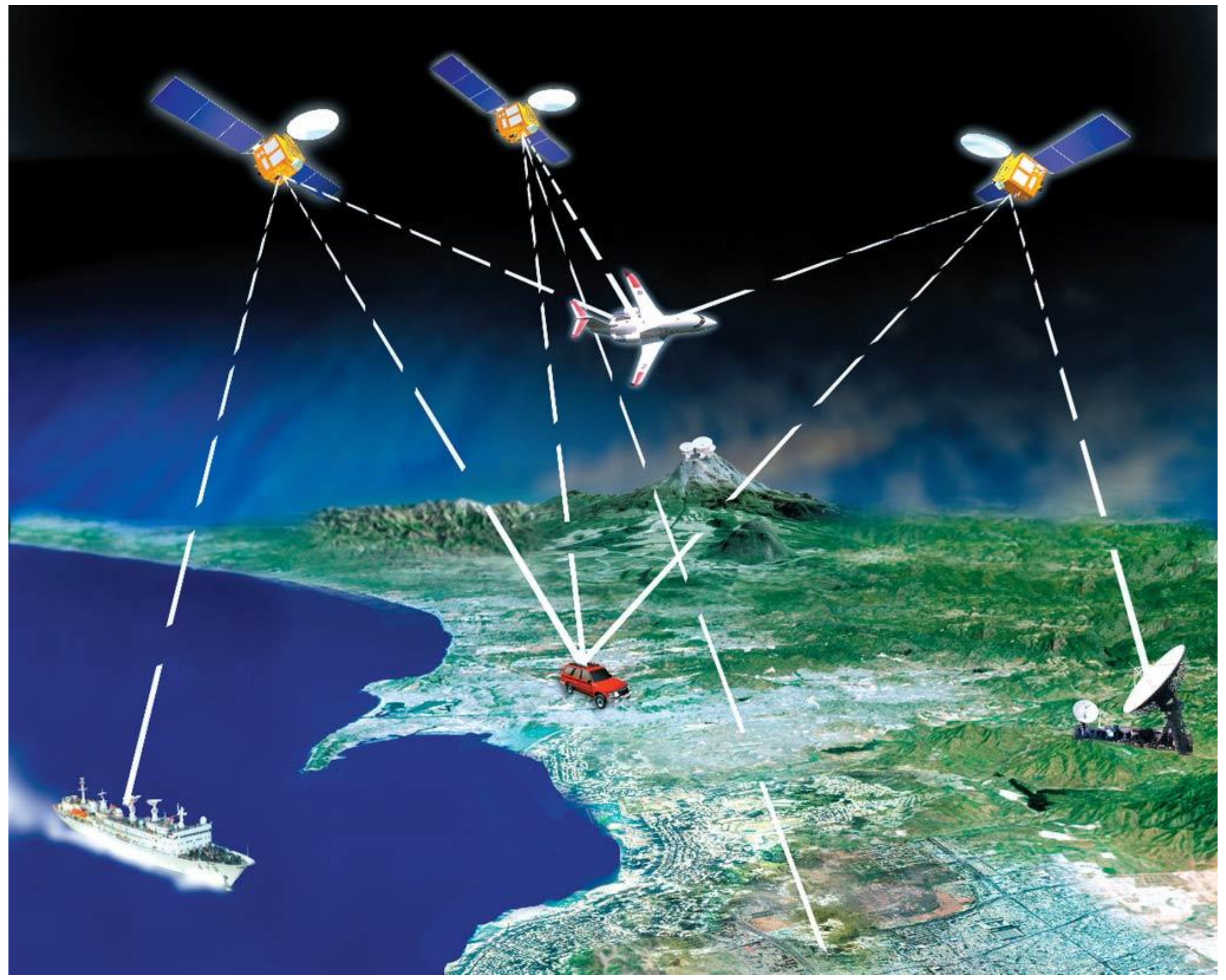
SDR Based NavIC and GPS Receiver



Source: [TechCrunch]

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Contents

Introduction

Software Defined Radio (SDR)

Why SDR?

- **Flexibility**
- **Multipurpose Platform**
- **Rapid Upgradability**
- **Reduced Innovation Cycle**
- **Reconfigurability**
- **Hardware Protection**
- **Protocol Adaptability**

Aim: Build a high-performance, upgradeable, and flexible navigation system using SDR.

Introduction
Popular Existing SDRs

SDR	Advantages	Limitations
ADALM-PLUTO	Affordable, Portable, Broad frequency range, Versatile	Limited RF performance, Latency issues, Low processing power
USRP	High RF performance, Wide bandwidth, Low latency	Expensive, Bulky, High power consumption
HackRF One	Affordable, Portable, Open-source support	Limited RF performance, Lower sampling rate, Noisy hardware
RTL-SDR	Affordable, Easy to use, Broad frequency range	Limited frequency precision, Low sampling rate

Paper Contributions

Challenges Addressed:

- High Performance and low latency.
- Multi-constellation navigation support.
- Cost effectiveness and scalability.
- Compatibility with new GNSS protocols.

Proposed Solution:

- RISC-V architecture for cost-effective, open-standard hardware and customizable SDR implementation.
- Developing custom algorithms for enhanced signal acquisition, tracking, and decoding.

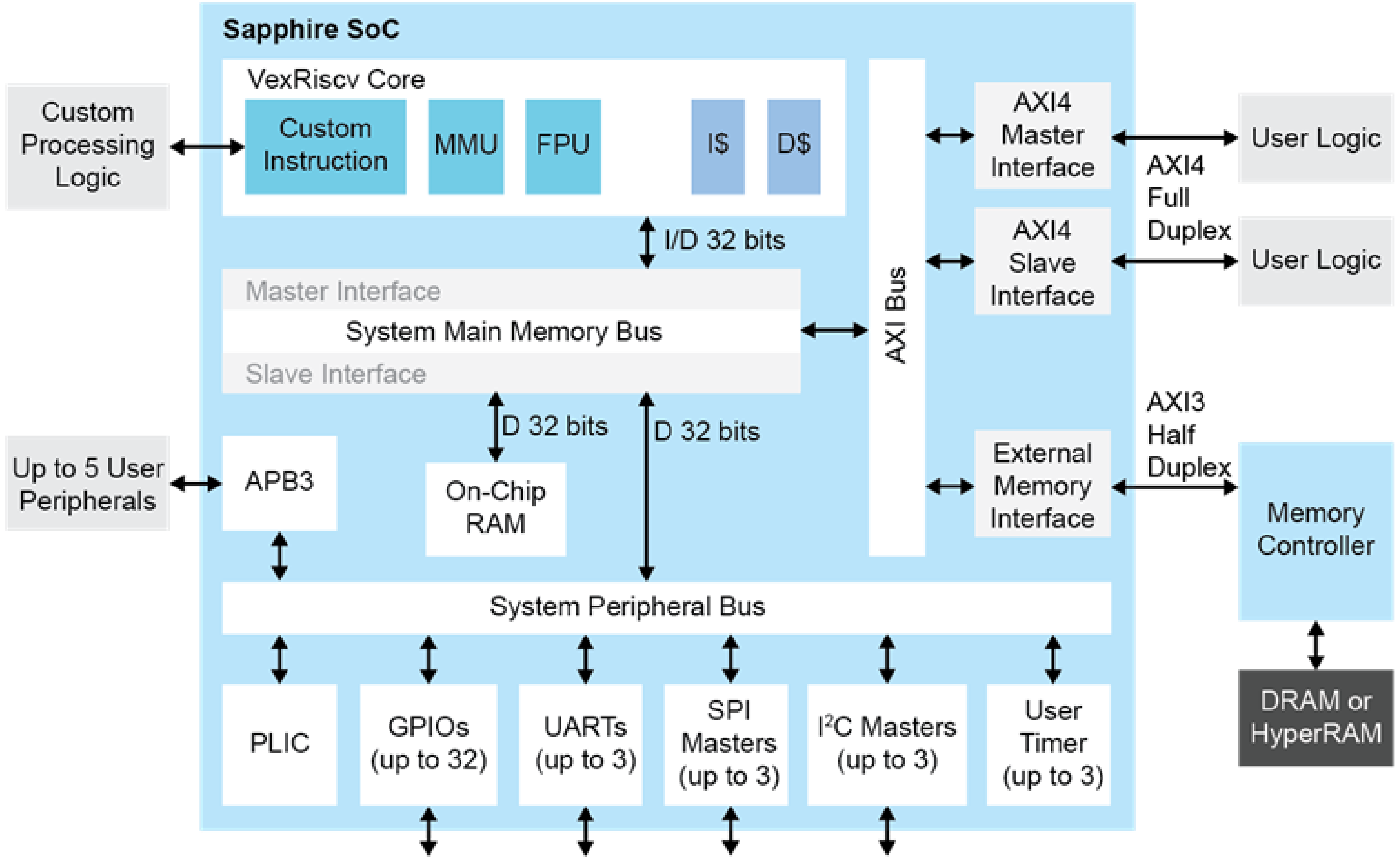
Problem Formulation
Why RISC-V?

