Universität der Bundeswehr München

The new ISO standard 17123 -8 for checking GNSS field measuring systems

Hans Heister

Institute for Geodesy

- Geodetic Metrology -

UniBw München
D-85577 Neubiberg

h.heister@unibw.de

FIG Working Week - Stockholm - Sweden, 17 June 2008

Universität der Bundeswehr München

Outline

- General remarks
- Checking and calibrating of GNSS systems
- The ISO series of standards 17123
- The new standard ISO 17123 – part 8
- Additional proposals for checking GNSS systems
- Conclusions

General Remarks

Universität der Bundeswehr München

Checking and testing of geodetic instruments:

Four – phases – model (FIG):

	Objectives / Operations	GNSS
• Phase 1 Simple functional check:	Evaluation of operability, visual inspection, short intervals before and after measuring, in the field.	☺ ✓
• Phase 2 Extended functional check:	Simple quantitative checking of significant deviations of specified thresholds in regular intervals or event dependant.	😐 (✓)

General Remarks

Universität der Bundeswehr München

Checking and testing of geodetic instruments:

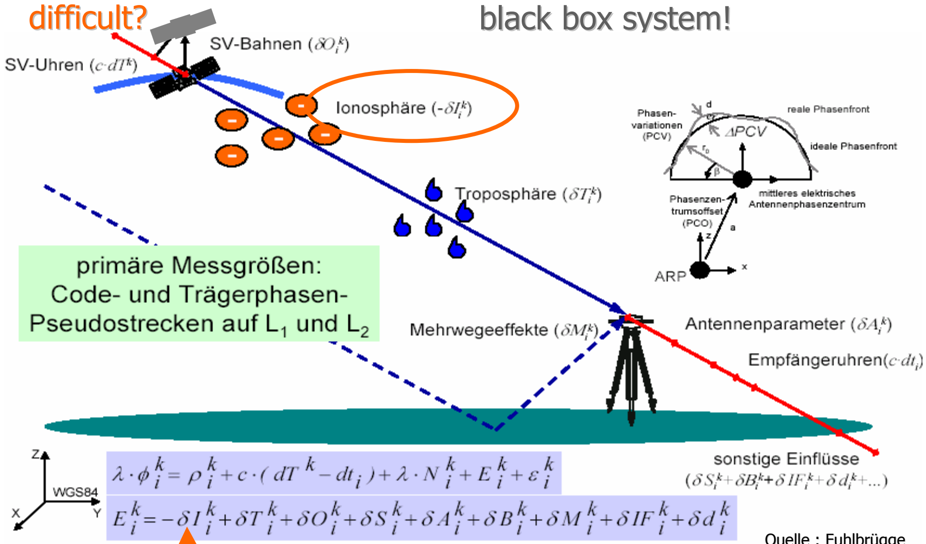
Four – phase – model (FIG):

	Objectives / Operations	GPS
• Phase 3 Calibration:	Nominal /actual value comparison of the defined measurands. Measuring reference (standard), special calibration facilities, traceability, certificate, fixed intervals, expenses	? ☹
• Phase 4 Specification test, type testing:	Checking of the technical specifications in conjunction with QM, independent testing of new instruments or prototypes, components and / or measuring systems, knowledge of measuring principles and software / firmware, event dependant, manufacturers certificate.	? ? ? ☹

General Remarks

Universität der Bundeswehr München

What makes checking of GNSS – measuring systems soo difficult? black box system!



Quelle : Fuhlbrügge

General Remarks

Universität der Bundeswehr München

„Original“ measuring quantities of GNSS measuring systems ?

3D – coordinates X – Y – Z in WGS 84

Product in the sense of a QM (ISO 9000)

⇒ Accuracy / measuring uncertainty

⇒ Correctness

⇒ Reliability

⇒ System integrity

Checking and Calibrating of GNSS Systems

Universität der Bundeswehr München

Measuring procedures

RTK

Local area,

Local, temporary reference station

Post processing

Influence quantities

Wide area,

Nationwide, permanent reference station, networked

Influence quantities

Kinematic applications,

e.g. machine guidance, mobile mapping

System Calibration / Checking

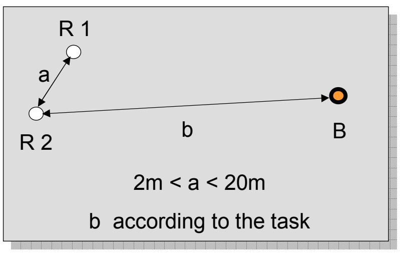
Calibration / Checks of instrumental components

