Development of Precise Point Positioning Algorithm to Support Advanced Driver Assistant Functions for Inland Vessel Navigation

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DLR

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1. SCIPPPER – What is it about?

SCIPPPER

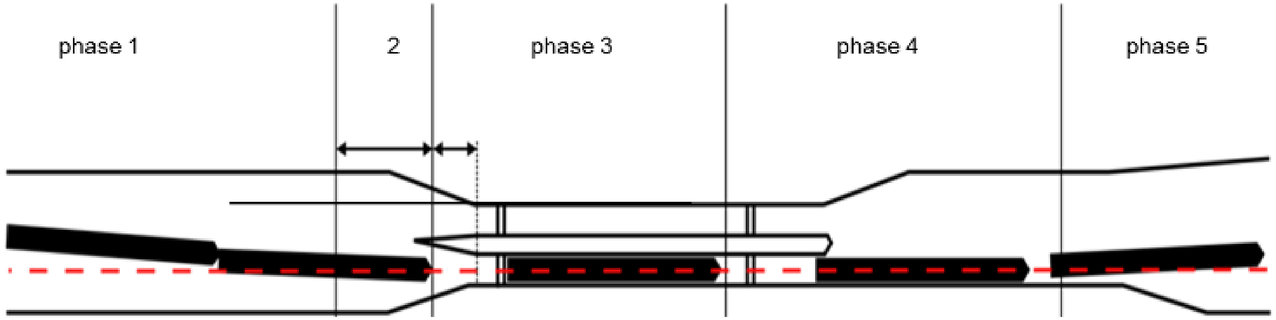
- Automatic passing of waterway lock
- Funded by German federal ministry for economic affairs and energy
- Duration: 11/2018 – 02/2022
- **Partners**

-Argonics GmbH
-in-innovative navigation GmbH
-Alberding GmbH
-Weatherdock AG
-German Aerospace Center (DLR)
-WSV (Traffic Technologies Center)
-BAW (Federal Waterways Engineering and Research Institute)

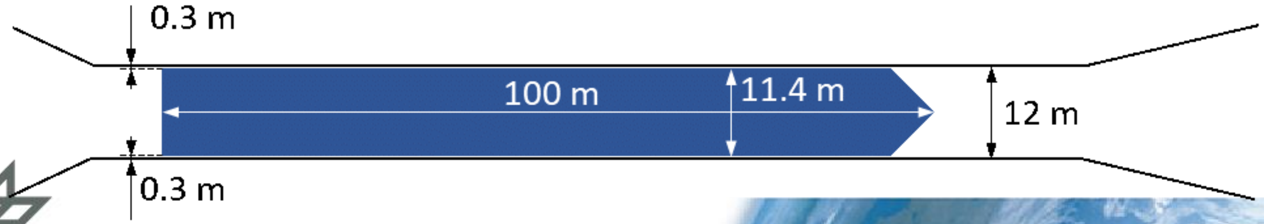
1. SCIPPPER – What is it about?

