Testing of multi-frequency smartphone grade GNSS chipsets - preliminary results

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27/05/2020

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Introduction

- Summary of the **preliminary results from three multi-frequency smartphone grade GNSS chipsets**
(evaluation kits connected to an external L-band antenna)

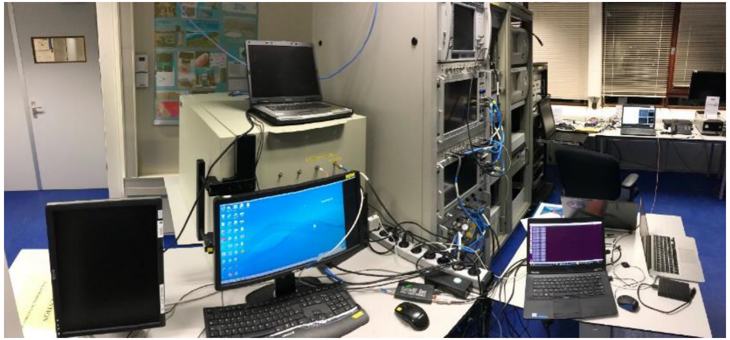
- These results are part of a Multi-Frequency Multi-GNSS chipset test campaign ongoing at ESA/ESTEC in coordination with GSA and several manufacturers from Europe, USA and China.

- The test campaign aims at verifying system performance and benefits of Galileo (also in combination with other GNSS systems) in realistic operational environments

Test Campaign description

The campaign included two type of test activities:

- Lab verification using GNSS RF simulator:
    - Power-ramp
    - Controlled dynamics



- Live mobile data collections:
    - Open-sky
    - Urban
    - Capability of RF record/replay

Testing methodology : exploitation of raw meas.

Ev. kit PVT

GNSS logger / PVT fix

MSP3 PPP-like

ESA Rinex Conv erter

GNSS logger / **Android GNSS Raw Meas**

L-band patch antenna

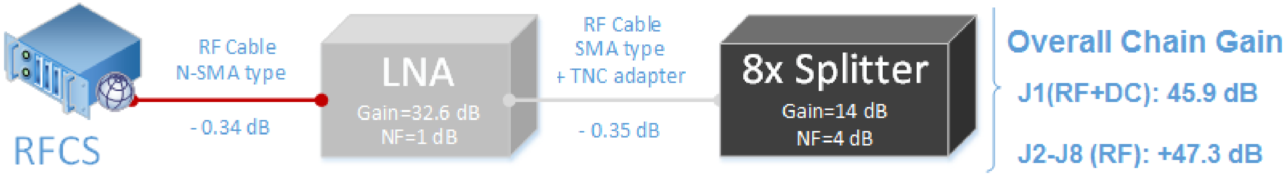
GNSS ev. kits

MSP3 and Android GNSS raw measurements

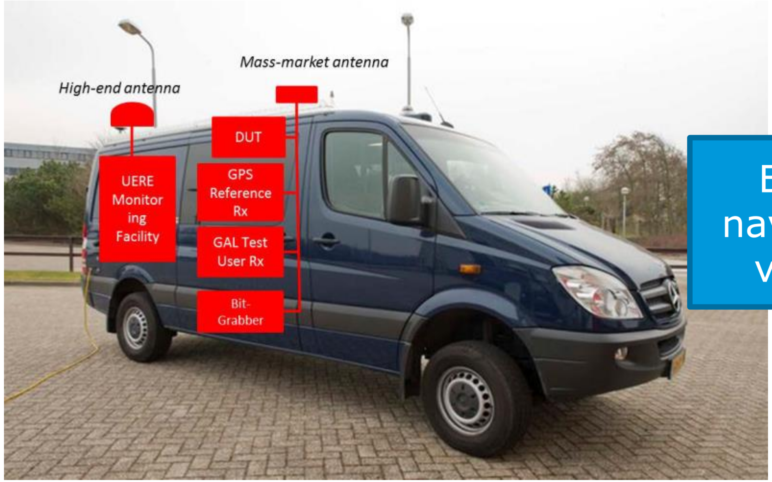
- **MSP3 processing tool** (result of ESA TRP project with NSL):
  - Raw observables (rinex format)
  - Multi-GNSS, multi frequency
  - PPP-like (float and fix ambiguities)
  - Sequential Extended Kalman Filter (EKF)
  - uncombined observations
  - iono-weighted model
  - RAIM (Receiver Autonomous Integrity Monitoring)
- Inputs:
  - **Raw observables** (Rinex format)
  - Broadcast or final precise orbital and clock products

