Accurate High-Sensitivity GPS for Short Baselines

FIG Working Week

TS 6C
GPS for Engineering

Volker Schwieger

Institute for Applications of Geodesy to Engineering
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Germany

Eilat, Israel, May 7th, 2009

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Accurate High-Sensitivity GPS

Structure

- Motivation
- High-Sensitivity GPS
- Hardware and Antenna Calibration
- Post-Processing Procedure
- Measuerements
- Results
- Summary and Outlook

Accurate High-Sensitivity GPS

Garmin eTrex Vista - Results

FIG Working Weeks, Cairo and Hong Kong, 2005 and 2007

- **fixing of „half“ ambiguities and cycle slips are important**
- **processing of sites in disturbed environment needs analysis of residuals**
- **RMS: 1 to 2 cm**
  - per coordinate
  - for baselines: < 1 km
  - observation period: appr. 30 minutes
  - antenna corrections are important, too

New technological and even more cost-effective developments

- enable new application fields and

- require new investigations with new receivers !

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Motivation

- **Geodetic Applications**
  - **Accuracy: mm – dm**
  - **Receivers: expensive (> 10 000 €)**
  - **Recent Crustal Moverments, state survey, cadastre, engineering geodesy**
- **Navigation Applications**
  - **Accuracy : 1 m – 10 m**
  - **Car-navigation systems, GPS-Mobiles, Location Based Services**
  - **Receivers: low-priced (clearly below 100 €)**

Combination of both applications possible ?

Use of low-priced receivers for geodetic applications ?

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High-Sensitivity GPS

C/A – code as strong as -160 dBW on earth surface !

Attenuation

- **5 dB in cars**
- **20 dB in buildings**
- **25 dB in subterranean garages**

material	attenuation [dB]
dry wall	1
glass	1 - 4
steel fabric mats	2 - 11
brick	5 - 31
concrete	12 - 43
reinforced concrete	29 - 33

HS-GPS receivers track below -180 dBW !

but this chracteristic is without importance for geodetic applications !

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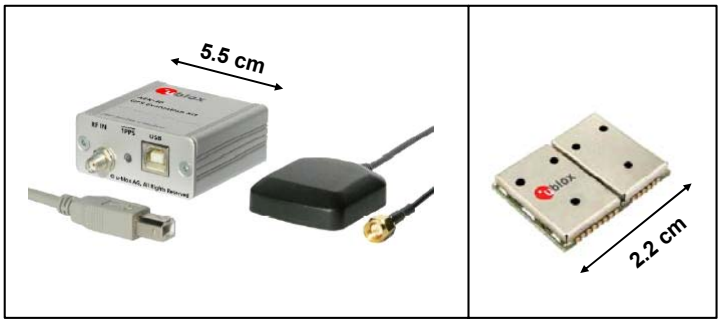
U-blox AEK-4T Evaluation Kit

- **cost-effective receiver that shows the avalaibility of phase data**
- **no „half“ ambiguities and cycle slips**
- **comprises GPS-Modul LEA-4T and antenna ANN-MS**



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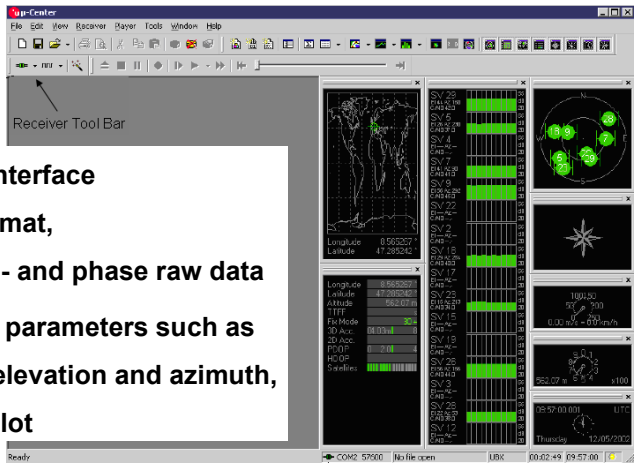
U-blox AEK-4T Evaluation Kit



Software

- configuration of interface
  NMEA or ubx - format,
  content: e.g. code- and phase raw data
- display of current parameters such as
  satellite number, elevation and azimuth,
  PDOP, RMS, Skyplot

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Hardware - Antenna ANN-MS and Adapter

- use of standard antenna to test a real low-cost receiver – antenna combination
- need for levelling and centering
- adapter is a compromise between multipath effect reduction and multipath near-field effect generation

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Antenna Calibration – TU Dresden

Source: TU Dresden

Source: TU Dresden

- determination of absolute offsets, and elevation- and azimuth-dependent phase-centre corrections
- ATX-Format is used
- antenna reference point: top edge of antenna