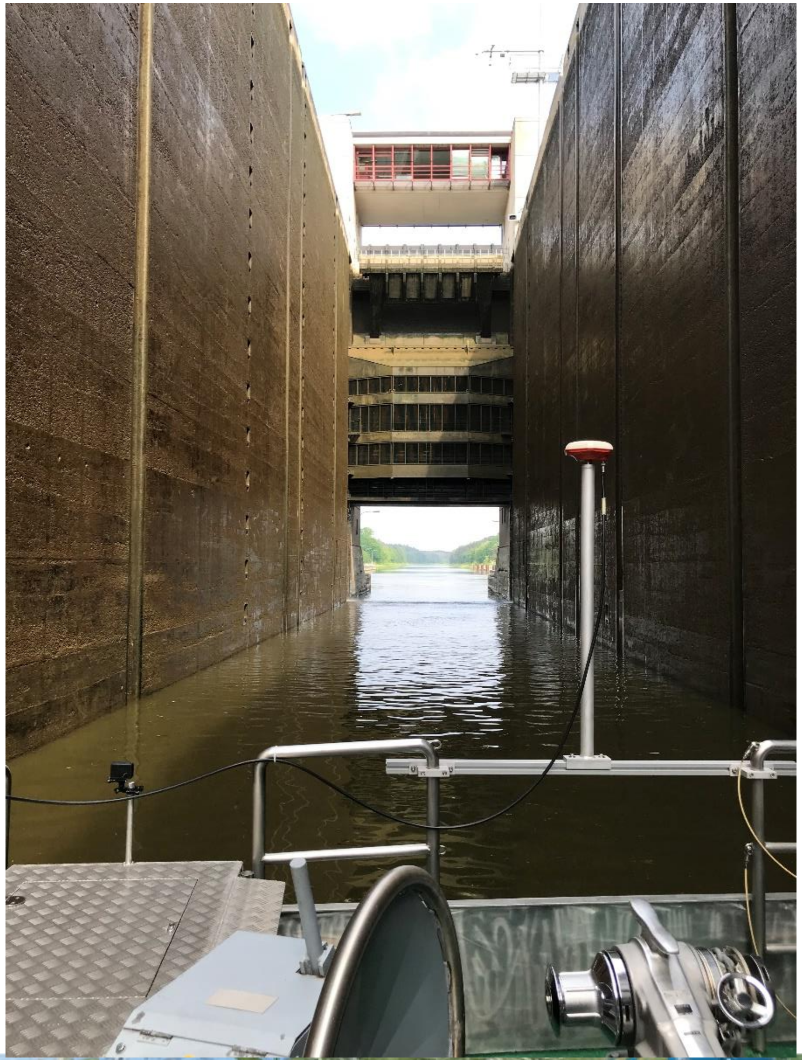
- Precise and reliable control of bow thruster, engine and rudder
- Highly accurate + reliable determination of ships PNT data via GNSS and near-field sensors
- Ship – shore communication using VDES and mobile internet connection

2. Requirements on PNT provision



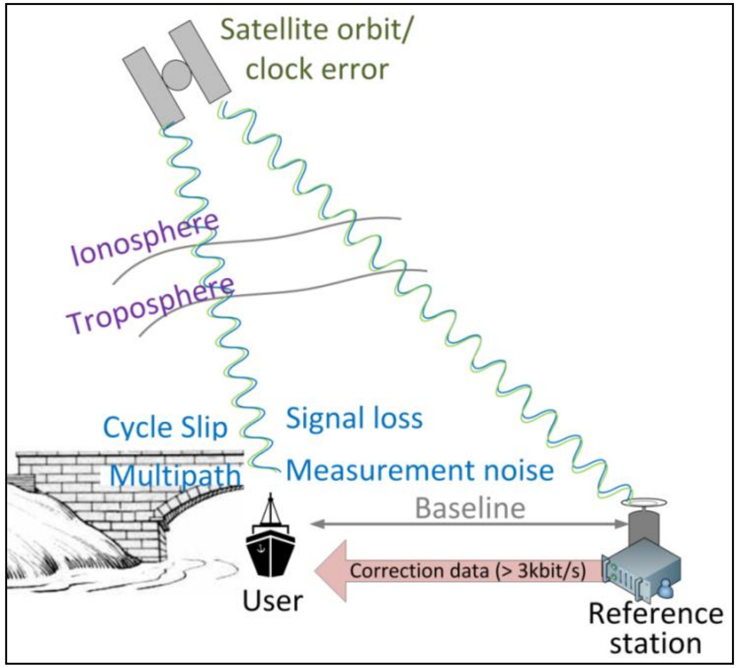
	Phase 1,5	Phase 2	Phase 3,4
Horizontal positioning accuracy [cm]	10	1 (Bow), 10 (Stern)	1
Heading accuracy [°] L = 100 m	11°/L 0.110°	11°/L 0.110°	0.5°/L 0.005°
Rate of Turn [°/min]	0.3	0.3	0.3
Velocity [cm/s]	1	1	1

