

High-Sensitivity GPS
an Availability, Reliability and Accuracy Test


FIG Working Week

TS 1C
Development of GNSS Measurement Technologies and Techniques

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Stockholm, Sweden, June 16th, 2008

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High-Sensitivity GPS – Quality Test

Structure

- **High-Sensitivity GPS**
 - general
 - exemplary sensors
- **Quality Criteria**
- **Static Positioning**
- **Kinematic Positioning**
- **Summary**

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High-Sensitivity GPS

C/A – code as strong as -130 dB on earth surface !

Attenuation

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

material	attenuation [dB]
dry wall	1
plywood	1 - 3
glass	1 - 4
shaded glass	10
construction timber	2 - 9
steel fabric mats	2 - 11
brick	5 - 31
concrete	12 - 43
reinforced concrete	29 - 33

HS-GPS receiver tracks below -150 dB !

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Exemplary Sensors

Receiver	u-blox LEA-4T	SiRFstarIII	Fastrax iTrax03-S
Tracking-Sensitivity	-158 dBm	-159 dBm	-156 dBm
Signals	L1, C/A Code	L1, C/A Code	L1, C/A Code
Cold Start	34 s	35 s	40 s
Warm Start	34 s	15 s	33 s
Hot Start	< 3.5 s	< 1 s	4 s
Number of channels	16	12	12
Output of phase data	yes	special agree-ment of SiRF	no
Protocoll	NMEA, UBX Binary, RTCM	NMEA, SiRF Binary	NMEA, iTalk Binary

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Exemplary Sensors

u-blox LEA-4T

SiRFstarIII

Fastrax iTrax03-S




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Quality Criteria (1)

$$A[\%] = \frac{T_t - T_n}{T_t} \cdot 100$$

T_t total measurement time

T_n measurement time without coordinates

$$R[\%] = \frac{n_{3\sigma}}{n_a} \cdot 100$$

$n_{3\sigma}$ number of observations within the $3 \cdot \sigma$ limit

n_a number of available measurements

Availability-Rate

Reliability-Rate

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Quality Criteria (2)

$$s_{in} = \sqrt{\frac{1}{n_{3\sigma}-1} \cdot \sum_{i=1}^{n_{3\sigma}} (x_i - \bar{x})^2}$$

repeatability standard deviation

$$s_{ou} = \sqrt{\frac{1}{n_{3\sigma}} \cdot \sum_{i=1}^{n_{3\sigma}} (x_i - \mu_x)^2}$$

reproducibility standard deviation

$$S = \sqrt{\frac{1}{2n} \cdot \sum_{i=1}^n (x_i^1 - x_i^2)^2}$$

reproducibility standard deviation
using double differences

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Static Positioning

The diagram illustrates static positioning in two environments. The top part shows an outdoor area with a coordinate system (X [m] from 5401050 to 5401120, Y [m] from 3507280 to 3507320). It features a 'grassland' area and two 'building' footprints. Points are marked as vp1, vp2, vp3, p1, s1, s2, and a cluster of indoor points (ind01, ind02, ind03, ind04). A blue circle highlights the indoor points, with an arrow pointing to a detailed floor plan below. The floor plan shows a room with two 'table's, two 'window's, and a 'door'. Indoor points are labeled ind01, ind02, ind03, and ind04.

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Static Positioning




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Static Positioning

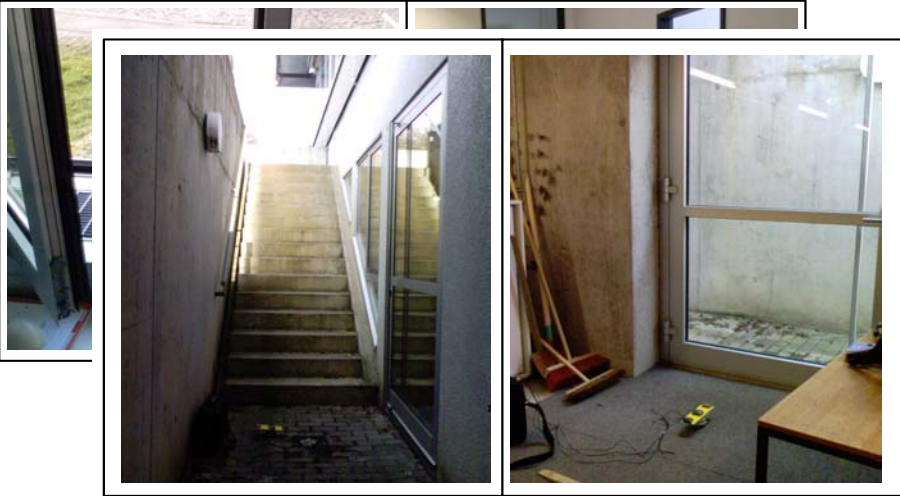


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Static Positioning – Results (1)

availability rate [%]	SiRF	u-blox	Fastrax
free horizon	100	100	99.5
shadowed area	99.6	92.6	93.6
indoor	71.6	42.2	18.1

reliability rate [%]	SiRF	u-blox	Fastrax
free horizon	100	99	99.8
shadowed area	100	100	99.9
indoor	99.4	99.5	98.7

