Universität Stuttgart
Institut für Ingenieurgeodäsie

Low-Cost GNSS for Geodetic Applications

Dr.-Ing. Li Zhang

Institute of Engineering Geodesy (IIGS),

University of Stuttgart, Germany

TS 05E – Future of Positioning

FIG Congress 2018, May 2018, Istanbul, Turkey

Introduction

Table 1: Receiver classes, applications and accuracy levels of static positioning

receiver class	used signal	applications	accuracy	appr. costs
low cost	code or phase-smoothed code, 1 frequency	car navigaton, location based services, sailing, mass market	1 to 10 m	100 – 500 €
geodata acquisition	phase-smoothed code, 1 frequency	infrastructure planning, architecture, GIS applications	0,5 to 3 m	5 000 – 10 000 €
geodetic	code and phase, in general 2 frequencies	surveying, geodynamics	0,001 to 0,1 m	10 000 € - 30 000 €

Schwieger and Gläser (2005)

EVK-M8
www.u-blox.com

Leica GS25
www.leica-geosystems.com

Low-Cost GNSS Receiver for Geodetic Applications, e.g. for monitoring, and machine control (Accuracy: mm to cm-level)?

Carrier Phase measurements should be accessible!

Introduction

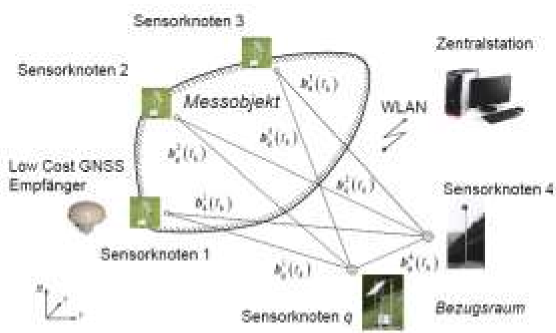
Test study with <u>u-blox GPS receivers</u> at University of Stuttgart, ETH Zurich und TU Graz

Schwieger (2009), Uni Stuttgart

Lanzendörfer (2007), TU Graz

Limpach (2009), ETH Zürich

The University of Armed Forces Munich with <u>Novatel GNSS receivers</u> (about 1200€)



Heunecke etal. (2011), Uni BW München

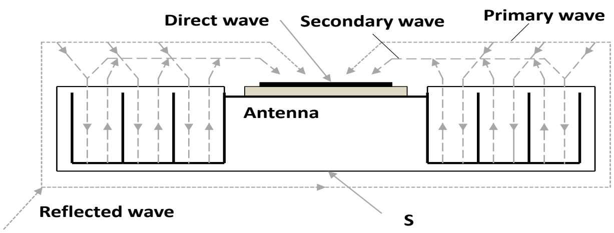
Low Cost GNSS is suitable for the monitoring applications, length - dependent error (tropospheric, ionospheric) are reduced for short baseline in relative module.

Geodetic Application: Monitoring

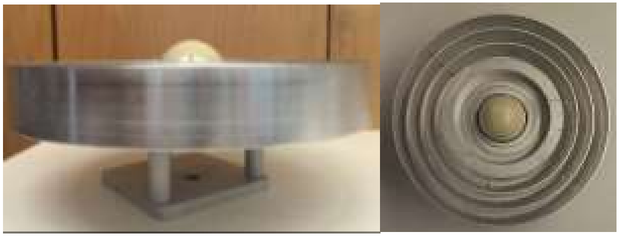
Dominate error for short baseline: Multipath effect

- Reduced by data processing (e.g. temporal and spatial correlations)
- Good antennas are important (e.g. Trimble Bullet III vs. Ublox ANN-MS, see Takasu and Yasuda 2008, Zhang and Schwieger 2013)
- Optimization of antenna shielding (ground plate vs. choke ring)