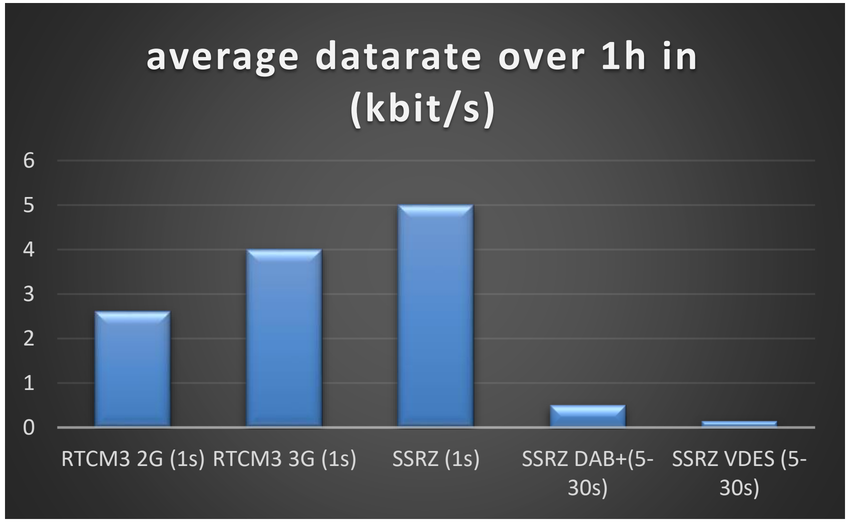




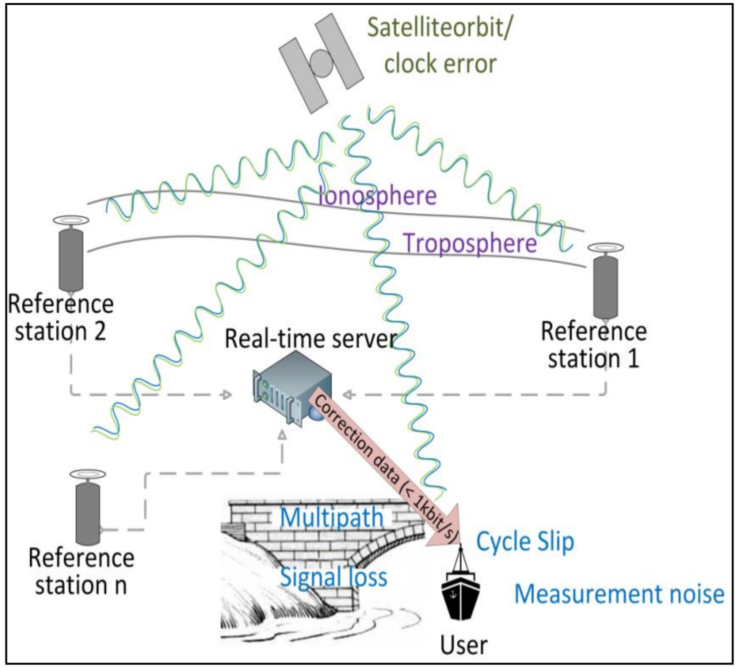
Positioning and bandwith considerations

Real Time Kinematic (RTK)





Precise Point Positioning (PPP)



PPP-RTK

- Absolute positioning
- Local\Regional corrections
- cm accuracy

3. Precise Point Positioning

General problem formulation

$$R_{i,s} = \|\boldsymbol{x} - x_s\|_2 + c(\boldsymbol{\delta t} - \delta t_s) + \boldsymbol{T_s} + \boldsymbol{I_{i,s}} + \varepsilon_{i,s}$$
$$\Phi_{i,s} = \|\boldsymbol{x} - x_s\|_2 + c(\boldsymbol{\delta t} - \delta t_s) + \boldsymbol{T_s} - \boldsymbol{I_{i,s}} + \lambda_{i,s}(\boldsymbol{A_{i,s}} + w_s) + \epsilon_{i,s}$$