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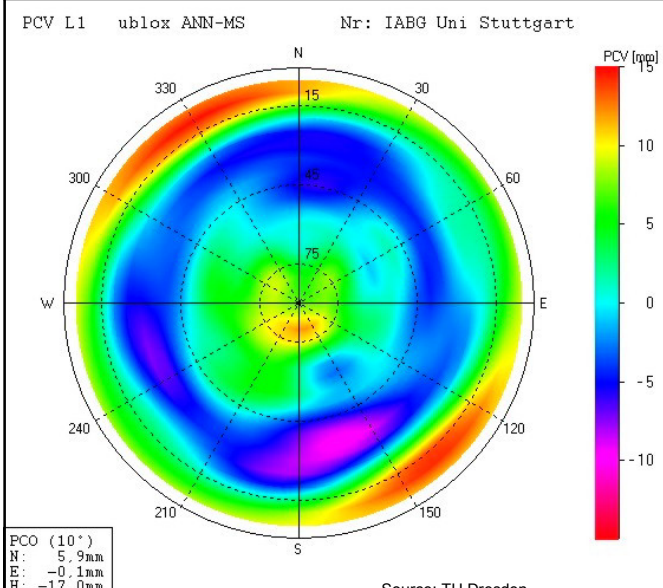

Source: TU Dresden

Offset

Height: -1.7 cm

Hz: < 6 mm

Variations

-1 cm to -1.5 cm

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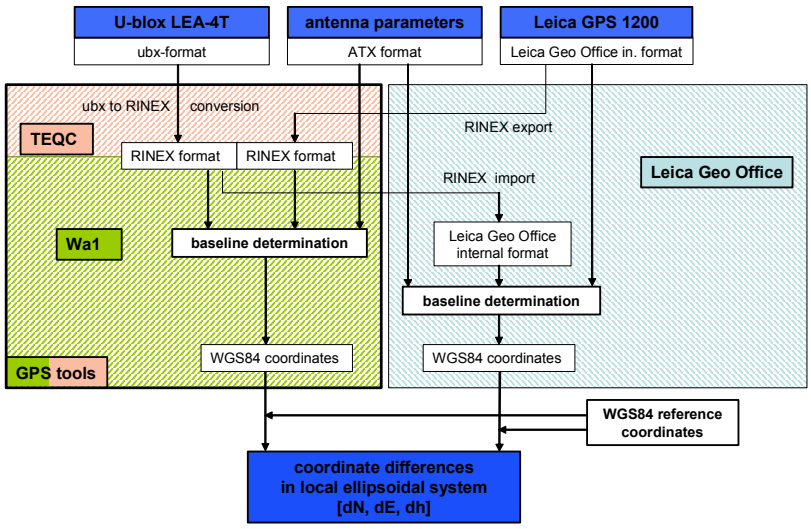
Post-Processing Procedure



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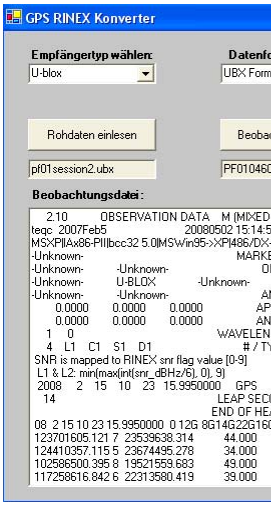
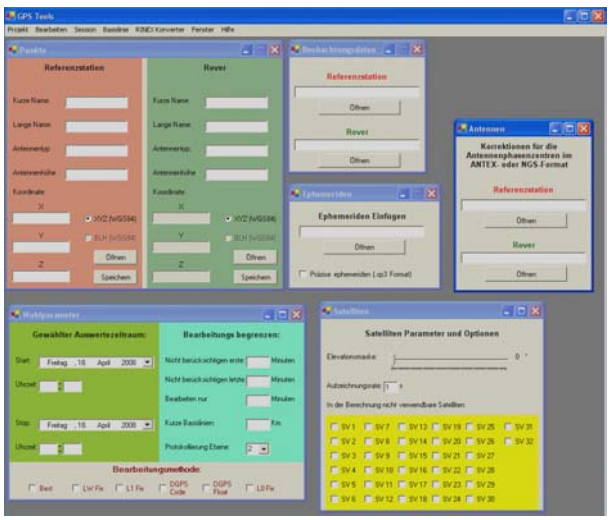
Control and Processing by „GPS-Tools“





RINEX-conversi GPS-processing by Wa1

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Measurements – Concept and Realisation

- **Quality of results** depending on
  - baseline length,
  - observation period, and
  - multipath and shadowing effects.

