Institut für Erdmessung

Leibniz Universität Hannover

Continuous Navigation of an Inland Vessel with a Synthetic GNSS Antenna

- **DGON • Posnav-ITS • Berlin** -

Session Technik III: Fusionierung

Tobias Kersten, Le Ren and Steffen Schön | Friday, November 16th 2018

Motivation • Inland Vessel Transport

Inland Waterway Transport (IWT)

- reliable, almost safe, eco-friendly and profoundly effective
- reducing traffic stress on rail and motorways
- future: combined transport (rail, waterway, motorway, regional & local)

Present transport vessel navigation

- precise navigation by Multi-GNSS real-time kinematic RTK (GPS+GLONASS)
- requires mobile data infrastructures / interfaces (RTCM, NTRIP, less GSM)
- navigation precision required / available: 2-5 cm / ≈dm

Challenges for the GNSS signal

- navigation in city canals with poor satellite sky distribution
- diffraction, interruption, complete loss-of-lock by bridge passages
- reliable height determination for guidance and driver assistance (RTK based)

Motivation • Inland Vessel Transport

Inland Waterway Transport (IWT)

- reliable, almost safe, eco-friendly and profoundly effective
- reducing traffic stress on rail and motorways (IWT: 240 mill. tons per year)
- future: combined transport (rail, waterway, motorway, regional & local)

Present transport vessel navigation

- precise navigation by Multi-GNSS real-time kinematic RTK (GPS+GLONASS)
- requires mobile data infrastructures / interfaces (RTCM, NTRIP, less GSM)
- navigation precision required / available: 2-5 cm / ≈dm

Challenges for the GNSS signal

- navigation in city canals with poor satellite sky distribution
- diffraction, interruption, complete loss-of-lock by bridge passages
- reliable height determination for guidance and driver assistance (RTK based)

Motivation • Inland Vessel Transport

Inland Waterway Transport (IWT)

- reliable, almost safe, eco-friendly and profoundly effective
- reducing traffic stress on rail and motorways (IWT: 240 mill. tons per year)
- future: combined transport (rail, waterway, motorway, regional & local)

Present transport vessel navigation

- precise navigation by Multi-GNSS real-time kinematic RTK (GPS+GLONASS)
- requires mobile data infrastructures / interfaces (RTCM, NTRIP, less GSM)
- navigation precision required / available: 2-5 cm / ≈dm

Challenges for the GNSS signal

- **navigation in city canals with poor satellite sky distribution**
- **diffraction, interruption, complete loss-of-lock by bridge passages**
- reliable height determination for guidance and driver assistance (RTK based)

Uelzen (GER): Skipper died
cabin and steel cable collides
as vessel entered lock
© 2017 kreiszeitung.de


Surwold/Emsland (GER): Vessel collides with bridge
skipper died
thick fog possibly the cause
© 2017 NWZonline.de

Synthetic GNSS antenna for Inland Waterway Transport

Scientific key questions for Inland Vessel Navigation

- driver assistant systems and safety relevant applications require high accuracy (GPS/GNSS carrier phase observables)
- carrier phase & code observables affected by discontinuities, interruptions or complete loss-of-lock due to e.g. bridge passages or similar
- benefits for code based navigation by combining several receiver antennas

Synthetic GNSS antenna - observation domain

- **enlarged field of view** combining observations of several antennas
- **applicable** arbitrary rigid navigation platforms (satellite, aircraft, ferry, vessel, ...)
- **lever arm** definition required (accurate and precise)

Synthetic GNSS antenna for Inland Waterway Transport

Scientific key questions for Inland Vessel Navigation

- driver assistant systems and safety relevant applications require high accuracy (GPS/GNSS carrier phase observables)
- carrier phase & code observables affected by discontinuities, interruptions or complete loss-of-lock due to e.g. bridge passages or similar
- benefits for code based navigation by combining several receiver antennas

