Multi-GNSS Receiver for Aerospace Navigation and Positioning Applications

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Introduction

Motivation

- Galileo and GPS modernization will soon provide new signals which will enable performance enhancements
- MBOC will provide a improvement in terms of precision and multipath robustness when compared with the current GPS L1 C/A and L2 C signals with a relatively low increase in receiver complexity

Objective

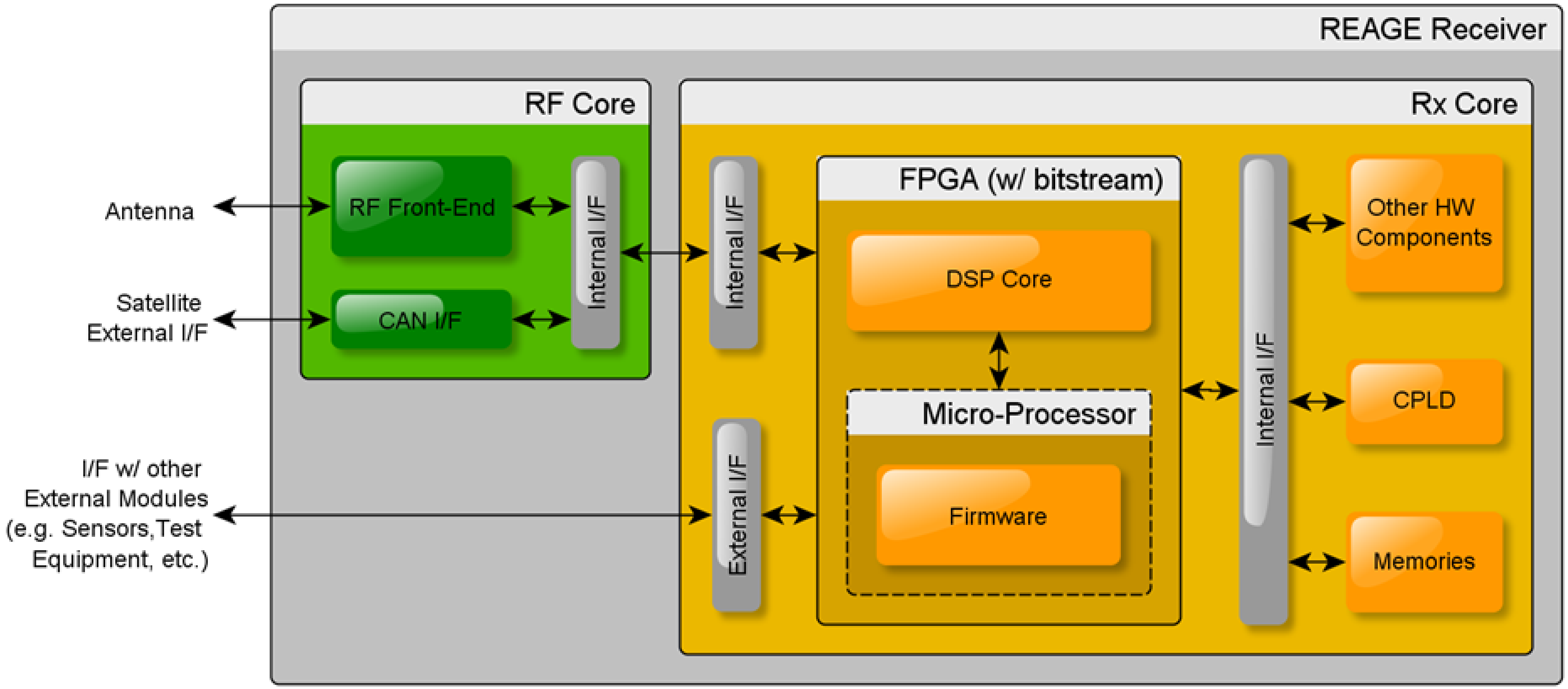
- **Development of a low-cost experimental Galileo and GPS receiver for the L1/E1 band**
  - Initially targeted for space missions as non-critical redundant sensor
  - Also applicable for terrestrial navigation and positioning applications (e.g. georeferencing and UAV navigation).
  - As flexible as possible to allow trade-off analysis of receiver parameters and performances.

