HANDS-CD	ESA Contract No.	40001737747/22/NL/CRS

Project
Architectures for Wide-Band Meta-Signal Processing in Low-Cost Devices
Document Title
Executive Summary Report

Responsible Contractor	Document Responsibility	Name	Signature
IGASPIN	Document Book Captain	Amir Tabatabaei	Signed by: Amir Tabatabaei Date: 13.11.2024 07:46:53 A TRUST This document is digitally signed! This document bearing a qualified electronic signature has the same legal standing as a handwritten document in accordance with Article 25 (2) of Regulation (EU) No. 910/2014 of 23 July 2014 ("eIDAS-VO") Validation: Information for checking the electronic signature can be found at: www.a-trust.at/pdf

Document Information	
Document Reference	IGA-HANDS-CD-ESR
Issue. Revision/DDL	1.0 / ESR
Date	10-August-2024
Document Category	R [I: for Information] [R: for Review] [A: for Approval]
Classification Level	U [U: Unclassified] [R: Restricted] [C: Confidential] [S: Secret]
Document Pages	8

IGASPIN Universität der Bundeswehr München ThalesAlenia Space m3 systems

Document Change Log

Document Change Status				
Issue	**Revision**	**Date**	**Reason(s) for Change**	**Sections affected**

Contents

1. Introduction

1.1. Purpose and Scope

This Executive Summary highlights the key technological achievements of the HANDS-CD project, focusing on innovations in signal processing, system design, and comprehensive testing that have collectively advanced the field of GNSS technology.

1.2. Reference Documents

The following table contains the reference documents used.

Table 1.1: Reference Documents

Ref.	Title
[RD-1]	

1.3. Definitions and Acronyms

The acronyms and abbreviations used within this document are given in the table below.

Table 1.2: Definitions and Acronyms

Acronym	Explanation
AltBOC	Alternative BOC
BJ	Bump Jumping
BOC	Binary Offset Carrier
BPSK	Binary Phase Shift Keying
CD	Concept Demonstrator
DDT	Double Discriminator Tracking
DE	Double Estimate
DLL	Delay Locked Loop
EKF	Extended Kalman Filter
FLL	Frequency Locked Loop
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
iDDT	Improved Double Discriminator Tracking
LAMBDA	Least-squares AMBiguity Decorrelation Adjustment
LOS	Line-of-Sight
NCO	Numerically Controlled Oscillator
NLOS	Non-Line-of-Sight
RF	Radio Frequency
RFFE	Radio Frequency Front-End
SAGE	Space-Alternating Generalized Expectation maximization technique

2. Project Overview

The HANDS-CD project represents a significant milestone in advancing GNSS technology, particularly for handheld and low-cost devices. The project aimed to develop a CD capable of achieving high positioning accuracy in challenging environments such as urban canyons and deep urban areas.

3. Proposed Signal Processing Techniques

The HANDS-CD project successfully developed and implemented innovative signal processing techniques, each tailored to enhance GNSS performance in environments with weak or obstructed signals.

3.1. BPSK-like Method

IGASPIN's approach introduces post-correlation shifts, where the E5a and E5b pilot components are correlated separately and then combined to produce E5ab BPSK-like correlation values. This requires deriving the E5a and E5b NCOs from a single E5ab NCO, ensuring that the code and carrier generators are aligned to accurately reproduce the BPSK-like E5ab components.

3.2. iDDT Method

The iDDT provides a smoother and faster transition to the main correlation peak than the traditional BJ algorithm, making it ideal for handling multiple side peaks in high-order BOC signals and meta-signals. By combining techniques like differential evolution, side-peak transition, and Double Discriminator Tracking (DDT), iDDT enhances tracking accuracy and reduces pseudorange errors, especially in multipath conditions.

3.3. SAGE Method

The SAGE algorithm, traditionally used in communication systems, has proven effective in GNSS navigation as well. In this context, SAGE is applied after the local correlation step, where ML estimation is used on the post-correlated signal to estimate the relative delay and Doppler of the signal paths. These estimations are then utilized to drive the GNSS tracking loops, similar to the role of DLL and PLL in classical navigation, enhancing the accuracy of time delay and phase measurements for LOS signals.

3.4. M-SiPE Method

The M-SiPE integrated the LAMBDA method for sub-carrier ambiguity resolution, achieving decimeter-level positioning accuracy even in challenging environments.

4. Proposed Architecture

The HANDS-CD system was built with a modular architecture, allowing for flexibility in system upgrades and integration of various signal processing techniques. The system was optimized for low power consumption while maintaining high accuracy though impairment induced by the low-grade devices.

