Combining Galileo's HAS and the E5 AltBOC signal for terrestrial mobile mapping

European Workshop on Calibration and Orientation

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Motivation

- Global Navigation Satellite Systems (GNSSs) have become a key infrastructure in our society
- High-accuracy positioning is required in progressively harsh scenarios
- Complex signals and freely available real-time correction services are expanding the possibilities for improved performance
- Effectively exploiting the full potential of these capabilities remains an active area of research
- This work is part of the ongoing efforts within European projects aimed at enhancing GNSS technologies

Motivation - EGENIOUSS project

The goal of EGENIOUSS is to provide affordable, accurate and assured positioning, navigation and timing using a GNSS-compatible device with a camera (e.x. a smartphone)

The idea is to use a hybrid EGNSS-based Visual Localisation cloud-based service for absolute positioning

The intended use-case are urban scenarios, where GNSS positioning is difficult (satellite occlusions, reflections, multipath...)

Geonumerics role: sensor fusion, leads of work package for demonstration, evaluation and system presentation

egeniouss
the better where

EUSPA
European Union Agency for the Space Programme

Motivation - GAMMS project

The goal of GAMSS is to develop an autonomous terrestrial mobile mapping system based on the tight integration of autonomous vehicle, navigation/geodetic, and artificial intelligence technologies

The idea is to have an accurate positioning and navigation system in real time that allows the mobile mapping system to be autonomous on its own

Geonumerics role: project coordinators.
Leaders of work package where all technical partners develop their own system and we are in charge of achieving the best trajectory in absolute mode with sensor fusion.
Responsible of test plan and report.

GAMMS
ROBOTS MAPPING FOR ROBOTS

EUSPA
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Agenda

galileo high accuracy service

Galileo High Accuracy Service (HAS)

HAS is a free, open-access positioning, navigation and timing service delivering real-time, high-accuracy positioning corrections

It can be seen like an augmentation service for Galileo and GPS constellations

Deployed in two service levels

- Service level 1 (current): orbit, clock, code, (phase) corrections. Distributed via E6-B signal and internet
- Service level 2 : regional atmospheric corrections

Accuracy target: 20cm horizontal error, 40cm vertical error (95% confidence level)

Current frequencies: GPS L1 and L2, Galileo E1, E5a, E5b, E6

galileo e5altboc signal

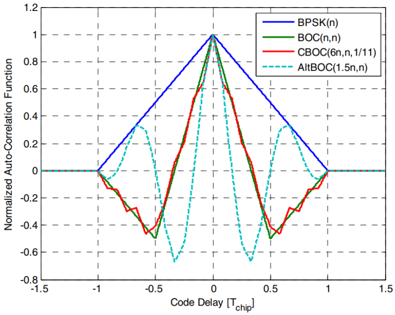
Galileo E5AltBOC signal

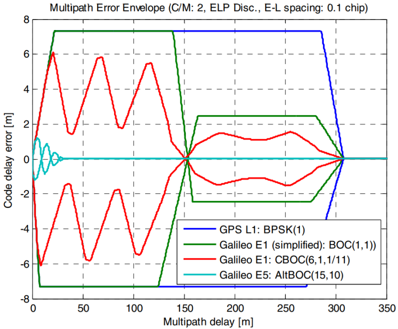
E5AltBOC is an advanced signal broadcast by Galileo in the E5 band

AltBOC stands for Alternative Binary Offset Carrier modulation. This modulation enables simultaneous transmission of four signal components: E5a-I, E5a-Q, E5b-I, E5b-Q, into a single unified wideband signal. This improves tracking robustness

The signal is centred at 1191.795 MHz, exactly between E5a and E5b frequencies. It has a bandwidth of 51 MHz, (more than double the width of E5a or E5b separately) which improves multipath resistance and code precision

E5AltBOC signal





Steeper main peak of ACF relates to lower tracking noise. Secondary peaks improve multipath robustness