(in the scope of the REAGE Project, in cooperation with ISEL)

REAGE Receiver Prototype

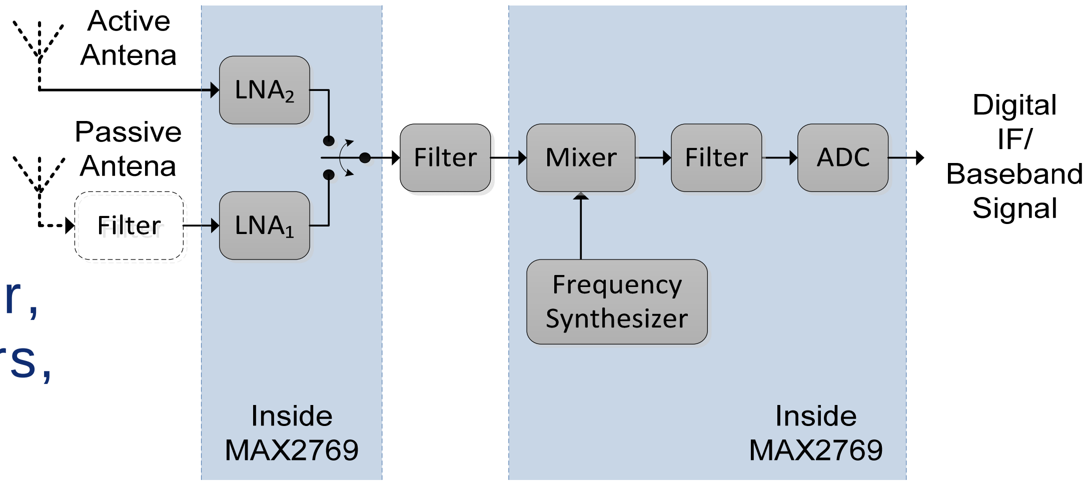
Receiver Architecture

- Two main modules: the **RF Core** and the **Rx Core**



RF Core (HW)

- RF signal conditioning, down-conversion, and sampling
  - Based on Maxim's MAX2769
  - Dual-input LNA, mixer, (programmable) filters, ADC, frequency synthesizer, and programmable gain amplifier.



RF Core (HW) [cont’d]

