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## Permanent Monitoring of the Reference Point of the 20m Radio Telescope Wettzell

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### Abstract

To achieve the goals of the VLBI2010 project and the Global Geodetic Observing System (GGOS), an automated monitoring of the reference points of the various geodetic space techniques, including Very Long Baseline Interferometry (VLBI), is desirable. The resulting permanent monitoring of the local-tie vectors at co-location stations is essential to obtain the sub-millimeter level in the combinations. For this reason a monitoring system was installed at the Geodetic Observatory Wettzell by the Geodetic Institute of the University of Karlsruhe (GIK) to observe the 20m VLBI radio telescope from May to August 2009. A specially developed software from GIK 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 co-located systems for the different space techniques are well known [1]. The determination of position and orientation between the reference points of the space geodetic instruments is done by highly precise and regularly made local surveys. But in general these measurements are just snapshots that neglect variations over time such as temperature changes over the course of a day or a year. Indeed there is a correction model for height differences for VLBI antennas due to temperature changes (see [9] and [7]); however, changes in position 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 three 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 with sub-millimeter accuracy, as required by the Global Geodetic Observing System (GGOS, see [8]).

### 2. The Used Monitoring Concept HEIMDALL

In order to realize a permanent monitoring system for the geometric reference point of the radio telescope at the Geodetic Observatory Wettzell in Germany, the special software HEIMDALL was developed at the Geodetic Institute of the University of Karlsruhe (GIK), Germany. The acronym of the mostly Java software HEIMDALL stands for “High-End Interface for Monitoring and spatial Data Analysis using L2-Norm” and is also the name of the god of protection in old northern

European mythologies. The myth says that the god can see with the same high quality during the day and night and that he can hear the grass growing [2]. In Wettzell, HEIMDALL was installed on a laptop connected to several sensors (see Fig. 1). The main instrument was a programmable total station (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 was used. In addition, readings from the four permanently installed temperature sensors in the telescope tower, strain measurements along the azimuth axis, and telescope angles in azimuth and elevation were recorded. All collected data were saved in a MySQL database from which dynamic services offered a Web presentation of the measuring processes. For refraction corrections during post-processing, a parallelly installed scintillometer provided momentum flux and heat flux data, which were used to determine temperature gradients using the Monin-Obukhov-Similarity-Theory [4].

