Quanta Series

GNSS aided Inertial Navigation System

Performance assessment

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2	October 24th 2022	CM and MP	Simplified tables
1	October 10th 2022	CM and MP	Initial published version

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1. Introduction

1.1. Purpose of this document

This test reports aims to summarize the actual performance of a Quanta Micro INS used in "real world environment."

The Quanta micro is a MEMS based INS embedding a full featured RTK GNSS receiver and designed for balance of performance and an Incredible SWaP-C: a size of 50 x 37 x 23 mm^3 and a weight of 38 g ; making it the perfect product to use in space constrained applications such as UAV surveying, Unmanned vehicles, indoor mapping…

The data used for this report originates from a test performed in July 2022 to validate the performance of the Quanta Micro product before its commercial release. During this test, the new Quanta Micro INS has been evaluated in various GNSS environments, from open sky to deep urban canyon and proven to provide excellent quality data.

1.2. Prerequisite

Reading this test reports requires some level of knowledge of the inertial navigation and post-processing concepts. Our knowledge base (https://support.sbg-systems.com/sc/kb/latest) will help you start your journey into the wonderful world of inertial navigation.

1.3. Acronyms

CORS: Continuously Operating Reference Stations
DUT: Device under test
EUT: Equipment under test
FOG: Fiber Optic Gyroscope
GNSS: Global Navigation Satellite Systems (GPS + GLONASS + BEIDOU + GALLILEO)
IGN: Institut Géographique National (official French geographic agency)
IMU: Inertial Measurement Unit
INS: Inertial Navigation System
LiDAR: Light Detection And Ranging
MEMS: Micro Electro-Mechanical System
Merged: Forward + Backward post-processing using Qinertia
PPK: Post-processed Kinematic
RGP: Réseau GNSS Permanent (French national CORS network)
RMS: Root Mean Square
RTK: Real-Time Kinematic
Std: Standard deviation
SWaP-C: Size Weight and Power – Cost
TC: Tight Coupling
UAV: Unmanned Aerial Vehicle

2. Test mission objectives and specifications

2.1. Mission planning and execution

The test has been conducted onboard SBG Systems test vehicle on July 7th, 2022. It was a 115 minutes long drive, under good weather conditions, in the neighborhood of SBG System facility including:

- 45 minutes of contiguous operations under open sky conditions.
- 35 minutes of contiguous operations under semi-dense urban environment.
- 35 minutes of contiguous operations under harsh urban environment, including tunnels.