*Originally developed by **JPL***



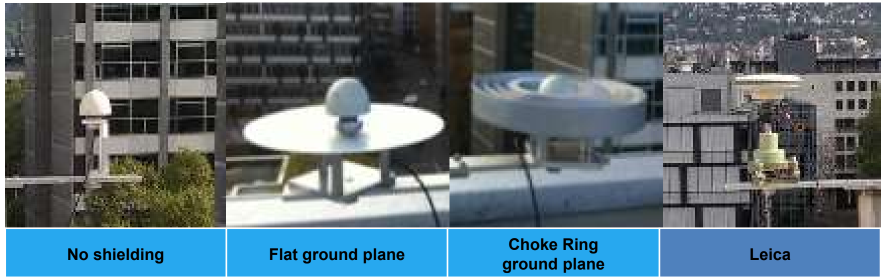
Zhang (2016)



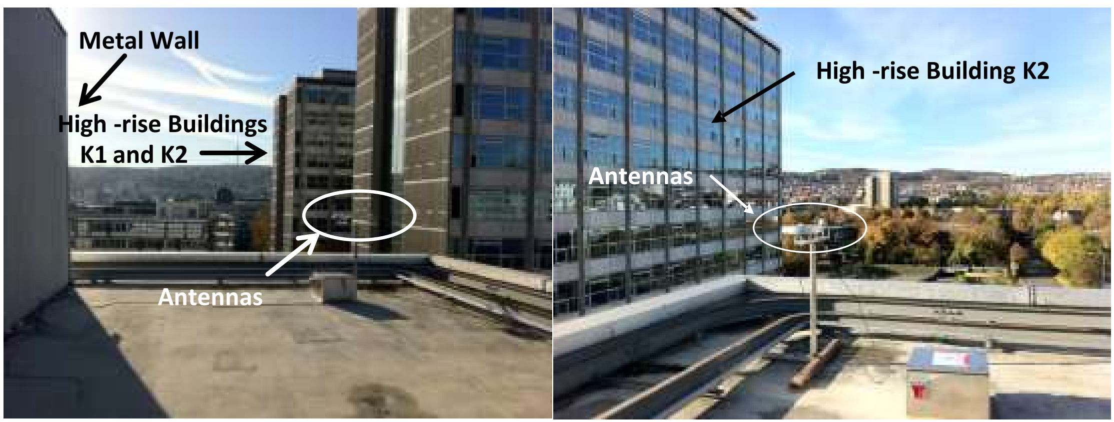
self-constructed L1-optimized CR-GP at IIGS
with Trimble Bullet III antenna (side view and top view)

- Groove depth: ¼ of wave length
- Diameter: 1.5 of wave length

Comparison of different Shieldings

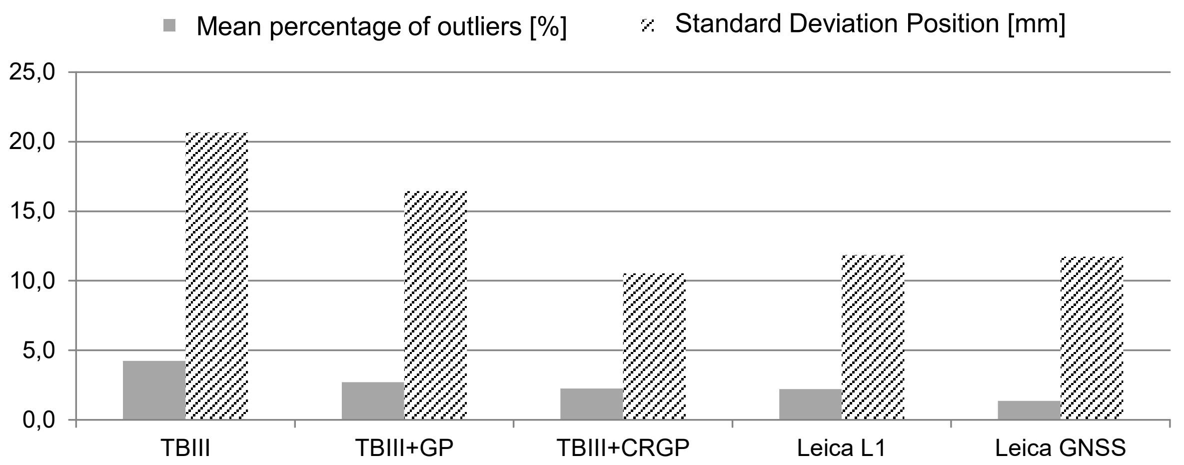


1) TBIII antenna without shielding + Ublox LEA-6T single-frequency GPS receiver,
2) TBIII antenna with flat GP + Ublox LEA-6T single-frequency GPS receiver,
3) TBIII antenna with CR-GP + Ublox LEA-6T single-frequency GPS receiver,
4) Leica AX1203 GNSS antenna without additional shielding + Leica GX1230 GNSS receiver.



