# PPP WITH EXTERNAL ANTENNA ADDITION ON SMARTPHONES


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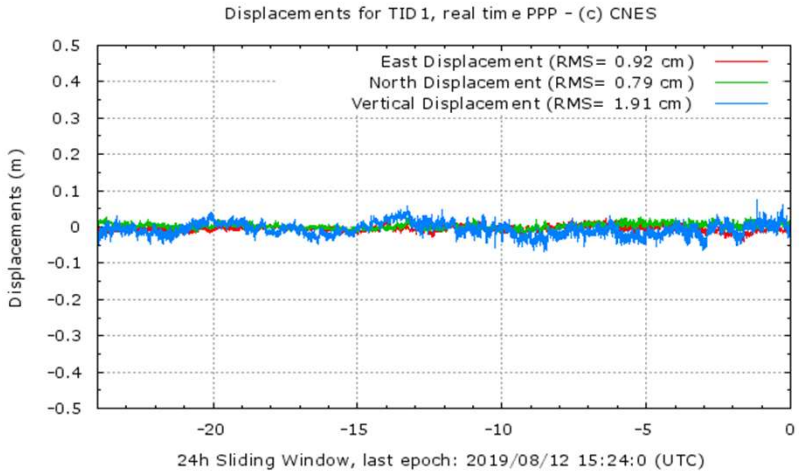
CENTRE NATIONAL D'ÉTUDES SPATIALES

# Introduction

- Precise Point Positioning (PPP) is a GNSS technique reaching centimeter-level accuracy globally in real-time
  - uses of ALL methods that can improve the convergence time and accuracy of the GNSS solutions
- PPP CNES website: [www.ppp-wizard.net](http://www.ppp-wizard.net)




- Android gives access to GNSS raw measurements using a smartphone
- Strong evolution of mobile technologies can be combined with the PPP powerful technique
- Port of CNES PPP algorithms on smartphones
  - PPP WizLite application
  - Android App available on Google Play

| | |
|---|---|
| Measurements | Code, Phase, Doppler |
| Constellations | GPS, Glonass , Galileo and Beidou |
| Frequency | Single, Dual, Triple |
| Ambiguity resolution | Dual or Triple (GPS) frequency<br>Bootstrap method<br>Cascading: Extra-widelane, widelane, N1 |
| Ionoshere source | SBAS via RTKLIB or Caster<br>VTEC via RTCM |
| Orbits/Clocks corrections | RTCM or SBAS via RTKLIB |
| RAIM | improved |
| Gap-bridging | YES |
| Doppler smoothing | YES |

*Implemented features in PPP Wizlite ( green)*


*PPP Wizlite interface*

# Motivation and organization

- Chipsets now supporting Galileo, Beidou and dual frequency
- Important degradation of the measurements
  - mainly due to the poor quality of the integrated GNSS antenna
  - real limitation for high accuracy level applications
  - What is the contribution of an external antenna for precise positioning on smartphones?

**SMARTPHONES**


*2 Xiaomi Mi8*
- ✓ *dual-frequency*
- ✓ *Broadcom BCM47755 chip*

*Huawei P20*
- ✓ *single-frequency*
- ✓ *Broadcom BCM47531 chip*

**ANTENNA**

*Novatel GNSS-850*
*all GNSS frequencies*

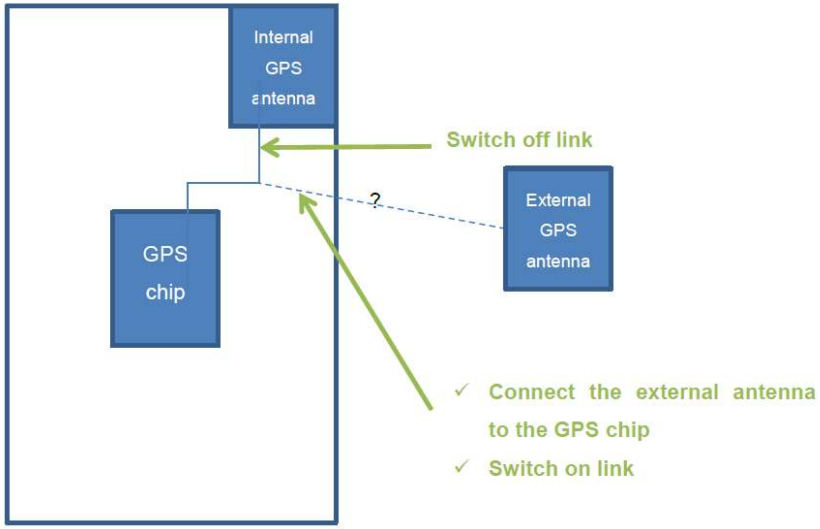
**ANDROID APP**

PPP WizLite

- ✓ *Code measurements only (phase not available in Android 8)*
- ✓ *Use of NMEA modified lines for PPP (proprietary line $PPPP)*
- ✓ *L5 Galileo frequency not available (flag status problems)*

# Hardware modification (1)

- Establish a method to add an external antenna:
  - reducing hardware modification of the smartphones and Android development
  - without impacting data reception (WIFI or 4G needed for the PPP Wizlite App)
  - reversible to switch from internal to external antenna depending on the requirement



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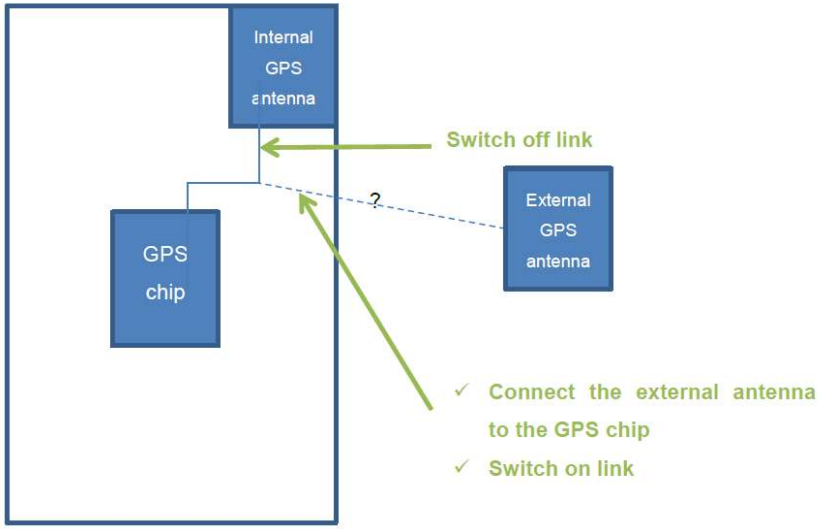