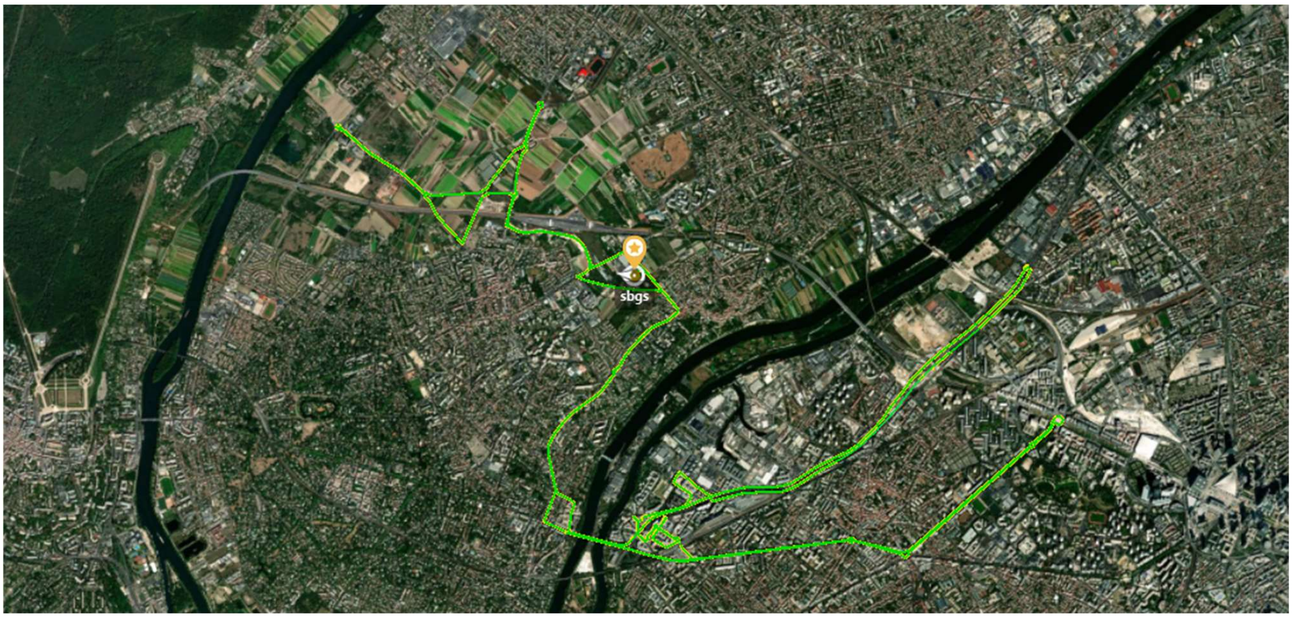

Figure 1: Actual mission driving path

Considering the complexity of the environment, no particular care has been given to mission planning to select a favorable time of day with respect to satellites visibility.

2.2. Mission objectives

This mission was specifically designed to demonstrate how the Quanta Micro INS behaves in a real-world scenario. This allowed us to validate that the Quanta Micro meets (and exceeds) its specifications, but also to demonstrate its outstanding performance even under the most difficult GNSS conditions.

During the mission we collected data measuring real-time performance of the Quanta Micro; we then performed post-processing of the same datasets (PPK). This allows us to provide a full view of the performance of the Quanta Micro INS in an automotive environment; and to a lesser extent other applications (which will be the subject of specific tests). The advantage of using optimized motion profiles is demonstrated by comparing processing in automotive and airplane motion profiles.

2.3. Test setup

2.3.1. Equipment Under Test

The EUT were two units of SBG Systems Quanta Micro INS (which is based on our PULSE-40 IMU):

Short name		Description	HW Rev.	Serial Number	Firmware version
EUT #1		Quanta Micro Standard perf. (PULSE-40 based) General Purpose.	1.1	000041817	4.1.5929-Dev
EUT #2		Quanta Micro Standard perf. (PULSE-40 based) General Purpose.	1.1	000041818	4.1.5929-Dev

For all tests installation parameters (misalignments, lever arm, etc.) were known *a priori* either from CAD drawings or from previous calibrations.

2.3.2. Reference trajectory

The reference source used to assess the Quanta Micro errors is a Qinertia processed tightly coupled trajectory with data coming from the SBG Systems Horizon IMU (FOG based ultimate performance), Navsight-S and Pegasem odometer installed onboard the vehicle along with the EUT. Qinertia version used for post-processing was 3.2.881-stable

Short name		Description	Position accuracy	Attitude accuracy	Heading accuracy
Navsight Horizon		FOG based INS PPK (TC Merged)	0.01m (0.01m @ 10s) (0.05m @ 60s)	0.004° (0.004° @ 10s) (0.005° @ 60s)	0.008° (0.008° @ 10s) (0.010° @ 60s)

The two VSP6037L GNSS antennas feeding the Navsight-S are shared with the EUT (see test setup diagram)

From the *a posteriori* data analysis, the quality indicators (position and attitude standard deviation estimators) of the post-processed Horizon trajectory fully allow the latter to be used as a reference with respect to the EUT.

Each of the three INS positions installed onboard has been transferred to a common point to allow for direct comparisons.

2.3.3. Base station

All PPK and RTK operations were performed using a single base, the SBGS station which is installed on the roof of SBG Systems facilities and included into the IGN RGP, the French CORS network.

SBGS provides full GNSS constellations tracking (GPS + GLONASS + GALILEO + BEIDOU). All four constellations were used for real-time RTK operations.

2.3.4. Test vehicle

The test vehicle was SBG Systems dedicated van, fitted with our standard equipment as presented on the following setup diagram.

The baseline between both GNSS antennas is about 2 m and most installation parameters are known with very good precision.

