On Use of FGI System Calibration Comparator

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Key words: Digital level, system calibration, precise levelling, CCD camera, type testing.

SUMMARY

The high precision digital levelling systems use bar code rods where the code is etched on the surface of an invar band. The scale of code is a function of temperature plus a constant, which both are determined by the rod calibration. When carrying out the digital levelling, the scale of the whole system, in fact the scale given by the instrument is expected to be equal with the scale of the rod. However, with time, the scale of an instrument and a rod can change. To check the behavior of the whole system we use the "system calibration" procedure, where the rod readings are taken from different sectors on the bar code rod and compared with their true values obtained by a laser interferometer.

In the Finnish Geodetic Institute (FGI) automated rod calibrations have been carried out since 1996 using the FGI vertical laser rod comparator. Design of a comparator for the system calibration of digital levels was started in 2000 and today we have a system calibration comparator, where the sight distances of 3 m and 8 m are available. Preliminary measurements to calibrate the Zeiss DiNi12 systems have been carried out and many experiences of the behaviour of the digital levelling system have been obtained.

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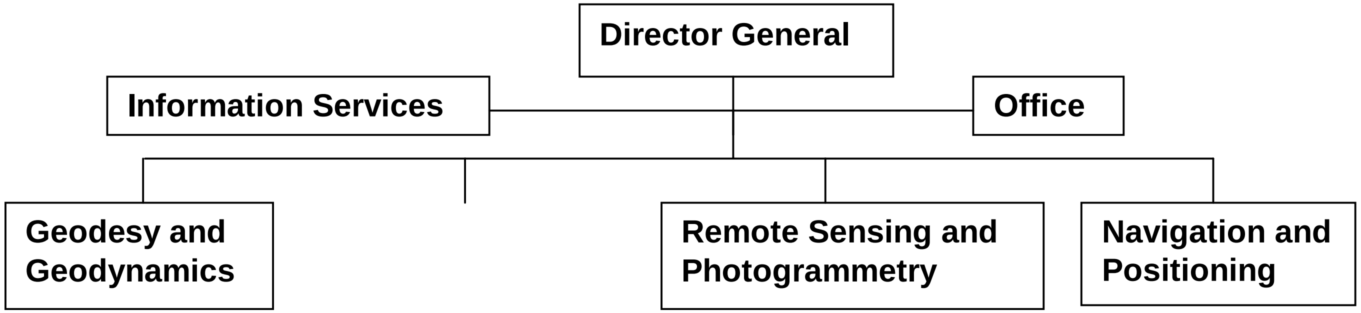

The main building of the FGI in Masala.

The Väisälä interference comparator in Nummela standard baseline.

The FGI absolute gravimeter, JILAg–5 in Metsähovi laboratory.

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Why we need calibration of digital levels?

- Levels are advanced and automated
- They contain a lot of electronics and optics
- Apply CCD camera and image processing technique
- Use bar code in rod scale and software, not open for users
- Imperfections in hardware are mostly corrected by software.

- Levelling instrument including CCD camera and software, rod with bar code scale
- The code observed from rod is compared with the code stored into memory of the level

How it differs from a conventional level

- Digital system uses more than one graduation line to process a rod reading
- Instead of human eye it uses CCD cell
- Observations are automatically controlled, computed and stored

Fig. 1. *Zeiss DiNi12 digital levelling system*.

Type testing is performed

- in laboratory to verify potential errors of DLS and
- in test field (Fig. 2) to determine uncertainty of DLS

System calibration is carried out

- with the vertical system calibration comparator (VSCC) (Fig. 3) to determine a scale of DLS. The existing VSCC in Europe are
  - in Masala, Finland,
  - in Graz, Austria and
  - in Munich, Germany.

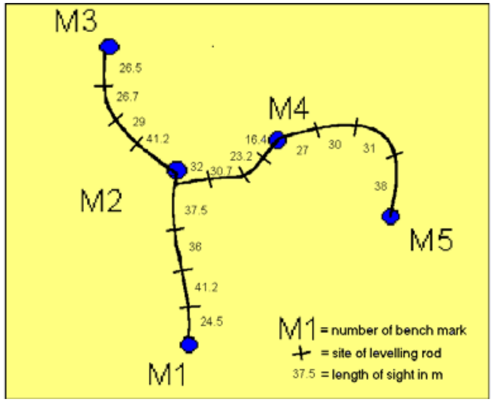


Fig. 2. *The Metsähovi test field*.

Fig. 3. *The FGI system calibration comparator*.