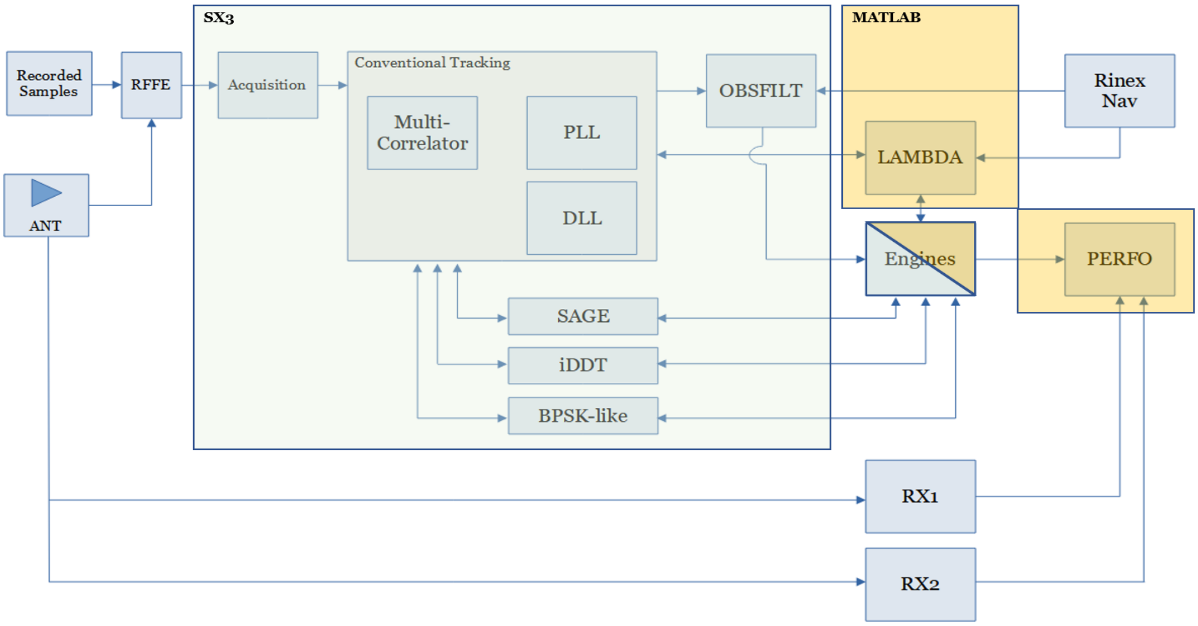

Figure 4.1: The high-level design of the HANDS-CD.

After simulations and trade-offs, the iDDT together with MSiPE methods were implemented for meta-signal processing on the SX3 platform, supporting both E5a+E5b and L2+L5 signals.

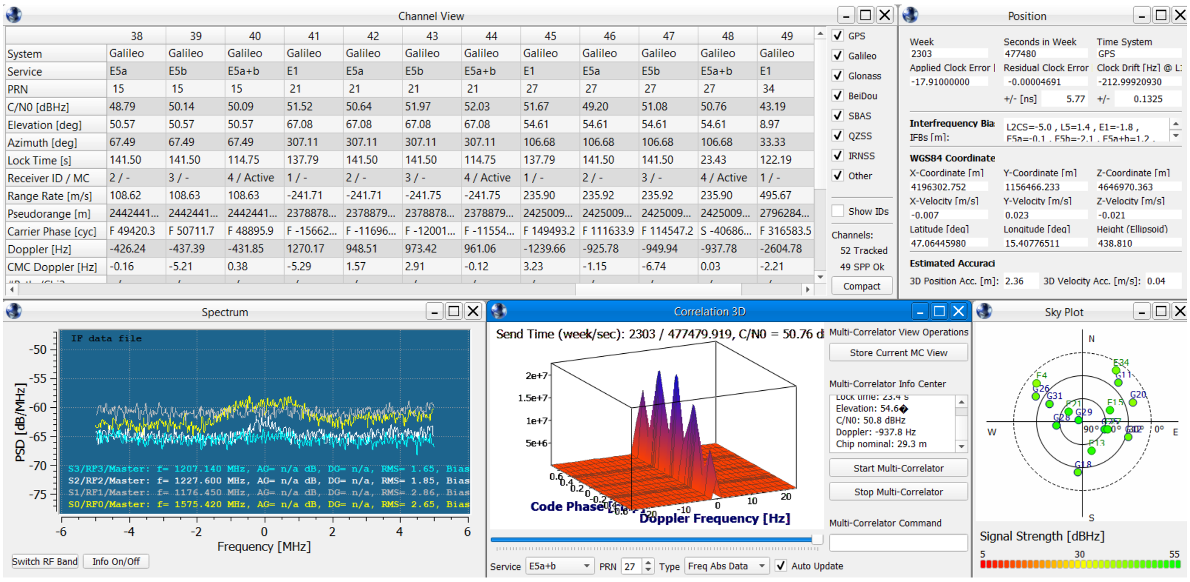

Figure 4-2: A screenshot of the SX3 software receiver when processing the E5ab signals using the proposed iDDT method.