Figure 2: SBG Systems test vehicle

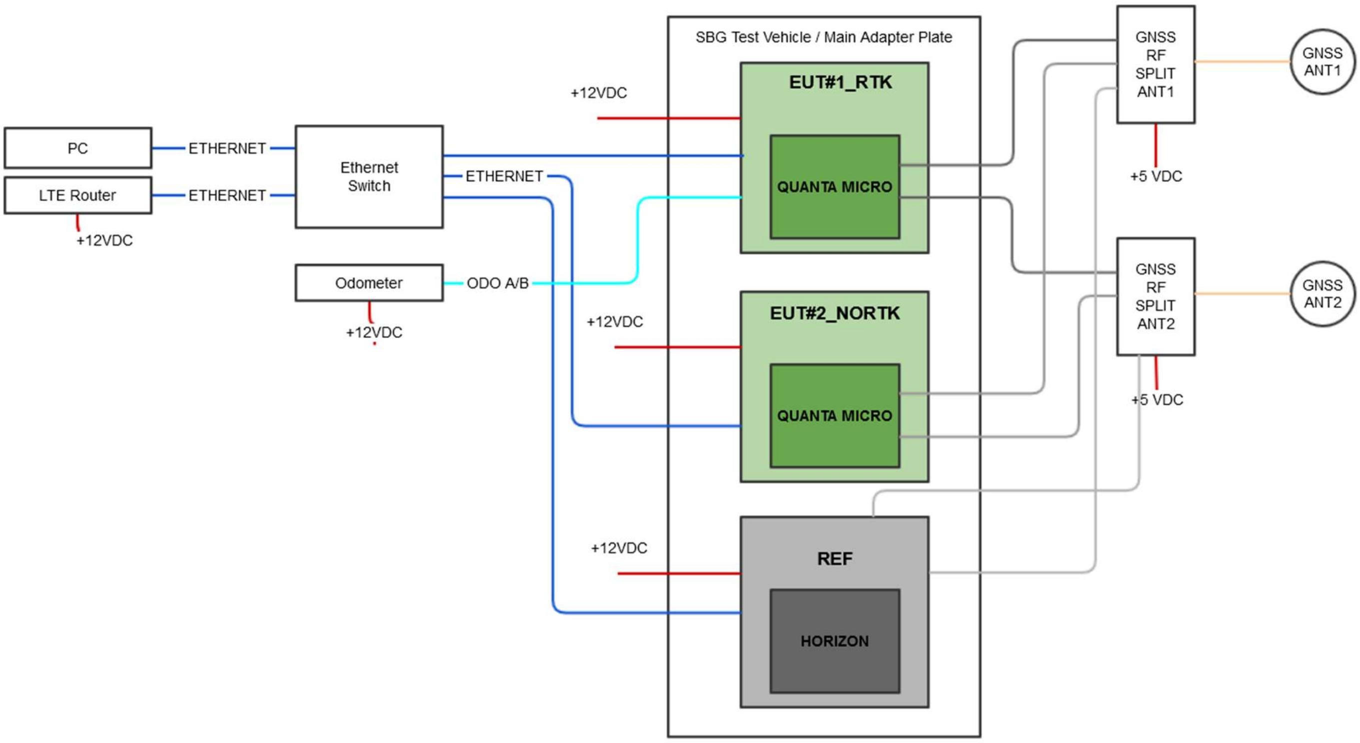

Figure 3: Test setup

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2.3.5. EUT configuration

The Equipment under test (EUT) were configured as follows for real-time measurements:

- EUT1: GNSS with all 4 constellations, RTK and odometer aiding.
- EUT2: GNSS with all 4 constellations, no RTK, no odometer aiding.