- **Realisation**
  - two reference sites, for baselines of 250 to 400 m and appr. 7.7 km,
  - two hours´ measurements are divided into shorter intervals (observation periods),
  - sites with and without shadowing effects above 10° elevation.

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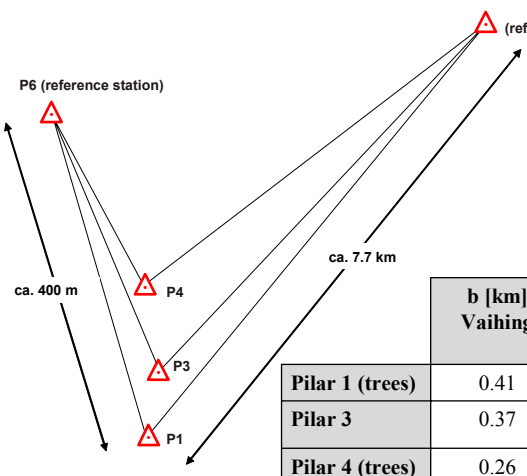
Measurements – Concept and Realisation



coordinates in pilar network known within 1 mm

	b [km] Vaihingen	b [km] Stuttgart centre	observation time [hh:mm]
Pilar 1 (trees)	0.41	7.70	11:20 – 13:00
Pilar 3	0.37	7.69	13:40 – 15:40
Pilar 4 (trees)	0.26	7.69	09:00 – 11:00

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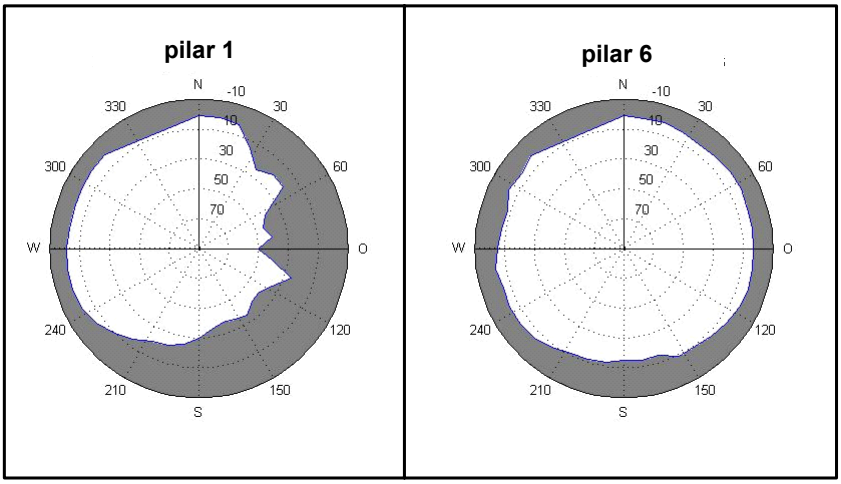
Measurements – Concept and Realisation



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Measurements – Concept and Realisation

AEK-4T

Leica SmartRover

- notebook and power supply for AEK-4T required
- 1 Hz sampling rate
- measurements on 2 days for redundancy reasons
- reference site „Stuttgart-centre“ set up with tripod, reference coordinates estimated using Leica data only

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Results – Comparison to Known Coordinates

- investigation of 2 hours – solutions
- day 2 / Stuttgart-centre shows non-reliable reference solution

differences [mm]		known – Wa1			known - Leica			Wa1 – Leica		
Ref. / Tag	Punkt	dN	dE	dh	dN	dE	dh	dN	dE	dh
Vaihingen / day 1	1	-17.6	-1.7	-7.9	-17.3	-1.8	-12.1	0.3	0.1	4.2
	3	-8.7	-2.1	-12.7	-8.6	-2.4	-14.5	0.1	0.3	1.8
	4	-6.8	7.0	-24.8	-6.5	6.9	24.7	0.3	0.1	0.1
Vaihingen / day 2	1	-18.9	-1.5	-9.9	-18.8	-1.4	-13.1	0.1	0.1	3.2
	3	-10.7	1.0	-20.2	-11.1	0.9	-24.3	0.4	0.1	4.1
	4	-5.1	7.4	-33.2	-4.6	7.1	-33.4	0.5	0.3	0.2
Stuttgart-centre / day 1	1	-18.6	-3.3	-2.0	-16.4	-2.1	-26.1	2.2	1.2	24.1
	3	-9.4	-4.0	-8.1	-7.4	-2.6	-28.5	2.0	1.4	20.4
	4	-7.5	2.9	-15.6	-5.6	3.3	-36.1	1.9	0.4	20.5

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Results – Comparison to Known Coordinates