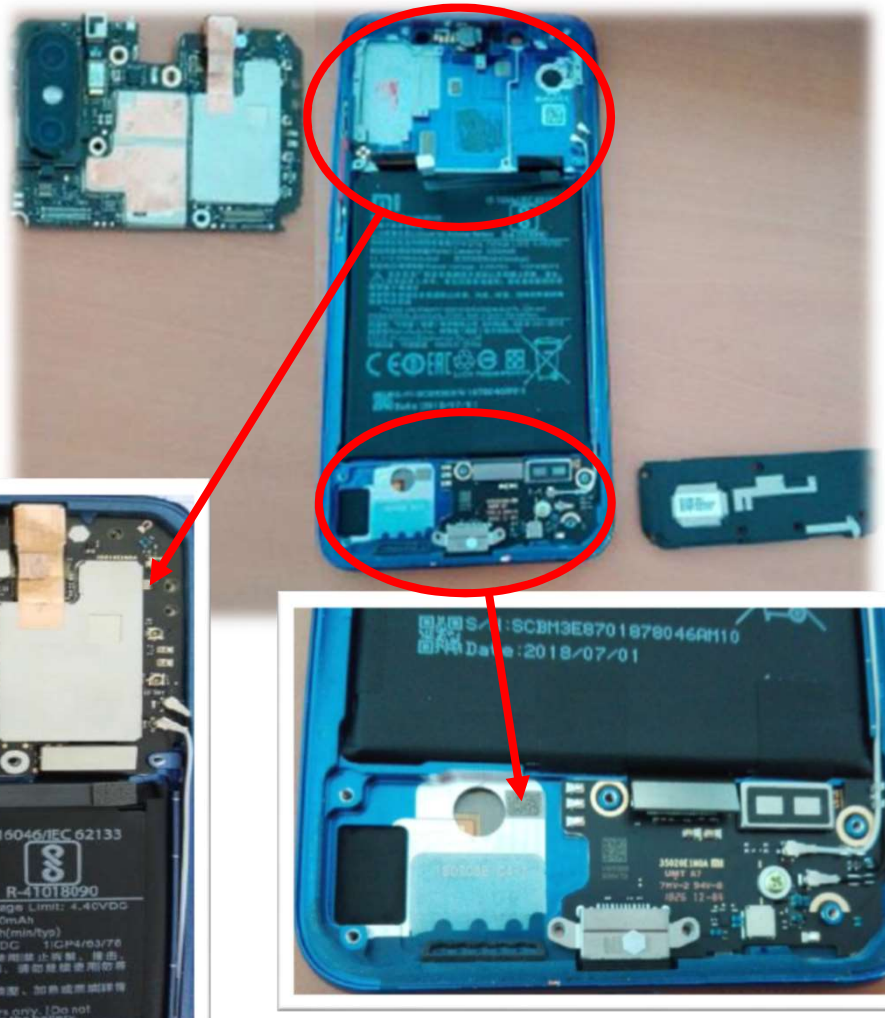

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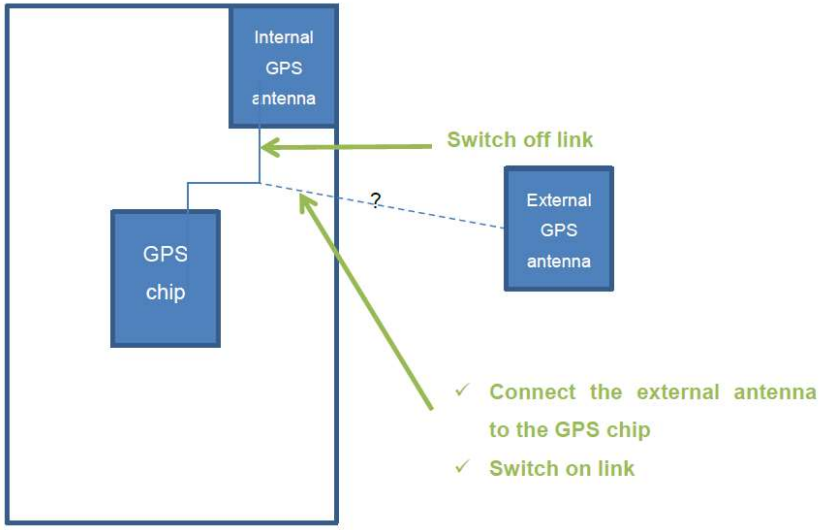
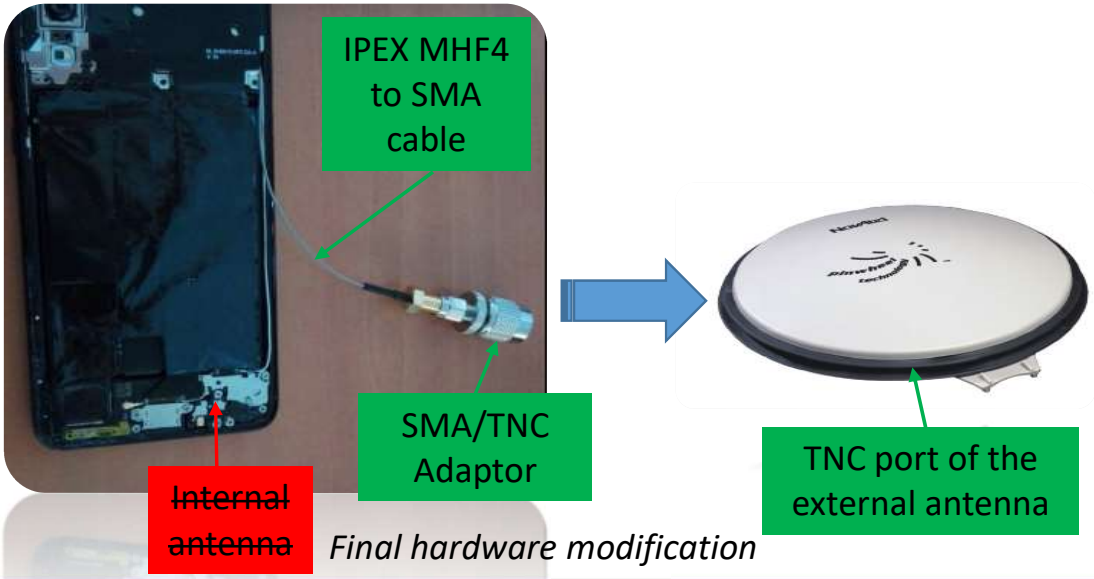




