Determination of the reference point of the Metsähovi SLR telescope

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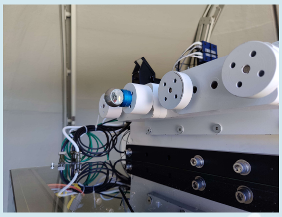
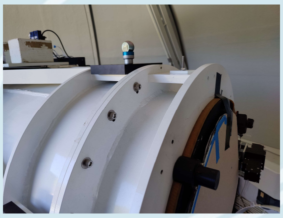
Introduction

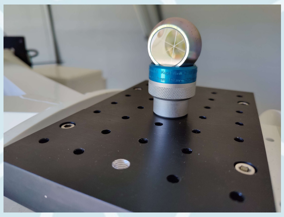
Metsähovi Geodetic Research Station (MGRS) is one of the core stations of the GGOS. MGRS hosts all the major geodetic techniques with the next generation SLR and VLBI systems being finalized. The Finnish Geospatial Research Institute (FGI) has been a part of a large EMPIR (European Metrology Research Programme) funded consortium to study the best methods for measuring and establishing reliable and accurate local ties between all the geodetic infrastructure.

Method for the SLR telescope axis intersection determination

To determine the intersection of the azimuth and elevation axis of the SLR telescope and tie it to the local and global coordinates, we used a robotic total station Leica TC50 to measure accurate locations of two Bohnenstingl 1.5" retroreflectors attached on the telescope's optical tube assembly, images below. Measurements were done from two pillars outside the dome in several Az and El positions of the telescope and connected to benchmarks around the observatory. The telescope was rotated around the azimuth axis in two different elevation positions. The elevations were approximately 0 and 19 degrees in the first session and 0 and 33 degrees in the second one. The telescope was rotated manually without accurate angle information from encoders, since the telescope control system was not fully functional. We used three different methods for the reference point estimation**: 1) fitting spheres to the measured points.2) Fitting circles at different elevations. 3) A more comprehensive antenna model**. The purpose of the measurements was to get the first accurate reference point coordinates, possibly reveal major offsets in the axis intersection, and to learn how the process should be automated at MGRS in the future.







1. Model: Sphere fitting

In the simplest model we fitted spheres to the measured prism points, **Figure 1**. and **Table 1.** The points of tracked two prisms are on the surfaces of the spheres with the same centre providing that there is no axis offset and no deformations.

2. Model: Circle fitting

In the 3D circle fitting method, we only have circled the azimuth axis. The elevations are kept fixed as well as possible. With the assumption that the circles have rotated around the same axis, we estimated the central points of each eight circles and the common axis, see **Figure 2.** and **Table 1.** The position of the reference point in the axis remains unknown**. The centre from the sphere fitting method fits well to the axis**.

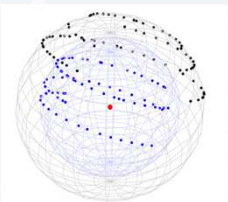


Figure 1. Sphere fit. *Two spheres with the same centre have been fitted to the coordinates of tracked prisms*

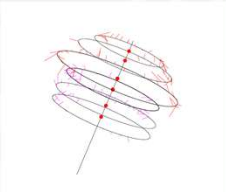


Figure 2. Circle fit. *Eight circles with the common axis have been fitted to the coordinates of tracked prisms*

Model std	N[m] sN[mm]	E[m] sE[mm]	U[m] sU[mm]
Metsähovi antmod	-17,181606	1,771162	-0,348779
	0,03	0,03	0,08
Spherical fit	-17,181595	1,771195	-0,348638
	0,04	0,04	0,1
circle 0° pr1 P1	-17,181302	1,770286	0,085747
	0,05	0,04	0,08
circle 0° pr2 P1	-17,181458	1,770668	-0,076755
	0,05	0,04	0,08
circle 19° pr1 P1	-17,181041	1,769651	0,35579
	0,05	0,05	0,08
circle 19° pr2 P1	-17,181691	1,771234	-0,317344
	0,05	0,05	0,1
circle 0° pr1 P2	-17,181301	1,770286	0,08584
	0,05	0,04	0,08
circle 0° pr2 P2	-17,181458	1,770667	-0,076188
	0,05	0,04	0,08
circle 33° pr1 P2	-17,180905	1,76932	0,496397
	0,05	0,05	0,08
circle 33° pr2 P2	-17,181854	1,771633	-0,486884
	0,05	0,05	0,08

Table 1. *SLR reference point coordinates in North, East and Up from MET3 GNSS (2892583,91443, 1311799.61990, 5512619.89799, ITRF2014, epoch 20:232:00000) for the spherical, circle and antenna models. P1 and P2 designate the pillars from which the prisms pr1 and p2 were observed, angle is the approximate elevation angle of the telescope. See also Figures 1, 2 and 3*

3. Model: Metsähovi antenna model

In the third method, we have the coordinates and rotation angles of the telescope as observables. However, we did not get any telescope angles because of the lack of a functional telescope control system. We calculated approximate rotation angles using the centre point of the spheres and the coordinates of tracked points. With the assumption that one Az-El position was common for the prisms we got a small axis offset of 0.33mm +-0.14mm. Without the assumption, the axis offset was only 0.06mm. The reference point coordinate between the two calculations was [0.13 -0.07 -0.19]mm for North, East, and Up **and agrees very well with sphere fitting result,** see **Figure 3.** and **Table 1.**

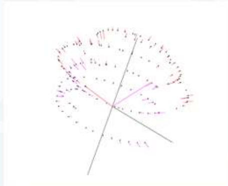


Figure 3. Antenna model. *Reference point coordinates, azimuth axis, elevation axis, offset of axes and vectors to the points in zero position have been fitted to the coordinates of tracked prisms*

Results

The results of the three approaches are collected to the **Table 1.** and agree very well. The standard deviations show mainly how well the measured points agree with the chosen model. It seems that we have achieved the goal: **less than 1 mm uncertainty** (k=1) for the vector components from IGS GNSS station MET3 to the SLR reference point.

However, to fully deploy the antenna model, we need more measurements from different elevation angles and accurate angle information of the telescope pointing. Once the telescope control system is finalized, we can automate the measurement process.

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