Aspect	RISC-V	ARM
Architecture	• Open Source and modular. • Easily customizable for SDR-specific needs.	• Proprietary and fixed. • Limited customization for application-specific designs.
Cost	• No licensing fees. • Ideal for cost-effective development.	• Requires licensing fees, increasing development costs.
Flexibility	• Fully adaptable for GNSS protocols (e.g., NavIC, GPS, Galileo).	• Adaptation limited by pre-defined IP and licensing restrictions.
Performance	• Optimized for specific GNSS functions (acquisition, tracking, navigation).	• General-purpose cores may require additional optimization layers for SDR applications.
Upgradability	• Firmware updates allow rapid upgrades for evolving GNSS standards	• Limited by vendor-defined architecture and firmware policies

Problem Formulation

Sapphire SoC

- Built on VexRiscv core.
- Quantum® architecture enables dynamic optimization of logic and routing resources.
- Power-conscious design suitable for SDR applications.
- Integrates processing cores, memory, and I/O subsystems, optimized for high-performance applications

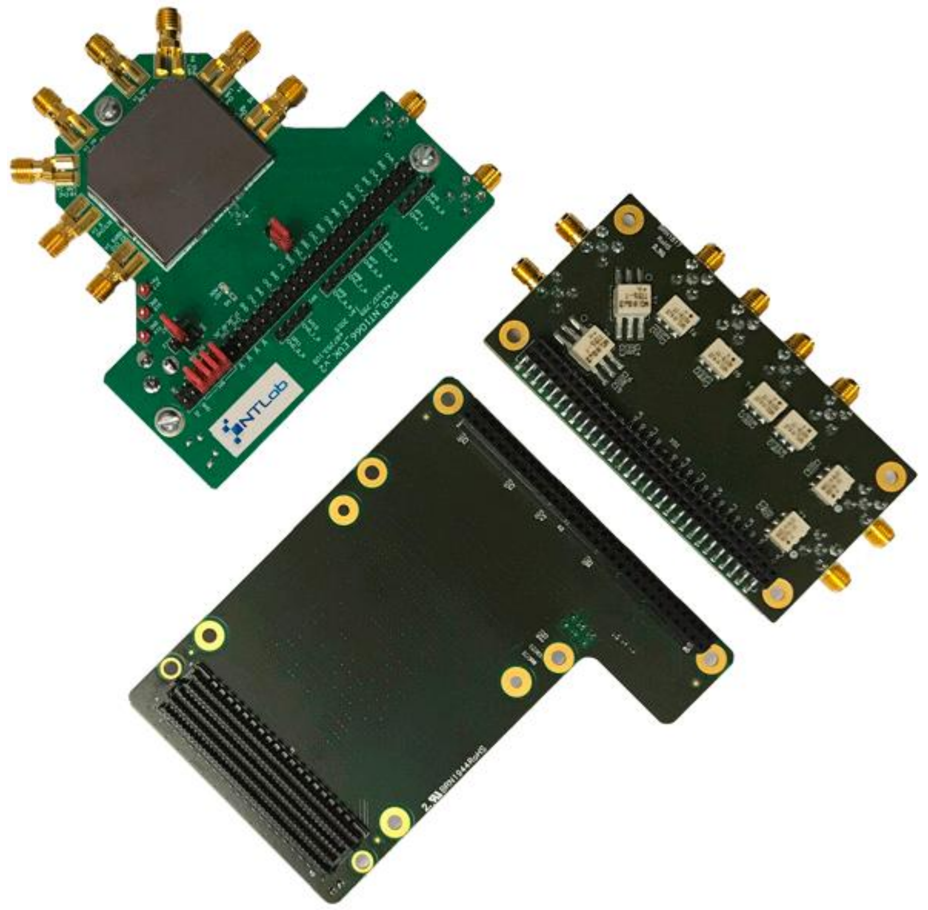


Hardware Architecture

Key Components

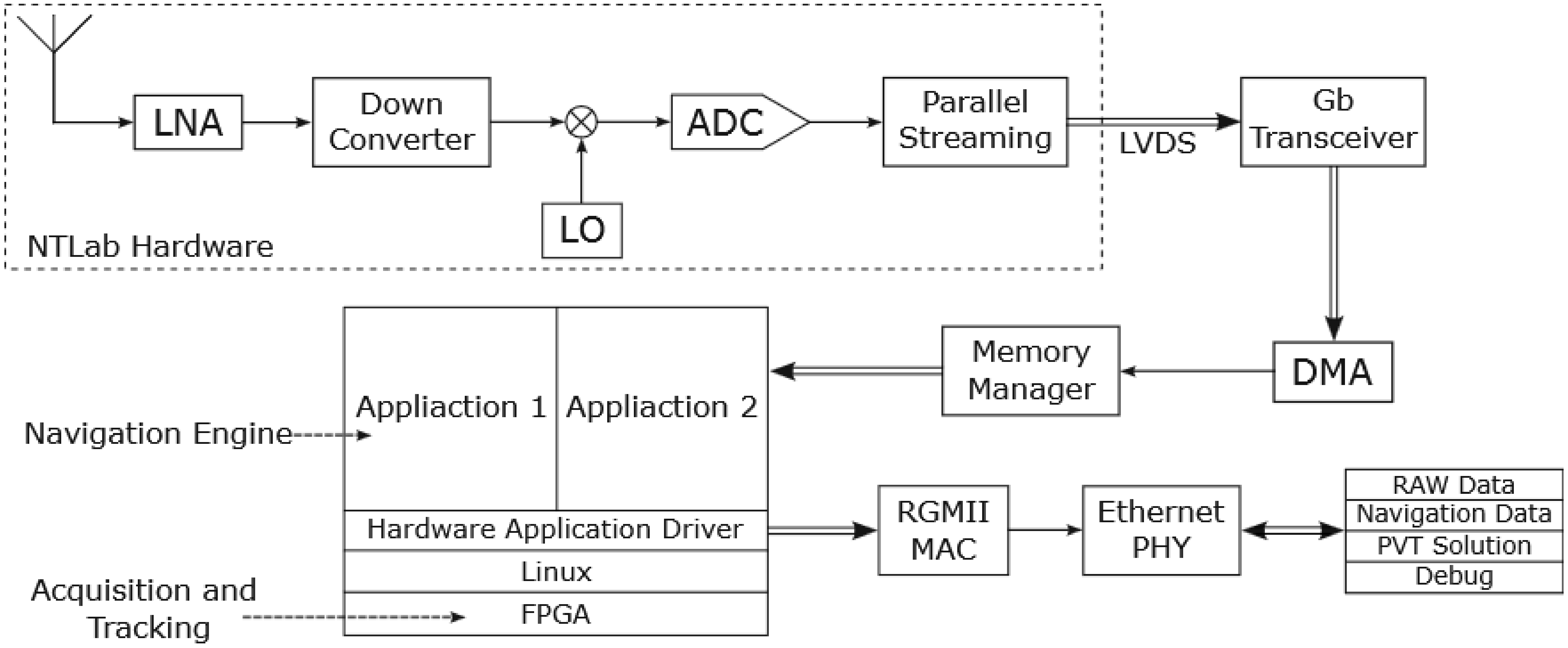
- **NT1066 EVK RF IC:** Supports multi-GNSS signal reception, including NavIC, GPS, GLONASS, and Galileo.
- **Trion T120 FPGA Board:** Enables real-time processing of GNSS signals with high precision.
- **Low Voltage Differential Signaling (LVDS):** Maintains signal integrity and reliability in high-speed data transmission.