Principle of System Calibration

Main principle is

- to observe laser interferometer and digital level readings, simultaneously
- Measurements are done by shifting bar code rod in vertical comparator certain amount e.g. 25 mm and recording the both readings (Fig. 4) to determine correction
- Scale correction for each rod is determined by adding corrections of successive intervals
- Two pillars at the distance of 3 and 8 m are used in FGI, because Zeiss DiNi12 changes its calculation mode at 6 m

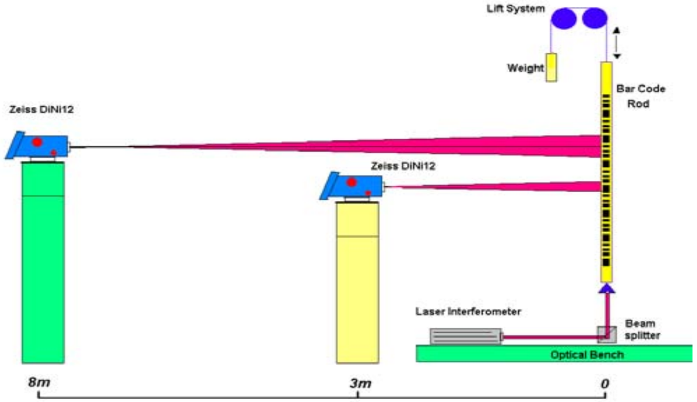
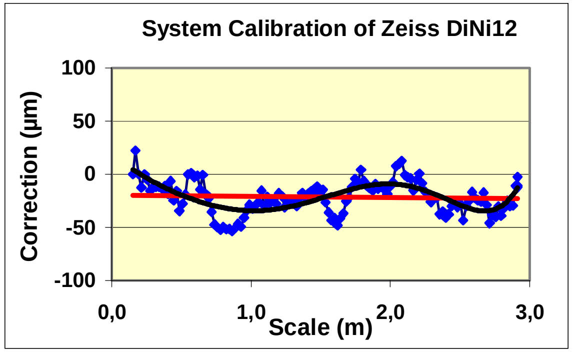


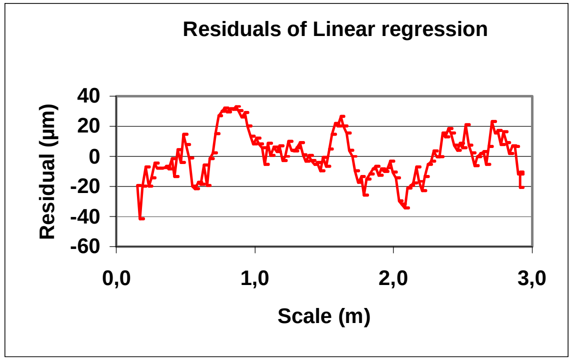
Fig. 4. *(Up) Principle of the FGI system calibration comparator, (low) system calibration in FGI in 2003.*

Goals of System Calibration

- Correction for each rod reading
- Polynomial fitting-first degree
- Scale of digital levelling system is slope of regression line
- Searching for abnormal corrections, e.g., ±100 µm
- Determination of uncertainty for calibration, e.g., using residuals of first or higher degree polynomial fitting

Fig. 5. *(Up) Correction curve of first and 6. degree polynomial fitting, (low) residual of linear regression*





Uncertainty of FGI Comparator

Standard uncertainty of

(1) HP Laser interferometer 5529A derived from repeatability	±0.02 µm
(2) Wavelength compensation in laboratory conditions (20°C, 1013 mbar, 50%)	±0.2 µm
(3) Unstability of rod conveyor during observation	±0.3 µm
(4) Total for single **measurement**: (1)+(2)+(3)	±0.4 µm
(5) and for an arbitrary **interval**: $\sqrt{2}$ x (4)	**±0.5 µm**

Uncertainty of System Calibration

Standard uncertainty of rod reading of Zeiss DiNi12

(6) Resolution of level 0.01 mm

Estimate (EA4/02) $\pm \sqrt{(10^2/12)}$ = **±2.9 µm**

(7) and for a difference $\pm \sqrt{2} * 2.9$ µm **= ±4.1 µm**

Standard uncertainty of FGI system calibration

by pooling (5) + (7) we get **±4.1 µm**

and hence

Expanded uncertainty (k=2) **±8.2 µm**

Error Propagation

Sequential Measuring method

Rod is moved by vertical conveyor in step of 25 mm and length of each interval is measured with laser and Zeiss DiNi12. Correction for each rod reading is determined by adding sequentially corrections of intervals. Treatment causes an increasing error propagation.