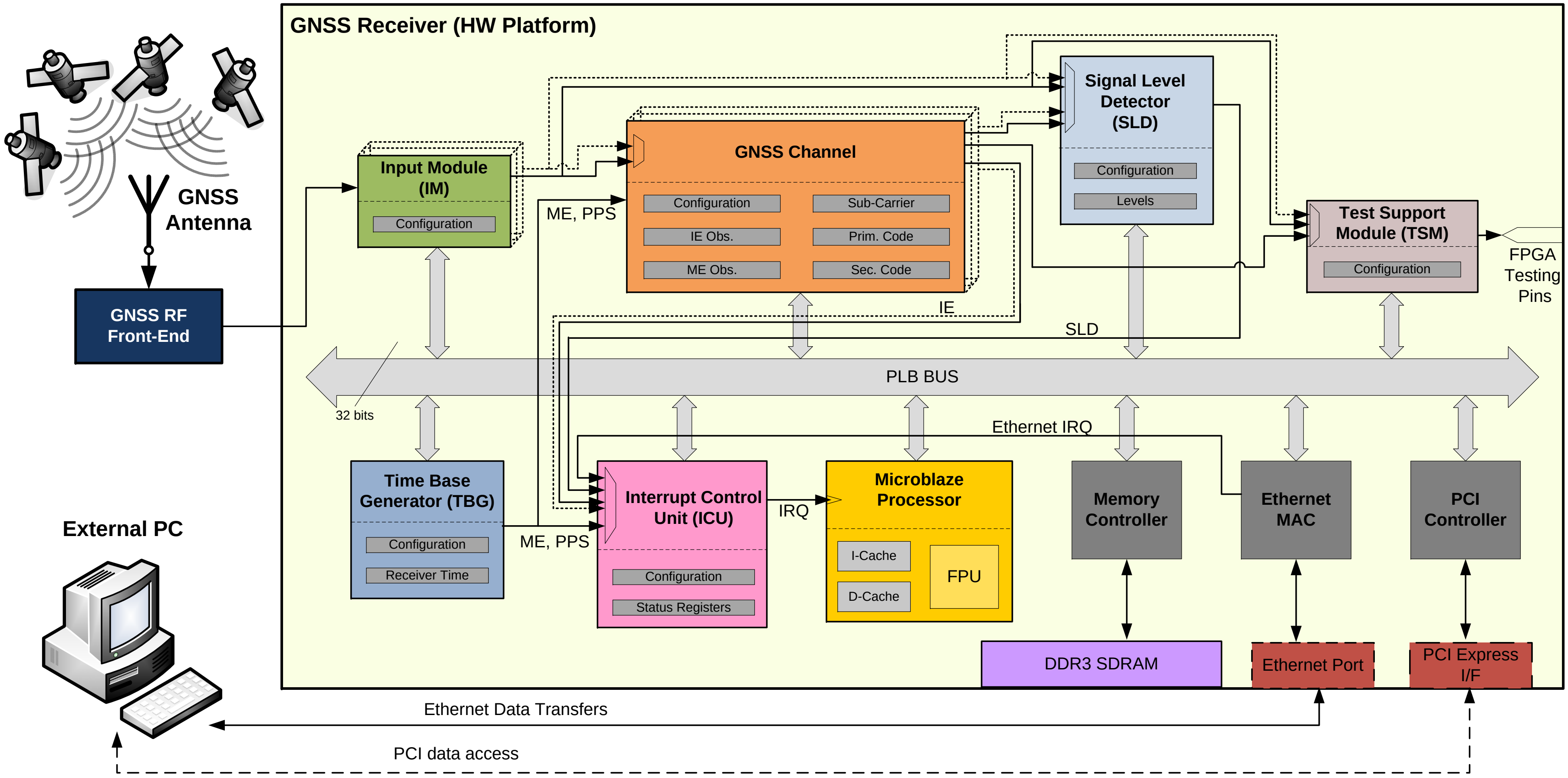
- Includes a CAN Bus I/F for communication with external system (e.g. a satellite)
- RF Core board

Rx Core (HW+FW)

- IF/BB signal processing, measurement generation, and PVT solution computation
- Main modules:
  - FPGA (programmable HW in which the DSP Core and processor were implemented)
  - (Redundant) memory modules (RAM, PROM)
  - A CPLD-based system controller (in charge of receiver reconfiguration and external communication via the CAN interface on the RF Core);
  - Different internal (RF Core) and external (CAN Bus, Ethernet, UART, FMC, PCIe, and GPIO pins) interfaces.