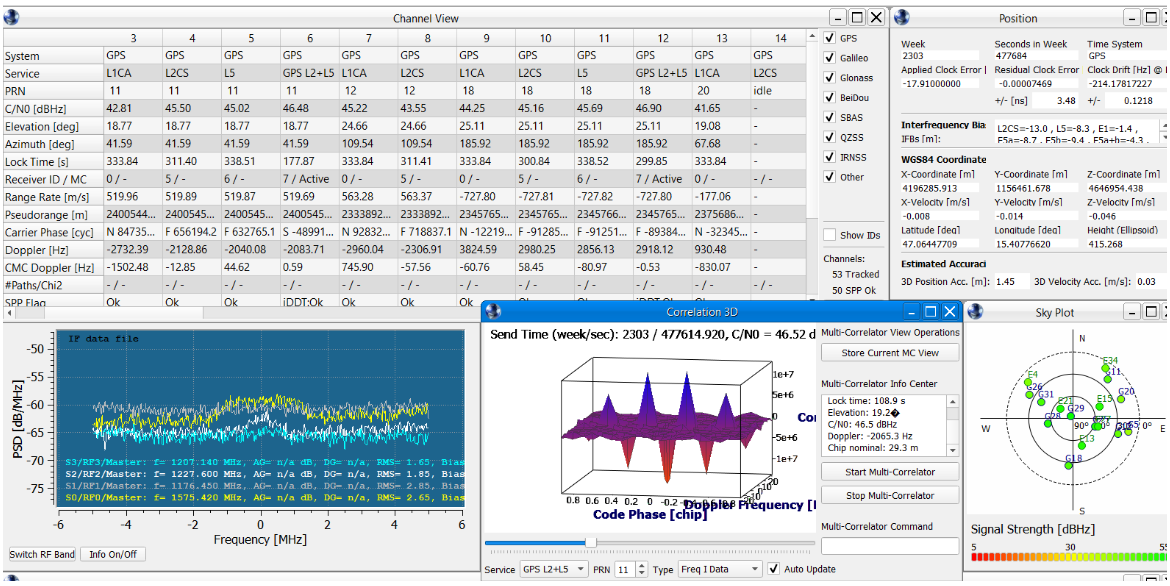

Figure 4-3: A screenshot of the SX3 software receiver when processing the L2+L5 signals using the proposed iDDT method.

5. Testing and validation

The project involved rigorous testing across diverse environments, including urban canyons and deep urban areas. The HANDS-CD system demonstrated superior performance in positioning accuracy, signal availability, and tracking sensitivity compared to state-of-the-art professional GNSS receivers.

6. Requirements Compliance

The HANDS-CD met all the technical requirements presented under the ESA's Statement of Work. System components and their modules were tested inside out for validating against required performance.

7. Future Directions

Building on the successes of the HANDS-CD project, several future research directions are proposed:

1. **Optimization of Hybrid Meta-Signal Techniques:** Further refinement of hybrid meta-signal processing techniques, potentially integrating peer-to-peer ranging solutions, will enhance real-time processing capabilities and system robustness.
2. **Exploration of Additional Frequency Combinations:** Investigating other frequency combinations, such as Galileo E1/E6 and GPS L1/L5, will expand the system's versatility and improve performance in specific environments.
3. **Development of a Flexible Breadboard Platform:** A flexible, scalable breadboard platform based on COTS hardware will be developed to serve as a proof of concept for hybrid meta-signal solutions.

4. **Field Testing in Diverse Scenarios:** Extensive field testing in representative urban and deep-urban environments, covering both pedestrian and vehicular scenarios, will validate the practical applicability of the developed techniques.
5. **Market Applications and Collaborations:** Leveraging the innovations from HANDS-CD, there is potential to explore new market applications and opportunities for collaboration with other ESA projects and industry stakeholders.

8. Conclusion

The HANDS-CD project has made substantial technological advancements in the field of GNSS for handheld devices, offering new possibilities for consumer and professional applications alike. The success of this project sets the stage for the next generation of GNSS systems capable of delivering high accuracy in environments previously considered too challenging for reliable positioning.