New standard ISO 17 123 - 8

Universität der Bundeswehr München

„GNSS field measurement systems in real-time kinematic (RTK)"

Concept of the test procedures



- Horizontal distances and height differences determined by tacheometry, $s_d < 3$ mm

⇨ Nominal values D*, h*

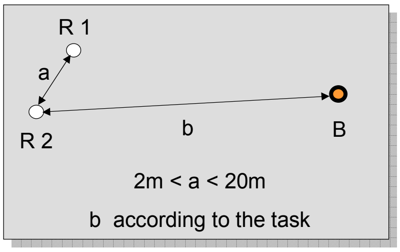
- Observables, measurements: Coordinates x, y
  ellipsoidal height h (WGS 84)
  ⇨ D, Δh

Comparison D* ⇔ D and h* ⇔ Δh

New standard ISO 17 123 - 8

Universität der Bundeswehr München

„Procedure 1: Simplified test procedure"



Limited number of measurements

1 Series

5 Sets

Measurements at R1 and R2

⇨ $\mathbf{x}_{1,1,1}$ $\mathbf{x}_{1,1,2}$

$\mathbf{x}_{1,2,1}$ $\mathbf{x}_{1,2,2}$

↓

$\mathbf{x}_{1,5,1}$ $\mathbf{x}_{1,5,2}$

Time lag

5 min !

⇨ ~ 25 min

$$D_{i,j} = \sqrt{(x_{i,j,2} - x_{i,j,1})^2 + (y_{i,j,2} - y_{i,j,1})^2}$$

$$\Delta h_{i,j} = h_{i,j,1} - h_{i,j,2}$$

$$\mathbf{x}_{i,j,k} = \begin{pmatrix} x_{i,j,k} & y_{i,j,k} & h_{i,j,k} \end{pmatrix}$$

New standard ISO 17 123 - 8

Universität der Bundeswehr München

„Procedure 1: Simplified test procedure"

$$\varepsilon_{D\,i,j} = D_{i,j} - D^*$$

$$\varepsilon_{h\,i,j} = h_{i,j} - h^*$$

ε Deviations of horizontal distances and height differences

Standard Deviation

$s_{x,y}$

a) Specified by manufacturer

b) determined by full test procedure

$$|\varepsilon_{D\,i,j}| \leq 2{,}5 \cdot \sqrt{2} \cdot s_{xy}$$

$$|\varepsilon_{h\,i,j}| \leq 2{,}5 \cdot \sqrt{2} \cdot s_{h}$$

If any deviation fails the two conditions,

the inclusion of outliers is suspected

! Repeat test procedure !

New standard ISO 17 123 - 8

Universität der Bundeswehr München

„Procedure 1: Simplified test procedure"

- Objective: Determination of the operational reliability of the GNSS-equipment and a simple quantitative check carried out under minimal exterior influences and minimal effort (FIG phase 1)

„Procedure 2: Full test procedure"

- Objective: Extended functional check, quantitative investigations of significant deviations of specified thresholds (statistical evaluation) in regular intervals or event dependant (FIG phase 2).

New standard ISO 17 123 - 8

Universität der Bundeswehr München

„Procedure 2: Full test procedure"

Objective:

Best achievable measure of precision

- experimental standard deviation for a single position, height

Higher measuring effort

3 Series

5 Sets

Measurements at R1 and R2

$\mathbf{x}_{1,1,1}$ $\mathbf{x}_{1,1,2}$ $\mathbf{x}_{2,1,1}$ $\mathbf{x}_{2,1,2}$ $\mathbf{x}_{3,1,1}$ $\mathbf{x}_{3,1,2}$

$\mathbf{x}_{1,2,1}$ $\mathbf{x}_{1,2,2}$ $\mathbf{x}_{2,2,1}$ $\mathbf{x}_{2,2,2}$ $\mathbf{x}_{3,2,1}$ $\mathbf{x}_{3,2,2}$

↓ ↓ ↓

$\mathbf{x}_{1,5,1}$ $\mathbf{x}_{1,5,2}$ $\mathbf{x}_{2,5,1}$ $\mathbf{x}_{2,5,2}$ $\mathbf{x}_{3,5,1}$ $\mathbf{x}_{3,5,2}$

Time lag

> 90 min !

⇨ ~ > 3 h 15 min

$$\mathbf{x}_{i,j,k} = \left(x_{i,j,k} \quad y_{i,j,k} \quad h_{i,j,k}\right)$$

1. Step:

Individual measurements are compared with the nominal values.