AltBOC modulation presents reduced multipath error and shorter time impact

Images from (Silva et al., 2012)

main goals

Goals for this work

- Evaluate the performance of Galileo HAS capabilities in different scenarios
- Asses the positioning accuracy of Galileo E5AltBOC signal using pseudorange measurements only
- Study the combination of both HAS and E5AltBOC features for enhanced performance
- Explore applicability in a real kinematic urban dataset

study outline

Study outline

- We build E5AltBOC corrections from available HAS: orbits and clocks corrections are frequency independent. We calculate a pseudo-correction for the code bias

$$d^S_{AltBOC} = \frac{d^S_{E5a} + d^S_{E5b}}{2}$$

- Static positioning: use pseudorange-only positioning models to observe HAS impact

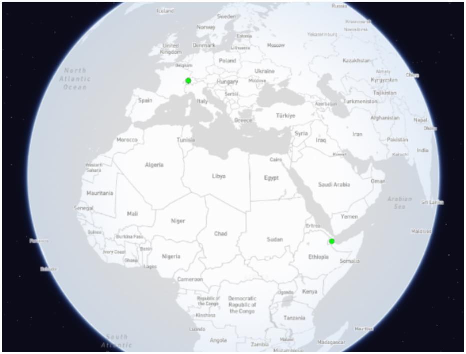
- Kinematic positioning: use a car route in an urban scenario to test HAS and E5AltBOC capabilities in difficult environments

static positioning under nominal conditions

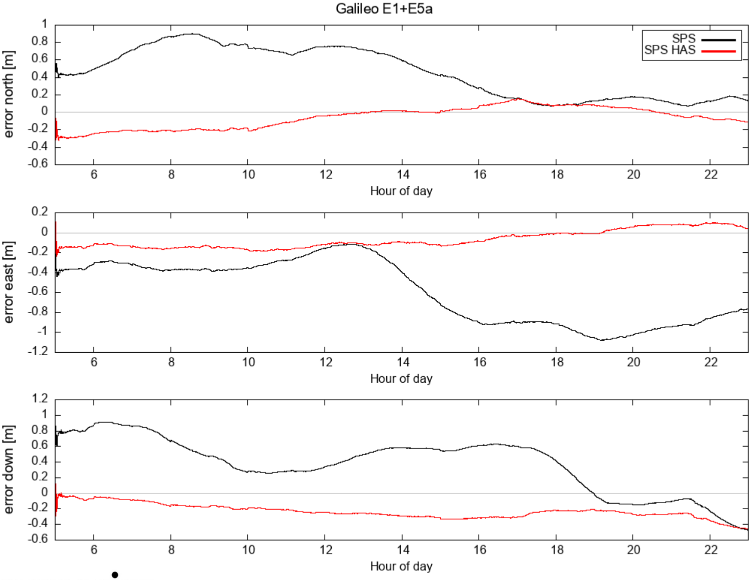
Permanent stations

Use data from two permanent stations of the International GNSS Service (IGS) network

- ZIM (ZIM200CHE) station, Switzerland Latitude 46.877, Longitude 7.465
- DJI (DJIG00DJI) station, Djibouti Latitude 11.526, Longitude 42.847



ZIM station


Galileo E1+E5a
SPS
SPS HAS
error north [m]
error east [m]
error down [m]
Hour of day
Hour of day
Hour of day
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0.2
-0.8
-1
-1.2
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6
8
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12
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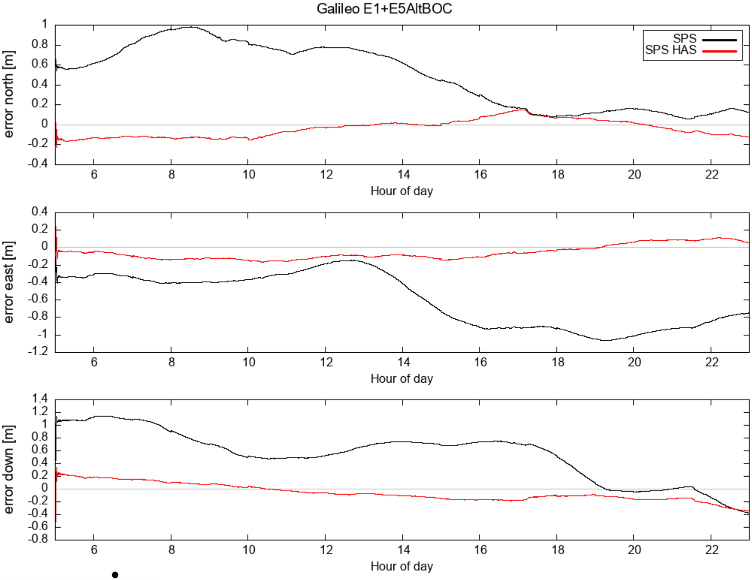
16
18
20
22