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Static Positioning – Results (2)

standard deviations [m]	SiRF		u-blox		Fastrax	
	repeat	reproduce	repeat	reproduce	repeat	reproduce
free horizon	2.74	7.33	2.65	5.17	1.70	3.75
shadowed area	7.41	34.69	17.42	36.69	16.80	36.78
indoor near window	18.37	41.36	36.54	48.30	33.49	51.86
indoor room middle	54.54	88.11	37.21	60.90	-	-

- **Accuracy:** 3.75 – 7.33 for free horizon, > 34 m for other scenarios
- **Reliability:** almost 100 %
- **Availability:** 92 – 99 % shadowed area, 18 – 71 % indoor

SiRFstarIII shows best performance !

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Kinematic Positioning

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Kinematic Positioning – Results (1)

availability rate [%]	Leica	SiRF	u-blox	Fastrax
total track	20.5	97.4	97.6	97.1
curves (slow drive)	10.2	100	100	100
curves (fast drive)	0	100	100	99.8

Reliability rates: almost 100 % !

Reduced availability for phase measurements

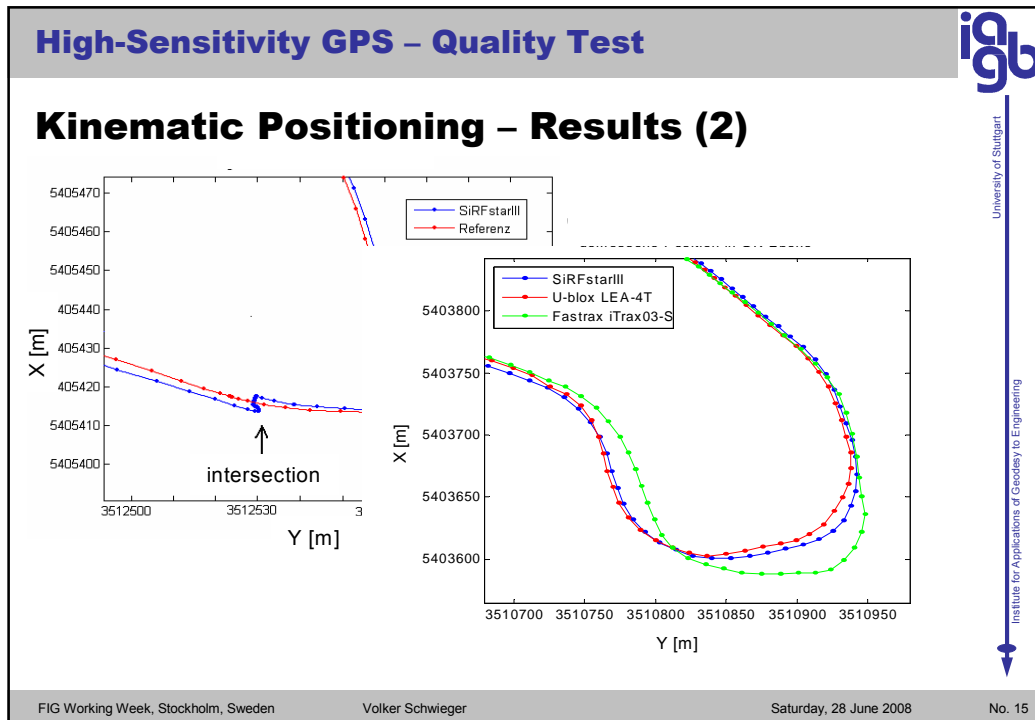
standard deviation [m]	SiRF	u-blox	Fastrax
total track	7.85	4.92	6.31

← reference trajectory

↓ double differences

standard deviation [m]	SiRF / u-blox	u-blox / Fastrax	Fastrax / SiRF
total track	10.67	10.83	12.22
curves (slow drive)	10.37	15.46	13.43
curves (fast drive)	13.93	19.34	25.10

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Summary

Static Performance

- Availability high in shadowed areas, indoor low
- Room-accurate indoor positioning by GPS not possible due to bad accuracy and availability

Kinematic Performance

- Availability higher than in static case
- Accuracy comparable to static case
- Filter algorithms implemented on receiver, no real GPS raw values available

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Thank you very much for your attention !

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