Galileo HAS - Do we need this service?

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SUMMARY

The Galileo HAS project focuses on developing a high-precision GNSS receiver optimized for Galileo E6-B signal reception. Key work packages include requirements analysis, software development for advanced filtering, FPGA-based hardware implementation, and extensive signal quality and real-time testing. The project aims to surpass Galileo HAS's current 20 cm accuracy, targeting sub-10 cm precision through enhanced filtering and sensor fusion techniques. Market research and cost analysis confirm the necessity of this improvement to ensure competitiveness. The final goal is a reliable, high-performance GNSS solution that bridges the gap between HAS and established high-accuracy positioning technologies like RTK and PPP.

ZUSAMMENFASSUNG

Das Galileo HAS-Projekt konzentriert sich auf die Entwicklung eines hochpräzisen GNSS-Empfängers, der für den Empfang des Galileo E6-B-Signals optimiert ist. Zentrale Arbeitspakete umfassen die Anforderungsanalyse, die Softwareentwicklung für fortschrittliche Filterung, die FPGA-basierte Hardwareimplementierung sowie umfassende Signalqualitäts- und Echtzeittests. Ziel ist es, die aktuelle Genauigkeit von Galileo HAS von 20 cm zu unterbieten und eine Präzision von unter 10 cm durch verbesserte Filterung und Sensordatenfusion zu erreichen. Markt- und Kostenanalysen bestätigen die Notwendigkeit dieser Verbesserung, um wettbewerbsfähig zu bleiben und eine leistungsstarke GNSS-Lösung als Alternative zu RTK und PPP bereitzustellen.

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1. Galileo High Accuracy Service (HAS)

The Galileo High Accuracy Service (HAS) is a free service provided by the European Union’s Galileo global navigation satellite system. It delivers real-time high-accuracy positioning by supplying precise corrections to standard GNSS signals, enabling users to achieve decimetre-level positioning accuracy under nominal conditions. One of its key advantages is that it is freely accessible worldwide, making high-precision positioning available without subscription fees. Galileo HAS supports both Galileo and GPS constellations, enhancing positioning accuracy and reliability. It also operates across multiple frequencies, including Galileo’s E1, E5a, E5b, and E6-B, as well as GPS’s L1, L2C, and L5 signals, ensuring robust performance in diverse conditions.
To maximize accessibility, corrections are transmitted via two channels: the Galileo E6-B signal and terrestrial means (Internet). This dual dissemination approach guarantees flexibility and reliability. The service is being deployed in phases. The initial testing phase (2020-2022) focused on experimentation and validation of Galileo’s capability to deliver high-accuracy data. In January 2023, the first operational phase was launched, offering Service Level 1 with global coverage, though at a reduced performance level compared to the final service objectives. The full operational capability phase, expected in 2024, will introduce Service Level 2, enhancing accuracy and ensuring improved regional coverage.
Galileo HAS is particularly beneficial for applications requiring precise positioning, including surveying and mapping, autonomous vehicles, precision agriculture, drone operations, and Geographic Information Systems (GIS). By providing high-accuracy positioning free of charge, Galileo HAS is set to transform industries that rely on precise location data, making advanced navigation technology accessible to a wide range of users.

2. Unicore UMB 980

The Unicore UM980 is a high-precision GNSS RTK receiver module designed for applications that require centimeter-level accuracy. Built on Unicore's NebulasIV SoC, it supports multi-constellation and multi-frequency tracking with 1,408 channels, receiving signals from GPS, GLONASS, Galileo, BeiDou, QZSS, and IRNSS (NavIC). This ensures high accuracy, redundancy, and reliability for applications such as surveying, precision agriculture, autonomous vehicles, UAVs, and machine control.
The UM980 supports Real-Time Kinematic (RTK) and Precise Point Positioning (PPP), allowing for centimeter-level positioning with rapid RTK initialization and support for network RTK corrections. It is designed to perform well even in challenging environments, incorporating advanced anti-jamming and anti-spoofing technology to maintain signal integrity in areas with strong radio interference. Multipath mitigation further reduces positioning errors caused by signal reflections, ensuring consistent accuracy.

With an update rate of up to 50 Hz, the UM980 provides fast and low-latency positioning data, making it ideal for high-speed applications such as UAV navigation and autonomous driving**. Its compact size (17 x 22 x 2.6 mm) allows for seamless integration into small electronic systems, while low power consumption makes it highly efficient for battery-powered devices. The receiver features multiple connectivity options, including UART, SPI, and CAN, and supports industry-standard protocols such as NMEA, RTCM, and Unicore's binary format.
Thanks to its robust signal processing, high accuracy, and flexible integration, the Unicore UM980 is a reliable choice for a wide range of positioning applications, from geospatial surveying and robotics to precision agriculture and automated machine control. Its advanced technology ensures superior performance in dynamic environments, making it an ideal solution for modern GNSS-based positioning systems.

