Co-location of space geodetics techniques in Space and on the ground

J. Kodet, Chr. Plötz, K.U. Schreiber, A. Neidhardt, S. Pogrebenko, R. Haas, G. Molera, I. Prochazka

Abstract The most demanding goal of the Global Geodetic Observing System (GGOS) initiative is the definition of station positions to an accuracy of 1 mm and the corresponding velocities to 0.1 mm/year. Fundamental stations are core sites in this respect, because they collocate the geodetic relevant space techniques. However this requires unprecedented control over local ties, intra- and inter-technique biases. To improve the accuracy of the geodetic techniques, new concepts for the monitoring and controlling of local ties and biases have to be implemented. We are developing a symmetric two-way measurement technique to identify unaccounted system delays within and between the instrumentation of the Geodetic Observatory Wettzell. It requires redesign of the VLBI (Very Long Baseline Interferometry) phase calibration generator to be compatible with such an two-way measurement technique and VLBI2010. Another activity is the mapping of Global Navigation Satellite System (GNSS) satellites into the frame of the quasars using VLBI telescope, in geodetic mode. This corresponds to a collocation of geodetic techniques in space. The receiver of the 20 m radio telescope Wettzell (RTW) has been modified to measure the GNSS L1 signal without changing the physical reference point. Preliminary experiments have already been executed.

Keywords GNSS with VLBI, Two-way Measurement, L-band receiver

1 Introduction

All the major measurement techniques of the space geodesy are characterized by a very high measurement sensitivity, which resolves the measured quantities, such as the range to satellites or delays between radio telescopes for signals from quasars sources to about 1 part in 10^9. While all the different observing stations have an impressive precision, the accuracy still carries biases in excess of estimated measurement precision. Within each of the techniques, these errors are minimized by a non linear data fitting process.

Fundamental stations on the other side are important, because they are providing a link from one measurement technique to the other. However this is also the link, where discrepancies between precision and accuracy become evident. The Geodetic Observatory Wettzell is one of these fundamental stations and has repeatedly carried out survey campaigns, which reproduce the geometric relationship between the various geodetic markers on the observatory with 2 mm accuracy. A history of nine such consistent campaigns covering more than 20 years in time has been built up in Wettzell. Summarizing up the results of the local surveys in Wettzell, one can conclude that local ties in Wettzell lies in order of 1-2 mm. It is well below the biases, which one can observe between different observations techniques. Therefore it is important to take a closer look on the intra-technique biases, to undertake every effort for its reduction. In Wettzell we are systematically working on new calibration techniques, which try to capture not measured biases.

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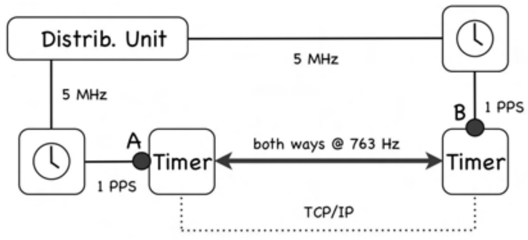

Fig. 1 Block diagram of the TWTT concept for the estimation of the offset and drift of two clocks.

2 Inter-Technique Comparison and Two-Way Measurement Concepts

The Two-Way-Time-Transfer (TWTT) method is a powerful tool for finding offsets and drifts in distributed timing systems (fig. 1). A highly reciprocal system with two highly resolving timers was developed at the Czech Technical University in Prague. The event timers use a measurement method that is based on the fact that a transversal SAW filter, which is excited by a short pulse generates a finite-time signal with highly suppressed spectra outside a narrow frequency band. It results from the sampling theorem, which tells, if the responses to two excitations are sampled at clock ticks, they can be precisely reconstructed from a finite number of samples. Then they can be compared to determine the time interval between the two excitations [Panek (2007)]. A detailed analysis of measurement errors of this method has been given in [Panek (2008-1)] and [Panek (2008-2)].

Using TWTT concepts the differences between the two clocks can be characterized to better than 1ps between two points A and B with a distance of more than 100 m apart. The principal of operation consists of two steps. At first a pulse generator in the timer A generates a pulse, which is timed at both devices, using the interconnecting coaxial cable. Then the process is repeated with a pulse generator in the timer B passing through the cable in the other direction. From this pair of measurements the timescale offset between the two timers can be obtained as

$$\Delta\tau = \frac{1}{2}\left((t_{B1}-t_{A1})+(t_{B2}-t_{A2})\right). \tag{1}$$

On the Geodetic Observatory Wettzell we have investigated the stability of the local time offset between the Caesium master standard and the GNSS laboratory. The results are given in fig. 2. Both event timers were connected to a local 100 MHz source at point A (time laboratory) and point B (GNSS room) derived from a common 5 MHz frequency distributor of the observatory. Timing the 1 pps pulses at the master clock and in the GNSS room with the TTWT concept provided a stable offset of around 549.7 ns over almost 20 days.

