Performance Assessment of GNSS Timing Using Advanced Grades of PVT Engines

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The goal of this study

Reveal and discuss the GNSS 1PPS stability of various grades of PVT engines:

- Meter level
- Submeter level
- Centimeter level

The meter and submeter engines were originally developed for automotive navigation use, while the centimeter engine was developed specifically for this study.
All of them are implemented in our low-cost chipset and run in real time, even when in motion.

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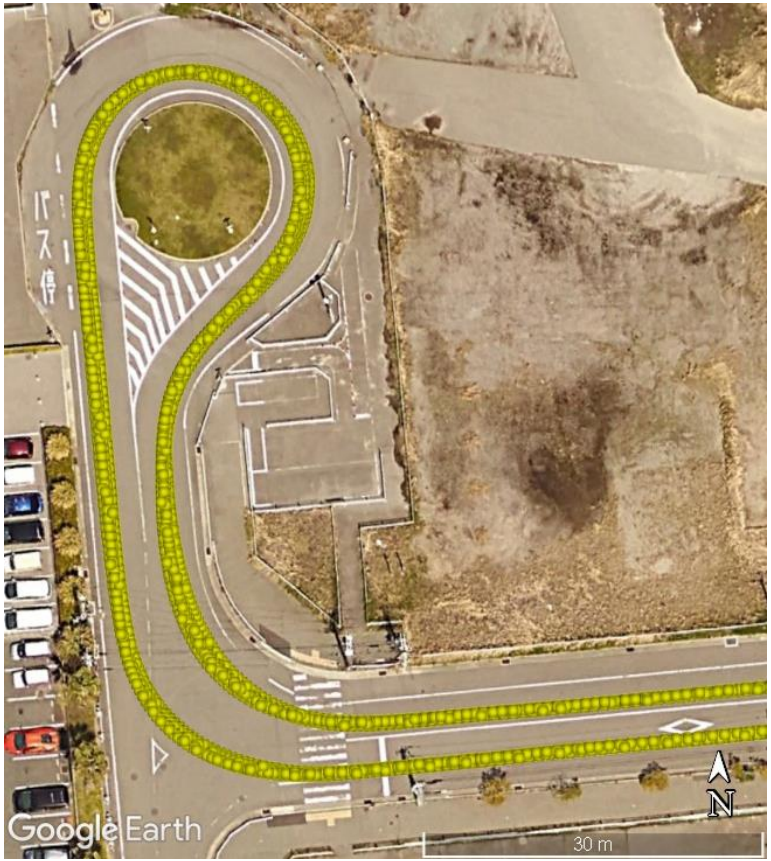
Introduction to submeter engine



Specialized to lane-level navigation, running on a low-cost chipset.

Multi-constellation, L1 + L5 dual frequency available.

Any correction service is not required, including L1 SBAS.

Introduction to centimeter engine

A precise point positioning (PPP) algorithm implemented in our low-cost chipset for this study. Similar to the other engines, we take automotive navigation use into consideration.

Some complement correction service providers of PPP;

- Galileo High Accuracy Service (HAS) by EU
- MADOCA-PPP by Japan

Here, we introduce the performance of the Galileo HAS internet data distribution service, which is implemented in this test.

Summary of Galileo HAS

Provides free access to the correction information required for the PPP algorithm in real-time.

Users need to implement the PPP to process the corrections and obtain a high-accuracy PVT solution.

Currently in the Initial Service phase, it will transition to the final Full Service phase in the near future.

	Service Level 1 (SL1)	Service Level 2 (SL2)
Coverage	Global	European Coverage Area (ECA)
Corrections	Orbit, clock, biases	Orbit, clock, biases + atmospheric correction
Dissemination	Galileo E6B / terrestrial (internet)	
Constellations	Galileo and GPS	
Horixontal Accuracy (95%)	<20cm	<20cm
Vertical Accuracy (95%)	<40cm	<40cm

Ref.https://www.gsc-europa.eu/galileo/services/galileo-high-accuracy-service-has

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Summary of the PVT engines

	Meter Lv.	Submeter Lv.	Centimeter Lv.
Frequency	**L1-only**	**L1+L5**	**L1+L5**
Constellation	**GPS+Galileo**	**GPS+Galileo**	**GPS+Galileo**
Positioning method	**SPP*1**	**SPP*1**	**PPP*2**
Correction service	**n/a**	**n/a**	**Galileo HAS**