Trion T120 BGA324 Board



NT1066 EVK RF IC

Hardware Architecture



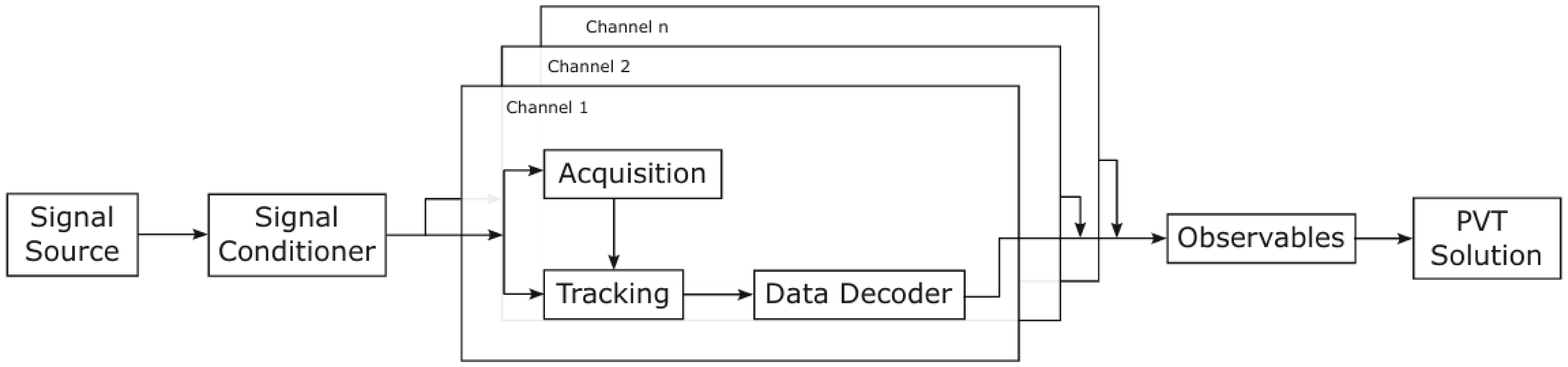
Software Architecture

Signal Processing Stages

- Acquisition
- Tracking
- Data Decoding

Implementation

- FPGA handles baseband processing.
- Custom Python modules compute navigation data and PVT solutions.
- Real-time data managed by Direct Memory Access (DMA) controller.