Lab test set-up

RF simulator **GSS9000** (GAL E1/E5a/E5b +GPS L1/L2/L5) + **calibrated RF chain**



Mobile test campaigns set-up



ESTEC navigation vehicle

GNSS ev. kits

GNSS ev. kits

Mobile test campaigns set-up (II)

L-band antennas:

- Reference multi-GNSS antenna
- Mass-market patch antenna

Reference trajectory system

- Tactical grade IMU gyro and accelerometer
- Rubidium reference clock
- RTK based (IMU+GNSS solution)

RF record/replay system (L-band enabled)

Simulation tests

Power-ramp scenario

GAL+GPS

E1/E5a+L1/L5

Error-free simulation

Rx implementation:

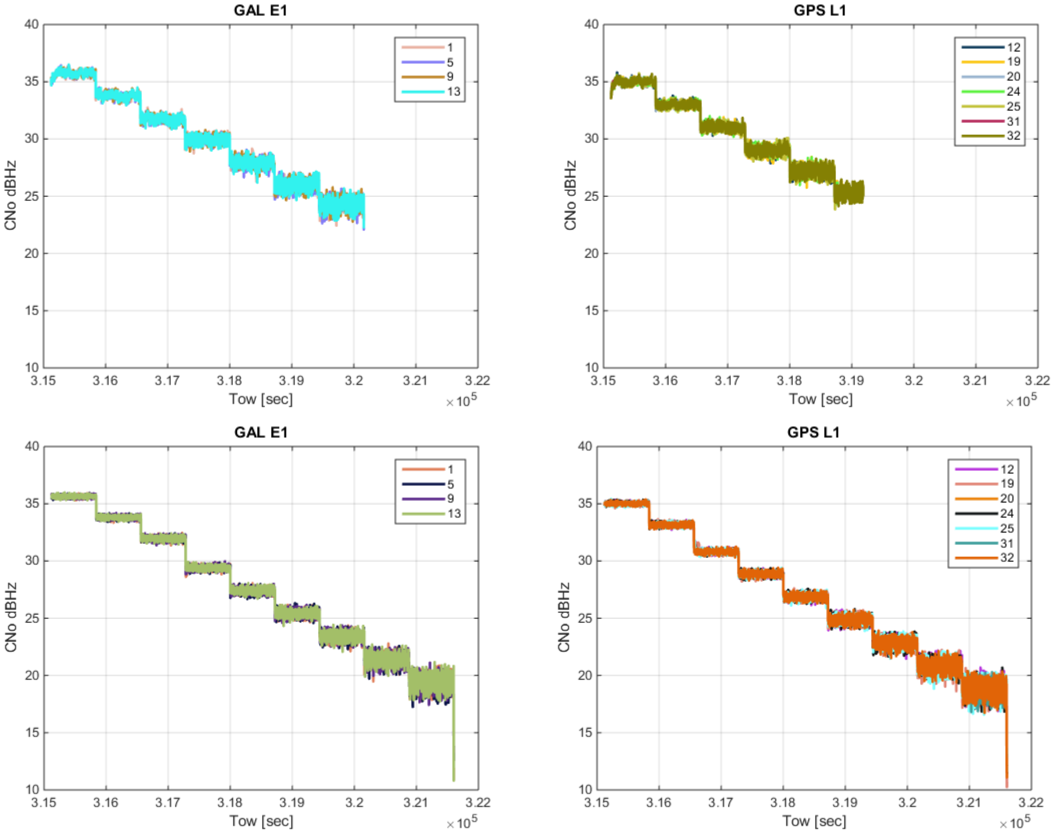
6dB diff in

Tracking

sensitivity

PRO grade

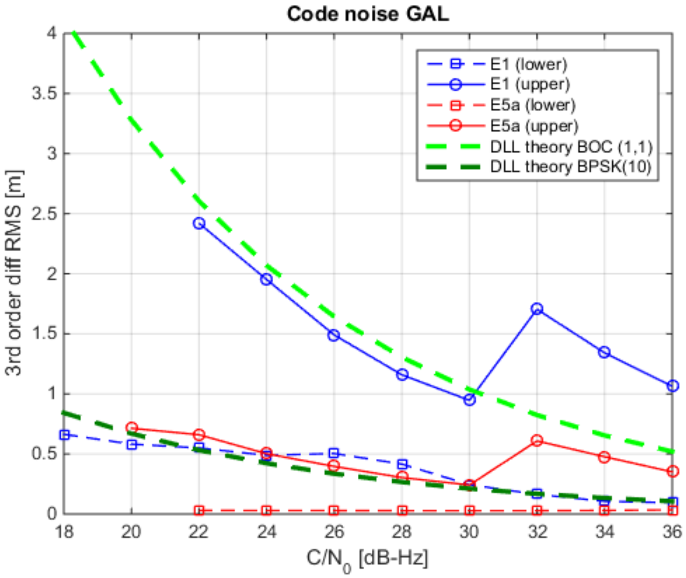
Smart-phone grade



Simulation test results

Code noise assessment

$$\hat{\varepsilon} = \frac{\emptyset_C - 3\emptyset_C(n-1) + 3\emptyset_C(n-2) - 3\emptyset_C(n-3)}{\sqrt{20}}$$



Perfo based on individual implementation

- **Upper bound**:

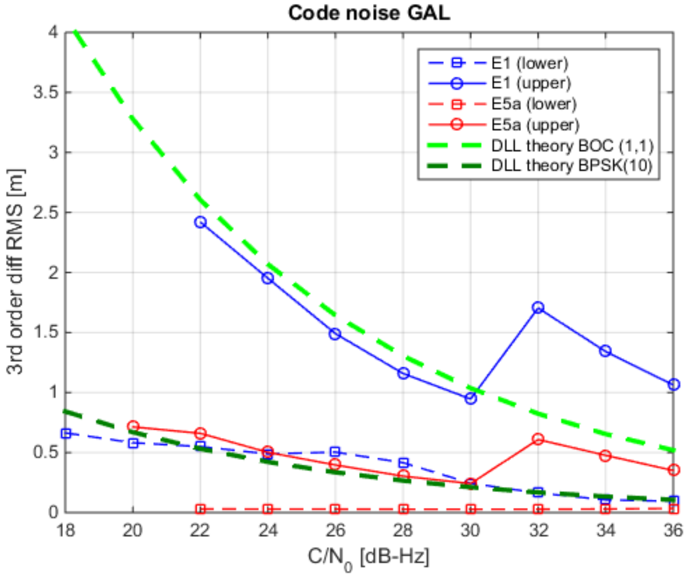
BPSK DLL jitter theory
Std = LIGHTSPEED/Rc*sqrt(B*D./(2*cno)) [m]
E-L Delta & bandwidth config
For certain thresholds