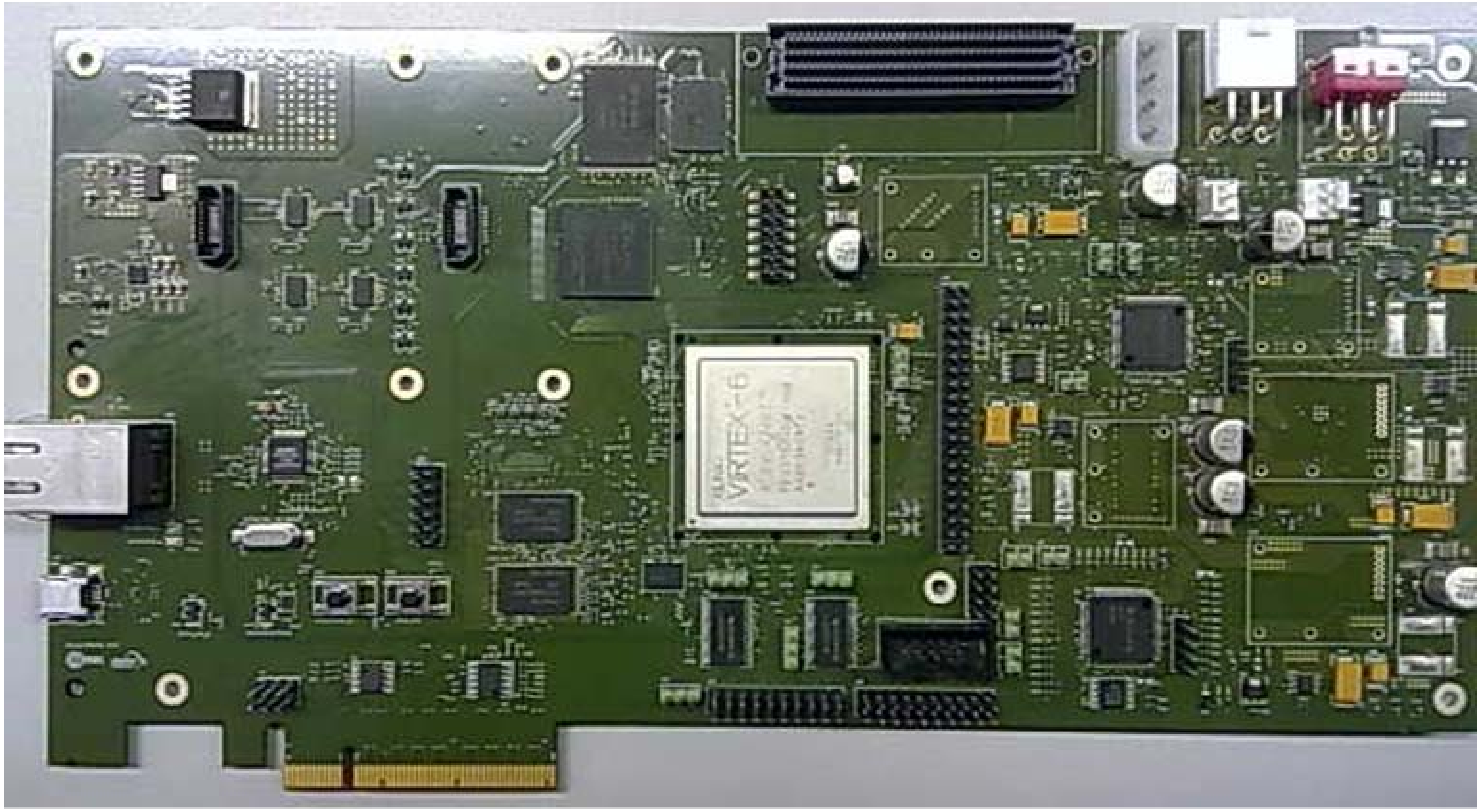
Rx Core (HW+FW) [cont'd]

- FPGA (Xilinx's Virtex-6)



Rx Core (HW+FW) [cont'd]

- Rx Core board

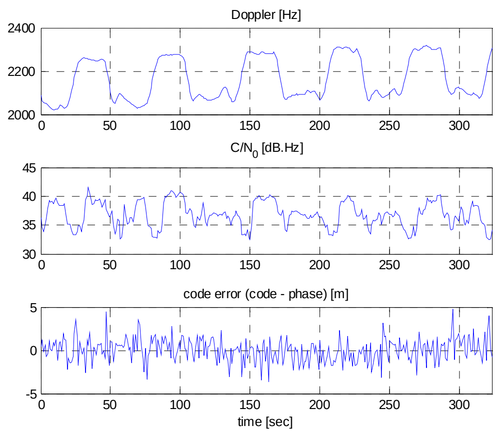


Supported Signals and Main Features

- Supports current and modernized GPS civil signals (C/A,C) and Galileo E1 Open Service signals (B,C)
- RF Core features:
  - Dual-input LNA (supporting active and passive antennas)
  - CAN Bus interface (for connection with satellite's OBC or other external systems)