Synthetic GNSS antenna - observation domain

- **enlarged field of view** combining observations of several antennas
- **applicable** arbitrary rigid navigation platforms (satellite, aircraft, ferry, vessel, ...)
- **lever arm** definition required (accurate and precise)

Synthetic GNSS antenna and the Virtual Receiver (VR)

Virtual Receiver - processing mode

- **input** observables from synthetic antenna
- **position** solution for robust and strengthened satellite geometry
- **angles** transport rate (specific approach for inland vessels)
- **synchronisation** coordinate observations of individual antenna locations

Synthetic GNSS antenna and the Virtual Receiver (VR)

Virtual Receiver - processing mode

- **input** observables from synthetic antenna
- **position** solution for robust and strengthened satellite geometry
- **angles** transport rate (specific approach for inland vessels)
- **synchronisation** coordinate observations of individual antenna locations

Specifications to our approach

- cost effective omit Inertial Navigation System (INS)
- lever arm multiple and optimal distributed GPS/GNSS antennas
- heading considering the transport rate (moving baseline)
- synchronise individual receiver / antenna units

Dedicated studies - the navigation platform *MS Jenny*

© 2016, LUH-IfE

The Navigation platform *MS Jenny*

- dimensions: 100 m length, 9.5 m width, 3.16 m depth
- two antennas / receiver units alongside the vessel, at bow (FRNT) and stern (BACK)
- datasets recorded in summer 2016 (DOY179) and 2018 (under investigation)
  - **static**: mooring point Hannover, duration 1 hour
  - **kinematic**: trip westward from Hannover, duration 2.5 hours

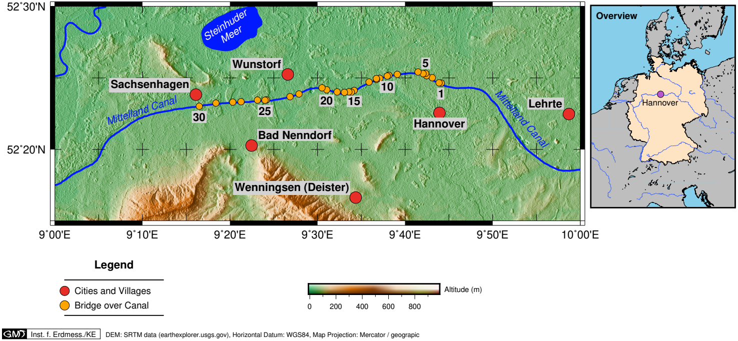
Dedicated studies - the navigation platform *MS Jenny*

© 2016, LUH-IfE

The Navigation platform *MS Jenny*

- dimensions: 100 m length, 9.5 m width, 3.16 m depth
- two antennas / receiver units alongside the vessel, at bow (FRNT) and stern (BACK)
- datasets recorded in summer 2016 (DOY179) and 2018 (under investigation)
  - **static**: mooring point Hannover, duration 1 hour
  - **kinematic**: trip westward from Hannover, duration 2.5 hours

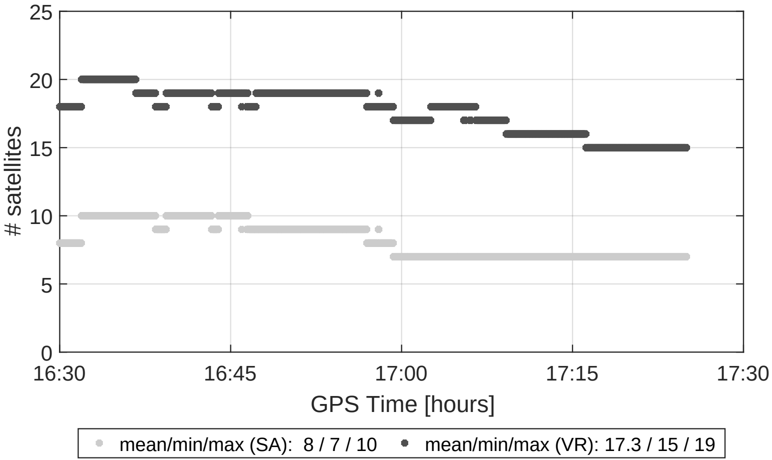
Dedicated studies - trajectory for investigations