3. Test result analysis

> ***For all tests, the statistics have been computed with purposeful inclusion of the warm-up phase. This choice has in most cases a negative impact on most figures especially for the heading errors which decreases very fast in the first 5-10 minutes of the mission and were high values have a significant impact on std and RMS.***
>
> ***In addition, the no RTK, RTK and PPK dual antennas statistics which are the most representative of automotive profiles have been computed with purposeful inclusion of all three mission parts (open-sky, medium and harsh GNSS environments). This choice also has a negative impact on most figures.***
>
> ***These two choices mean that the values can be considered pessimistic. However, they demonstrate that Quanta Micro is still usable with very good performance straight out of the alignment phase (even if no warm-up is possible) and prove the robustness of the Quanta Micro algorithms which are able to almost meet the product performance specifications even in a test environment much harder than specified.***

3.1. Real-time scenarios

Quanta Micro is able to function in real time, providing a high frequency low latency navigation solution with or without RTK corrections. The following tables and figures are given for both EUT and provides detailed information about the real-time results for the following conditions:

- automotive motion profile
- odometer aiding for EUT #1 (RTK), no odometer aiding for EUT #2 (No RTK)
- with dual antenna GNSS heading input

	EUT #1 (RTK + odo)		EUT #2 (no RTK, no odo)	
Error	**68%**	**95%**	**68%**	**95%**
2D position	0.021 m	0.246 m	1.155 m	2.734 m
Vertical position	0.023 m	0.157 m	1.865 m	7.329 m
Roll/Pitch	0.011°	0.026°	0.015°	0.035°
Yaw	0.060°	0.140°	0.078°	0.190°

Table 1 : EUT #1 & EUT#2 errors

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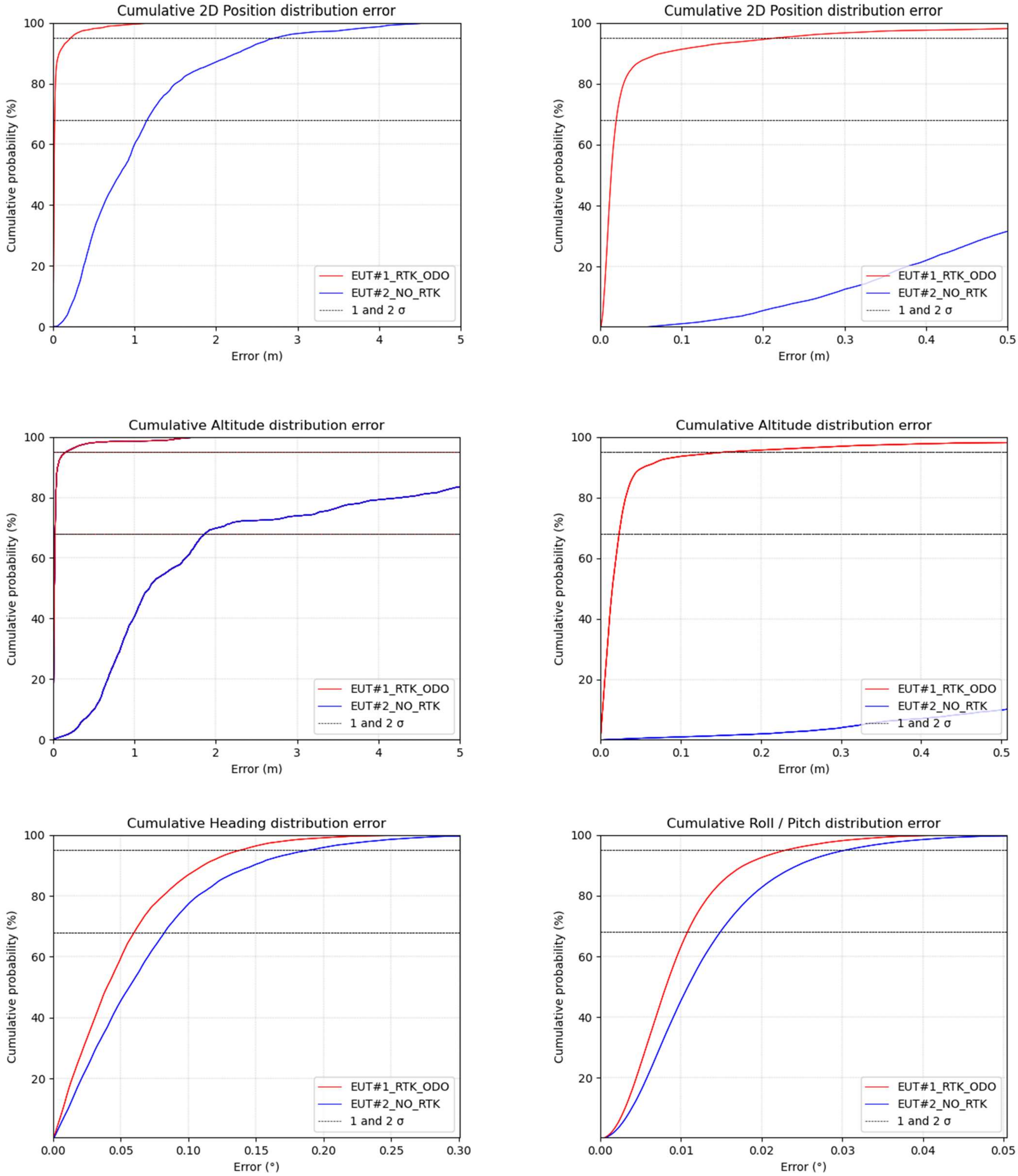