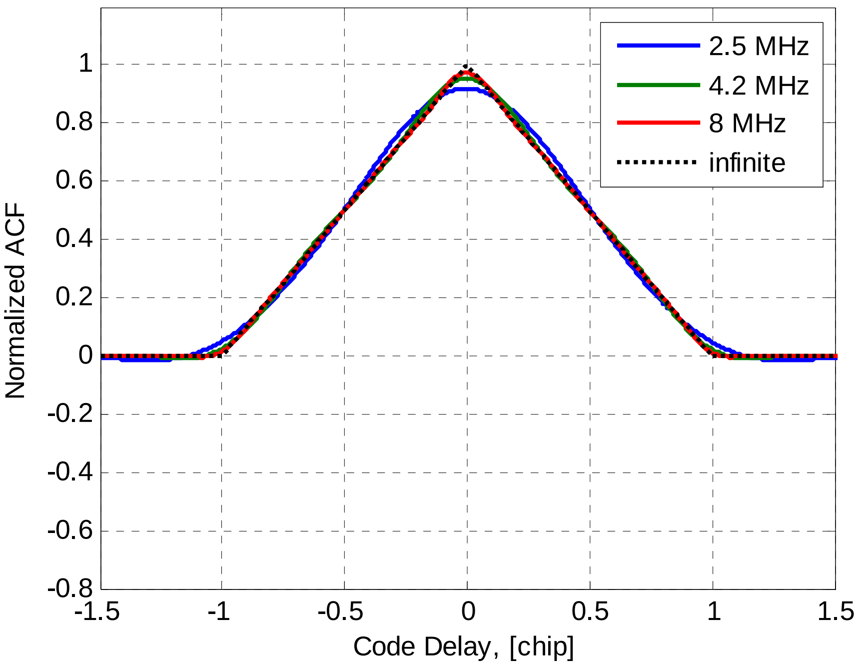
Supported Signals and Main Features [cont'd]

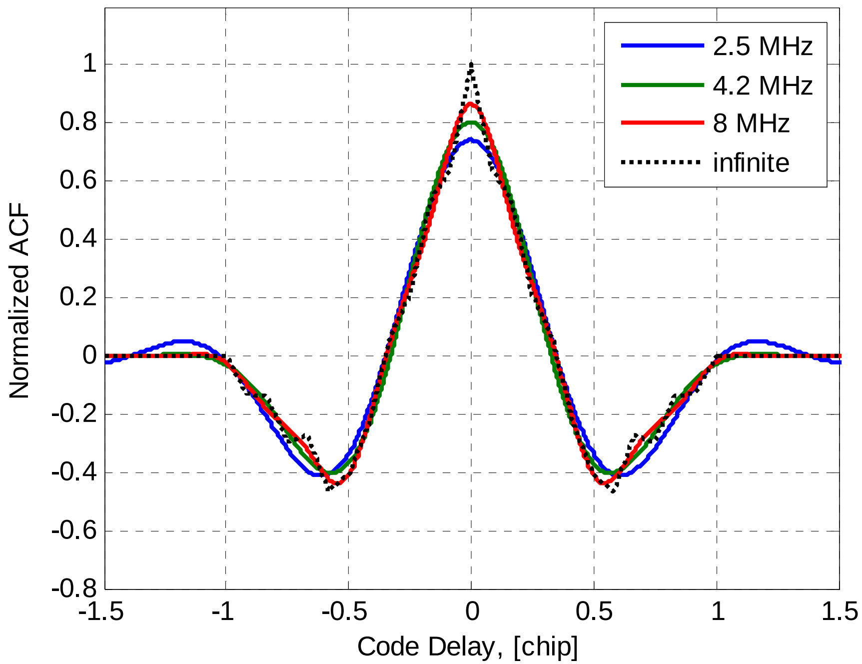
- RX Core features:
  - Input module with (up to) 4-bit inputs and programmable digital filters
  - 16 Independent and slavable HW channels w/ code and carrier NCOs, mixers, primary and secondary code generators and 5 complex correlators each, for a total of 80 complex correlators;
  - Embedded microprocessor (in charge of overall receiver control and navigation solution computation);
  - Simultaneous tracking of both pilot and data channels.
  - Redundancy for some critical components and the ability of self-programming
  - Additional external interfaces (as Ethernet and GPIO)



