ANALYSIS OF EDM INSTRUMENTS CALIBRATION AT THE KYVIŠKĖS CALIBRATION BASELINE

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Abstract. Calibration laboratory of Institute of Geodesy, VGTU was established in year 2000. Laboratory is accredited for EDM instruments calibration by Lithuanian National Accreditation Bureau since 2001-09-20. Laboratory fulfills LST EN ISO/IEC 17025:2005 standards. Calibration of EDM instruments is performed at Kyviškės calibration baseline. The baseline consists of six observation pillars at intervals from 20 to 1320 meters. Seventh pillar was built for baseline extension and possibility of angular measurements. Accuracy of baseline is 0,2 ±1,2 mm. Calibration laboratory performs EDM instruments verification and calibration at the Kyviškės Calibration Baseline. Statistic of EDM instruments calibration used in Lithuania are presented. Regularity of calibration in Lithuania - 2 years. Statistical analysis of calibration results is presented. Over 60 total stations instruments are calibrated every year.

Stability of Kyviškės calibration baseline is analysed and confirmed. Every 5 years Kyviškės calibration baseline is calibrated by specialists of Finnish Geodetic Institute.

Keywords: geodetic baseline, calibration, EDM, total station.

1. Introduction

The Kyviškės Calibration Baseline was founded by the Institute of Geodesy of the Vilnius Gediminas Technical University (VGTU) in 1996 (Jokela et al. 1999). The purpose was to establish calibration facilities for EDM instruments. Six observation pillars were fundamented on the grassland on the western side of the Darius and Girėnas squadron airport, 15 km east of centre of Vilnius. Observation pillars are located in line from north to south. Distances from first to sixth pillar are 100 m, 360 m, 1 120 m, 1 300 m and 1 320 m. 10 more calibration line combinations are possible from other than first pillar. Seventh pillar was built in 2000 on the eastern side of the runway, 644 m to 949 m from the other pillars. The triangle-shaped test field provides more possibilities for testing of surveying instruments (Būga et al. 2008).

Calibration of the Kyviškės Calibration Baseline is done on the regular basis at approximate 5 years interval. Repeated high precision measurements with traceability to Finnish National Standard are essential in validating new measurement standards.

The original baseline was first measured in June 1997 in co-operation between the Institute of Geodesy of VGTU and the Finnish Geodetic Institute (FGI). Since 1997 a three more calibrations of the Kyviškės Calibration Baseline were performed by cooperating FGI and VGTU. Baseline calibration results proved stability of the baseline and suitability for EDM instruments calibration.

In this paper the results of the regular EDM instruments calibration and their analysis are presented.

Calibration laboratory of VGTU is accredited for EDM instruments calibration by Lithuanian National Accreditation Bureau since 2001-09-20.

Metrological activities at the VGTU are guided by quality management system and meet the requirements of ISO 17025 standards.

2. Regulations

Law on Metrology in Lithuania was introduced by Seimas of the Republic of Lithuania in 1996. The goal was to establish the basis for ensuring traceability in the Republic of Lithuania, organisational structure of the Lithuanian system of metrology, regulate the relations between state institutions and legal and natural persons, arising due to manufacture, trade, use, hire and repair of the measuring instruments attributed to legal metrology. Under resolution of the Government of Republic of Lithuania No 321 of 20 March 1998, State Metrology Service was authorised to carry out metrology policy in Lithuania, co-ordinate uniformity of measurements, organise and carry out scientific, legal and administrative activities in metrology field. Calibration laboratory of Institute of Geodesy, VGTU is appointed by State
Metrology Service of Lithuania to perform periodic verification of the EDM instruments.

Measuring instrument verification means assessment of a measuring instrument fitness examining its metrological characteristics by means of an experiment and verifying conformity to the established requirements. General verification methods prepared by Calibration laboratory of Institute of Geodesy, VGTU and accepted by State Metrology Service is used for EDM instruments verification. Many customers would like to have EDM calibration certificate therefore along with verification a calibration of EDM instrument is performed and calibration certificate is issued.

Laboratory is accredited for EDM instruments calibration by Lithuanian National Accreditation Bureau since 2001-09-20. Laboratory fulfils LST EN ISO/IEC 17025:2005 standards.