Figure 4 : Graphs of RTK and no RTK errors distribution (position, altitude with full and reduced horizontal scales, heading, roll/pitch) across all environments (open sky, medium urban and harsh urban)

Despite of the challenging conditions, the real time attitude and heading performance enables precise navigation, with better than 0.08° heading accuracy without RTK and better than 0.06° with RTK. Roll and pitch angles are also highly accurate (< 0.015° with or without RTK).

On the position side, the INS is able to cope with short GNSS outages, impacting very positively the 68th and 95th percentiles, compared to traditional GNSS technology.

However, the typical position performance specification cannot be met in such challenging environments. When we restrict the analysis to open-sky and mid urban GNSS environments, they are easily met.

3.2. Post-processed scenarios

These scenarios aim to assess the product ultimate performance that can be reached with Qinertia post-processing software in TC merged (forward + backward) computation mode, and compare the influence of motion profile. Only one EUT (EUT #2) is displayed, but results were very similar for both units.

	TC Automotive motion profile odometer dual ant.		TC Airplane motion profile single ant.	
Error	68%	95%	68%	95%
2D position	0.014 m	0.093 m	0.014 m	0.100 m
Vertical position	0.008 m	0.032 m	0.008 m	0.034 m
Roll/Pitch	0.011°	0.032°	0.011°	0.032°
Yaw	0.051°	0.211°	0.041°	0.208°

