Permanent monitoring of the reference point at the 20m radio telescope Wettzell

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Abstract

To achieve the aims of the VLBI2010 agenda and of the Global Geodetic Observing System (GGOS) an automated monitoring of the reference points of different geodetic space techniques, such as Very Long Baseline Interferometry (VLBI), is desirable. The resulting permanent monitoring of the local-tie vectors at co-location stations are essential to obtain the sub-millimeter level in the combinations. For this reason a monitoring system was installed by the Geodetic institute of the University of Karlsruhe (GIK) to observe the 20m radio telescope for VLBI at the Geodetic Observatory Wettzell from May to August. A specially developed software from the Geodetic Institute of the university collected data from automated total station measurements, meteorological sensors, and sensors in the telescope monument (e.g., Invar cable data). A real-time visualization directly offered a live view of the measurements during the regular observation operations. Additional scintillometer measurements allowed refraction corrections during the post-processing. This project is one of the first feasibility studies aimed at determining significant deformations of the VLBI antenna due to, for instance, changes in temperature.

1. Introduction

The combination of different reference frames is only possible, when the positions of the collocated systems for the different space techniques are well known[1]. The determination of position and orientation between those reference points is done by highly precise and regularly made local surveys. But in general these measurements are just snap-shots with no regard to variations over time, e.g. given by temperature changes during one day or during the year. Indeed there is a correction model for height differences for VLBI antennas according to temperature changes (see [9] and [7]) but changes in positions are not yet considered. Therefore a permanent monitoring concept was realized at the 20m radio telescope of the Geodetic Observatory Wettzell to evaluate the movements of the reference point over a period of 3 months in the summer of 2009[5]. It also shows a possible realization of a permanent monitoring system for the determination of the local-ties in sub-millimeter accuracy, as requested for the Global Geodetic Observing System (GGOS, see [8]).

2. The used monitoring concept HEIMDALL

For the use case to realize a permanent monitoring system of the geometric reference point of the radio telescope at the Geodetic Observatory Wettzell in Germany, a special software concept was designed by the Geodetic Institute of the university of Karlsruhe, Germany. The acronym of the mostly in Java written software HEIMDALL stands for "High-End Interface for Monitoring and spatial Data Analysis using L2-Norm" and is also the name of a god for protection in old northern European mythologies. The myth says that the god sees during the day and night in the same high quality and that he can hear the grass growing[2]. In Wettzell, HEIMDALL was a measuring laptop connected to several sensors (see fig. 1). Main instrument is a programmable total station from Leica (TCA2003) with an accuracy for distances of 1mm+1ppm and for angles of 0,15mgon. For the EDM corrections of the distances a meteorological data logger of the type MSR145W were used. In addition, four permanently installed temperature sensors in the telescope tower, the strain measurements along the azimuth axis and the telescope angles for azimuth and elevation were registered. All collected data were saved in a MySQL database from where dynamic services offered a web presentation of the measuring processes. For refraction corrections during post-processing a parallel installed scintillometer offered momentum flux and heat flux data which are used to determine temperature gradients with Monin-Obukhov-Similarity-Theory[4].