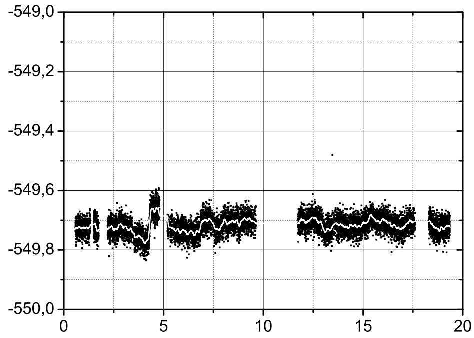

Fig. 2 Time offset comparison between the Master Clock (MC) in the time laboratory and the GNSS room: the time scales in both places are formed by cesium standards and are located in different buildings with a distance of 100 m apart.

3 GNSS satellite observations

Observing the GNSS satellites with telescopes of the VLBI Service for Geodesy and Astrometry (IVS) in near real-time, with high precision and directly in the reference frame, which is defined by the extragalactic radio sources (International Celestial Reference Frame) is challenging, because it can be used for the combining of data from the Satellite Laser Ranging (SLR), the GRACE satellite mission, the DORIS systems, and from the GNSS receivers themselves [Dickey (2010)].

In order to facilitate the inter-technique comparison between GNSS and VLBI, we have added a receiver chain in parallel to the standard S band channel of the 20 m radio telescope Wttzell. The additional receiver allows the detection of L1-band signals of the GNSS satellites with VLBI, keeping the physical reference point of the feed (fig. 3 and 4). The new receiver chain was very helpful in establishing the total power level balance from GNSS satellites. We found that the limiting part of the S-band receiver chain cannot be found in the S-band Low Noise Amplifiers (LNAs), however there is a strong attenuation of the microwave component, which transfers circular to the rectangular waveguide.

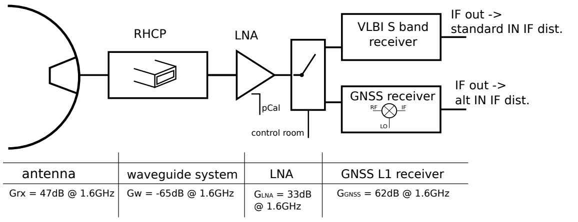

Fig. 3 The block diagram shows, how the L1-band GNSS receiver is connected in parallel with the old S-band receiver.

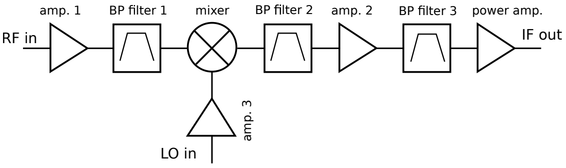

Fig. 4 The principal block diagram of the used components in the new GNSS receiver.

To observe satellite passages with the 20 m radio telescope Wettzell, it was necessary to prepare suitable schedules for the NASA Field System, which is used to control the observation session. To enable this, the prediction software from the Satellite Laser Ranging System, which uses the orbit predictions in form of the Consolidated Prediction Format (CPF), was extended. Now it is able to produce elementary schedule files with pointing information for different time intervals with sampling steps of the passage greater or equal to one second. Another tested possibility was the direct usage of Two-Line Elements, which were converted to track points for the antenna control unit. The preliminary experiments were focused on finding a GNSS signal, which was recorded using the usual Mark5B system. With a preliminary Matlab script we generated Glonass ranging codes and performed a signal acquisition (fig. 5).

We are now working towards a number of common test measurements with the Onsala station. A first common observation with Onsala, Sweden was already possible. The used schedule for this satellite tracking was gently offered by the Joint Institute for VLBI in Europe (JIVE) and used right ascension and declination pointing data with sampling steps of 15 seconds. The first common experiment was already executed successfully. Correlations between the station Onsala and Wettzell were found during the correlation at JIVE. Currently the correlation results are under further analyses.

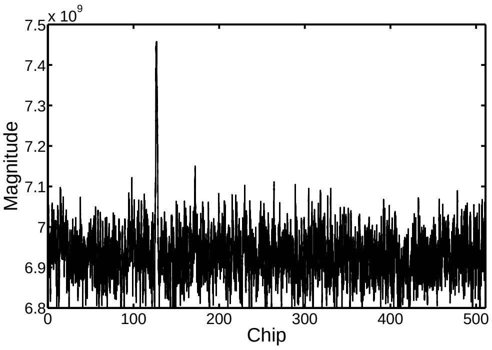

Fig. 5 Results from the correlation between the raging code of Glonass 118, which was generated in a PC, and the recorded VLBI data.

4 Conclusions

The Global Geodetic Observing System (GGOS) requires both, a reduction in measurement errors as well as a considerable reduction of systematic errors within the measurement techniques of space geodesy. At the same time, new demands like highly accurate time transfer emerge. Current geodetic observatories are not yet equipped for these demands. The Geodetic Observatory Wettzell has embarked on the modernization of the time and frequency distribution for all the techniques of space geodesy. It also applies highly resolving two-way time transfer techniques in order to find and eliminate unaccounted systematic errors within VLBI, SLR and GNSS. It must be well assisted by inter- and intra-technique collocations on ground and in space in response to the challenging GGOS demands.

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