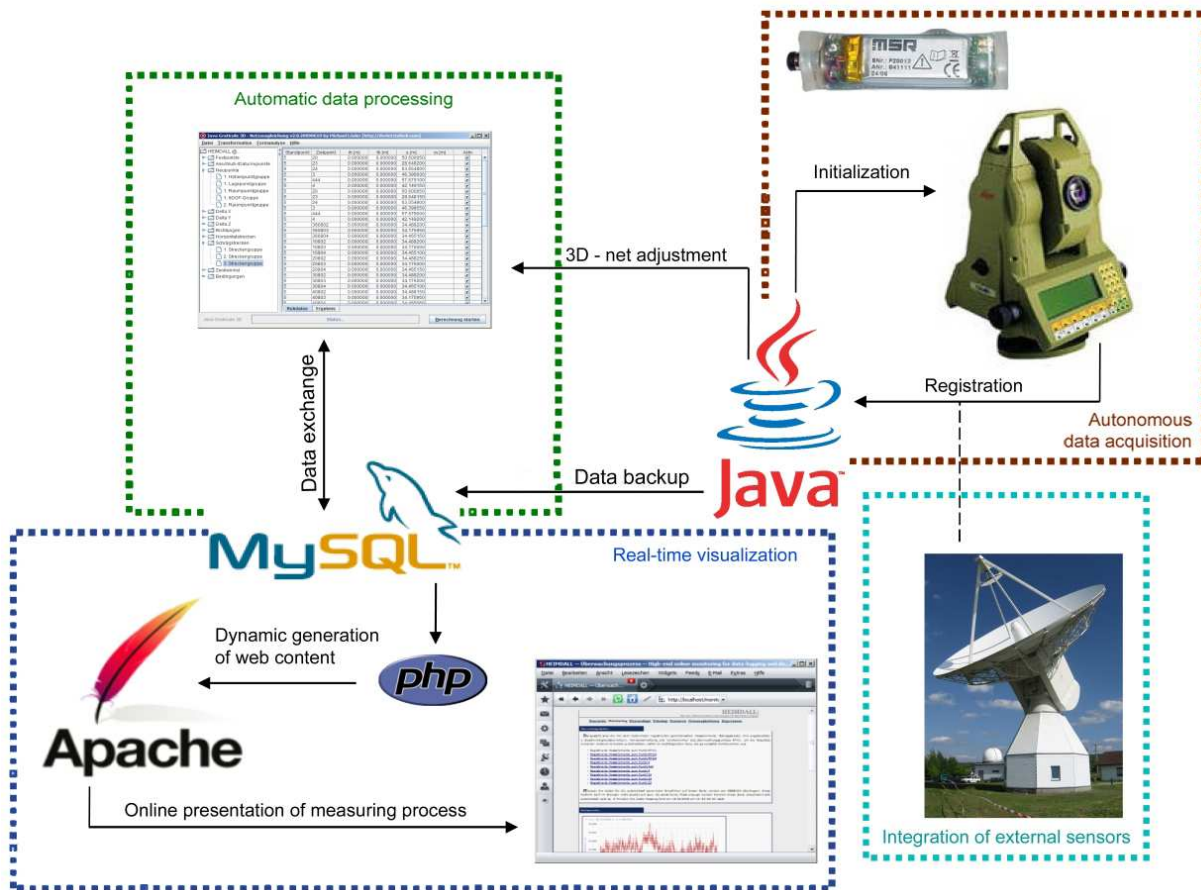


Figure 1. Scheme of the used monitoring system HEIMDALL.

### 3. The Observing Concept

The observation time was three months total, from mid-May to mid-August 2009. As the geometric reference point, which is the intersection of the azimuth and elevation axes, is not directly accessible, very small, externally mounted reflectors on the outside of the elevation cabin were installed. With this rigid setup, variations of the reference point can be derived indirectly. The whole net was observed in 15-minute intervals. Seven points of the local surveying net in 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 the network points were classically identified. To offer the possibility of refraction corrections, a scintillometer was installed permanently during the whole project. The correction is done during the post-processing. A gradient of  $1^{\circ}\text{C}/\text{m}$  can cause an apparent uplift of 0.8 mm over a distance of 40 m [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 parallelly operated dedicated measurements of declinations with a leveling instrument and distances with a laser tracker.