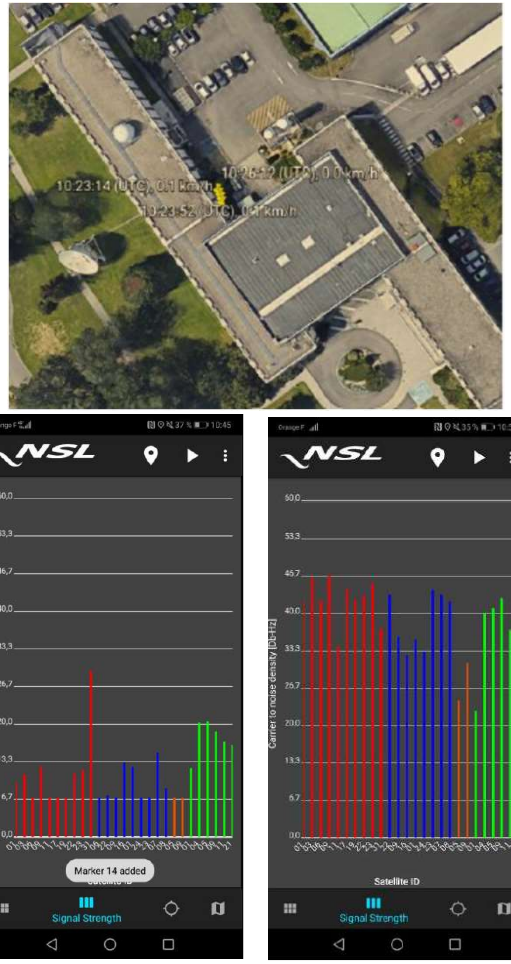
Black flex cable to be removed

# Hardware modification (2)

- IPEX MHF4 to SMA cable needed
- Same modifications have been made on both smartphones
- Validation of the material modification
  - signal-to-noise ratio analysis (SNR)
  - positioning tests with PPP Wizlite app
- Modified smartphones named *m-Xiaomi* and *m-Huawei* afterwards



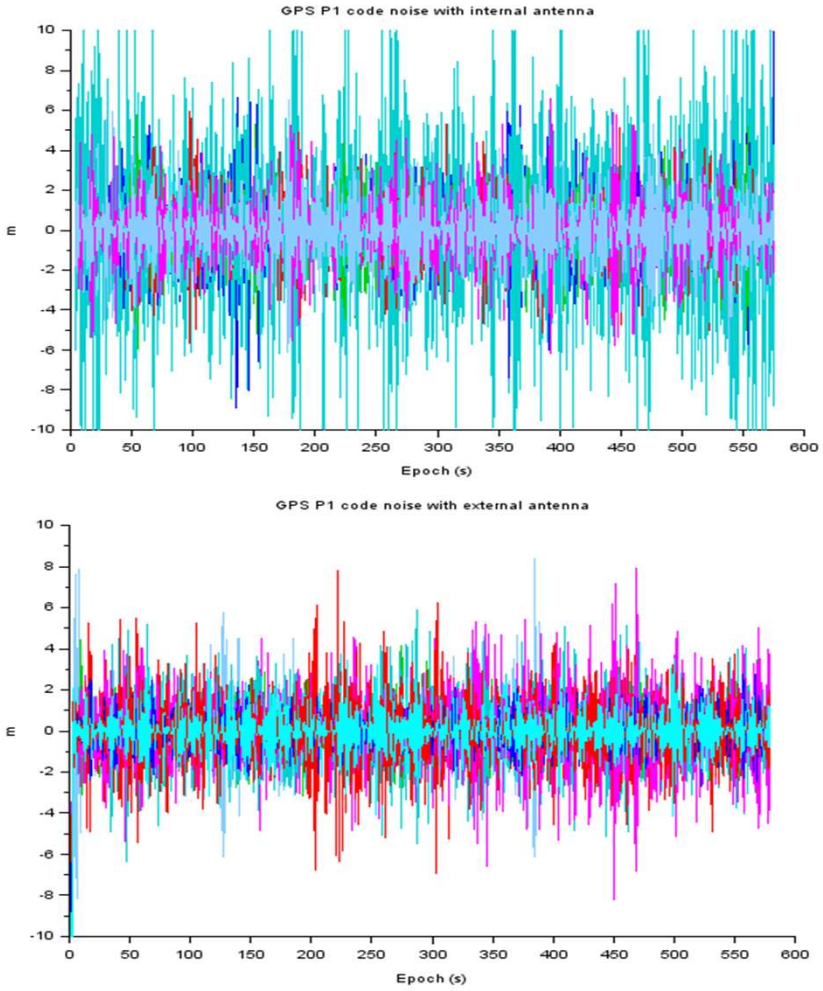

*Final hardware modification*




*RinexON app: GPS mode with the cable alone (left) and with external antenna (right)*