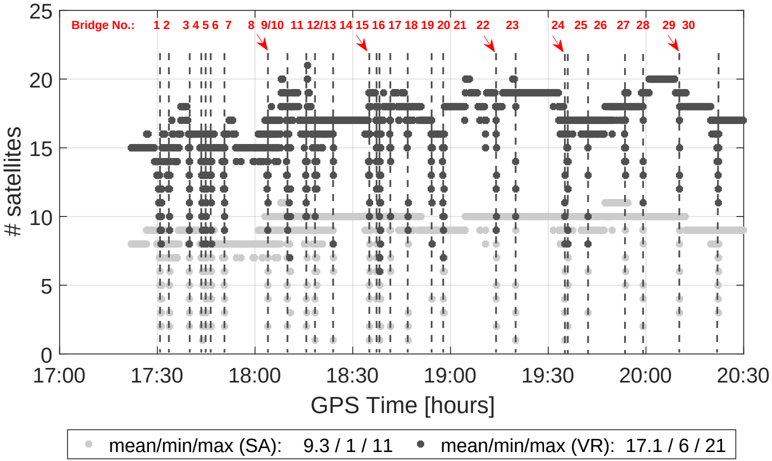
Experimental set-up

- sessions in 2016 (*static* and *kinematic*) investigated
- reference trajectory (double difference, phase based, NRCan and GrafNav)
- lever arm between FRNT and BACK by tachymetre and RTK (57.346 m$\pm$2 cm)

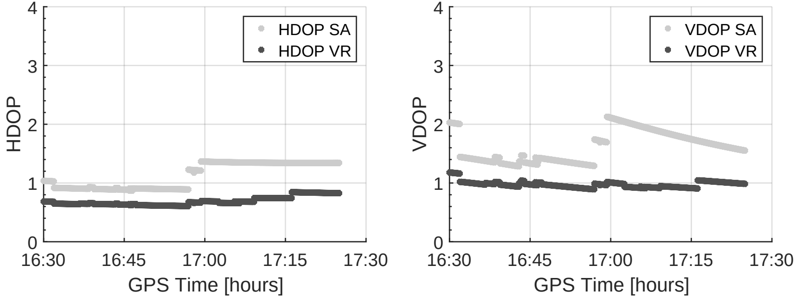
Satellite visibility - static session



Satellite visibility - kinematic session



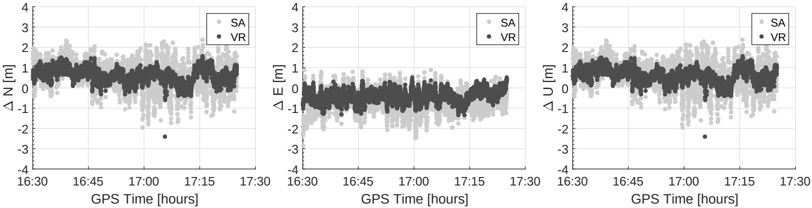
Code observables: position accuracy



Improvements for DOP Values

- synthetic GNSS antenna and VR advantageous to strengthens the satellite geometry
- provide significant reduction of expectable DOP-values
- significant improvements for the VDOP and some for HDOP

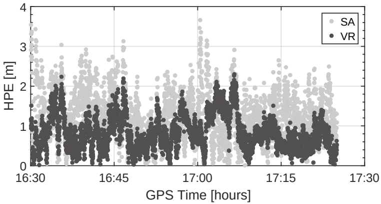
Code observables: position availability and continuity



Results

- **static session**
  - availability: 100% (VR) and 99.9% (SA)
  - HPE/VPE (VR): **0.70/0.46 m** HPE/VPE (SA): **1.02/0.54 m**
- **kinematic session**
  - availability: **94.5% (VR)** and **76.7 (SA)**
  - HPE/VPE (VR): **0.68/0.48 m** HPE/VPE (SA): **0.97/0.71 m**