ZIM station


Galileo E1+E5AltBOC
SPS
SPS HAS
error north [m]
error east [m]
error down [m]
Hour of day
Hour of day
Hour of day

ZIM station

		RMS of errors [m]		
second freq.	mode	n	e	d
E5a	SPS	0.536	0.668	0.513
AltBOC	SPS	0.582	0.671	0.665
E5a	SPS HAS	0.135	0.112	0.249
AltBOC	SPS HAS	0.091	0.098	0.144

DJI station

		RMS of errors [m]		
second freq.	mode	n	e	d
E5a	SPS	2.243	2.287	5.584
AltBOC	SPS	2.211	2.257	5.520
E5a	SPS HAS	0.131	0.165	0.203
AltBOC	SPS HAS	0.105	0.135	0.283

kinematic positioning in an urban scenario

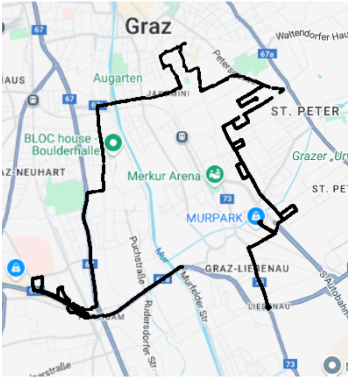
Data acquisition

Car route from GAMMS second test campaign, May 7, 2025

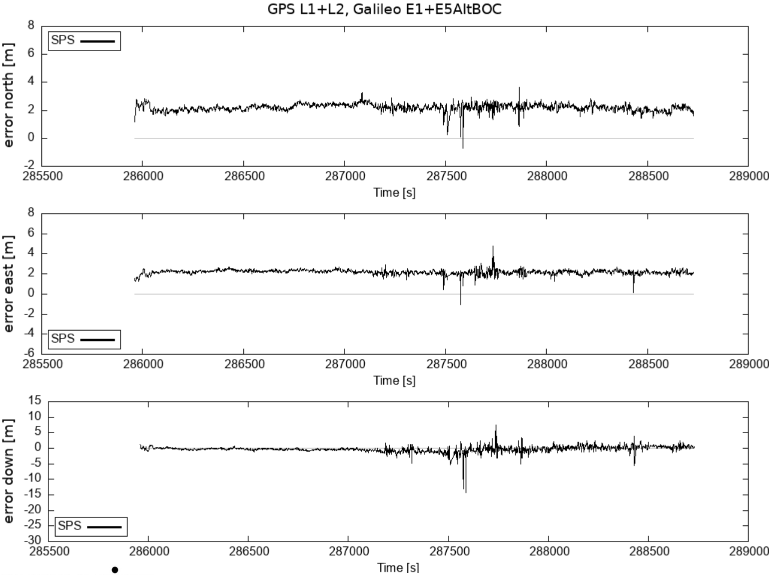
Rinex file from Mosaic-x5 receiver

Reference solution computed with commercial software, with differential PPP, using GRAZ station as base

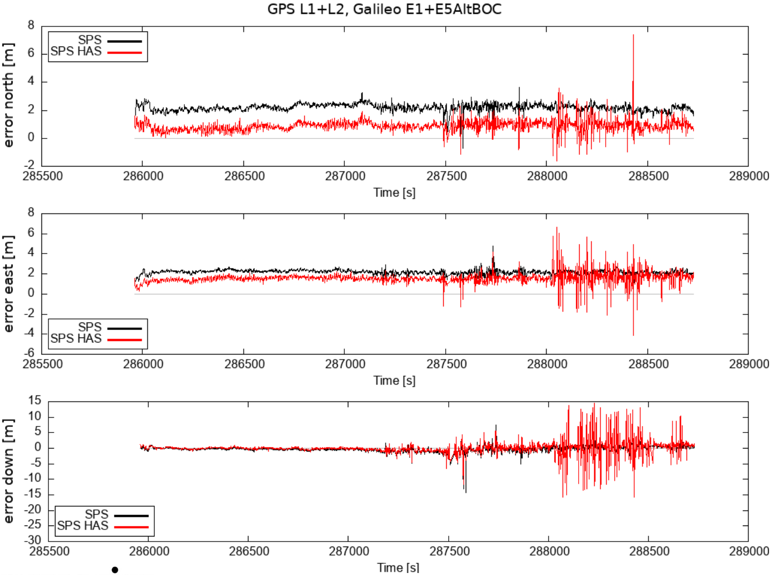
40 minutes analysed: static period + route at urban area with low houses