Comparison of different Shieldings

Quality Analysis



- Improvement of the std.: Flat GP: 35 %, CR-GP: ca. 50 %
- TBIII with CR-GP std. ca. 3/5/9 mm (E/N/h) in this reflexion intensive environment
- TBIII with CR-GP comparable with Leica AX 1203 antenna with GX1230 receiver in this test

Low-Cost GNSS RTK System

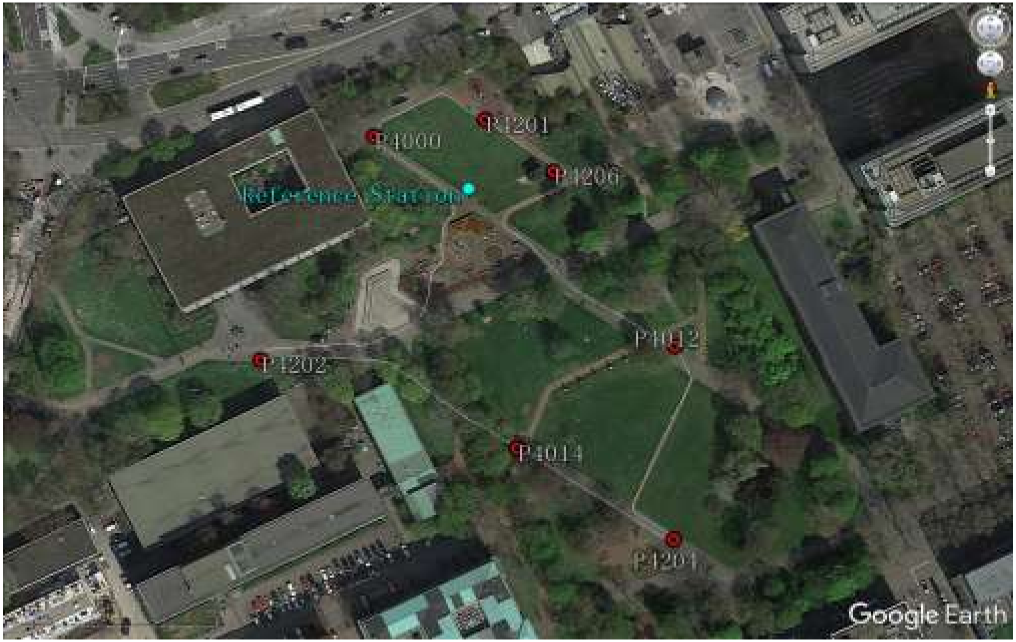
U-blox C94-M8P RTK Application Board

- 2 Neo-M8P-2 GNSS (GPS, GLONASS, Beidou, QZSS) modules
- 2 GNSS antennas + ground plate
- 2 UHF antennas

(~350€)

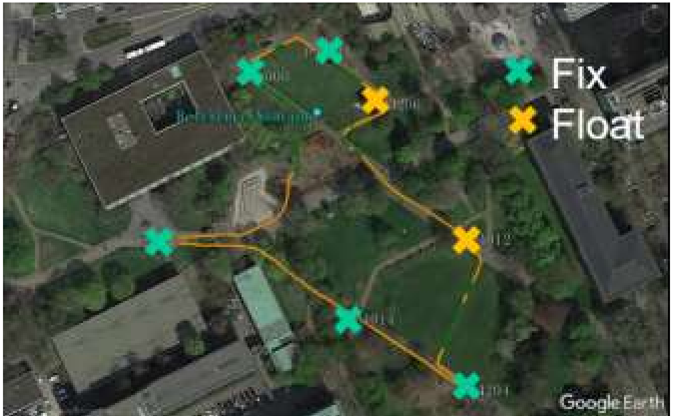
Investigation of U-blox C94-M8P

Test Scenario



December 2016 in Campus University of Stuttgart (buildings, trees)
RTK measurement for ca. 1 hour, stop at 7 fixed-points for 3 to 5 minutes