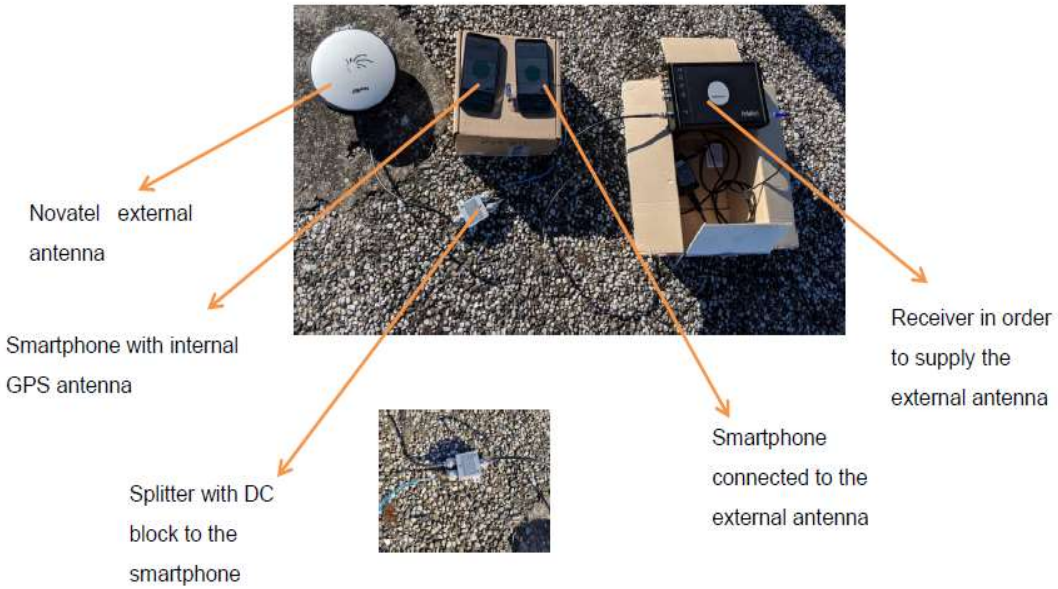
# Preliminary noise study

- Visible reduction of noise for GPS L1 code measurements
  - GAL E1 code to a lesser degree
- No improvement with L1 phase and the second frequency
- Noise of m-smartphones with geodesic antenna still 3 times higher than a good receiver can achieve
- Hypothesis
  - GNSS receiver tracking parameters adjusted for poor antennas only
  - hardware floor values reached

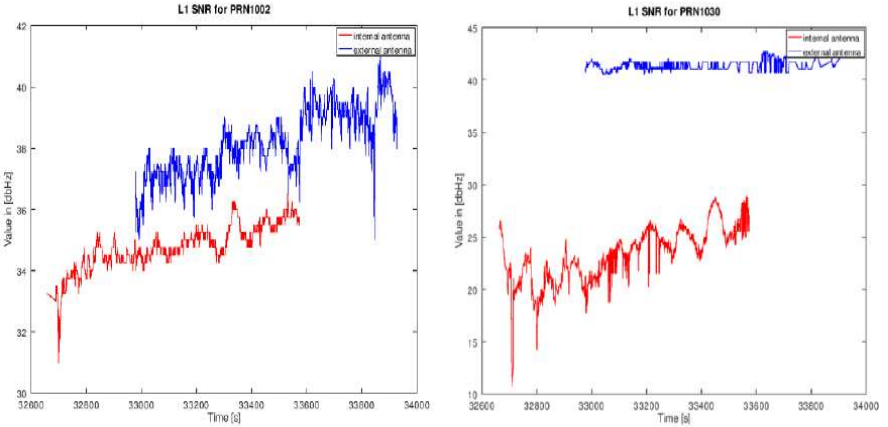


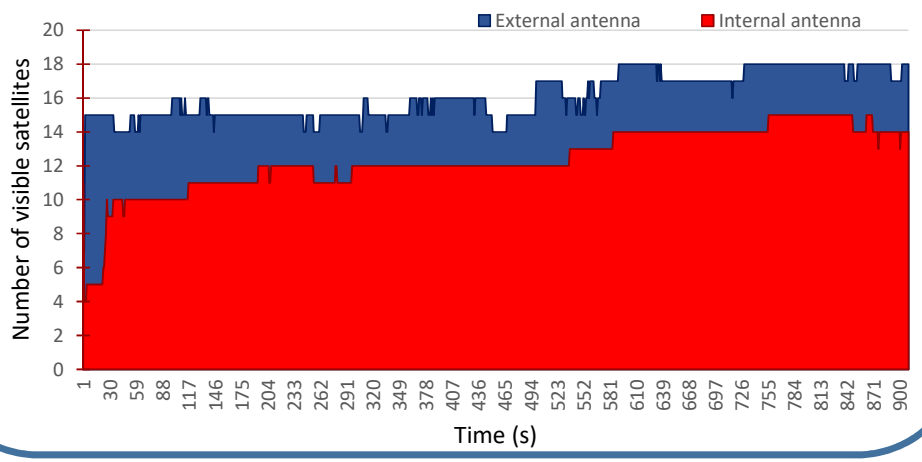
# Static open-sky tests (1)

- Static open-sky case on a geodesic point at CNES
- First signs of the gain of a good antenna
  - SNR
  - number of visible satellites
- Same trends for Xiaomi and Huawei smartphones