Table 2: Post-processed dual antenna errors in two different motion profiles

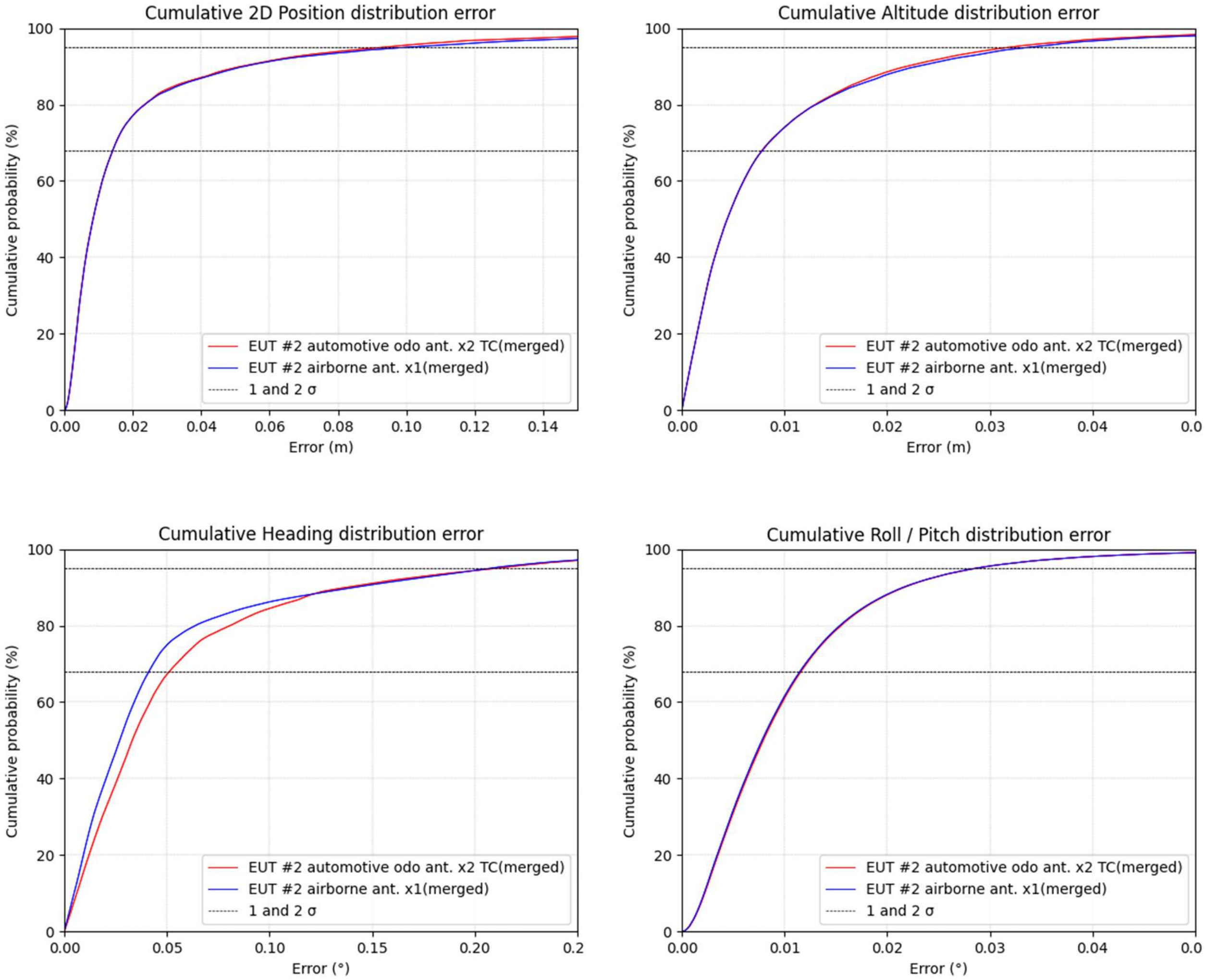

Figure 5 : errors distribution of PPK tightly coupled with odometry aiding (position, altitude , heading, roll/pitch) across all environments (open sky, medium urban and harsh urban)

As it can be seen from the previous table and plots, the influence of motion profile is somehow marginal when it comes to post-processing performance.
Even though the GNSS environment was very difficult, the product behaves very well and produces very accurate results. As for real time, restricting the mission to open sky and medium urban environment leads to results better than product specifications.

4. Conclusion

The test and data analysis that followed demonstrates the Quanta Micro capabilities, robustness and accuracy in single and dual antenna modes ; including in medium to harsh environments.

For applications without real-time requirements (LiDAR surveying, photogrammetry, ...), post-processing with SBG Systems Qinertia software provides an outstanding performance improvement, enabling centimeter level positions even in harsh GNSS environments. In addition, the excellent attitude performance enables the implementation of accurate direct georeferencing or SLAM based techniques for LiDAR and photogrammetry payloads.

This study confirms the adequation of Quanta micro for all applications with both major size & weight constraints, and survey grade performance requirements. Quanta Micro meets both requirements, with an incredible SWaP-C (50 x 37 x 23 mm, 38 g), while featuring an outstanding performance level in challenging conditions. Quanta Micro is the perfect choice to integrate for UAV surveying, indoor or vehicle based mobile mapping systems, but is also a perfect choice for real-time applications that demand a more robust and precise measurement than achievable with our ELLIPSE Series or competing products.

For surveying applications with relaxed SWaP-C constraints and that require extreme level of precision in a wider range of conditions, SBG Systems Quanta Extra, EKINOX, APOGEE or NAVSIGHT products, which are also fully compatible with Qinertia post-processing, are higher performance alternatives to be considered.