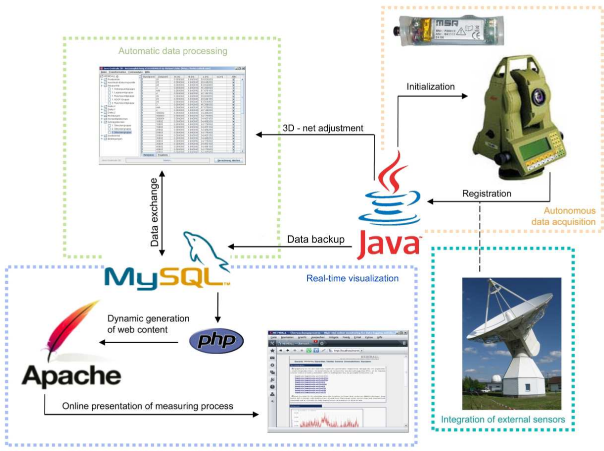

Figure 1. Scheme of the used monitoring system HEIMDALL

3. The observing concept

The observation time was 3 months total, from mid May to mid August 2009. As the geometric reference point, which is the intersection of azimuth and elevation axis, is not directly usable, very small, externally mounted reflectors on the outside of the elevation cabin were installed. Therefore variations of the reference point can be derived indirectly from this rigid setup. The whole net was observed in 15 minute intervals. Seven supporting points from the local surveying net on the area of the observatory offered the stable geometry to observe the five object points on the telescope (see fig. 2). For a later 3D-adjustment, the tipping axis and reflector heights of supporting net points were classically identified. To offer a possibility for refraction corrections, a scintillometer was installed permanently during the whole project. The correction is done during the post-processing. Therefore $1\,^{\circ}\mathrm{C}/m$ can lead into an apparent lift of 0.8mm over a distance of 40m[3]. This variation can be corrected by the setup. But the derived temperature gradients are used at overall zenith angles, which reduces the effectiveness of this method. The setup was completed by parallel operated dedicated measurements of declinations with a Nivel and distances with a laser tracker.

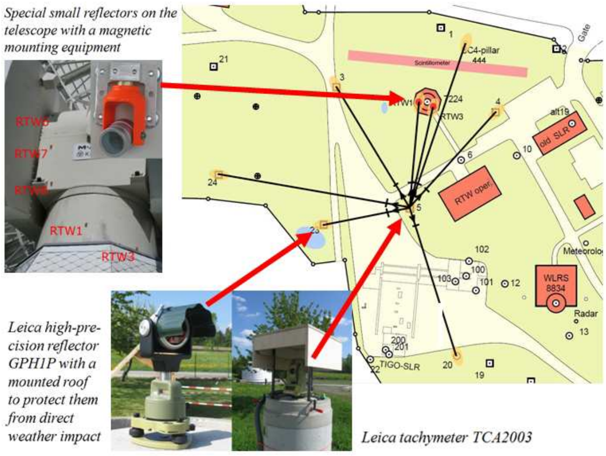

Figure 2. Monitoring network, used total station and reflectors

4. The analysis and results

Changes of the reference point were investigated under different load situations, induced by different elevation positions, using a high-precise tilt-meter "Nivel210". For these experiments the antenna was moved to 10 defined positions in elevation each time on 12 different azimuth angles. At each azimuth position the tilts were registered during the up and down path of the elevation. Additionally the whole experiment was repeated bringing the Nivel onto different height positions in the telescope tower. The registered data show significant deformations depending on different elevation positions. It shows that the reference point moves it's position 0.05mm between an elevation of 0° and 90°.

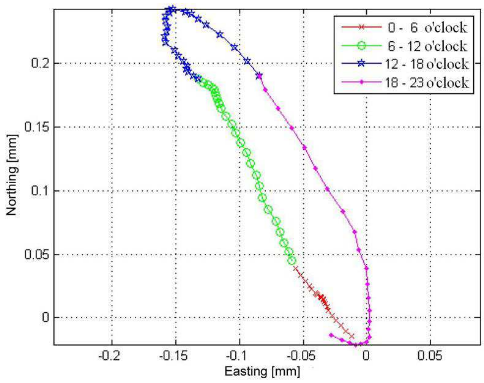

Figure 3. Estimated daily variation of the reference point position

Using the adjusted data from the total station measurements, a daily, periodic variation for positions could be derived, which is superposed by a long-term trend. A fourier analysis allowed it to create a model, to transfer the results from the cabin surface to the internally located reference point. It showed that the reference point moves its position in both axis of about 0.2mm over the period of one day (see fig. 3). For a reliable statement about the annual trend a longer observation campaign would be needed.

The permanent measurements at the Geodetic Observatory Wettzell showed that changes in position could be detected due to load changes or insolation (temperature changes). Concerning the variations defined within GGOS of about 0.1mm[8], the results become more and more relevant. Similar to the used height correction, the usage of derived mapping functions could possibly increase the reliability of VLBI-results. Therefore future research on that point are strongly recommended.

5. Conclusion

A major requirement in the agenda 2010 for the usage of future VLBI telescopes is a permanent monitoring of relevant system parameter[6]. With HEIMDALL a system test for a possible reference point monitoring was shown[1]. The derived time series showed an impressive stability of the reference point of the 20m radio telescope Wettzell. But to evaluate also the long-term stability longer lasting monitoring series should be conducted.

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