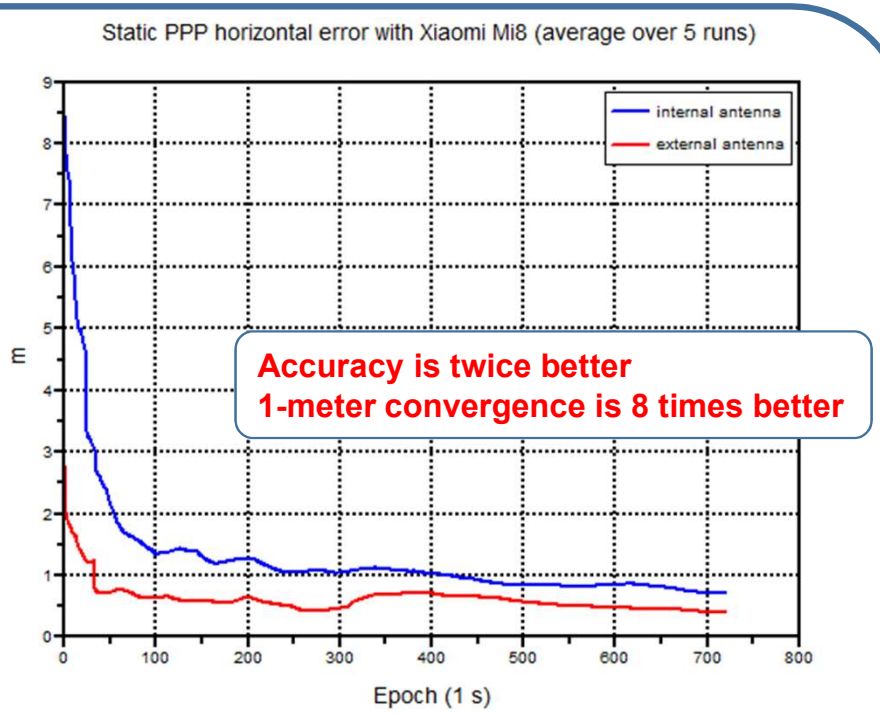

XIAOMI



# Static open-sky tests (2)

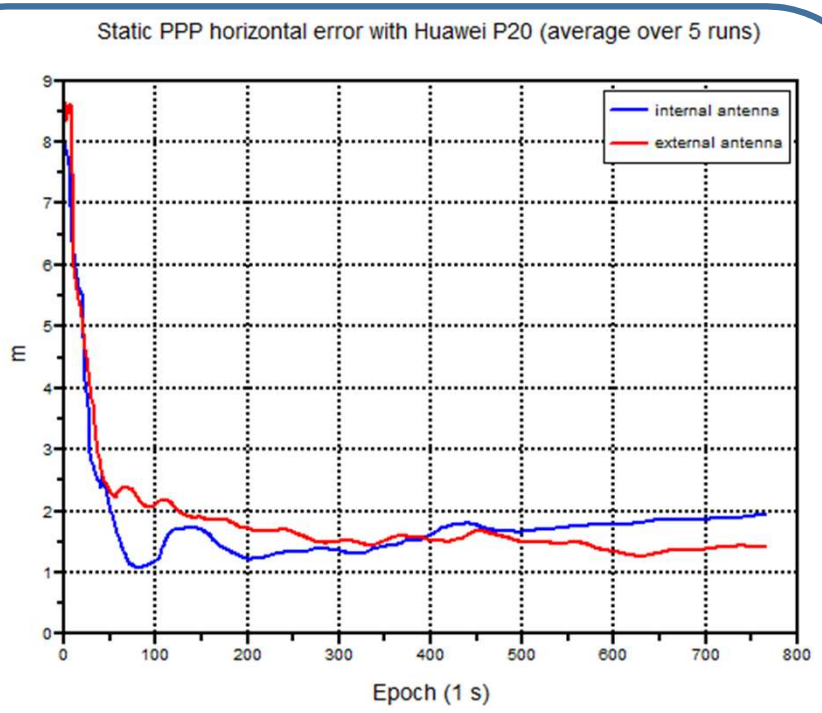
**XIAOMI**




**Accuracy is twice better**
**1-meter convergence is 8 times better**

- Meter accuracy with an internal antenna
- Obvious gain with an external antenna
  - fast convergence (2 meters instantaneously and below 1 meter in 30 seconds)
  - sub-meter accuracy (50 cm)

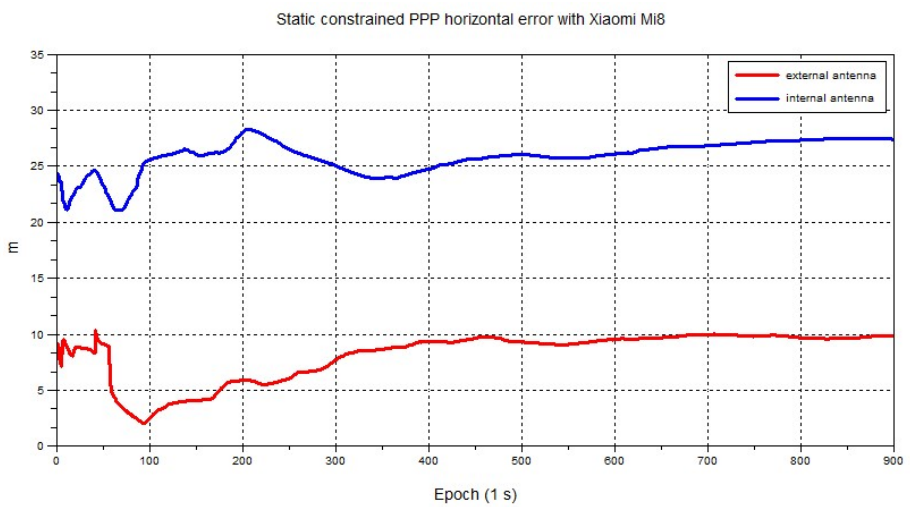
**HUAWEI**



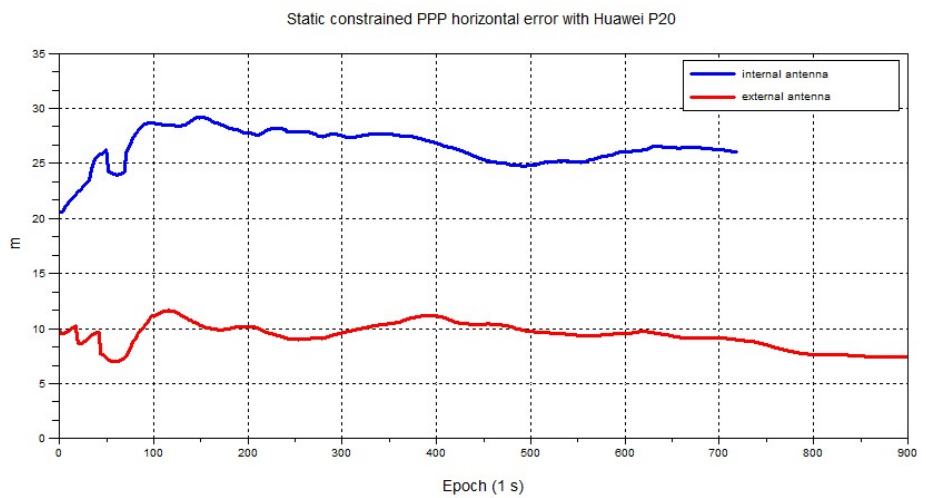

- No real gain with an external antenna
  - no fast convergence
  - meter accuracy (1.5 meters)