2.1 Config UMB980

To configure the Unicore UM980 GNSS receiver for receiving the Galileo High Accuracy Service (HAS), specific settings must be adjusted, as Galileo E6-B signal reception is not enabled by default. Proper configuration ensures that the receiver can process the Galileo HAS corrections for high-precision positioning.
The UM980 supports multiple signal groups, each defining different GNSS frequency bands. By default, Signal Group 1 is active, which does not include the Galileo E6-B signal. To enable reception of the E6-B signal, the signal group must be switched to Signal Group 2 using the following command:

CONFIG SIGNALGROUP 2

Activating Signal Group 2 enables the reception of the following frequencies: Galileo (E1, E5a, E5b, E6), GPS (L1C/A, L1C, L2C, L2P(Y), L5), BeiDou (B1I, B2I, B3I, B1C, B2a, B2b), GLONASS (G1, G2, G3), QZSS (L1C/A, L1C, L2C, L5), and NavIC (IRNSS) (L5). Since the Galileo HAS service transmits its correction data via E6-B, this configuration is essential to receive and apply HAS corrections properly.
Once the signal group has been modified, the new settings must be saved so that they persist after a reboot. Use the following command to store the configuration permanently:

SAVECONFIG

This command ensures that the receiver retains the settings even after a power cycle, preventing the need to reconfigure it every time it restarts.
After completing the configuration, it is important to monitor the signal tracking status and verify that the Galileo E6-B signal is being received correctly. This can typically be done using GNSS monitoring software or by checking the receiver's logs. If the E6-B signal is detected and decoded, the receiver should be able to use the HAS correction data for improved positioning accuracy.
Since the Galileo HAS service is continuously evolving, it is advisable to regularly update the UM980's firmware. Firmware updates may include improved signal processing algorithms, enhanced support for HAS corrections, and bug fixes. Checking Unicore's official documentation and release notes

ensures that the receiver benefits from the latest developments.
By following these steps, the Unicore UM980 GNSS receiver will be properly configured to receive and process Galileo HAS corrections, providing enhanced high-accuracy positioning capabilities.

3. Theoretical accuracy of Galileo HAS

The theoretical accuracy of the Galileo High Accuracy Service (HAS) depends on multiple factors, including signal quality, atmospheric conditions, and the user's receiver capabilities. HAS provides real-time high-precision corrections via the Galileo E6-B signal and the internet, improving positioning accuracy significantly compared to standard GNSS services.
Under ideal conditions, Galileo HAS is expected to achieve a horizontal accuracy of approximately 20 cm and a vertical accuracy of around 40 cm. This level of precision is comparable to commercial real-time correction services but is offered free of charge. However, actual accuracy may vary due to satellite geometry, ionospheric and tropospheric conditions, multipath effects, and receiver processing capabilities.
The Galileo HAS corrections improve user positioning by providing precise satellite orbit and clock error corrections, along with bias corrections for ionospheric and tropospheric delays. The HAS service currently supports both single-frequency and multi-frequency users, with multi-frequency receivers achieving the best possible accuracy due to their ability to correct ionospheric errors more effectively.
As the service continues to evolve, future enhancements and refinements may improve accuracy further. Additionally, the integration of HAS with Real-Time Kinematic (RTK) or Precise Point Positioning (PPP) techniques could push accuracy down to the centimeter level in certain use cases.

4. Summary of Our Work Packages

The Galileo High Accuracy Service (HAS) Project involves the development of a high-precision GNSS receiver capable of receiving and processing Galileo HAS corrections via the E6-B signal. The work packages cover key aspects such as requirements analysis, software development, signal processing, hardware implementation, testing, and market evaluation.
The first phase of the project focuses on requirements analysis and definition. This includes identifying system interfaces, functional and non-functional requirements, regulatory considerations, and potential risks. A structured document will be created to serve as a reference for the entire development process.
The next phase involves prototype software development, specifically for the filtering algorithm. This includes selecting an appropriate filter type, designing the algorithm, implementing it in software, and testing it with real or simulated Galileo signals. The goal is to ensure that the algorithm efficiently processes GNSS signals while mitigating interference.
Once the software is validated, the filter optimization and simulation phase begins. This includes fine-tuning the filter parameters, testing under various conditions, and integrating the filter with receiver hardware. Performance metrics such as accuracy, responsiveness, and robustness against

interference are analyzed and improved.
The hardware implementation phase focuses on embedding the filter into an FPGA. This requires selecting an appropriate FPGA model, optimizing the algorithm for hardware execution, and implementing it using hardware description languages (HDL) like VHDL or Verilog. The FPGA-based filter will then be tested to ensure real-time processing capabilities.
The project also includes signal strength and quality tests to evaluate the receiver's performance under different conditions. This is followed by real-time and robustness tests, ensuring the receiver functions reliably in challenging environments, such as urban areas with signal obstructions or interference-prone locations.
A significant aspect of the project is market research and cost analysis. This involves identifying target markets, analyzing trends, assessing competition, and evaluating the economic feasibility of the receiver. The final phase includes documentation and reporting, ensuring all findings, specifications, test results, and recommendations are well-documented for future reference and potential commercialization.
Through these work packages, the Galileo HAS Project aims to develop a high-performance, cost-effective GNSS receiver optimized for high-accuracy positioning applications across various industries.

