessions in June and for 5 minutes at the beginning and at the end of the satellite sessions during August. The observed GLONASS satellites were PR10, PR19 on June 28 and PR13, PR11, PR21 on August 16 2010. The length of the scan on each satellite was of five minutes in June and of 15 minutes in August. Each telescope was re-positioned every 20 seconds to follow the satellite. Some glitches caused by the telescope re-pointing are present in the data residuals with a period of about 20 second (see Fig. 3). The installation of SatTrack module [1] in the VLBI FS (Field System) would simplify the satellite tracking procedure and it is thus strongly recommended. A bandwidth of 16 MHz was observed, and 2 RHCP (Right Hand Circular Polarization) and 2 LHCP (Left Hand Circular Polarization) channels were recorded. Additional attenuation for both RHCP and LHCP (lower for LHCP) channels was applied in order to avoid saturation of the receiving systems by the strong satellite signal. Several studies and data processing have been performed on the data recorded during both experiments. The initial detection of the spacecraft (S/C) carrier signal and tones was performed using the high-resolution spectrometer software (SWSpec) developed at Metsähovi Radio Observatory and JIVE in the framework of the Planetary Radio Interferometry and Doppler Experiments (PRIDE).**

**For GLONASS spacecraft spectrum analysis we used 1.6x106 DFT (Discrete Fourier Transform) points, 1 second as integration time and Cosine-squared windowing for a spectral resolution of 20 Hz over the 16 MHz bandwidth.**

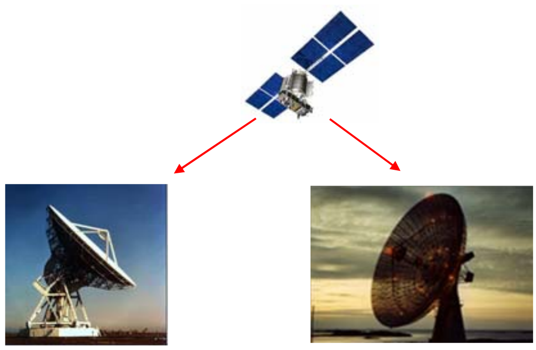

**Fig. 1: GLONASS satellite observed by Medicina (left) and Onsala (right) radio telescopes.**

## Spectral Analysis of the 2010-Jun-28 data

**The Onsala spectra (e.g. PR10 satellite) were very good centred (see Fig. 2 top). A Doppler analysis on the same data set was also performed (see Fig. 2 bottom) where a zoom-view was performed for the 2 kHz band around the carrier, after adaptive stopping of the Doppler.**

**The extracted signals were subjected to further post-processing, performed with the digital Phase-Lock-Loop (PLL) software (see Fig. 3).**

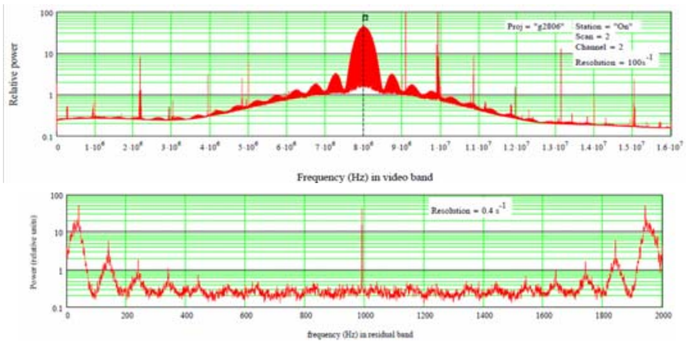


**Fig. 2: Spectrum of the GLONASS PR10 satellite observed at Onsala (top), a 16 MHz bandwidth with a spectral resolution of 100 Hz was used here, while for real operation a 20 Hz resolution was used. The carrier line is in the middle of the central lobe.**
**Corresponding SCTracker spectrum output (bottom). The GLONASS spacecraft signal is correctly stopped into a 2 kHz band around the carrier. The BW is 2 kHz with the spectral resolution of 0.4 Hz.**