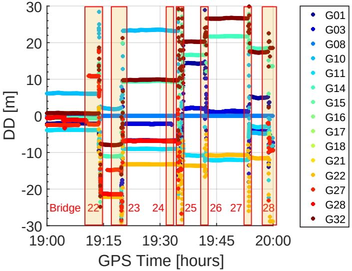
Code observables: position availability and continuity



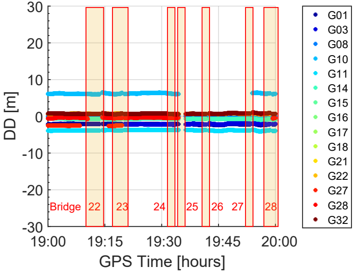
Results

- **static session**
  - availability: 100% (VR) and 99.9% (SA)
  - HPE/VPE (VR): **0.70/0.46 m** HPE/VPE (SA): **1.02/0.54 m**
- **kinematic session**
  - availability: **94.5% (VR)** and **76.7 (SA)**
  - HPE/VPE (VR): **0.68/0.48 m** HPE/VPE (SA): **0.97/0.71 m**

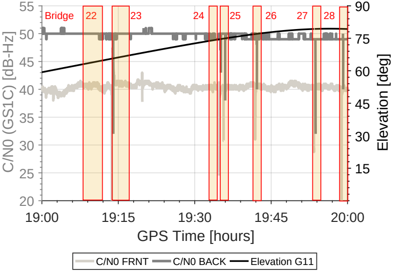
Impact of bridge passages on carrier phases (session 179-2)



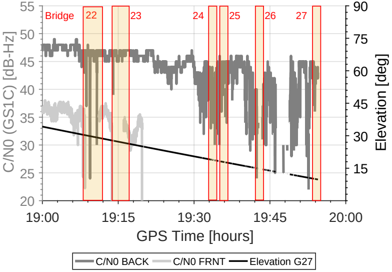
(a) cycle slips in double differences



(b) repaired double differences

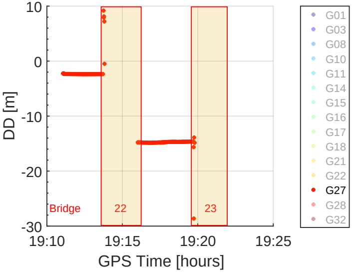


(c) GPS satellite G11

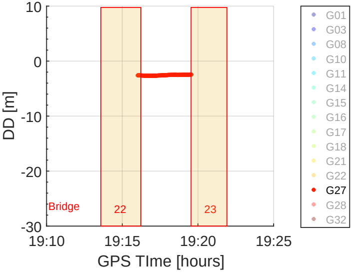


(d) GPS satellite G27

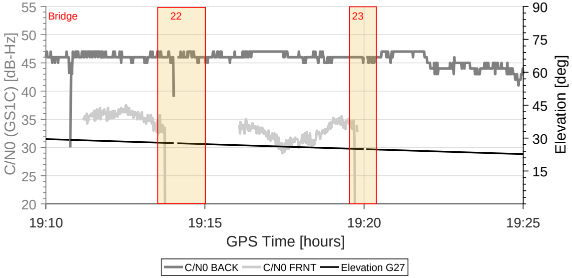
Impact of bridge passages on carrier phases (session 179-2) GPS G27