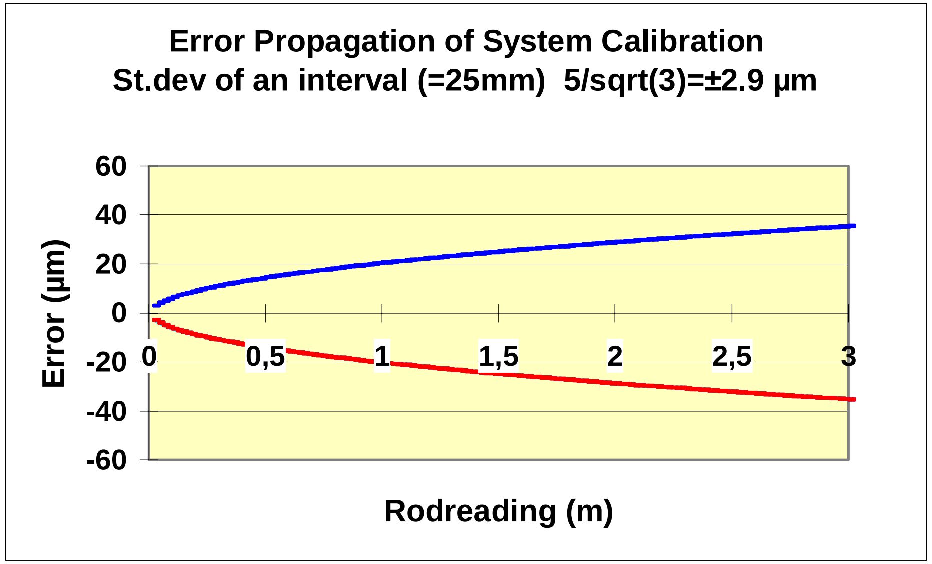
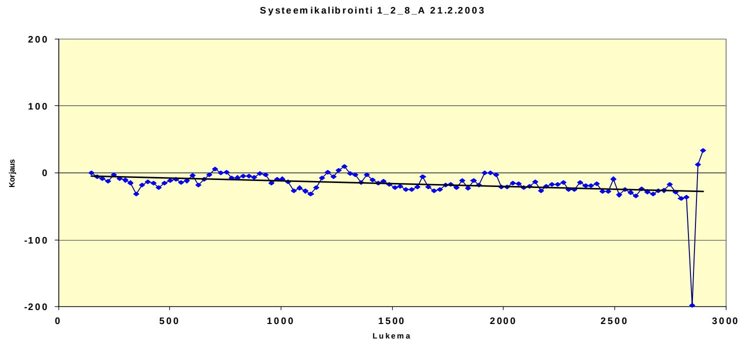


Fig. 6. *Error propagation of FGI system calibration*

Tool for research

System calibration comparator is an excellent tool to examine behaviour of digital levelling system. For instance:

- to study lower and upper end of bar code scale
- dependence on sight length and
- dependence on temperature
- effect of shaking
- effect of illumination
- effect of focusing



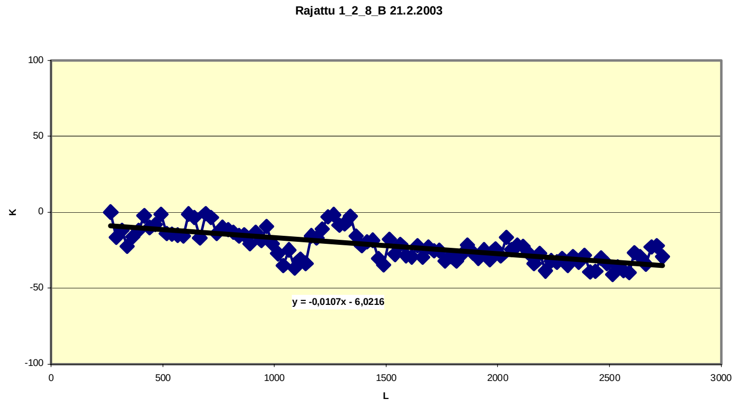


Fig. 7. *(up) Upper end effect, (low) scale determination*

Example of Scale Determination

Due to abnormal corrections at the end of scale, the limited range 0.25 – 2.75 m was applied to determine the linear scale of the Zeiss DiNi12. In this example (4 measurements) we obtained:

Scale = -6.52±0.55 ppm

- to determine and to control scale of digital levelling systems
- to examine behavior of digital levels

Future Works

- Further development of hardware and software
- Inter-comparison with another corresponding comparator

Thank you for your attention!