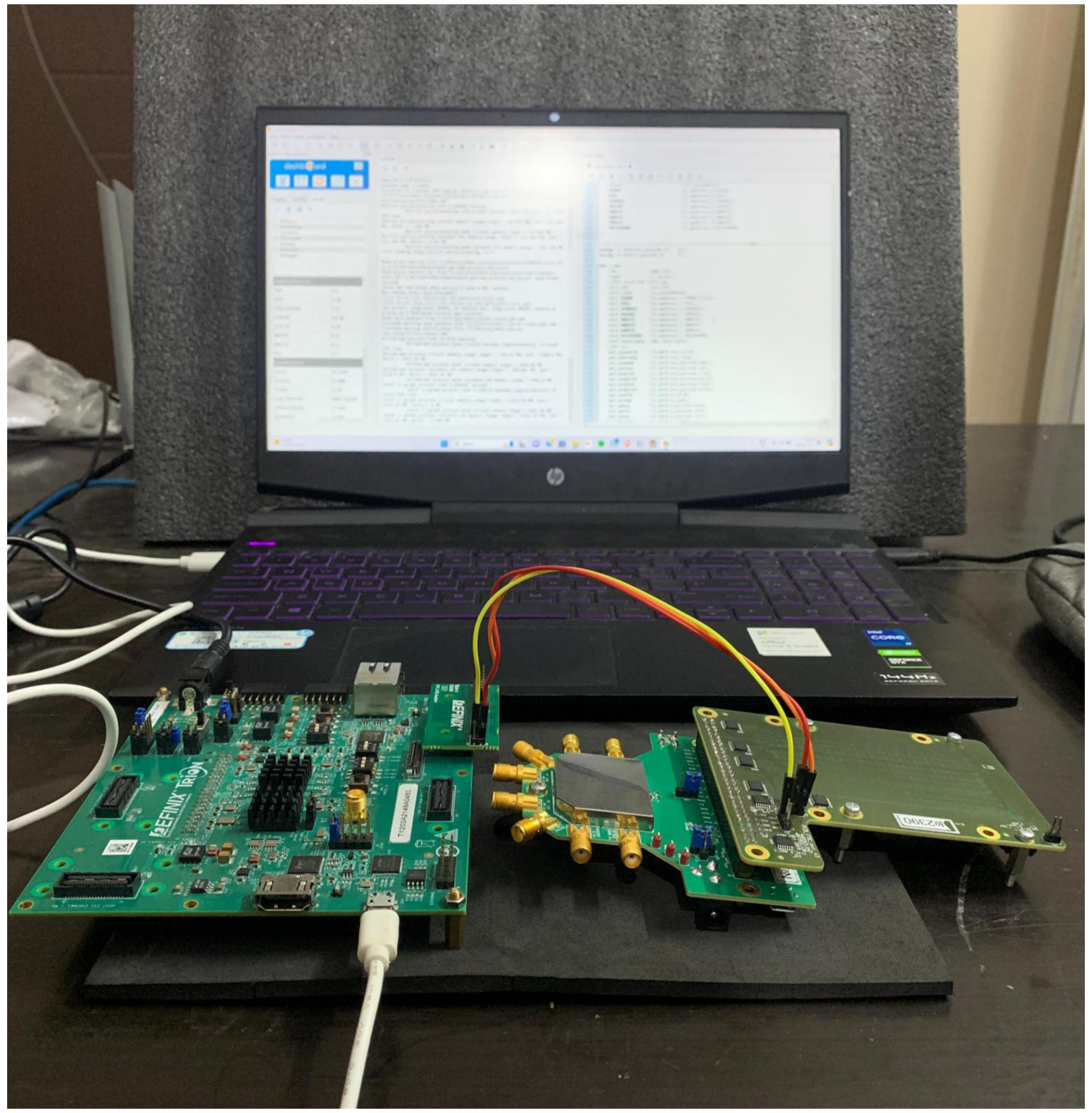


Flow graph of the developed receiver

Experimental Setup

System Components

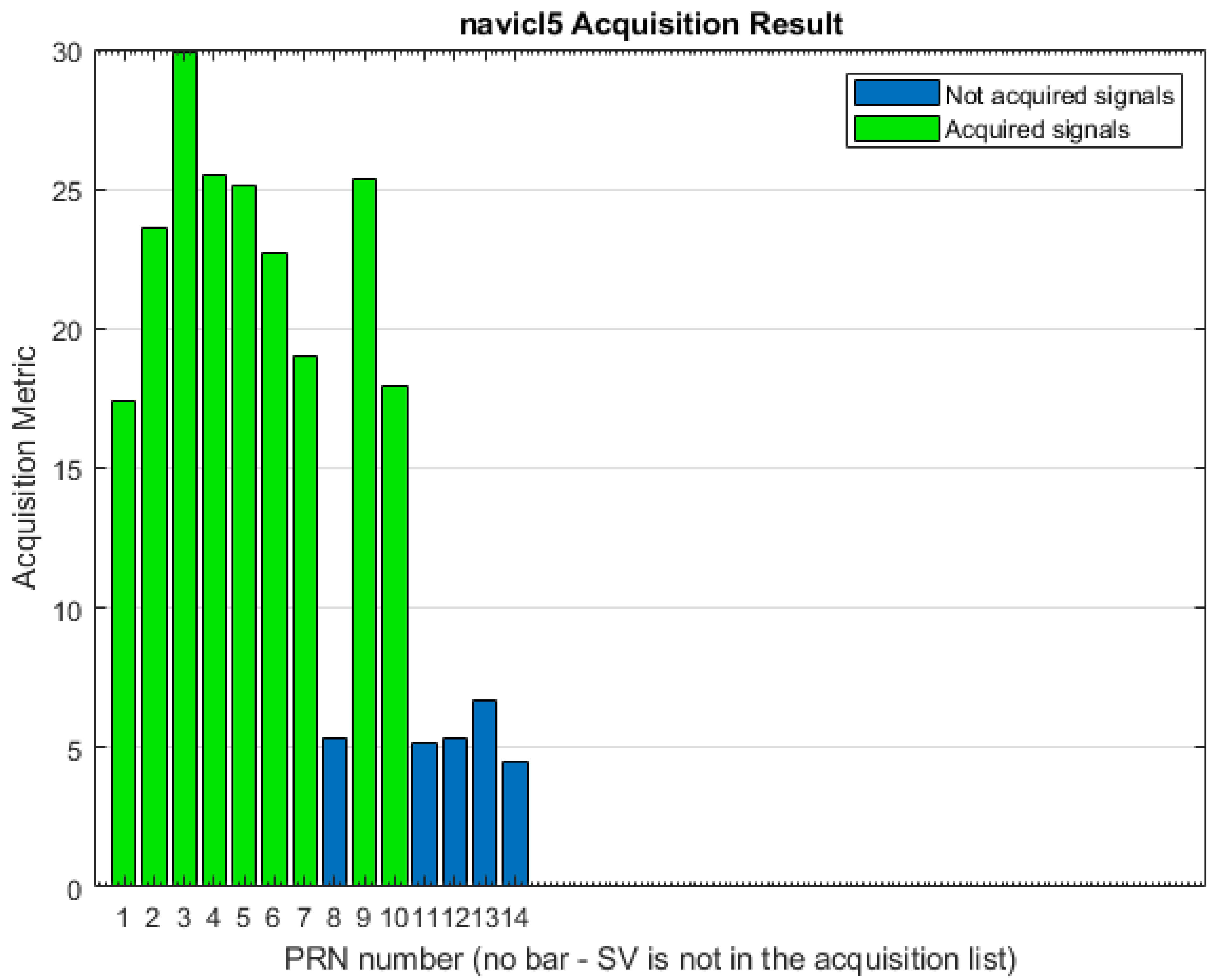
- **Host PC:** Windows 10, Intel Core i5 processor, 8GB RAM, serving as the central control and data processing unit.
- **FPGA Board:** Efinix Trion T120 for efficient real-time signal processing.
- **NT1066 RF IC:** Connected via an LVDS expansion card to ensure high-speed and reliable signal acquisition.



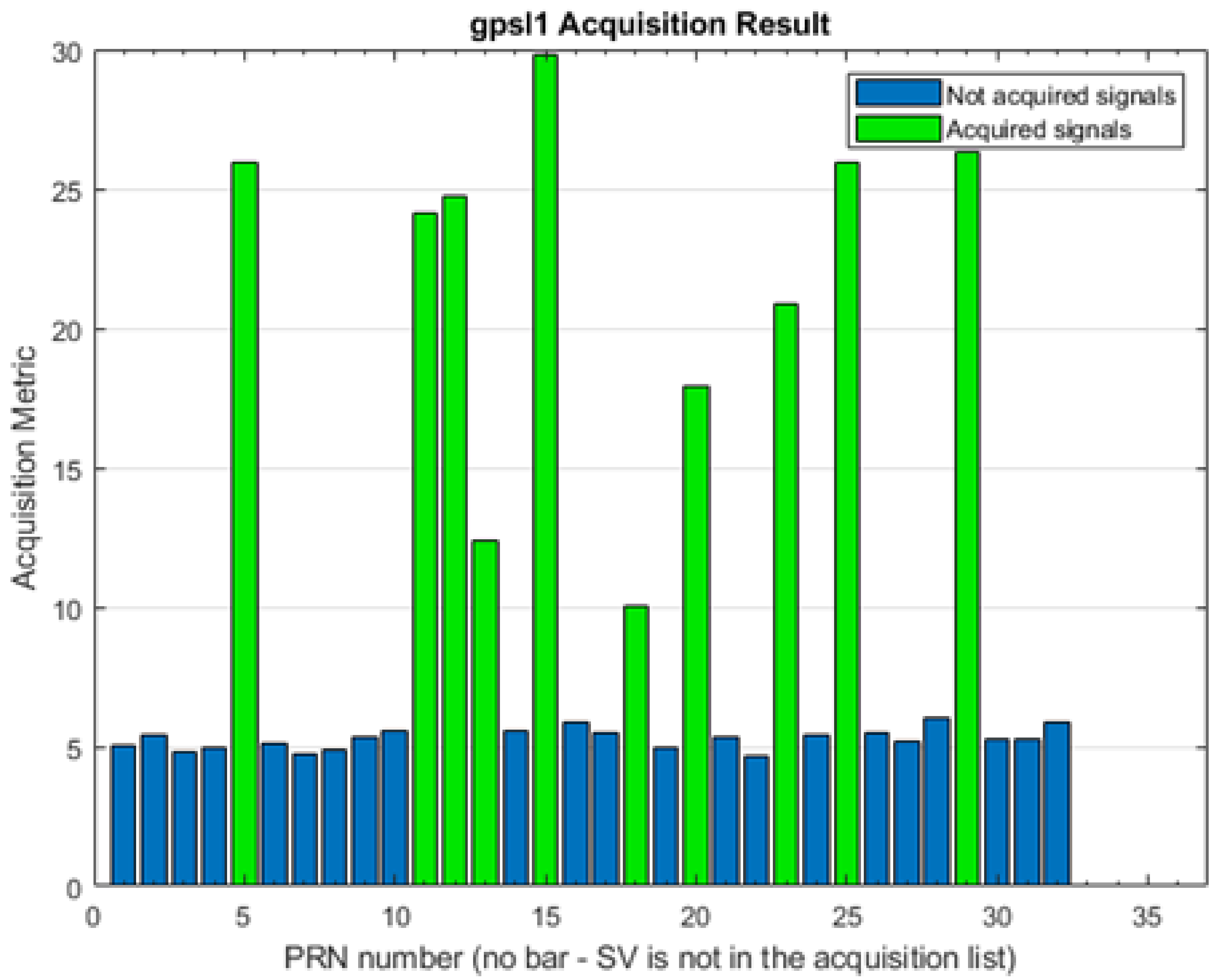
Integration

- USB interface establishes seamless communication between the host PC and FPGA board.
- All necessary drivers and processing modules are configured for smooth and efficient operation.