# Static constrained tests surrounding by buildings

XIAOMI




HUAWEI



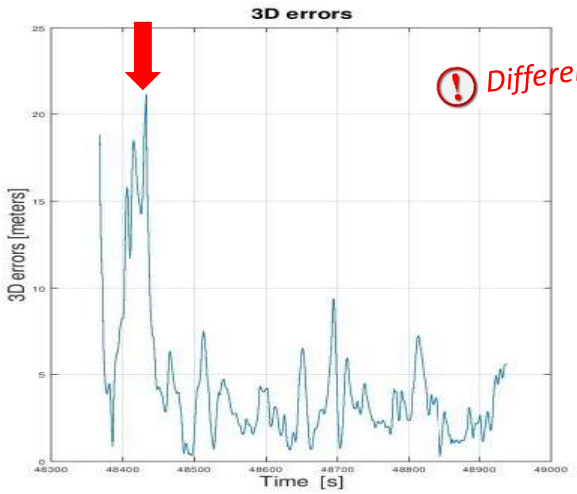

- Limited convergence for all smartphones
- The external antenna provides higher accuracy (more than twice better)
  - thanks to better SNR, a better number of visible satellites and mitigation of outliers (multipath)
- The main interest of m-smartphones occur in constrained and difficult environnement

# Dynamic tests (1)

- Reference trajectory provided by a Novatel SPAN IMU (Inertial Measurements Units)
- Simultaneous measurements with external antenna
  - m-smartphones, PolarX5 receiver and SPAN

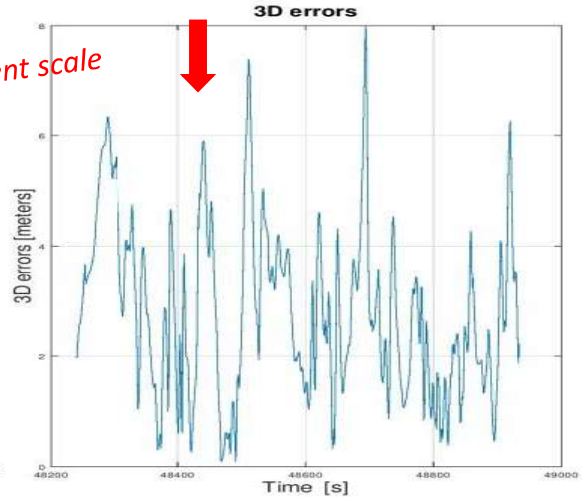
*Car testbed*

- ✓ Exemple of a passage under a long bridge
- ✓ Robustness of the navigation solution thanks to external antenna addition
- ✓ More than 3 times lower spike for 3D errors

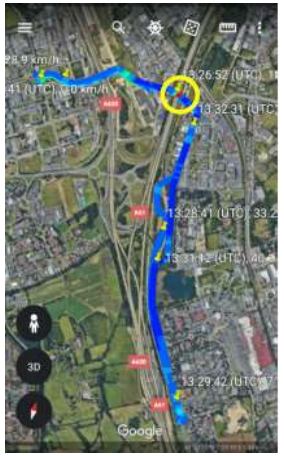



*Xiaomi*

Different scale

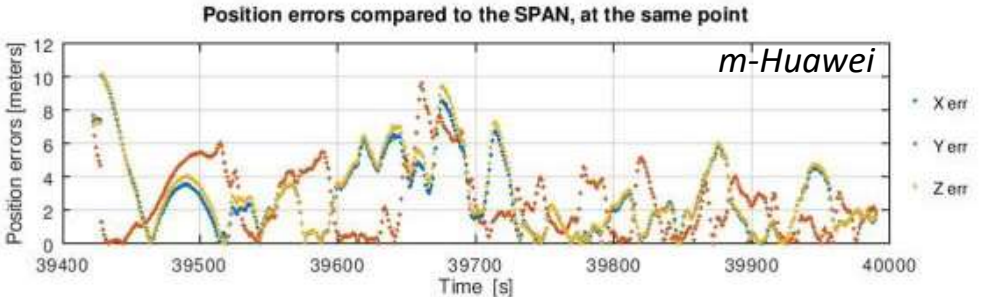


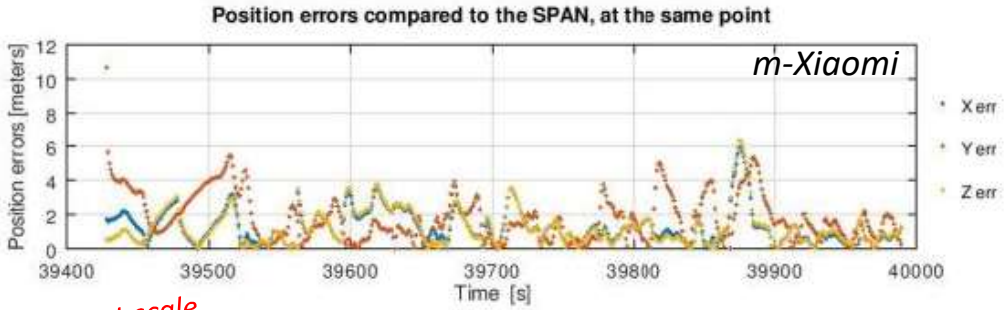

*m-Xiaomi*



*Fast speed case*

# Dynamic tests (2)

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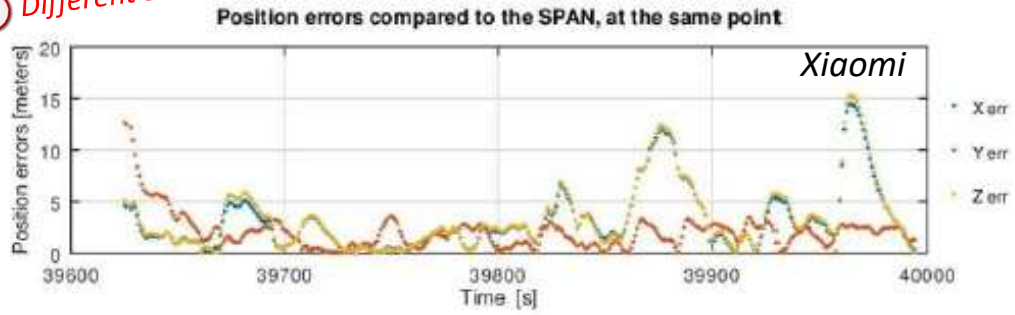