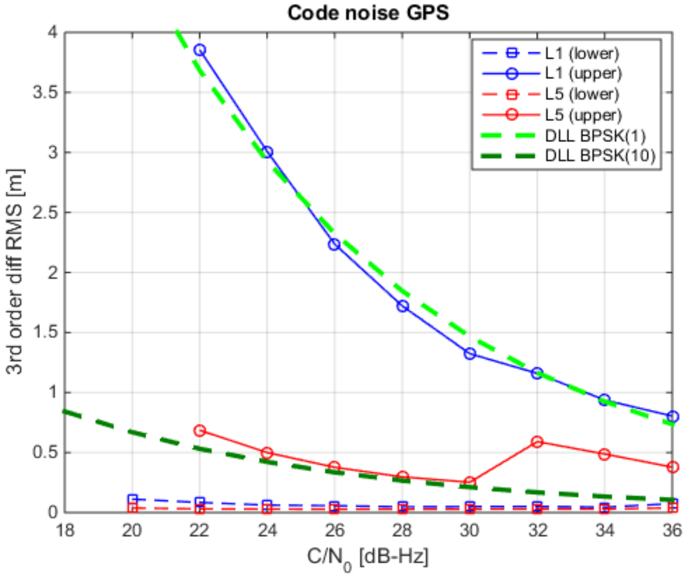
- **Lower-bound**:

Possible pseudorange smoothing
with carrier phase (maybe it would nice to get it flagged through the Android APIs)

Simulation test results

Code noise assessment

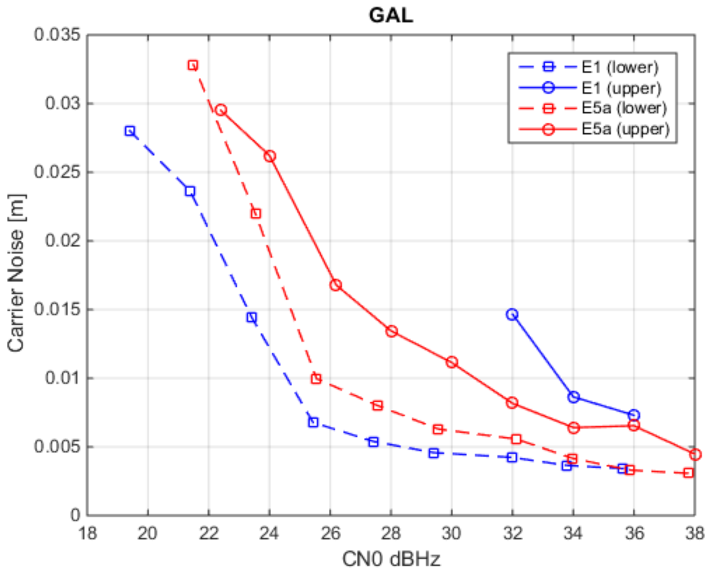


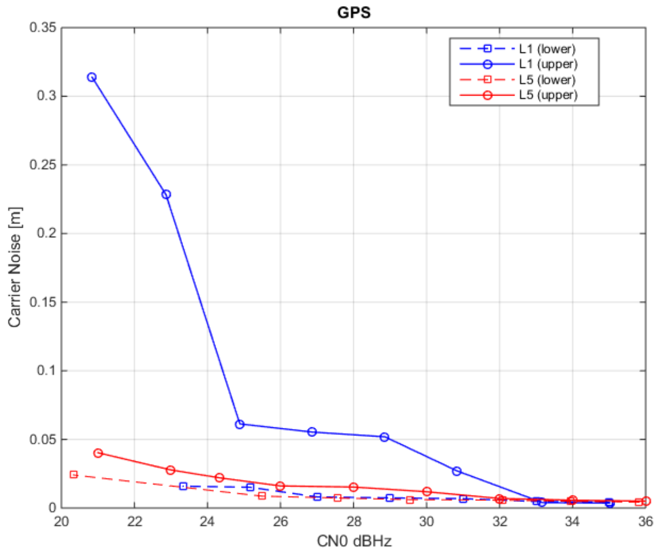


Simulation test results

Carrier-phase noise assessment (carrier phase before cycle slip)