Problem:

- Ionosphere and troposphere needs to be estimated and/or eliminated → Ambiguities $A_{i,s}$ need a long time to converge (~30 min)
- For real-time application we need additional corrections, especially for ionosphere and troposphere delay → SSR corrections
- Compact and flexible, but complex SSRZ format

State Space Representation (SSR)

- Satellite clock and orbit corrections (30 s)
- High rate satellite clock corrections (5 s)
- Code and phase bias (30 s)
- Troposphere corrections (30 s)
- Ionosphere corrections (30 s)

Time-differenced carrier phase measurements (TDCP)

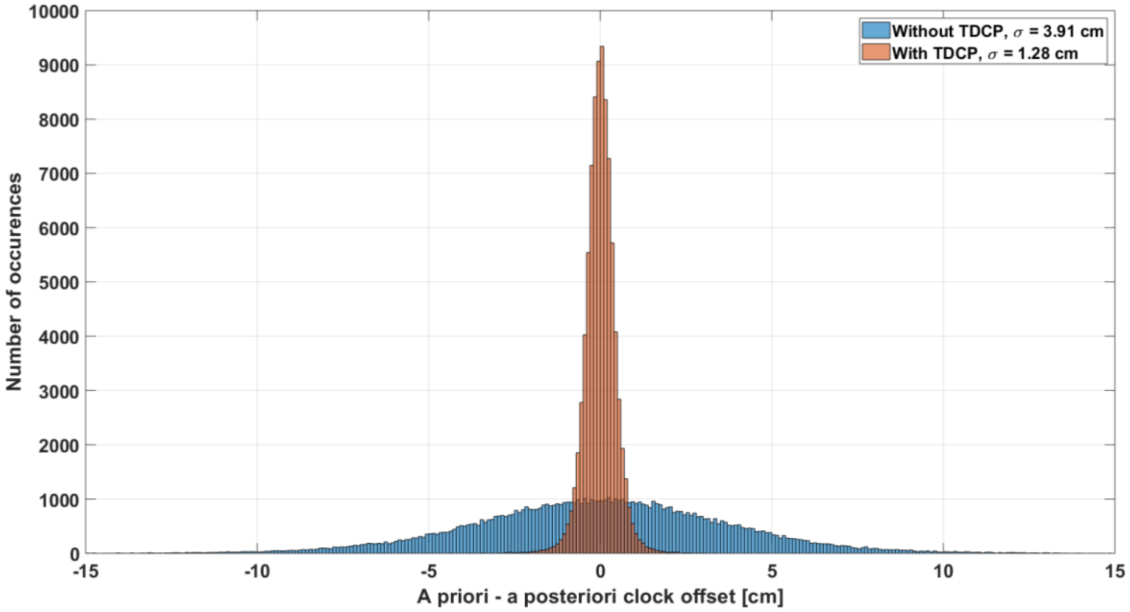
- Precise velocity determination without needing to know the phase ambiguities