Investigation of U-blox C94-M8P



RTK Results with u-center

- ca. 50 % fixed solution
- RMS: ca. 1 cm (3D) of fixed-points with fixed ambiguities

Raw Data processed in post-processing with RTKlib

- ca. 85 % fixed solution
- RMS: ca. 5 mm (3D) of fixed-points with fixed ambiguities

Monitoring of Rock fall at the Yangtze River near the Three Gorges Dam with U-blox C94-M8P

Measurement

Reference Station (R)

- Leica 1200 System (GPS only)
- Ublox C94-M8P application Board (GPS+Beidou)

Rover Station (M1)

Rover Station (M2)

Monitoring of Rock fall at the Yangtze River near the Three Gorges Dam with U-blox C94-M8P

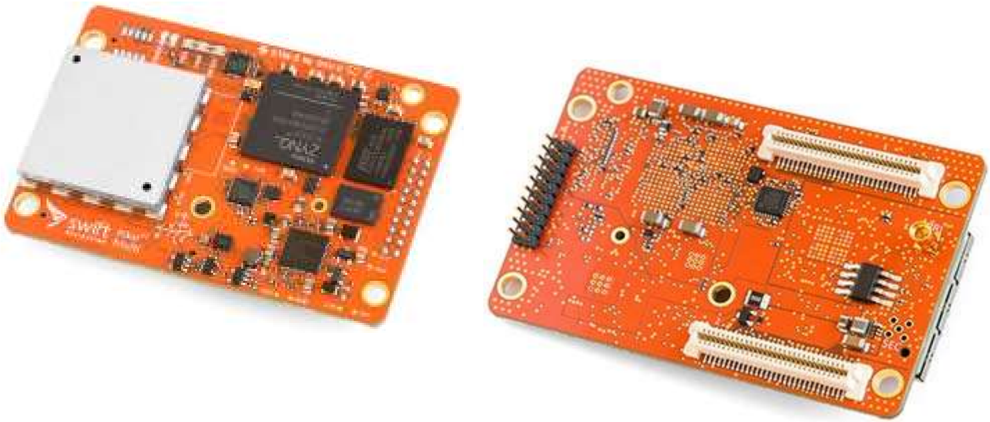
Results - Standard Deviation

Date	Session	Reference Station	Rover Station	Standard Deviation [mm]		
				E [mm]	N[mm]	h[mm]
09 March, 2018	1 (9:20-11:20)	Leica (R)	Ublox(M1)	5.2	3.7	11.1
		Leica (R)	Leica (M2)	5.3	3.7	11.4
	2 (14:00-16:00)	Leica (R)	Leica (M1)	3.8	4.0	12.3
		Leica (R)	Ublox(M2)	3.9	3.6	9.1
10 March, 2018	3 (10:15-12:15)	Ublox (R)	Ublox(M1)	3.7	2.7	9.7
		Ublox (R)	Leica (M2)	4.8	3.3	13.3
	4 (14:14-16:14)	Ublox (R)	Leica (M1)	3.9	3.9	9.6
		Ublox (R)	Ublox(M2)	2.8	2.4	7.3

*The difference of the Baselines is under 1 cm in all the coordinate components, there is no significant difference between the result of different sessions.

Outlook

Low-Cost multi-frequency GNSS Receiver?