- differences: horizontal < 2 cm, vertical < 4 cm
- pilar 4 shows worst differences,
  reasons: shadowing and temporal multipath effects
- differences on same level for baselines of 400 m and 7.7 km
- Wa1 - results for 7.7 km are better
- repeatability RMS for Wa1 < 1cm per coordinate

differences [mm]	Vaihingen / day 1 – day 2			day1 / Vaihingen – St.-centre		
pilar	dN	dE	dh	dN	dE	dh
1	1.3	0.2	2.0	1.0	1.6	5.9
3	2.0	3.1	7.5	0.8	1.9	4.6
4	1.8	0.4	8.4	0.7	4.2	9.2

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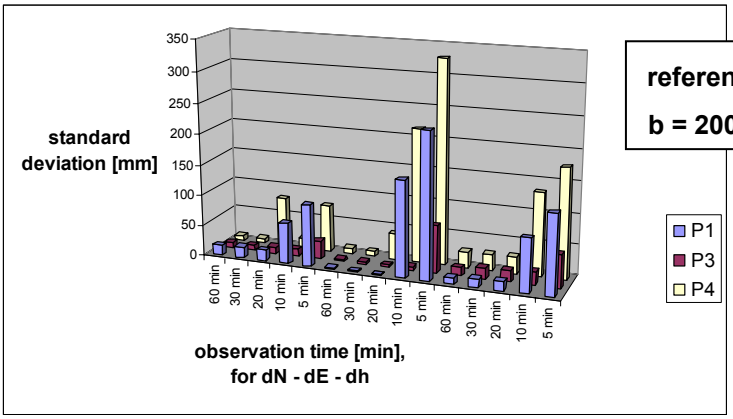
Dependence on Observation Period



RMS ≤ 8 cm for 20 minutes per dN/dE/dh

RMS ≤ 2.7 cm for 30 minutes per dN/dE/dh

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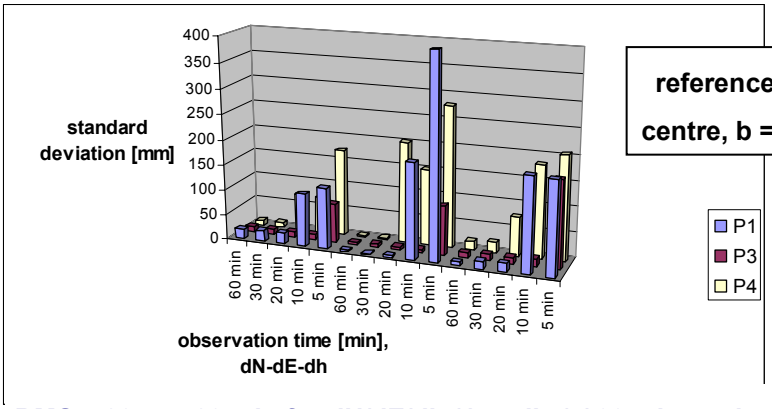
Dependence on Observation Period



RMS ≤ 20 cm 20 min for dN/dE/dh (1 outlier) / 30 min unchanged

average 3D-RMS ≤ 2.4 cm for 30 min (Vaihingen and Stgt-centre)

average 3D-RMS ≤ 2.0 cm for 20 min without shadowing (P 3)

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Availability and Correctness

Availability rate

- percentage share of processable solutions,
- reasons for non-availability:
  small satellite number or bad configuration (DOP)

Correctness rate

- percentage share of probably correct solutions related to available solutions
- non-correct: solutions without ambiguity fixing (float solutions)
  (correctness = reliability)

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Availability and Correctness

percentage [%]		correctness rate					availability rate				
period [min]		60	30	20	10	5	60	30	20	10	5
Vaihingen / day1	P1	100	100	80	83	92	100	100	100	100	96
	P3	100	100	100	75	83	100	100	100	100	96
	P4	100	100	100	75	46	100	100	100	100	100
Stuttgart-centre / day 1	P1	100	100	100	92	46	100	75	80	83	100
	P3	100	100	100	83	79	100	100	100	100	92
	P4	100	75	100	33	67	100	100	100	100	92

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Summary

- Use of High-Sensitivity AEK-4T Evaluation Kit for geodetic applications
- TEQC RINEX-generation, Wa1 post-processing

Average 3-dimensional RMS (up to 7.7 km):
- 2.4 cm for 30 minutes / disturbed environment
- 2.0 cm for 20 minutes / undisturbed environment
(here: 100 % Availability and Correctness)

General applicability for geodetic tasks shown !

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Outlook

- Aim: real-time or quasi-real-time solution
- Further improvement of correctness
- Typical field of application: Monitoring
- Set-up of GPS- and GNSS-sensor-networks respectively

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Prof. L. Wanninger, Dr. V. Frevert (TU Dresden) – assignment of W1 and antenna calibraton

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Thank you very much for your attention !

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