| X<br>Y<br>Z | Huawei<br>Novatel | Xiaomi<br>Novatel | Xiaomi<br>internal |
|---|---|---|---|
| RMSE | 2,18 | 0,85 | 3,08 |
| | 2,04 | 1,61 | 1,71 |
| | 2,3 | 0,84 | 3,22 |
| RMSE after conv, | 1,99 | 0,31 | 3,44 |
| ( without the 1st 100 data) | 1,99 | 1 | 0,93 |
| | 2,17 | 0,3 | 3,58 |
| Median | 2,1 | 1,08 | 2,19 |
| | 1,94 | 2,97 | 1,9 |
| | 2,3 | 0,76 | 2,37 |
| Median after conv, | 2,02 | 0,33 | 2,33 |
| | 1,83 | 0,84 | 1,74 |
| | 2,14 | 0,31 | 2,42 |
| 95% | 7,29 | 2,74 | 11,15 |
| | 6,45 | 4,83 | 5,39 |
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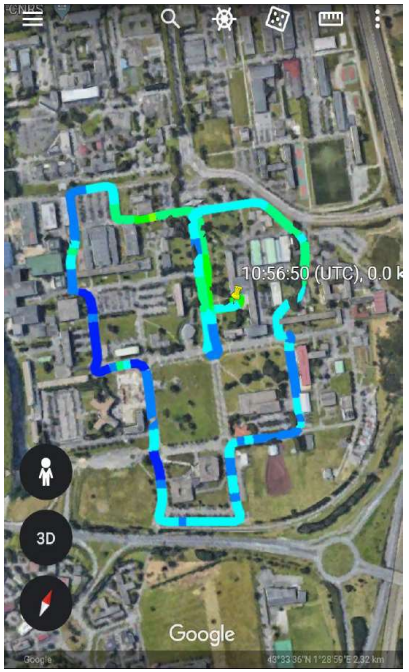
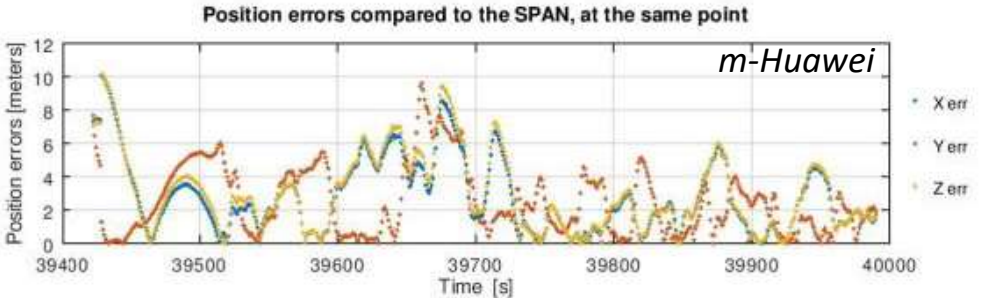
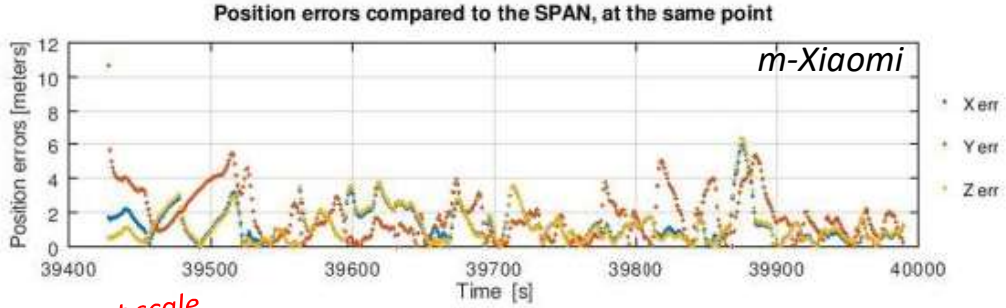



*Low speed case @CNES*

# Dynamic tests (2)

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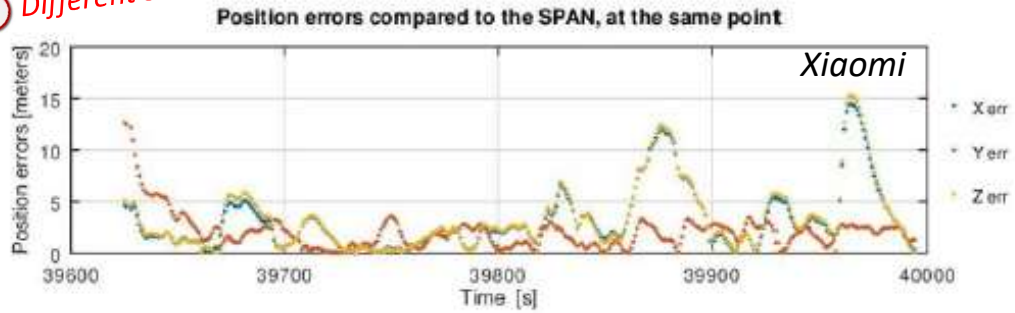


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Simultaneous 3D RMS results:

- **2,0 m for m-Xiaomi**
- 3,5 m for m-Huawei
- 5,0 m for Xiaomi

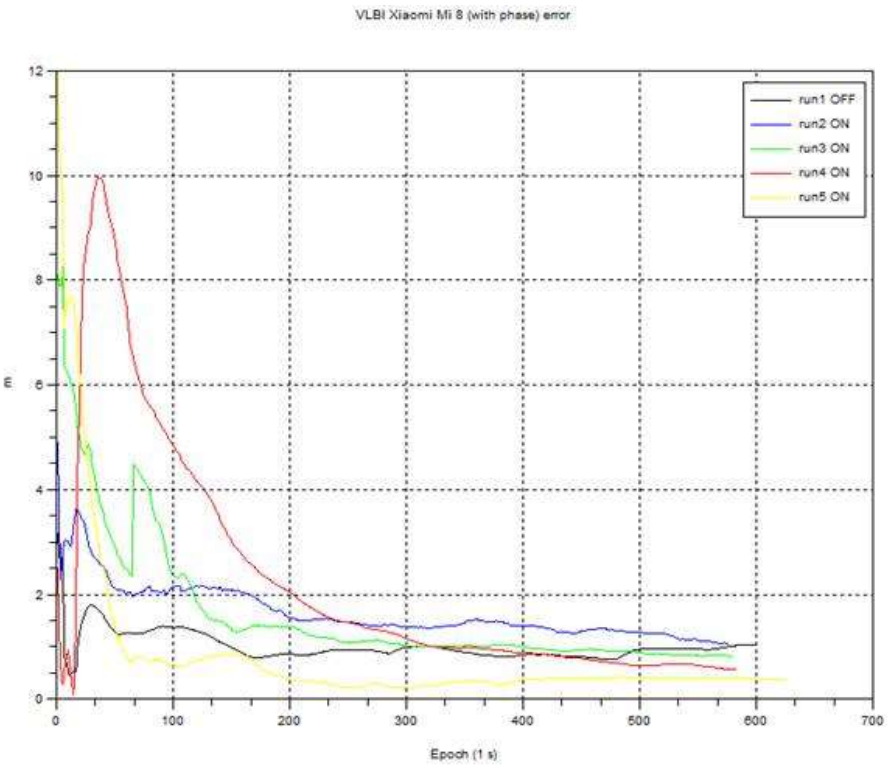
Simultaneous 3D 95% RMS results:

- **3,1 m for m-Xiaomi**
- 11,5 m for m-Huawei
- 17,0 m for Xiaomi

interest of combining good antennas with smartphones in dynamic case

# Phase with smartphones (overview)

- Campaign tests were performed with smartphones under Android 8 (Oreo)
- Phase measurements available in Android 9 (Pie) with a developer option to disable duty cycle
  - Patch of the PPP Wizlite app for phase acquisition
  - Static open-sky tests
- No accuracy improvement observed with smartphones and m-smartphones
  - PPP-Wizlite parameters to adjust ?




*Static PPP horizontal error with a Xiaomi Mi8 (phase available)*

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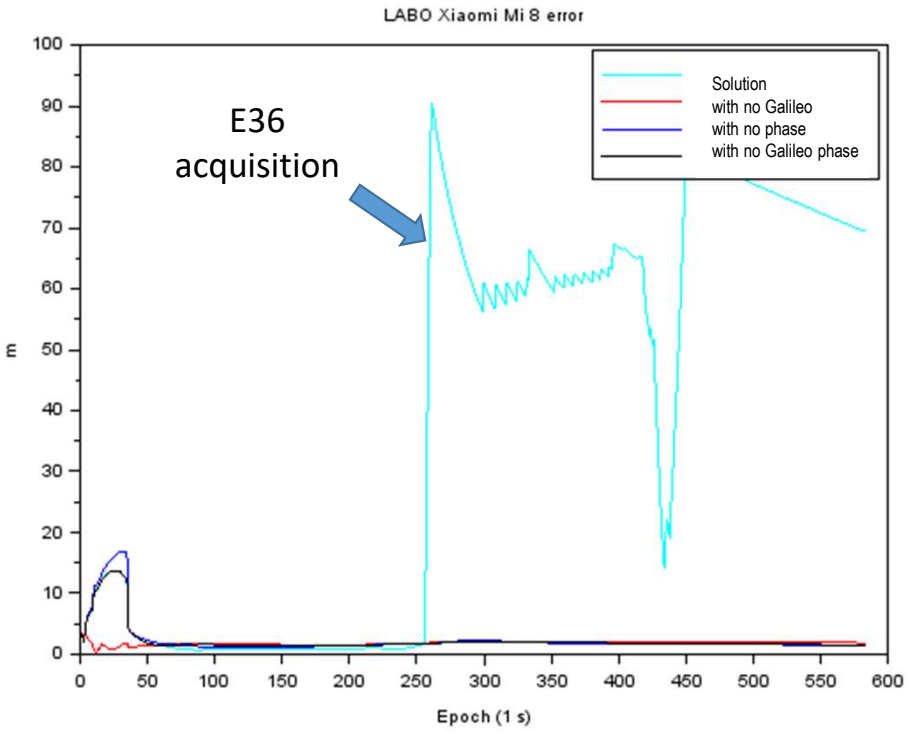
- chip issue or PPP Wizlite navigation algorithm error
  - ongoing analysis




*Static PPP horizontal error with a modified Xiaomi Mi8 (phase available)*

# Conclusion

- Successful hardware modification to plug an external antenna on smartphones
  - No loss of integrity and data reception
  - Reversible
  - No android development
- Tests campaign offers encouraging preliminary results
  - Level of performance limited compared to the capacity and cost of the powerful external antenna
- Useful for applications which need better accuracy and more robust solution with smartphones in static/dynamic and constrained environments
- Ongoing studies at CNES focused on instantaneous centimeter-level triple-frequency PPP (SNAPSHOT PPP)
  - Pioneering research in view of a forthcoming triple frequency chip on smartphones?

# Abstract reminder

Abstract: “PPP with external antenna addition on smartphones”

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C. Granger ALTRAN

Precise Point Positioning (PPP) is a recent technique for positioning using the Global Navigation Satellite System (GNSS) reaching centimeter-level accuracy globally in real-time. PPP provides the user absolute position without additional equipment, while other methods like Real Time Kinematics (RTK) need an expensive reference station in order to give the user his relative position to the reference.

This study is in line with the strong evolution of mobile technologies combined with the PPP powerful technique. In fact, Android has released the version 7 (and higher versions) of its operating system with new features giving access to GNSS raw measurements using a smartphone. In the past one could only determine the PVT solution (position, velocity and precise time) coming out of the chipset. This has worked CNES PPP algorithms (CNES PPP-Wizard user) to migrate on smartphones or tablets via the PPP-WizLite Android application. With classic GPS positioning users can have an approximate position around 10 meters. PPP-WizLite accessing raw measurements achieves meter level accuracy in static mode, after one minute of convergence and meter level accuracy in dynamic mode.

However, despite encouraging prospects with raw measurements access, chipsets now supporting Galileo and bi-frequency, we note an important degradation on the pseudoranges mainly due to the poor quality of the integrated GNSS antenna. The use of such antennas in mobile devices seems to be a real limitation for high accuracy level applications.

We first detail the hardware modification of different and recent smartphones in order to plug an external high quality geodetic antenna. Radio-frequency signals no longer come from the integrated GNSS antenna but from this new external one. Then, we present results of a test campaign in different environments and modes (static and dynamic). We compare the positioning performance and analyse pseudoranges noises between external geodetic antenna and internal patch antenna on smartphones. Finally, we study the contribution of multi-constellation in term of positioning accuracy.

Keywords: GNSS, PPP, smartphone, external antenna, chipset

INNOVATION:
In a context of strong evolution of mobile technologies combined with the PPP powerful technique this presentation enables to characterize the contribution of adding an external geodetic antenna on smartphones for high accuracy level application purpose.