Results and Analysis
Signal Acquisition



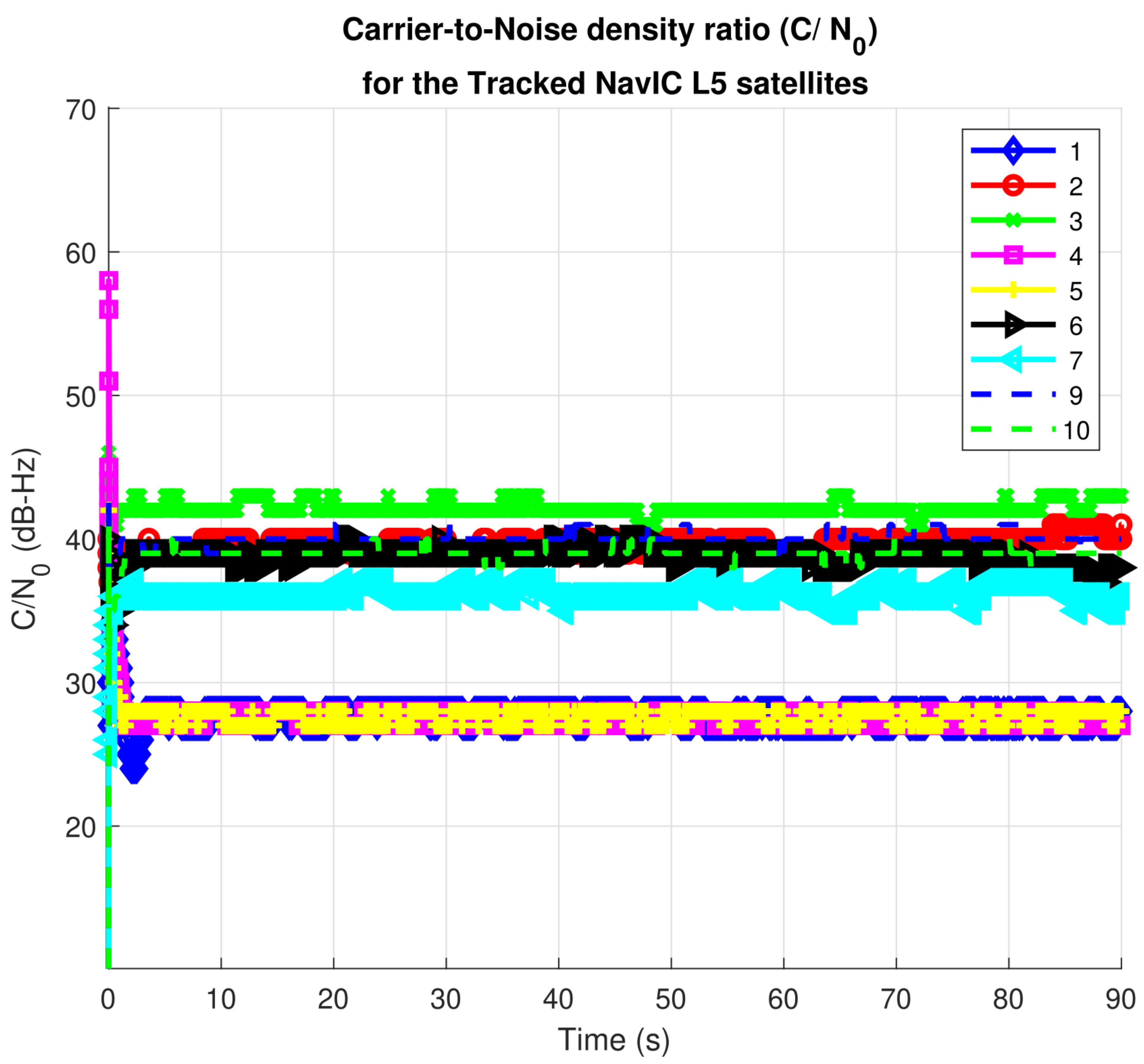
NavIC Acquisition Results



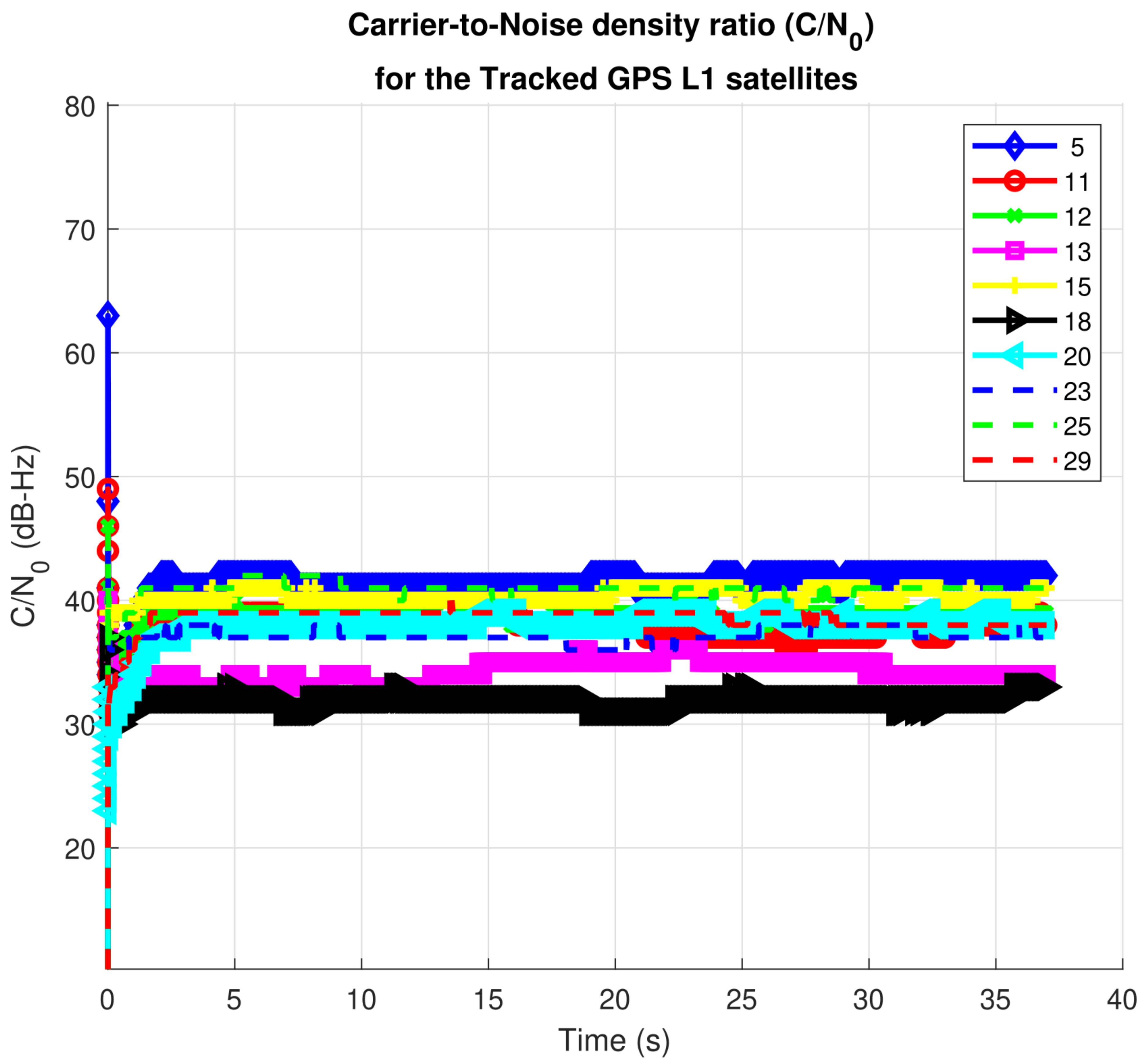
GPS Acquisition Results

Results and Analysis

Signal Quality (Tracking)