EDM calibration is performed in order to determine the instrument errors. The instrument errors can be used to monitor the performance of the EDM over time and if significant, should be applied to measurements taken subsequent to the calibration.

3. Facilities

Calibration laboratory of Institute of Geodesy, VGTU has established two baselines for EDM instrument verification and calibration. The shorter one (15 m length) is in the premises of the VGTU. The Kyviškės Calibration Baseline is 1320 m length and is located 15 km outside Vilnius in the Kyviškės Airport (ICAO code EYVK). It is a regional airport used mainly for pilot training purposes.


The lengths at Kyviškės are traceable to the definition of the metre. The Nummela Standard Baseline in Finland, measured regularly with the Väisälä interference comparator, and the quartz gauge system determining the scale in it, are essential measurement standards in the traceability chain (Kukkamäki 1969, 1978; Lassila et al. 2003; Jokela and Häkli 2010). The scale is transferred from Nummela to Kyviškės with a high precision EDM instrument Kern ME5000 (Mekometer) (Fig 1) of the Laboratory of Geoinformation and Positioning Technology of the Helsinki University of Technology.

4. Baseline calibration

The transfer standard, Kern ME5000 high precision EDM instrument (no. 357094) with prism reflector (no. 374414) was calibrated at the Nummela Standard Baseline.

For the scale transfer to Kyviškės, true distances from interference measurements in 1996 (Jokela and Poutanen 1998) were used in 1997 and 2001, in 2007 true distances from interference measurements in 2005 (Jokela and Häkli 2006) and in 2008 true distances from interference measurements in 2007. Standard errors of the true distances 24 m to 864 m are ±0.03 mm to ±0.07 mm. In 2005, only half of the Nummela Standard Baseline, 432 m, could be measured, because of constantly unfavourable weather conditions. The latest interference measurements were performed in 2007 and 2008 up to 864 m. The results fit very well as well as in the 60 years time series; the standard uncertainty of the 864 m length is again below 0.1 mm (Jokela et al. 2002,2009; Jokela and Häkli 2010).

![Fig 1. Kern ME5000 used in Kyviškės periodically](image1)

![Fig 2. Kyviškės baseline length variation](image2)

Kyviškės calibration baseline length variation reference to the first measurements in 1997 is presented (Fig 2). This graph illustrates high stability of the baseline. Slight but noticeable variations could be caused by temperature variations as baseline calibrations were made in June 1997, October 2001, August 2007, October 2008 and temperature was almost matching between interchanging calibrations in June 1997 and August 2007, in October 2001 and October 2008.
5. EDM instruments calibration procedure

During the common procedure of an EDM instrument calibration the 4 distances (4, 8, 12, 16 m) are measured in the laboratory and the 5 distances (20, 200, 760, 960, 1220 m) in Kyviškės Calibration Baseline. Every distance is measured 10 times. Temperature at the EDM instrument and at reflector as well as pressure is recorded for every measured distance. Forced centring using a 5/8” screws to fix instrument and reflector one the top plates of pillars was used.

Instrument should be calibrated in the set with the same reflector which is used in everyday measurements.

Systematic correction of observed distance (listed in calibration certificate) (Putrimas 2006):

\[
\Delta S_i = S_E - S_L, \quad (1)
\]

An EDM constant is computed using all obtained systematic corrections:

\[
R = \frac{\sum_{i=1}^{n} \Delta S_i}{n}, \quad (2)
\]

where \( n \) – is a number of calibrated distances.

Standard deviation of correction for every distance is computed:

\[
\sigma = \sqrt{\frac{\sum_{i=1}^{r} (\Delta S_i - \overline{\Delta S})^2}{r-1}}, \quad (3)
\]

where

\[
\overline{\Delta S} = \frac{1}{r} \sum_{i=1}^{r} \Delta S_i. \quad (4)
\]

Standard uncertainty of mean correction can be expressed as

\[
u_{\overline{\Delta S}} = \frac{m_{\Delta S}}{\sqrt{r}}. \quad (5)
\]

Total uncertainty is computed from formula:

\[
u_S = \sqrt{u_E^2 + u_{\Delta S}^2 + u_H^2}, \quad (6)
\]

where

\( u_E \) – uncertainty of etalon distance;

\( u_{\Delta S} \) – uncertainty caused by temperate, atmospheric pressure observation errors:

\[
u_{\Delta S} = \frac{D}{273} 10^6 \sqrt{774.10^6} \left[ \frac{P}{(273.10^6)^2} \right] u_T^2, \quad (7)
\]

where

\( D \) – EDM parameter from technical documentation;

\( P \) - atmosphere pressure in hPa;

\( t \) – atmosphere mean temperature in °C;

\( u_t \) – error of temperature observation in °C;

\( u_P \) – error of atmosphere pressure correction in hPa;

\( u_H \) – uncertainty due to instrument and reflector height determination.