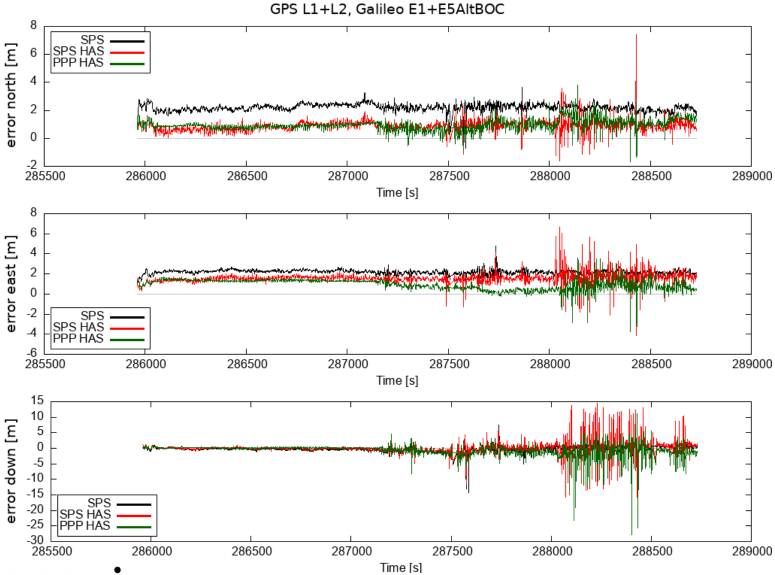
Kinematic trajectory



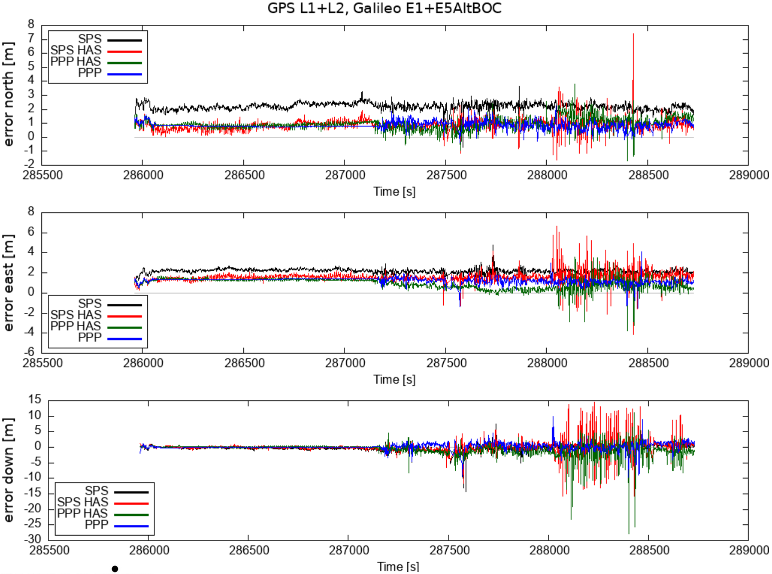
Kinematic trajectory



Kinematic trajectory



Kinematic trajectory



conclusions

Conclusions

- In this work we have used a simple code bias approximation for E5AltBOC. This enables practical use of HAS corrections for this signal
- Under nominal conditions, we have seen HAS improving pseudorange-only positioning, making it valuable for fast convergence or low-complexity receivers
- In urban scenarios, the use of HAS improves results but we do not reach target accuracy. Satellite occlusions and signal reflection effects remain dominant error sources, beyond the reach of satellite-side corrections
- Full exploitation of HAS in demanding applications will benefit from future phase corrections and integration with additional sensors

Thank you for your attention