An Agile Method to Detect Deformations of the VLBI Dish

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Abstract Gravity and temperature variations deform the radio telescope dish and structure during VLBI measurements, thus affecting the reference point determination. Full determination of the deformations is time-consuming and requires a dedicated campaign to investigate the form of the full paraboloid surface of the VLBI antenna dish. In this paper we investigate a more agile method using spherical prisms attached to the dish structure and a robot tachymeter. We tested the method at the Metsähovi Geodetic Research Station's VGOS antenna and measured the angles and distances to the points in the telescope and dish structure in different antenna elevation positions. The distances between the points were calculated and projected in each elevation position to the Cartesian system, axes of which are the pointing direction, the elevation axis direction, and the third one orthogonal to those. The projected distances were then analyzed. In our experiment we detect mm-level changes at different dish elevation positions. The method could be used to complement the full determinations, even during VLBI-sessions.

Keywords Gravitational deformations, VLBI telescope

1 Introduction

Temperature variations and gravity among other environmental parameters deform the telescope dish. Laser-scanning is currently the main method of getting information on the dish surface and the changes in focal length (e.g., [1]). Organizing or preparing a laser-scanning campaign is laborious. There is a risk of damaging the structure or the equipment, while the cost-benefit ratio might be low. A relevant option is to use close-range photogrammetry. Another problem is how and where the instrument should be placed. From ground level, the dish surface is not visible at higher elevation positions. One solution is to use drones (e.g., [2]).

Terrestrial measurements have been long used in the determination of the reference point (RP) of the telescope. The targets or prisms were measured in different antenna angle positions and the coordinates of RP estimated [3]. Sarti et al. [4] used tachymeter measurements with the laser-scanning and finite element model successfully also for modeling the signal path variation and gravitational deformations.

Developing an agile method to detect deformations is ongoing. The method could be used between the more complete deformation measurements. The agile method should be quick, to not allow unknown environmental parameters to change during the measurements. There should be no need for extra preparations and no need to touch the telescope. The measurements and processing should be automatic.

In this paper, we present the first results of tachymetric measurements for detecting changes in the distances between the points in the structure of the telescope.

2 Measurements

Angles and distances were measured to spherical prisms, attached to the dish structure, with a Leica

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Fig. 1 Measurements with Leica TS50 robot tachymeter.

TS50 robot tachymeter (Figure 1). The azimuth of the VLBI telescope was kept fixed to the angle optimal for the prism incident angle. The measurements were connected to the local pillar network (Figure 2). The same prisms were observed in 19 elevation positions. The left and right sides of the telescope were measured separately by rotating the telescope around the azimuth axis about 180°. The measurement session

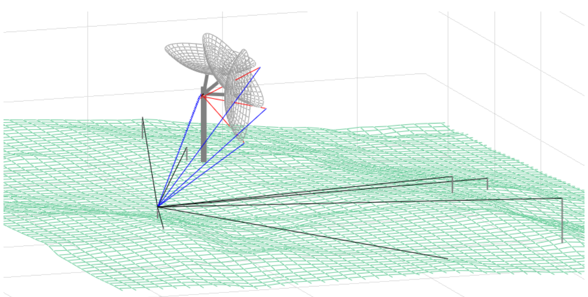

Fig. 2 Measurements: black lines are for instrument orientation, blue ones are for the prisms on the structure of telescope, and red lines are the vectors between the points to monitor.

was automated. The movement of the VLBI telescope was controlled with an in-house MATLAB routine using predefined azimuth and elevation angles, as well as elapsed time values for moving to the new position. The tachymeter measurements were synchronized with VLBI movements and controlled with another in-house software. The predefined approximate prism coordinates were used for quick automatic aiming and measurements. The whole measurement session took about 20 minutes.