(a) cycle slips in double differences

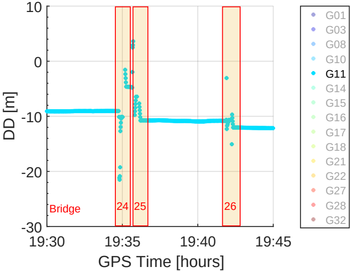


(b) repaired double differences

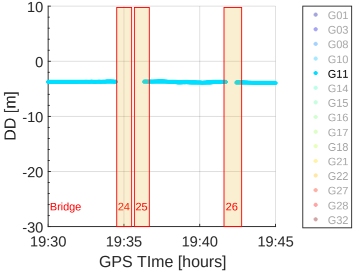


(c) GPS satellite G27

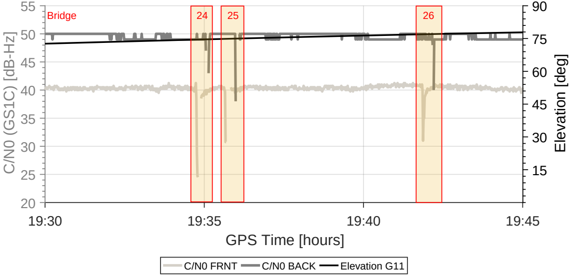
Impact of bridge passages on carrier phases (session 179-2) GPS G11



(a) cycle slips in double differences



(b) repaired double differences



(c) GPS satellite G11

Summary and outlook

Summary

- concept of synthetic GNSS receiver antenna and Virtual Receiver approach
- improved satellite visibility / navigation geometry by up to **50%**
- improved code-position accuracy (**13-16%**) / availability (**94% (VR)** v.s. **77% (SA)**)

Outlook and further work

- promising approach to avoid faults of the carrier phase ambiguity resolution due to enhanced observation continuity (ambiguity bridging)
- receiver clock modelling with chip scaled atomic clocks (CSACs) looks promising to derive reliable positions (esp. height component)
- identify bridge (e.g. building structure) by characteristics of GNSS signal distortion

Dr.-Ing. Tobias Kersten
Institut für Erdmessung
Schneiderberg 50
D-30167 Hannover, Germany

phone	+ 49 - 511 - 762 5711
web	http://www.ife.uni-hannover.de
mail	kersten@ife.uni-hannover.de

Leibniz Universität Hannover
Institut für Erdmessung

Acknowledgement

Investigations of this project are driven by student project in *Positioning and Navigation*. The authors like to thank Lucy Icking, Sara Brakemeier, Arman Kharmi, Fabian Ruwisch and Vahid Aghajani.

We grateful appreciate the support by the the captain family *Scheubner* for their grateful support and familiar hosting during the GNSS campaigns.

created with LaTeX beamer

References

Eurostat (2018). Modal split of freight transport in Europe.

Heßelbarth, A., Zeibold, R., Sandler, M., Alberding, J., Uhlemann, M., Hoppe, M., Bröschel, M., and Burmisova, L. (2017). Towards a Reliable Bridge Collision Warning System for Inland Vessel Navigation Based on RTK Height Determination. In *Proceedings of the 30th International Technical Meeting of The Satellite Division of the Institute of Navigation (ION GNSS+ 2017)*, pages 1866–1885.

Hilla, S. and Cline, M. (2004). Evaluating pseudorange multipath effects at stations in the National CORS Network. *GPS Solutions*, 7(4):253–267.

Kersten, T., Ren, L., and Schön, S. (2018). Continuous Navigation of an Inland Vessel with a Synthetic GNSS Antenna. In *DGON-Symposium Positionierung und Navigation für Intelligente Verkehrssysteme*. DGON.

Kube, F., Bischof, C., Alpers, P., Wallat, C., and Schön, S. (2018). A virtual receiver concept and its application to curved aircraft-landing procedures and advanced LEO positioning. *GPS Solutions*, 22(2):41.

Kube, F., Schön, S., and Feuerle, T. (2011). Virtual receiver to enhance GNSS-based curved landing approaches. *Proceedings of ION GNSS 2011, Portland, Oregon, USA*, pages 536–545.

Schön, S. and Alpers, P. (2018). A Virtual receiver for Pseudolites: Enhancing the positioning and Heading Determination of a Ferry. In *Proc ION GNSS+ Miami Florida, 24.-26.9.2018*.