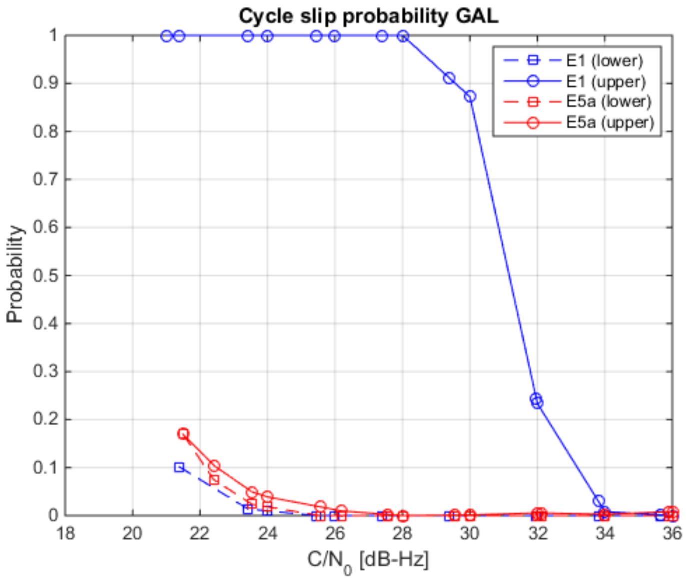
Double differences with the simulator reference





Simulation test results

Cycle slip probability



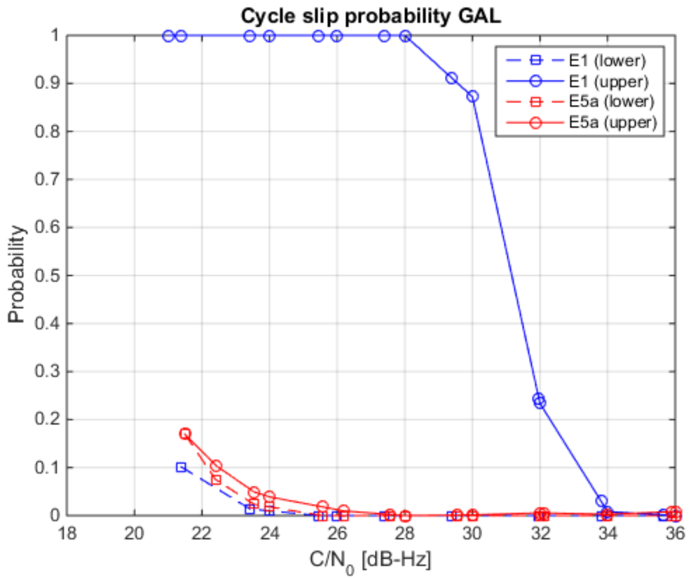
Huge difference based on implementation

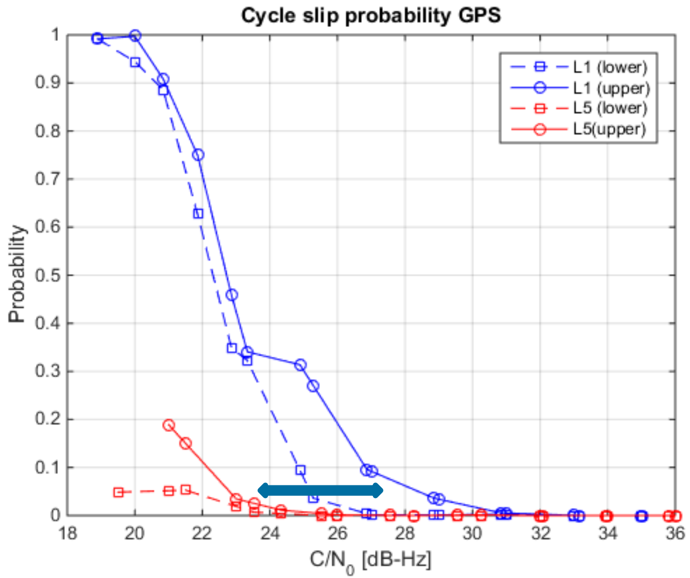
- **Upper bound**:
Sub-optimal implementation

- **Lower-bound**:
Pilot signal advantage (E1C & E5aQ)