3 Data Processing

The first velocity correction and scale and additive constant corrections were applied to slope distances. The angles were aligned to refer to the ellipsoid normal using the geoid model. The horizontal orientation came from the local pillar network, which is aligned to ITRF2014. The coordinates for each prism point were calculated.

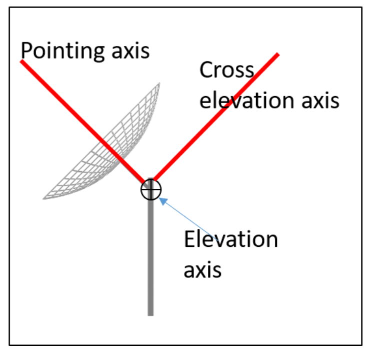

Fig. 3 Axis system where the monitored distances were projected.

4 Analysis

The distances between the determined prism points were calculated, and the coordinate differences were transformed into the Cartesian coordinate system of the telescope. Both of the tracked prism points rotate around the elevation axis, which was estimated by fitting the two circles with a common axis. The pointing axis was then calculated as a cross product of an estimated azimuth axis and elevation axis. The cross elevation axis was then orthogonal to the elevation axis and the pointing axis (Figure 3).

The azimuth axis or the pointing axis cannot be estimated from the collected data, so an estimated azimuth axis from previous reference point monitoring was used. The axis directions form the base of the coordinate system of the telescope. The vectors between the prism points are then transformed to that base and stan-

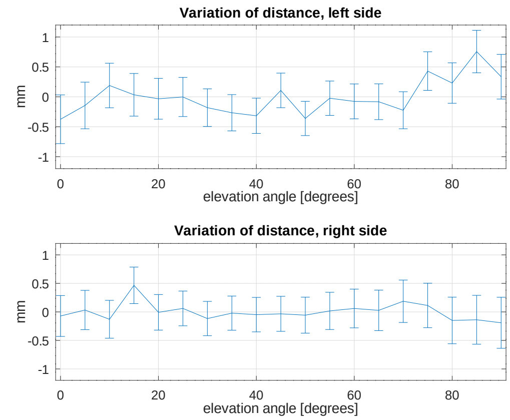

Fig. 4 Variation of the monitored inter-prism distances. The averages of the distances were 8.8544 for the left side and 9.6234 for the right side.

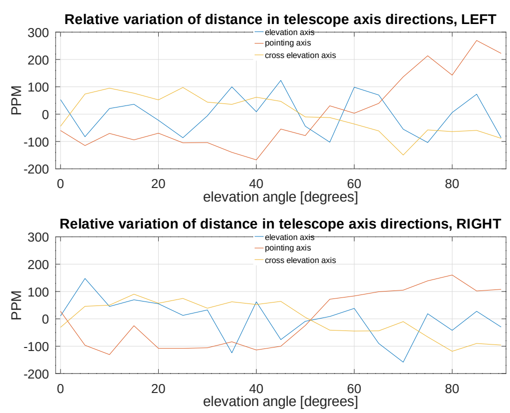

Fig. 5 Variation of inter-prism distances projected to the telescope axis system.

dardized by dividing them by the corresponding component and multiplying the result by 10^{-6} to obtain a PPM value (Figure 5).

5 Results

The results of the variation of the distance (Figure 4) and the PPM values (Figure 5) of each component in the telescope base are presented as a function of the elevation angle of the VLBI telescope. In the pointing direction, the distance increases when the elevation increases. The diameter of the dish seems to decrease in the cross elevation direction when the elevation angle increases. We are not able to see the deformation in the elevation axis direction.

6 Conclusions

The experiment was successful, showing the potential of the method. We also noticed several places which can be developed in the future. More prisms and simultaneous observations with two tachymeters from the left and right sides will give us more geometrical information, especially in the elevation axis direction. The prism points need to be carefully chosen to allow determination of the most relevant distances for the analysis of the dish deformation (or other purposes). This method is applicable also to other sites, and most importantly, it can be used during the normal operation of a telescope.

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