⇨ Same evaluation as described in the simplified test procedure

Objective: Detection of gross errors

2. Step: Statistical evaluation

- Estimates x, y, h of R1 and R2

$$\bar{x}_k = \frac{1}{15}\sum_{i=1}^{3}\sum_{j=1}^{5} x_{i,j,k} \quad \Rightarrow \quad \bar{y}_k\,,\ \bar{h}_k$$

- Residuals for all measurements

$$r_{x\,i,j,k} = \bar{x}_k - x_{i,j,k} \quad \Rightarrow \quad r_{y\,i,j,k}\,,\ r_{h\,i,j,k}$$

- Degree of freedom

$$\nu_x = \nu_y = \nu_h = (3 \cdot 5 - 1) \cdot 2 = 28$$

2. Step: Statistical evaluation

- Standard deviation of a single measurement

$$s_x = \sqrt{\frac{\sum r_x^2}{\nu_x}} = \sqrt{\frac{\sum r_x^2}{28}} \qquad s_y = \sqrt{\frac{\sum r_y^2}{28}} \qquad s_h = \sqrt{\frac{\sum r_h^2}{28}}$$

Experimental standard deviation for a single position (x,y)

$$s_{\text{ISO-GNSS RTK } xy} = \sqrt{s_x^2 + s_y^2}$$

Experimental standard deviation for a single height (h)

$$s_{\text{ISO-GNSS RTK } h} = s_h$$

New standard ISO 17 123 - 8

Universität der Bundeswehr München

Step 3: Statistical tests

- Is the calculated $s_{\text{ISO-GNSS RTK xy}}$ smaller or equal than the value σ_{xy} stated by the manufacturer?

$$s_{\text{ISO-GNSS RTK xy}} \leq \sigma_{xy}\sqrt{\frac{\chi^2_{0,95}(\nu_x+\nu_y)}{\nu_x+\nu_y}} \qquad \chi^2_{0,95}(56) = 74,47$$

$$s_{\text{ISO-GNSS RTK xy}} \leq \sigma_{xy} \cdot 1,15$$

- Is the calculated $s_{\text{ISO-GNSS RTK h}}$ smaller or equal than the value σ_h stated by the manufacturer?

$$s_{\text{ISO-GNSS RTK h}} \leq \sigma_h \cdot 1,22$$

New standard ISO 17 123 - 8

Universität der Bundeswehr München

Step 3: Statistical tests

- In the case of two samples, the Fisher test indicates whether two experimental standard deviations e.g. $s_{\text{ISO-GNSS RTK xy}}$ and $\bar{s}_{\text{ISO-GNSS RTK xy}}$ belong to the same population?

$$\frac{1}{F_{1-\frac{\alpha}{2}(\tilde{\nu}_x+\tilde{\nu}_y+\nu_x+\nu_y)}} \leq \frac{s^2_{\text{ISO GNSS RTK-xy}}}{\tilde{s}^2_{\text{ISO GNSS RTK-xy}}} \leq F_{1-\frac{\alpha}{2}(\tilde{\nu}_x+\tilde{\nu}_y+\nu_x+\nu_y)} \qquad F_{0,975}(56,56)=1,70$$

$$0,59 \leq \frac{s^2_{\text{ISO GNSS RTK-xy}}}{\tilde{s}^2_{\text{ISO GNSS RTK-xy}}} \leq 1,70$$

$$0,47 \leq \frac{s^2_{\text{ISO GNSS RTK-h}}}{\tilde{s}^2_{\text{ISO GNSS RTK-h}}} \leq 2,13$$

New standard ISO 17 123 - 8

Universität der Bundeswehr München

Questions to be discussed

- Time need of 3 ... 4 hours reasonable?
- Number of series of measurements sufficient?
- Fixing of allowable thresholds?
- Disadvantages of the procedures?
- Appliance of the tests on RTK using reference station networks possible?
- Is the indication of the experimental standard deviation strong enough for characterizing "quality " of the investigated measuring equipment?

Conclusions

Universität der Bundeswehr München

- The GNSS measuring system as a non autonomous and black- box system is for the practitioners hard to understand.
- Periodical checks or tests for GNSS systems in terms of a recent quality management system are unavoidable.
- In this sense applicable, standardized field checks – RTK -, <u>not</u> calibration, are urgently needed (FIG phase 1 and 2). The new ISO standard 17123-8 is a first move.
- Antenna checks / calibration demand further discussions (specifications, manufacturers information).
- New methods, techniques (kinematic!) und instrumental developments e.g. GPS-tacheometer, frequencies, etc. permit improved / extended test approaches.