Expanded uncertainty with coverage probability of approximately 95% is computed:

\[
U = k u_S, \quad (8)
\]

where \( k = 2 \) (according to EA-4/02).

Standard of uncertainty of mean constant:

\[
u_R = \sqrt{\frac{\sum_{i=1}^{n} (\Delta S_i - R)^2}{n(n-1)}}, \quad (9)
\]

where \( n \) – is number of calibrated distances.

Total uncertainty of EDM constant:

\[
u_R = \sqrt{u_E^2 + \sum_{i=1}^{n} \sigma_i^2}, \quad (10)
\]

where \( u_{S_i} \) – total uncertainty of i mean correction.

EDM constant expanded uncertainty coverage probability of approximately 95% is computed and presented in calibration certificates

\[
U_R = k u_R, \quad (11)
\]

where \( k = 2 \) (according to EA-4/02).

6. EDM instruments calibration

Calibration laboratory since establishment till the end of 2010 has calibrated 952 instruments. Absolute majority of them were EDM instruments. Different total station models of major producers such as Geodimeter, Leica, Nikon, Sokkia, Topcon and Trimble were brought for calibration (Table 1).

### Table 1. Distribution of calibrated total stations (listed by producer) during 2005 - 2010

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geodimeter</td>
<td>9</td>
<td>18</td>
<td>4</td>
<td>6</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Leica</td>
<td>9</td>
<td>16</td>
<td>7</td>
<td>15</td>
<td>22</td>
<td>18</td>
</tr>
<tr>
<td>Topcon</td>
<td>7</td>
<td>12</td>
<td>18</td>
<td>18</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Trimble</td>
<td>2</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Sokkia</td>
<td>4</td>
<td>28</td>
<td>2</td>
<td>7</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Nikon</td>
<td>2</td>
<td>23</td>
<td>6</td>
<td>14</td>
<td>13</td>
<td>15</td>
</tr>
</tbody>
</table>
Based on calibration results one can conclude that there is no relation between instrument correction and producer (Fig 3 and Fig 4.). As an example we present obtained corrections for Leica and Topcon instruments. Instrument corrections were computed with EDM constant.

Figure 5 illustrates distribution of 108 corrections determined for the 4 meters baseline. Similar histograms are obtained for other baselines too.

Corrections computed for 9 Geodimeter total stations are graphed in Fig 6. The 6 of 9 Geodimeter instruments calibrated were of 520N series. One can notice the tendency for Geodimeter total stations that for distances between 20 and 760 m the corrections are negative.

Next figure 7 represents variation of Nikon NPL-332 total station corrections over the period of 6 years. Determined EDM constant is taken into account.
EDM constants determined during period of 2007-2008 are presented in Fig 8. Except four cases all determined reflector constants fall into the interval between -5 and +5 mm. The above mentioned EDM constants were computed with taken into account producer provided reflector constant. Mean uncertainty of EDM constant determination for most reflectors is 0.6 mm or insignificantly higher (Fig 9).

7. Conclusions

1. The Kyviškės Calibration Baseline is a national measurement standard for calibration of EDM instruments in Lithuania. Regular calibrations of the baseline confirm perfect stability of the baseline. The obtained total uncertainty of the baseline is from ±0.3 mm to ±0.7 mm, and is accurate enough for testing and calibration of practically all EDM instruments.

2. Calibration laboratory calibrates approximately 60 total stations a year. Calibration period is 2 years (national requirement for periodic verification). 52 of 60 total stations are brought for calibration after every 2 years.

3. Results of EDM instruments calibration confirm necessity of their calibration for precision measurement. Determined new EDM constant is a good example of it. Absolute majority of determined EDM constants fall into interval between -5 and +5 mm. This definitely should be taken into account when instrument is used.

References