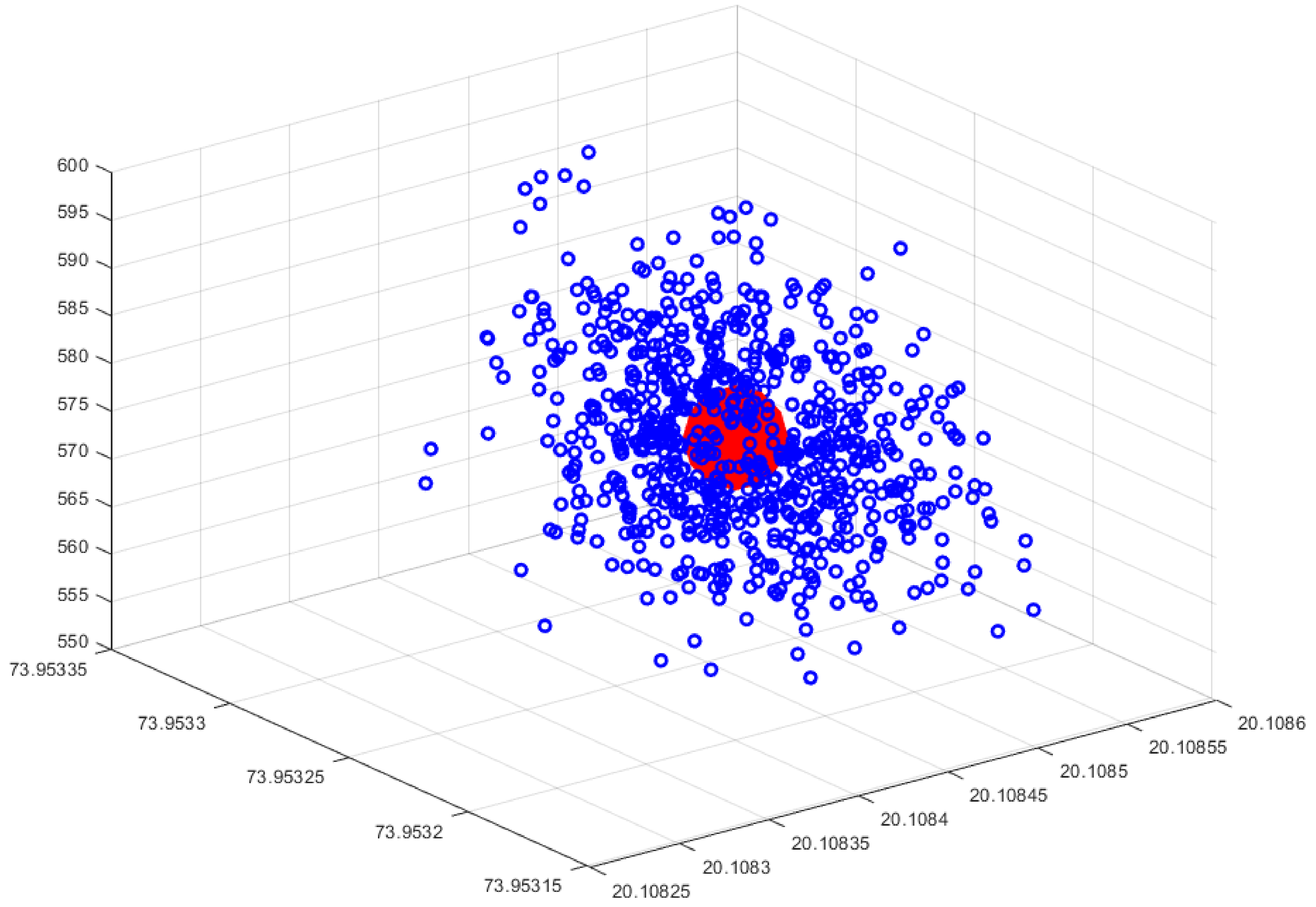
NavIC Carrier to noise density ratio



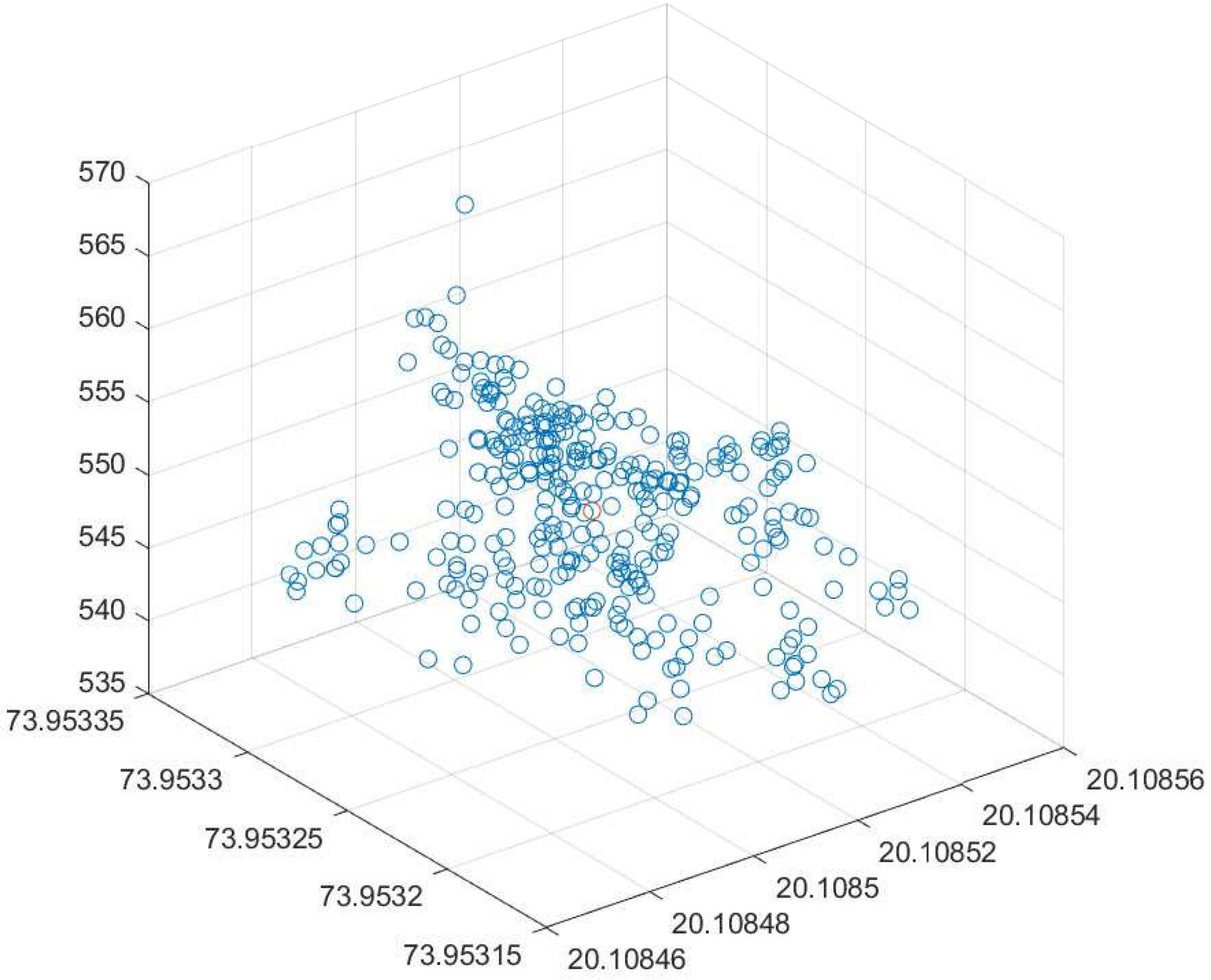
GPS Carrier to noise density ratio

Results and Analysis