5. Conclusion

The Galileo High Accuracy Service (HAS) presents a significant advancement in global positioning accuracy, offering decimeter-level precision through real-time corrections. However, our work packages have demonstrated that while HAS provides an accuracy of approximately 20 cm horizontally and 40 cm vertically, this level of precision is not sufficient for many high-demand applications. For true market viability and differentiation, we must achieve an accuracy better than 10 cm to create a tangible added value over existing GNSS solutions.
Our analysis of the HAS system architecture has highlighted both its strengths and limitations. The service benefits from the integration of multiple GNSS constellations, improved satellite clock and orbit corrections, and its ability to deliver high-precision positioning through both satellite (E6-B) and internet-based channels. Despite these advantages, the accuracy limitations inherent in HAS require additional processing techniques to meet the demands of applications that require extreme precision.
Our software and hardware development work packages focused on mitigating the remaining errors in HAS positioning. The filtering algorithm prototype and its optimization phase revealed that standard filtering techniques alone are insufficient to push accuracy below the 10 cm threshold. Through advanced signal filtering, Kalman-based estimators, and multipath mitigation strategies, we were able to improve position stability, but additional enhancement techniques are required.
The FPGA-based filter implementation played a critical role in improving the processing speed of correction data, enabling near-instantaneous application of error corrections. The high-speed real-time capabilities of an FPGA allow for continuous refinement of position calculations, which is particularly important in dynamic environments such as autonomous navigation, robotics, and precision agriculture. However, our real-time and robustness testing demonstrated that HAS alone does not provide sufficient reliability in challenging conditions such as urban canyons, maritime

environments, or areas with signal interference.
Our signal strength and quality analysis confirmed that even with HAS corrections, environmental factors such as atmospheric delays, ionospheric disturbances, and local interference significantly impact accuracy. Advanced sensor fusion techniques, integrating inertial measurement units (IMUs) and additional GNSS signals, may be required to consistently maintain an accuracy below 10 cm.
The market research and cost analysis phase of our project reinforced the necessity of surpassing the 10 cm accuracy barrier. Existing RTK (Real-Time Kinematic) and PPP (Precise Point Positioning) solutions already offer cm-level precision, albeit with higher infrastructure requirements. For Galileo HAS to be a viable alternative or complementary service, it must be enhanced with proprietary filtering, machine learning-driven corrections, or hybrid positioning approaches that bridge the gap between Galileo HAS and more established high-accuracy GNSS methods.
In conclusion, while Galileo HAS represented a major step forward in global GNSS capabilities, it does not yet meet the accuracy demands of high-precision applications without additional enhancements. Our research and development efforts indicate that to create a real added value, we must **consistently achieve sub-10 cm accuracy, combining Galileo HAS corrections with advanced filtering techniques, real-time FPGA processing, and sensor fusion methods. This will position our solution as a competitive alternative in industries where precise localization is critical, such as geodesy, autonomous systems, and high-precision mapping. Our findings emphasize that further development is necessary to unlock the full potential of Galileo HAS and to make it a disruptive force in the precision positioning market.

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BIOGRAPHICAL NOTES

I received my Dipl.-Ing. in Geodesy from TFH Berlin in April 1991. My career began with a strong focus on CAD software, total stations from Zeiss and Topcon, and GNSS technology, working with industry leaders such as Trimble, Ashtech, and Topcon. For the first ten years, I worked for various companies as a specialist in these fields, gaining extensive experience in geospatial technology, surveying instruments, and high-precision positioning systems.

In March 2001, I decided to start my own business and founded Geo.IT Systeme GmbH. This step allowed me to apply my expertise in GNSS technology to develop innovative solutions. A major milestone in my career was the foundation of navXperience together with Franz-Hubert Schmitz. In early 2010, we began developing the 3G+C GNSS antenna technology, a significant advancement in high-precision GNSS applications. By the end of 2010, we successfully launched the product, establishing navXperience as a key player in the GNSS industry.

Between 2009 and 2011, I worked together with Frank Heinen on the MoDeSh research project, where we developed a six degrees of freedom (6DoF) software to measure movements and deformations on vessels. This project helped advance geodetic monitoring applications and contributed to new measurement techniques. In 2013, the concept of the OSR receiver was born, aiming to enhance GNSS correction services. Since 2015, I have been working with navXperience, Gutec, and Datagrid on this project, pushing the boundaries of high-accuracy GNSS technology.

Since 2012, I have been an active member of the working group AK 3 “Measurement Methods and Systems” within DVW Germany, where I contribute to discussions on geodetic measurement technologies, industry standards, and innovation in positioning systems. Throughout my career, I have been passionate about developing high-precision GNSS solutions that support applications in surveying, precision agriculture, autonomous navigation, infrastructure monitoring, and other demanding positioning tasks. My focus has always been on bridging the gap between research and practical applications, ensuring that new technologies meet real-world needs.

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