*1 : Single point positioning, *2 : Precise point positioning

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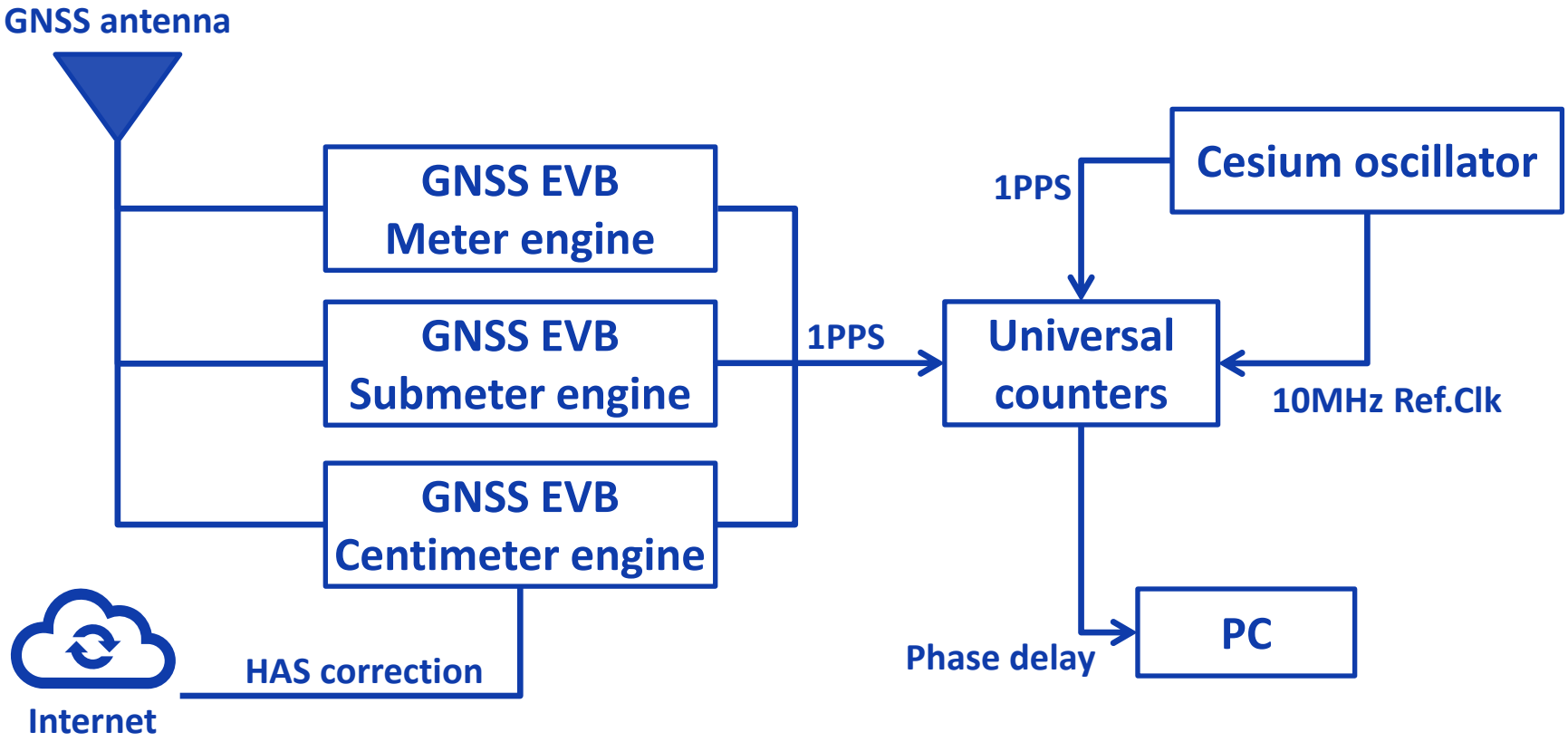
Test configuration 1/2



Test configuration 2/2

Date & time, place

Mar.15 12:00 - Mar.16 12:00, 2025 (JST, local time)
Nishinomiya, Japan (N34°40’ E135°30’, Near Osaka/Kobe)