Test Results

GPS L1 C/A and Galileo E1 B (~L1 C_D) ACFs

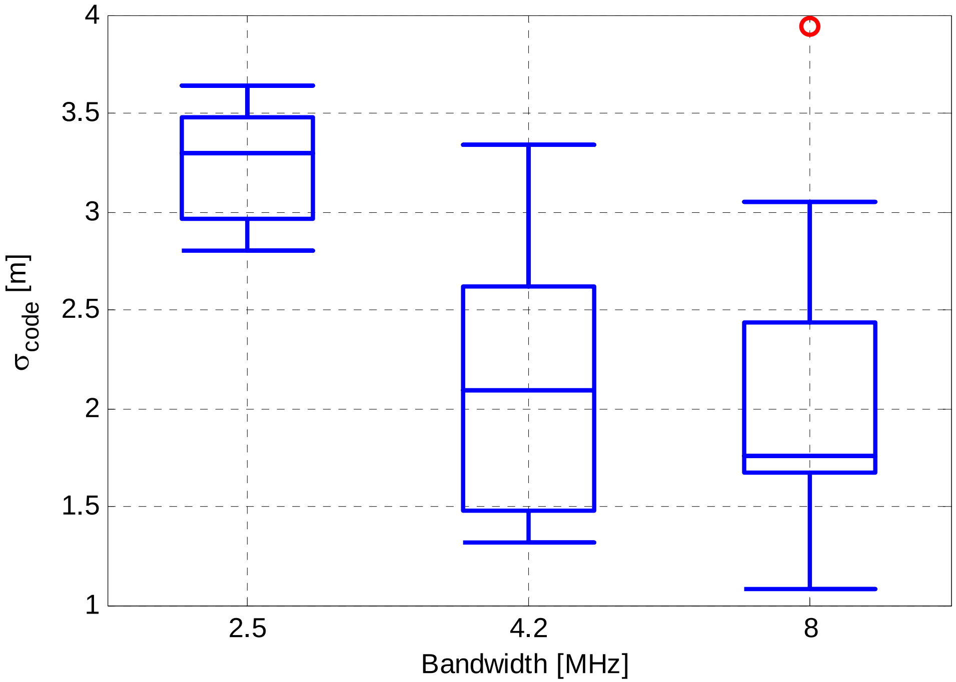




- E1 steeper ACFs boost tracking performance
- Higher bandwidths are required to take advantage of this characteristic