Simulation test results

Cycle slip probability





Pilot signal advantage (aprox 3dB L1 and L5)

Open-sky environment (Nieuw-Vennep)

Test Details	
Date	26/02/2020
Duration	12:22:30 – 15:15:30 (10381 sec)
Environment	Open Sky
Antenna	Tallysman TW7972
PVT Elevation Mask	5 degrees
Code-based PVT	Receiver internal PVT engine
PPP	ESA in-house algorithm

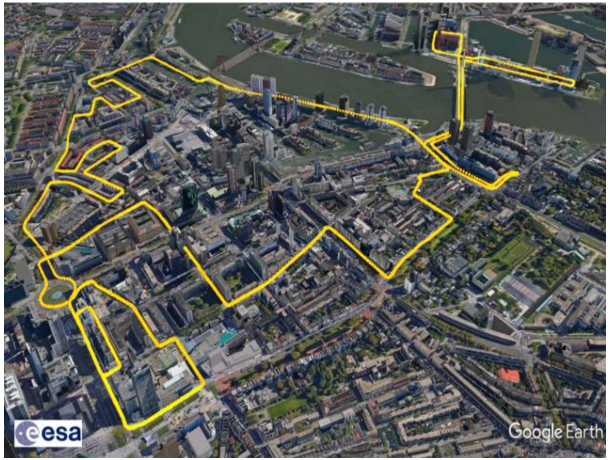
Open-sky results (High-accuracy assessment)

Figure of Merit	PVT	PPP GAL E1-E5a	PPP GPS L1-L5	PPP GPS+GAL L1/E1-L5/E5a
Horiz. Acc. 95% [m]	4.71	**0.90**	**1.00**	**0.73**
Vert. acc. 95% [m]	3.23	1.72	1.61	1.33
3D acc. 95% [m]	5.65	1.83	1.83	1.36
Availability [%]	100	100	100	100
Total #epochs	10381	10381	10381	10381

In smartphone platform antenna plays differential role in open-sky

Urban environment (Rotterdam down-town)

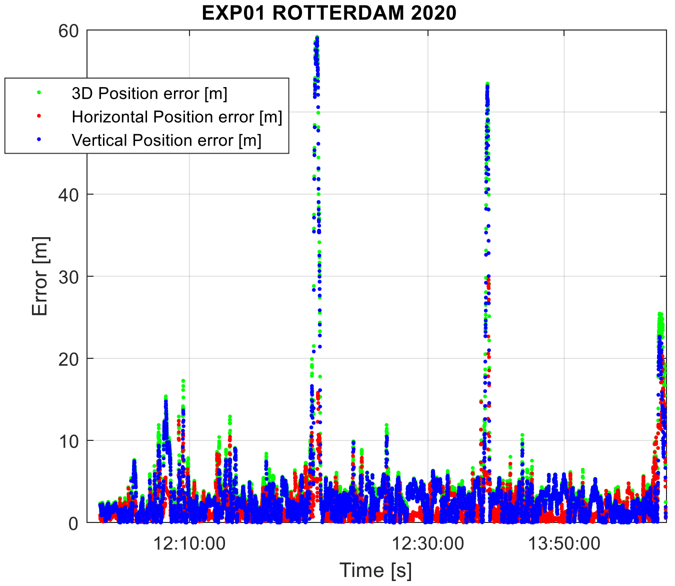
Test Details	
Date	10/03/2020
Duration	11:43:48 – 14:30:08 (9981 sec)
Environment	Open Sky (15 minutes) -> Urban (1:45 hr)
Antenna	Tallysman TW7972
PVT Elevation Mask	5 degrees
Code-based PVT	Receiver internal PVT engine
PPP	ESA in-house algorithm