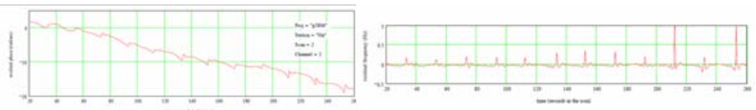

**Fig. 3: Post-PLL residual phase in the 1 Hz adaptive tracking band (left) and Post-PLL residual frequency (right). Glitches caused by the telescope re-pointing are present with a period of about 20 seconds.**

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## Data correlation of the 2010-JUN-28 experiment

**The GLONASS signal spectra detected at Onsala were very good centred for each of the tracked satellite. However because of a failure in the observing setup, Medicina spectra were far from the centre: they happened in the far away side lobes. Anyway, since the satellite signal is very strong and coherent, cross-correlation was calculated too. The DiFX software [2] was used, and cross-correlation fringes and residual phase of the fringe for the calibrator 3c286 are shown in Figure 4.**

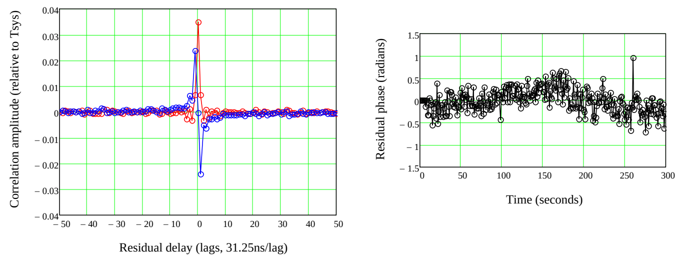


**Fig. 4: Cross-correlation function (fringe) of the clock offset calibrator radio source 3c286, as detected during our experiment on the baseline Onsala-Medicina using the DiFX software correlator (left). Residual phase of the fringe. Clock offset calibration accuracy is at a level of 0.2 ns, clock rate offset determination accuracy is better than 0.05 ps/s. Phase noise is at a level of 0.2 radians at 1 s sampling (right).**

## Data processing of the 2010-AUG-16 experiment

**The signals of the reference source were correlated with the software correlator DiFX in order to determine clock offsets and clock offset rates between the stations. The geometric part of the delay was computed using the Sekido-Fukushima [3] model for a near field radio source. Primary detection of the carrier of the satellite frequencies was conducted using again the Metsähovi/JIVE software. Processing, for phase stopping and narrow-band filtration of the carrier and its extraction was also performed using still spacecraft tone tracking software SCTracker. The frequency detection noise is at a level of several mHz in 1 second. Results of the narrow-band signal processing were then analysed at JIVE. The differential frequency of the PR21 GLONASS satellite (baseline Onsala – Medicina) shows a linear trend that is very close to zero (Fig. 5 left). Such differential frequency is used to compute the differential phase, which is then adopted for determination of spacecraft position corrections (Fig.5 right).**

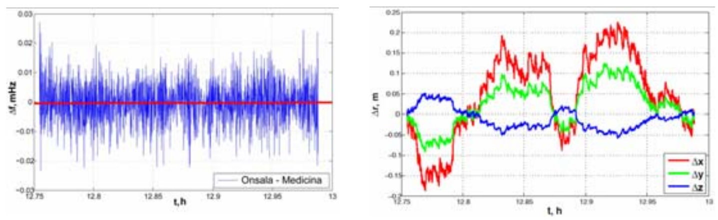


**Fig. 5: Differential frequency of the GLONASS PR21 satellite carrier (left); corrections to the ITRF position of the satellite (right).**

**Conclusions: These results show that the objectives of VLBI-observations of GNSS satellites can be achieved. Dual-frequency observations (G2/G1) are advised to allow ionosphere correction. We expect that increasing the number of observing telescopes, the length of baselines and the duration of observations will lead to a significant improvement of GNSS ephemeredes accuracy from current 5 cm.**

**References**

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