Position Scatter Plots



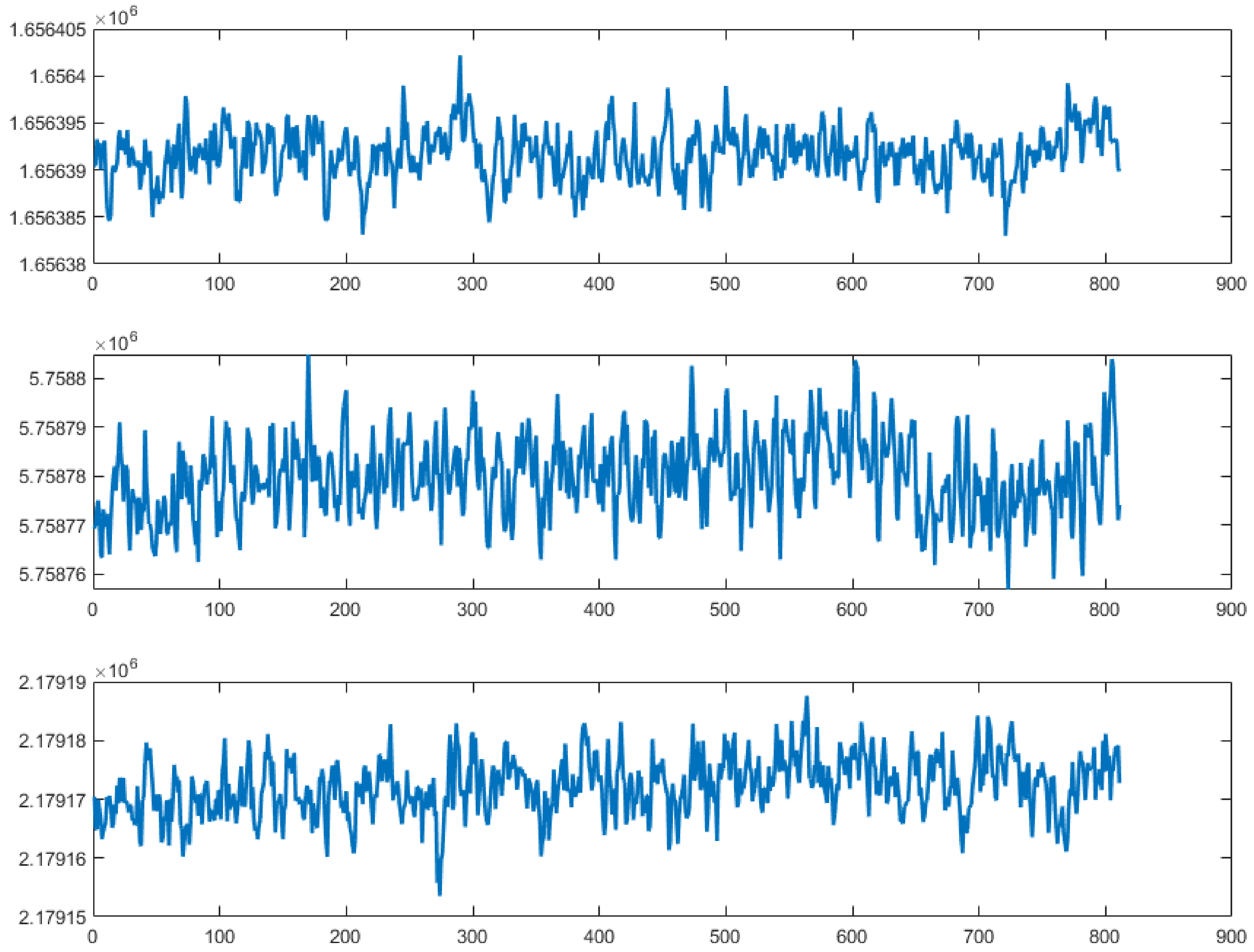
NavIC Latitude-Longitude-Altitude Scatter Plot



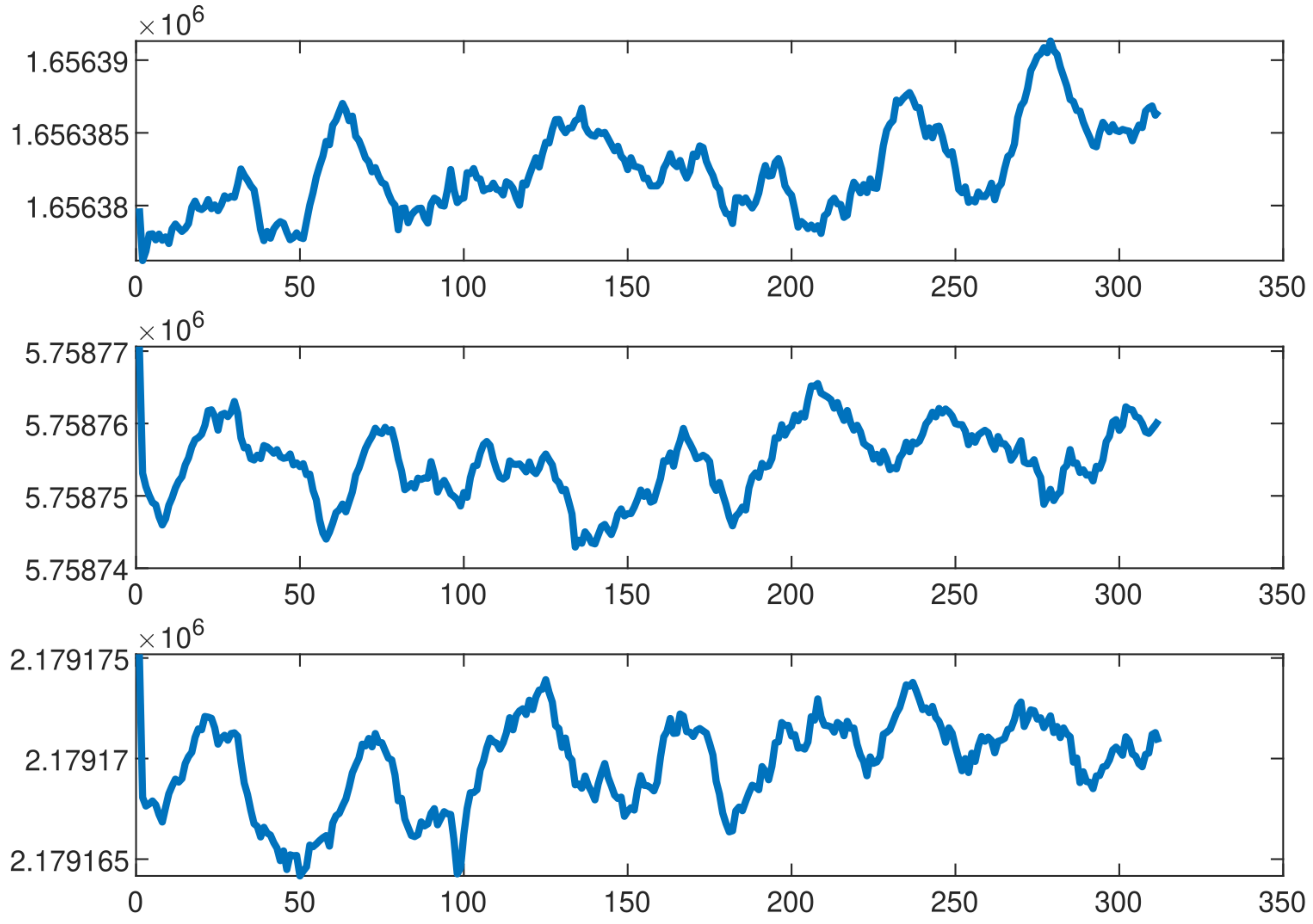
GPS Latitude-Longitude-Altitude Scatter Plot