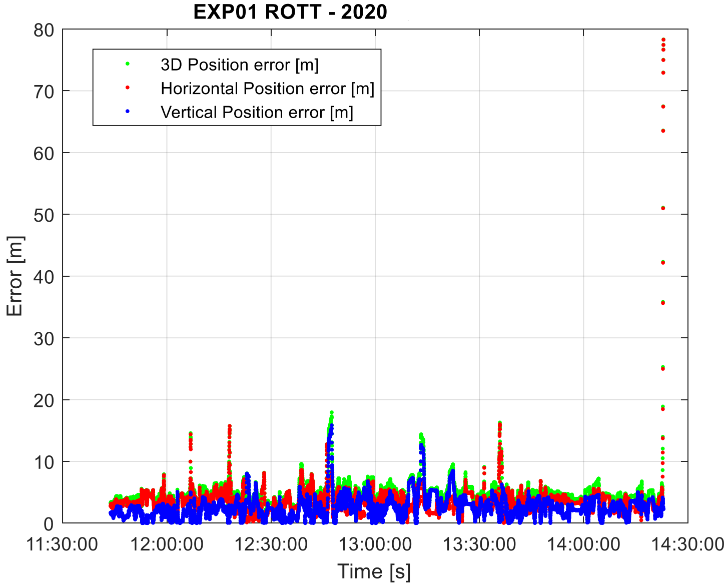
Urban results – Positioning accuracy

Time-series – real time Ev. Kit Fix

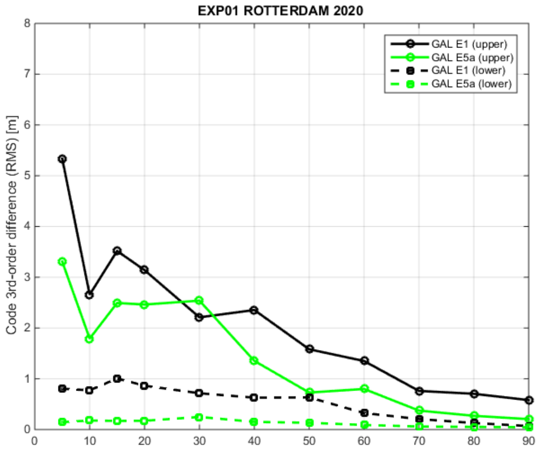
Rx1 (GPS+GAL)

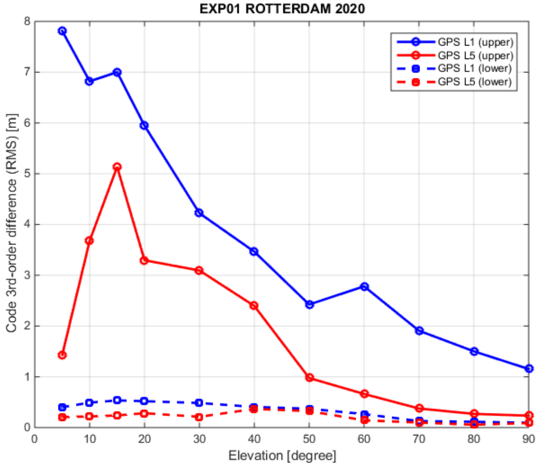


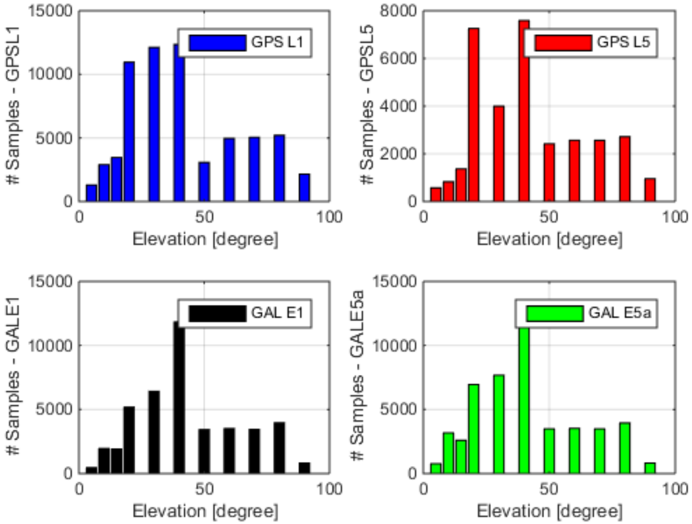
Rx2 (GPS+GAL+BEI+GLO)