Settings

Constellation	Galileo + GPS
Frequency	L1+L5 for submeter/centimeter engine L1 for meter engine
Update rate	1Hz
PPP correction	Galileo HAS Internet distribution (Ntrip)
Antenna	Trimble Zephyr 3 base, placed on the roof top of building

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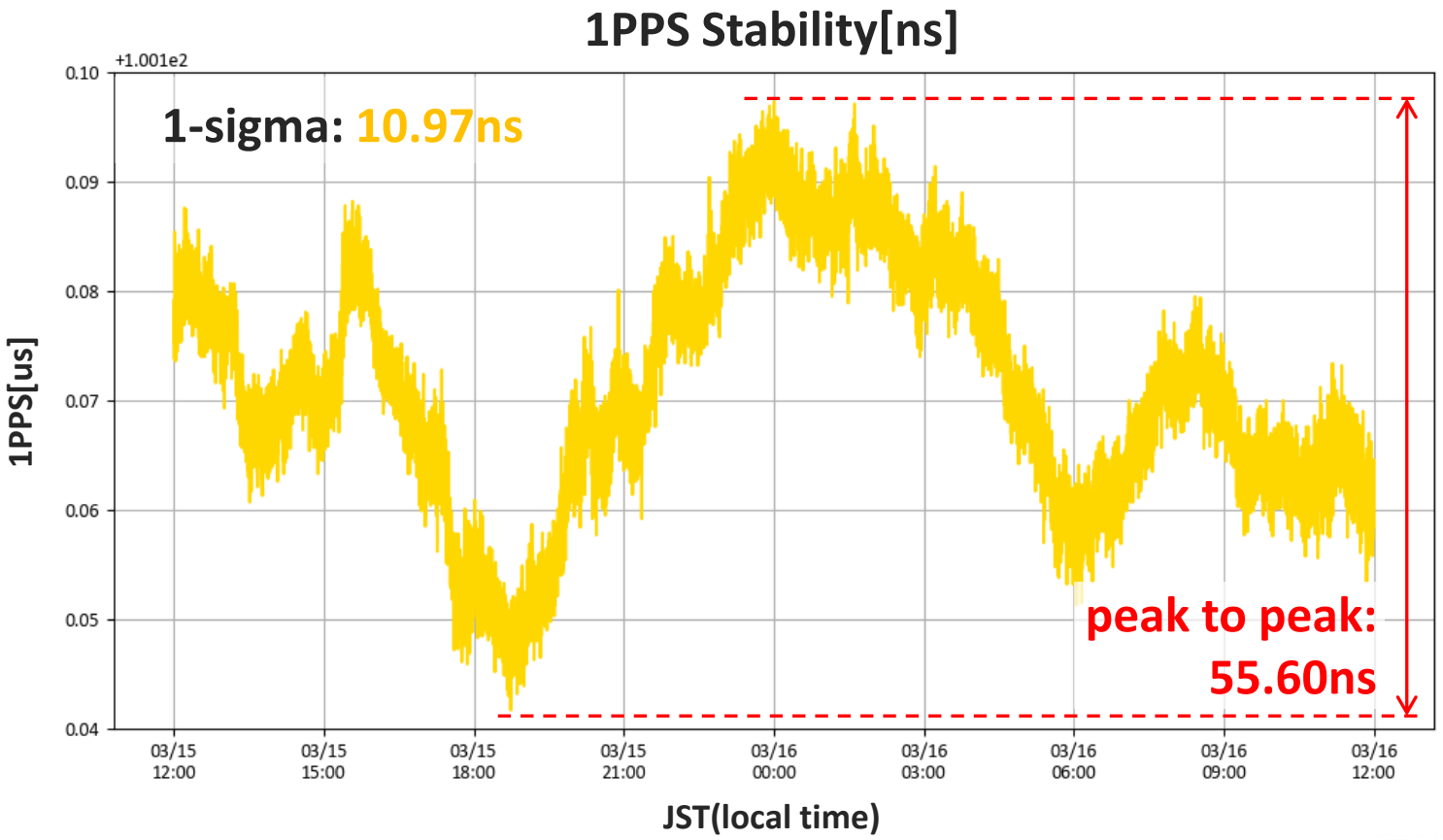
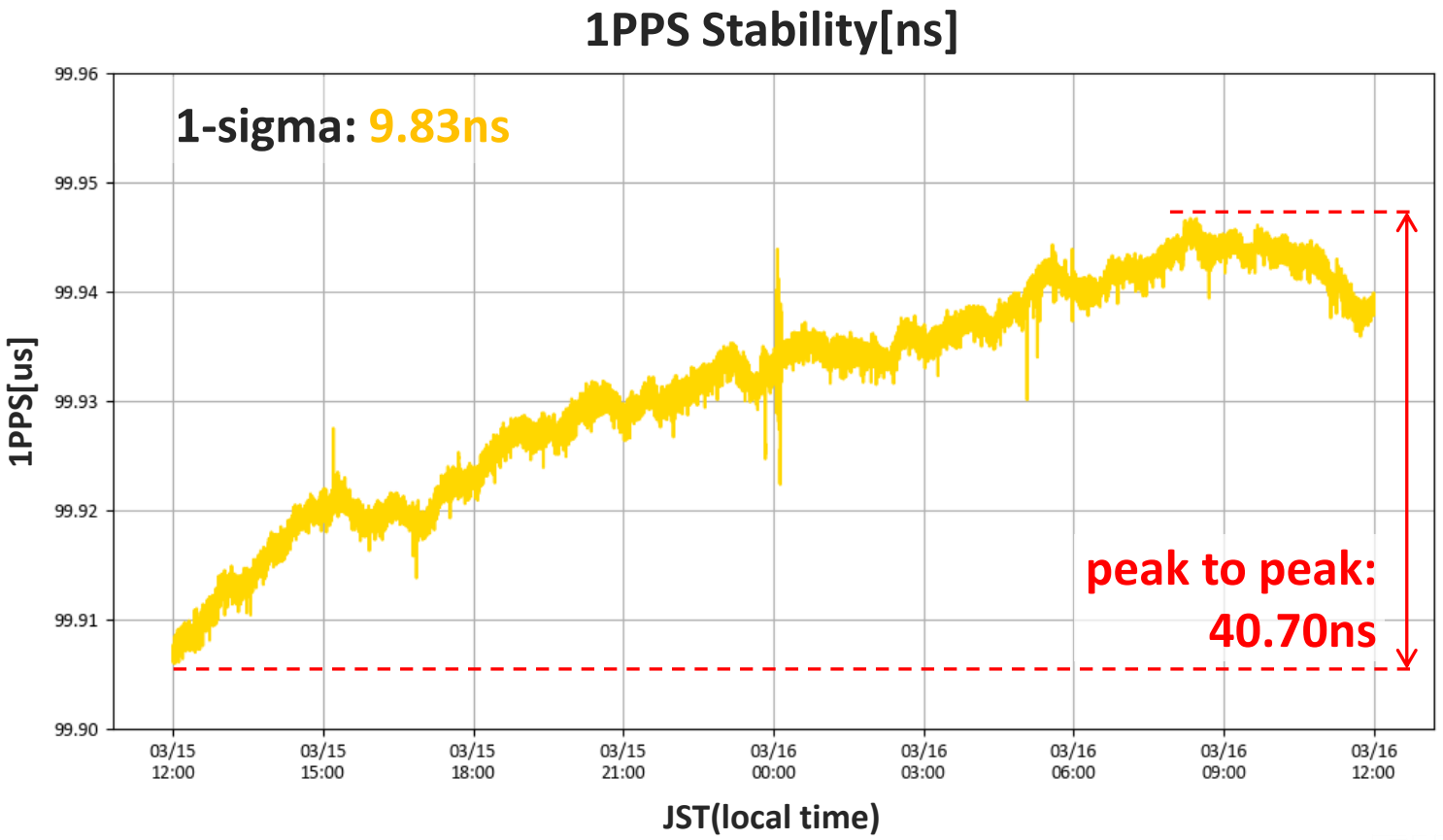
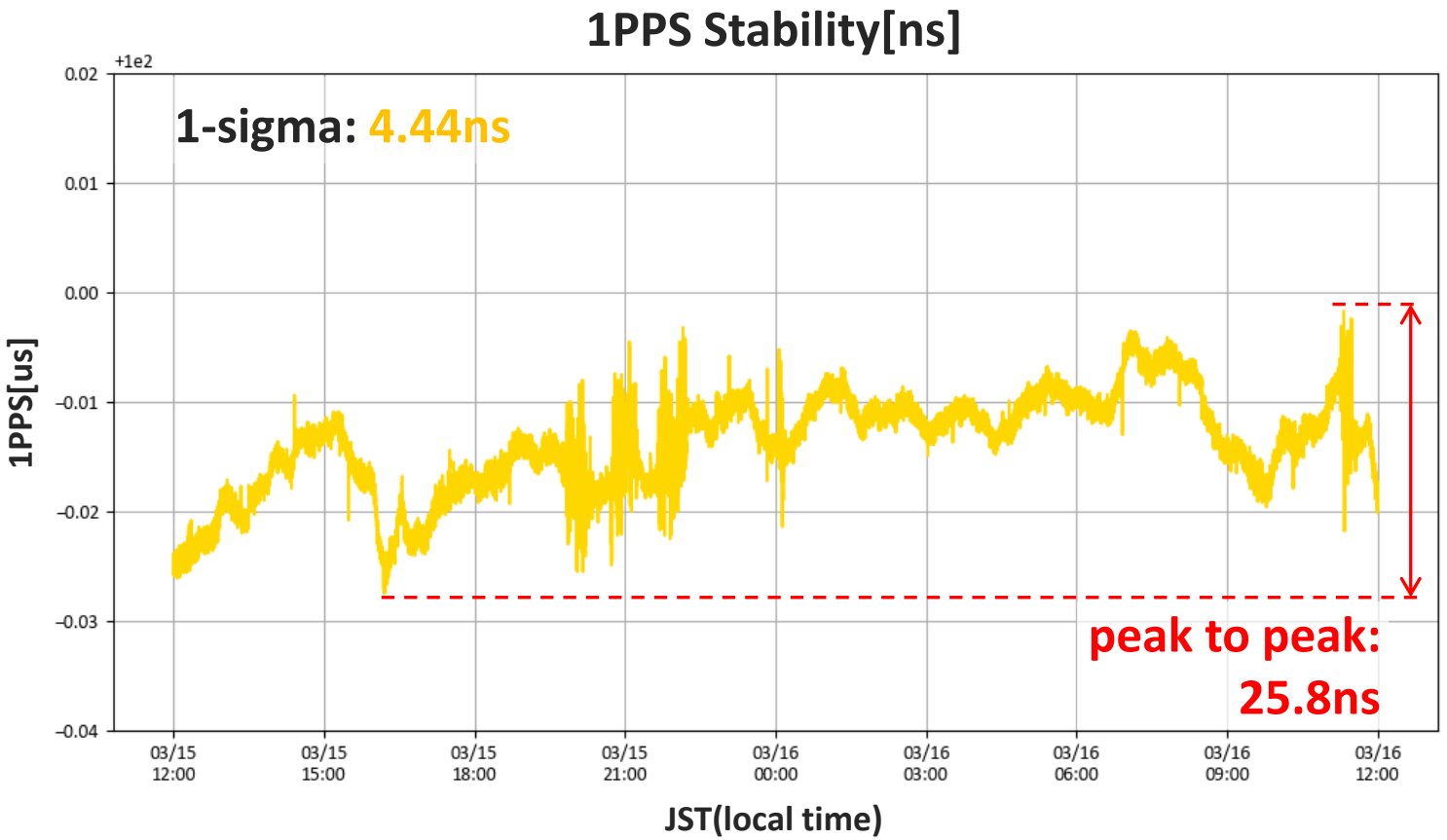
Results of meter level engine



Results of submeter level engine



Results of centimeter level engine



Summary of the experimental result

The single-frequency, meter-level engine demonstrated similar timing performance in terms of 1-sigma and peak-to-peak measurements compared to conventional products for automotive navigation.

The dual-frequency, submeter-level engine appeared stable but exhibited a trend not observed in other engines, resulting in a large peak-to-peak value.

The Galileo HAS-enabled, centimeter-level engine achieved the best performance compared to the other engines. Not only 1-sigma of 1PPS but also the difference between the peak-to-peak values were very small, unlike the other positioning engines.

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Conclusion and future works

The submeter engine has the potential to achieve more precise timing. Removing or reducing the trend of 1PPS should enhance its performance to be closer to that of the centimeter engine.

The Galileo HAS provided stable timing. While the timing accuracy or precision is not specified in any standards, it appears to be precise enough.

We look forward to evaluating it again in the Full Service phase.

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