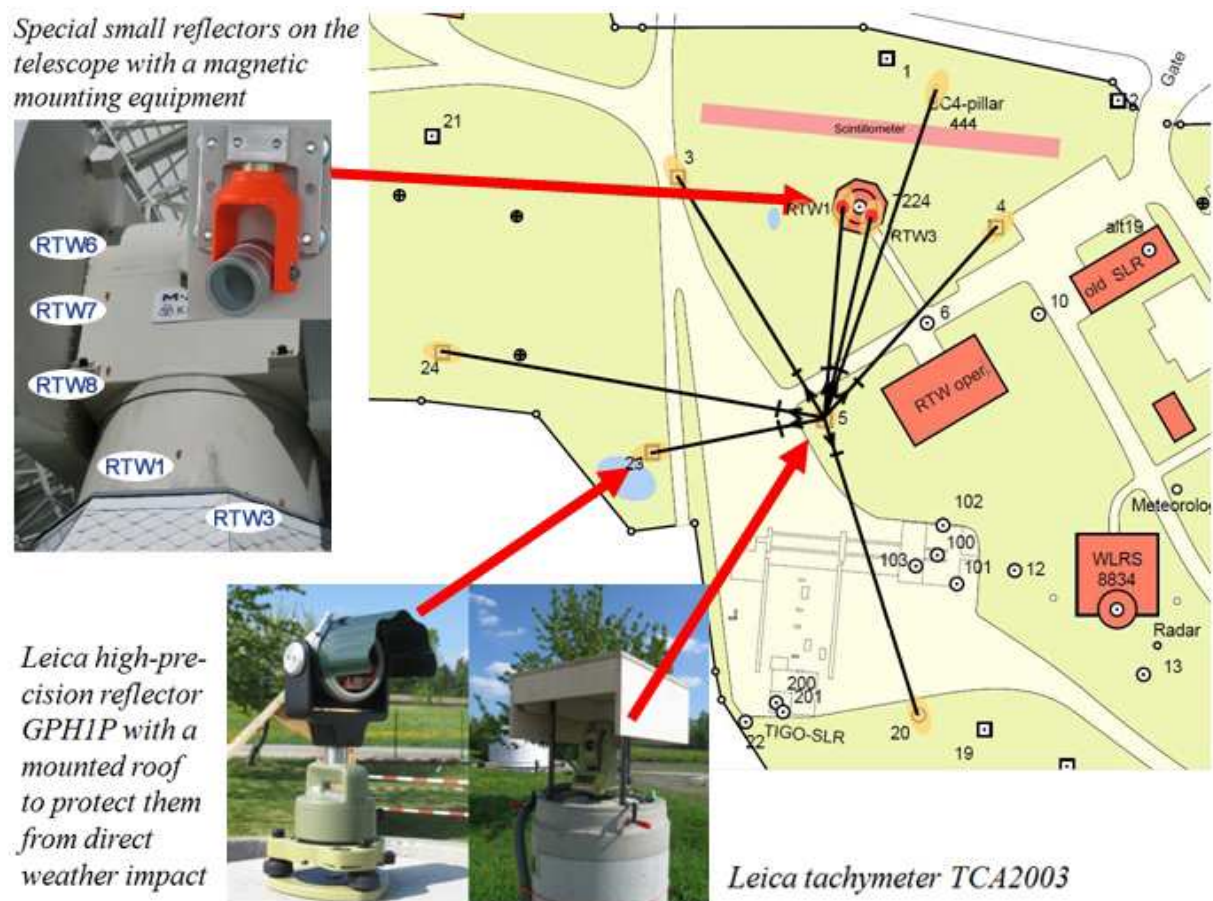


Figure 2. Monitoring network, total station, and reflectors.

#### 4. The Analysis and Results

Changes of the reference point were investigated under different load situations, induced by different elevation positions, using a high-precision tiltmeter “Nivel210”. For these experiments the antenna was moved to ten defined positions in elevation for each of twelve 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 with the tiltmeter at different height positions in the telescope tower. The recorded data show significant deformations depending on the elevation position. This indicates that the reference point changes its position by 0.05 mm between an elevation of  $0^\circ$  and  $90^\circ$ .

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 the creation of a model for the transfer of the results from the cabin surface to the internally located reference point. It showed that the reference point moves in both axes by about 0.2 mm over a period of one day (see Fig. 3). For a reliable statement about the annual trend a longer observation campaign would be needed.

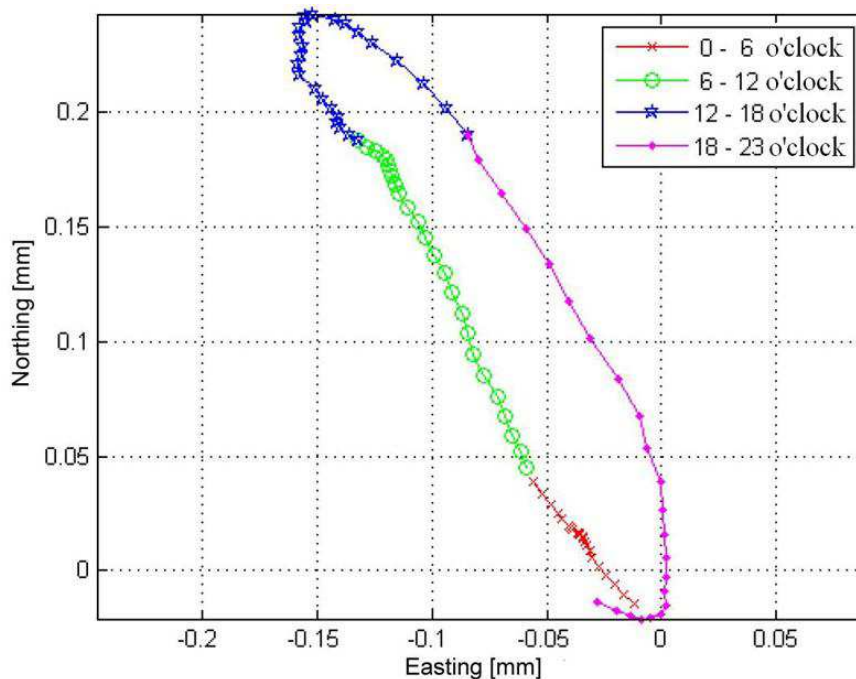


Figure 3. Estimated daily variation of the reference point position.

The permanent measurements at the Geodetic Observatory Wettzell showed that changes in position could be detected for load changes and insolation (temperature changes). Concerning the maximum variations allowed by GGOS of about 0.1 mm [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 is strongly recommended.

## 5. Conclusion

A major requirement for the telescopes of the VLBI2010 project is a permanent monitoring of relevant system parameters [6]. With HEIMDALL a proof-of-concept test for a possible reference point monitoring system was shown<sup>1</sup>. 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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