Urban results - Code noise



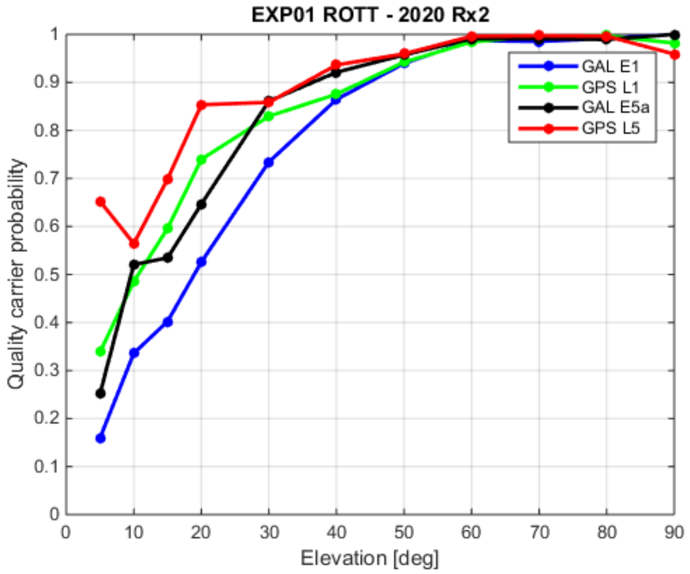


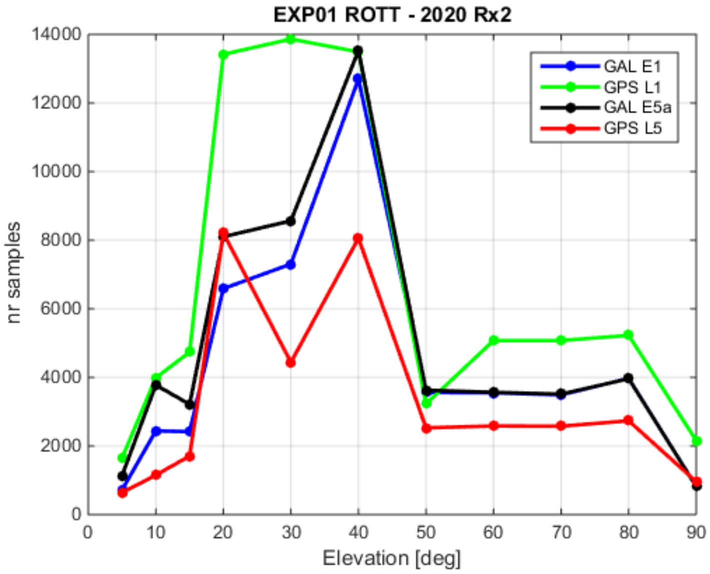


Urban results – position accuracy

Figure of Merit	PVT Rx1	PVT Rx2
Horiz. 95% [m]	5.66	5.68
Vert. 95% [m]	8.81	5.39
3D 95% [m]	10.18	7.29
Availability [%]	99.99	100

Urban results carrier-phase status (GNSS-logger)





Summary

Results on controlled scenarios confirm that:

- Raw measurements characteristics rely on the specific receiver implementation, this shall be taken into account as different weighting factors may be applied at PVT level depending on the manufacturer
- Pilot signals show more robust performance in terms of cycle slip probability at low C/No
- Wide-band signals L5/E5a enhance the noise performance as expected

Summary (II)

Results from live testing indicate:

- In open-sky conditions, the carrier-phase can be fully exploited for high-accuracy applications leading to sub-meter level accuracy
- In challenging environments (urban), the availability of valid carrier phase measurements decreases and this can be a challenge for carrier-phase based positioning techniques
- Additional results from urban test are being processed and they will be presented in future publications