Results and Analysis

WGS84 Plots



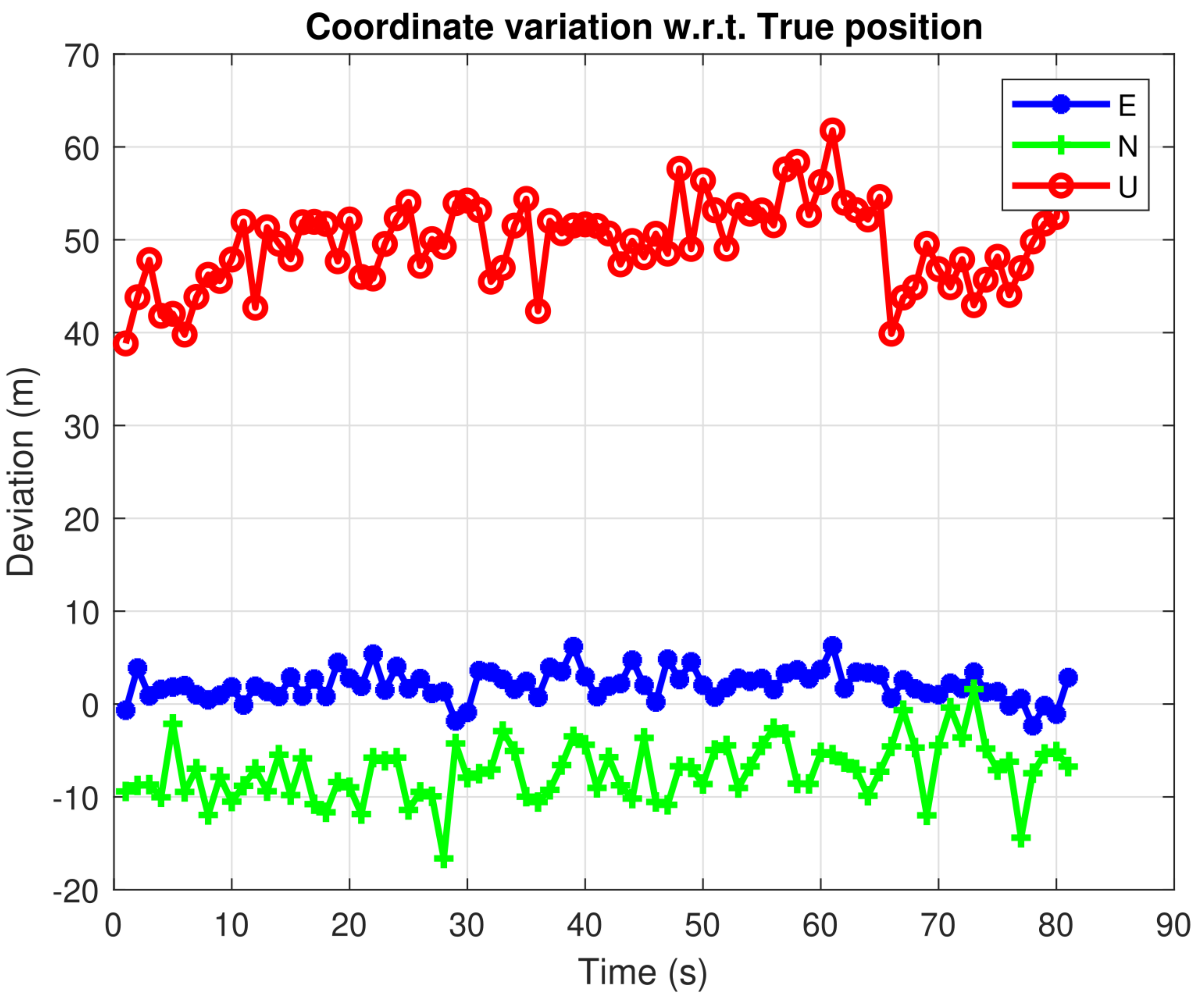
NavIC WGS84 X-Y-Z



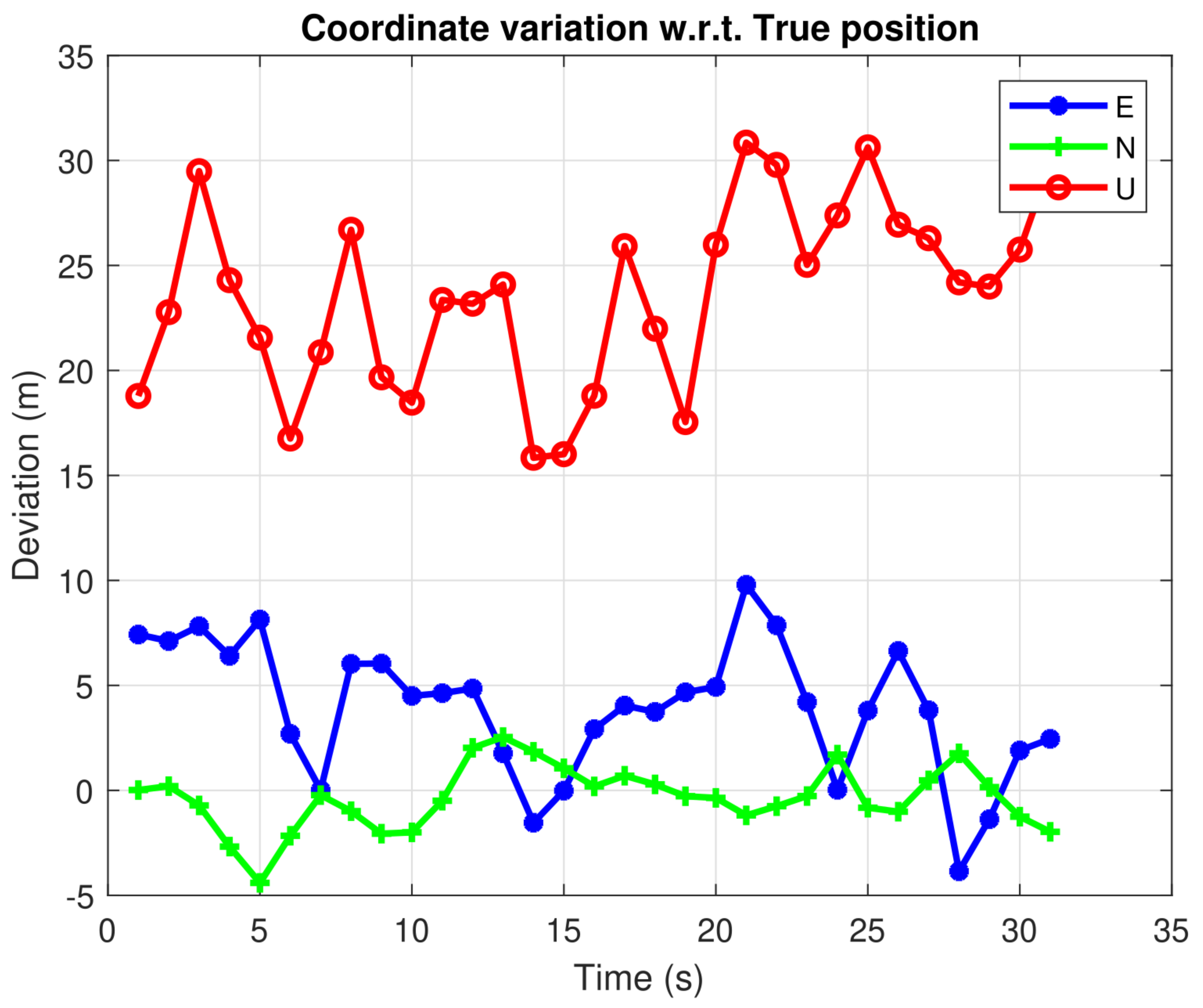
GPS WGS84 X-Y-Z

Results and Analysis

ENU Position Error Variation



NavIC ENU Position Error Variation



GPS ENU Position Error Variation

Results and Analysis

Performance Analysis

Performance measures	IRNSS	GPS
No. of Satellites	5	8
GDOP	4.11	2.15
HDOP	3.08	1.59
TDOP	2.16	0.99
VDOP	1.67	1.04
PDOP	3.50	1.90

Conclusion

- Presented a real-time SDR-based GNSS receiver for IRNSS/NavIC and GPS using RISC-V and Sapphire SoC.

- Demonstrated multi-constellation support for accurate and reliable navigation.

- Highlighted flexibility and upgradeability for GNSS applications, ensuring future-proof design.

Future Work

Hardware and Software Optimization

- Improve integration for enhanced system performance.
- Leverage complete IRNSS/NavIC broadcast data for better accuracy.

Precise Positioning

- Utilize atmospheric and dual-frequency corrections for refined navigation solutions.

Real-Time Performance

- Enhance speed and responsiveness for real-time applications.

Precise Positioning

- Expand compatibility to include additional GNSS constellations..

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