Piksi Multi GNSS Module
https://www.swiftnav.com

~$600

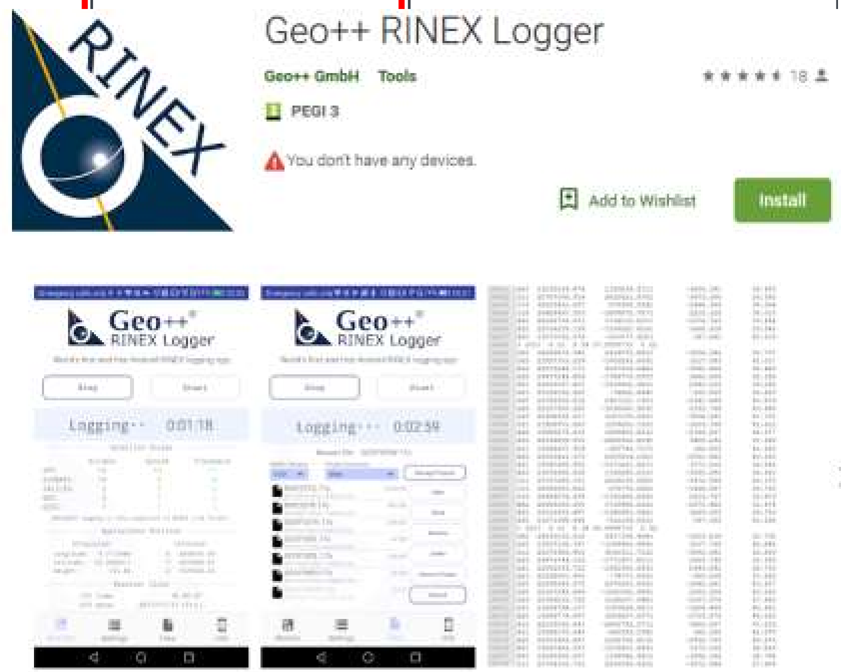
GPS L1+L2
(Hardware-ready for GLONASS G1+G2, BeiDou B1+B2, Galileo E1+E5b, QZSS L1+L2 and SBAS)

Outlook

GNSS Raw measurements of smartphone are accessible (since 2016)!

Carrier Phase

Model	Pseudorange data	Accumulated delta range	Global systems
Huawei Mate 10	yes		
Huawei P10	yes		
Huawei Honor 9	yes		
Samsung S8 (Exynos)	yes		
Nexus 9 (non cellular version)	yes		

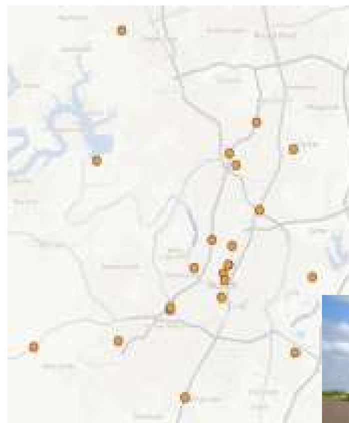


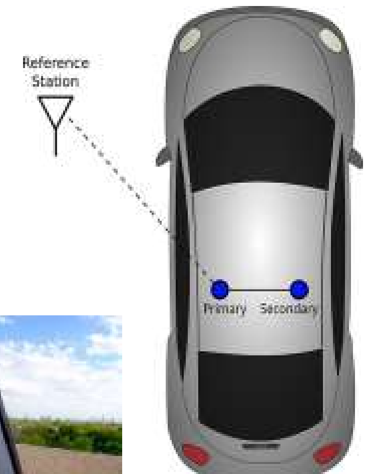
Selectived from https://developer.android.com

Precise positioning is possible with smartphones (sensor intergration)

Outlook

Precise Positioning with Low-Cost GNSS for automated vehicles?





A dense reference network (20 km) facilitates low-cost carrier-phase differential GNSS positioning with rapid integer-ambiguity resolution (PPP-RTK), centimeter-accuracy can be achieved.

Murrian et al. (2016)

Vielen Dank! Thank you! Teşekkür Ederim!

Dr.-Ing. Li Zhang

E-Mail li.zhang@iigs.uni-stuttgart.de
Telefon +49 (0) 711 685-84049
www. uni-stuttgart.de/ingeo

Universität Stuttgart
Institute of Engineering Geodesy
Geschwister-Scholl-Str.24D
70174 Stuttgart