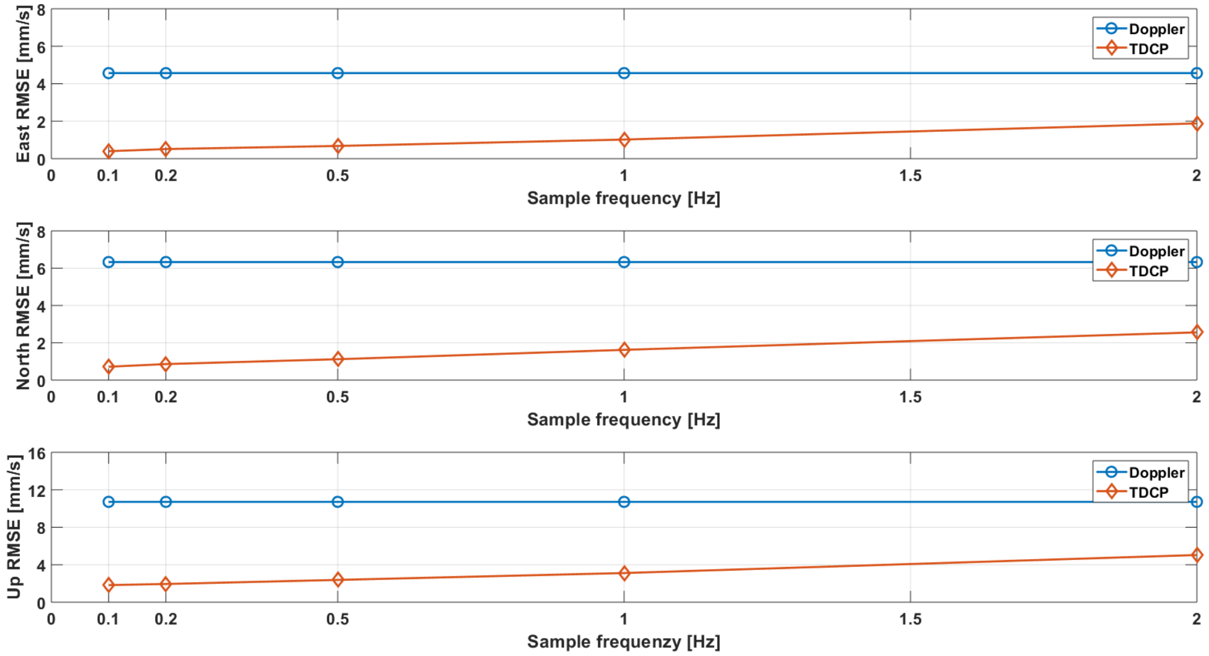
$$\frac{\Phi_{i,s}^{t+\tau} - \Phi_{i,s}^{t}}{\tau - (\delta t^{t+\tau} - \delta t^{t})} \approx \frac{x^{t+\frac{\tau}{2}} - x_s^{t+\frac{\tau}{2}}}{\left\| x^{t+\frac{\tau}{2}} - x_s^{t+\frac{\tau}{2}} \right\|_2} \cdot \left(\boldsymbol{v}^{\boldsymbol{t+\frac{\tau}{2}}} - v_s^{t+\frac{\tau}{2}} \right) + \boldsymbol{c\dot{\delta}t}^{\boldsymbol{t+\frac{\tau}{2}}}$$

- Use calculated values as a priori estimates in the Kalman Filter

$$\begin{aligned} x^{t+\tau} &= x^{t} + \tau v^{t+\tau/2} \\ v^{t+\tau} &= v^{t+\tau/2} \\ c\delta t^{t+\tau} &= c\delta t^{t} + \tau c\dot{\delta} t^{t+\tau/2} \\ c\dot{\delta} t^{t+\tau} &= c\dot{\delta} t^{t+\tau/2} \end{aligned}$$

Advantages of using TDCP





→ Useful for analysis of a priori phase residuals

Sampling frequency	0.1 Hz	0.2 Hz	0.5 Hz	1 Hz	2 Hz
Doppler [mm/s]	13.25	13.25	13.25	13.25	13.25
TDCP [mm/s]	2.00	2.19	2.72	3.66	5.96

4. Conclusions & Outlook

Summary

- Driver assistant function for passing waterway locks
- Real-time PPP using SSR corrections
- Precise velocity determination needing just one prior epoch

Outlook:

- Two antenna approach for heading and bridge passing
- Integration of IMU
- Final demonstration beginning of 2022

Thank you for your attention!

Video of simulated entering of waterway lock:
www.scippper.de

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