Code Tracking Performance

- Laboratory test results confirm benefit of higher BW for GPS L1 C/A



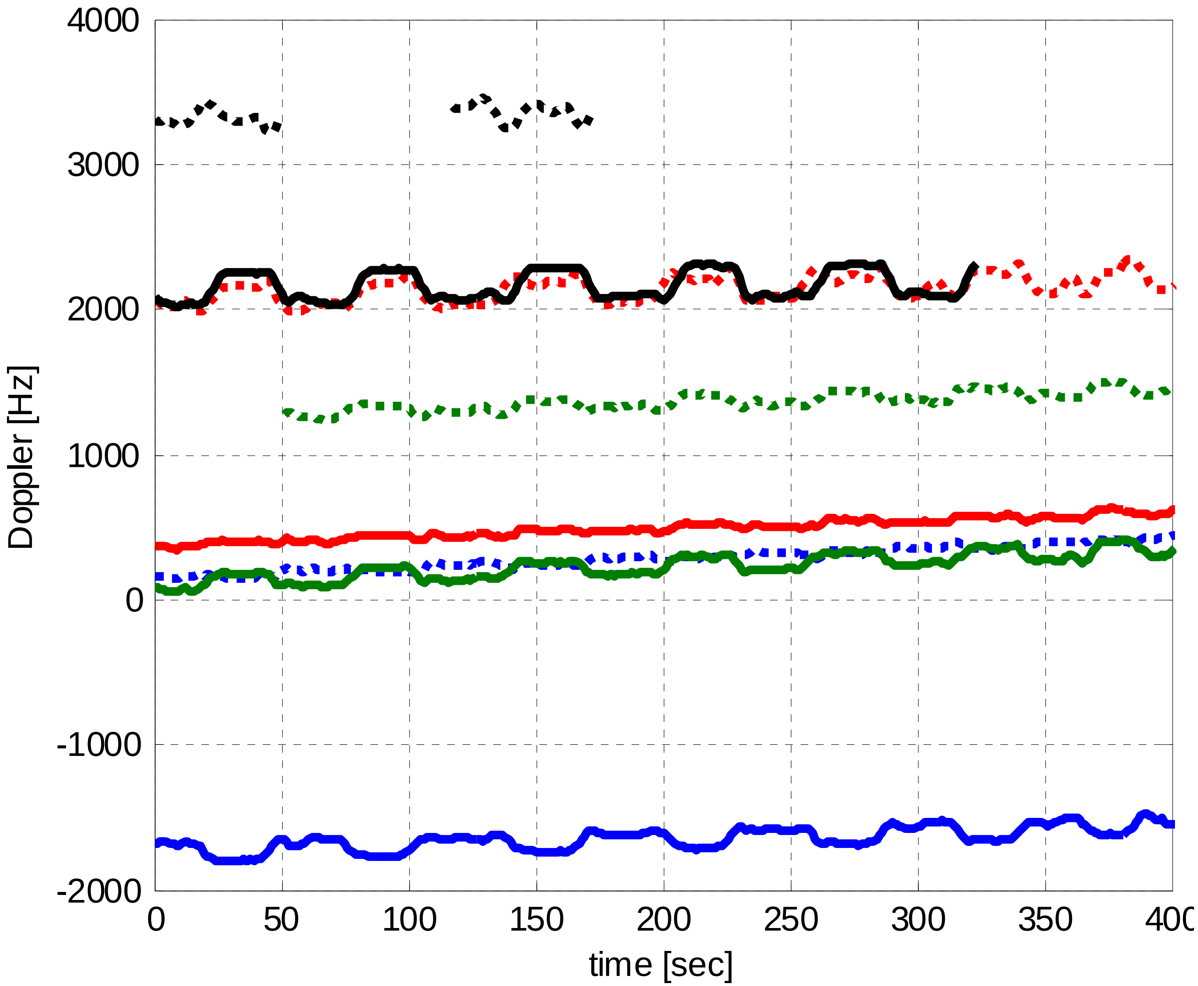
- Effect shoud be even more visible for Galileo E1 due to the higher bandwidth of this signal

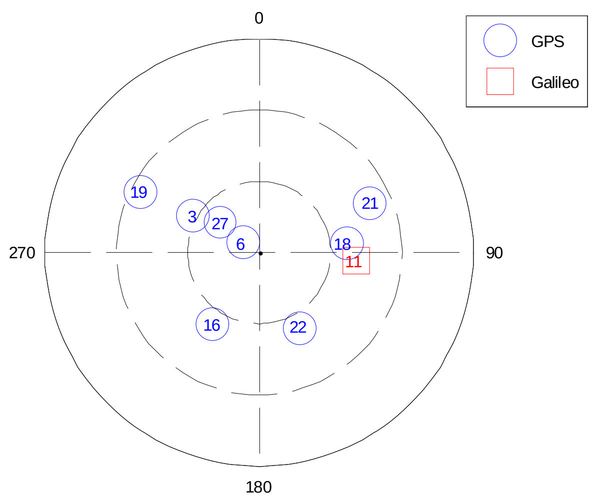
Flight Trials

- Flight trials with Portuguese Airforce's *Alfa Extended* UAV at GATE facility (Galileo test range)

Flight Trials [cont'd]

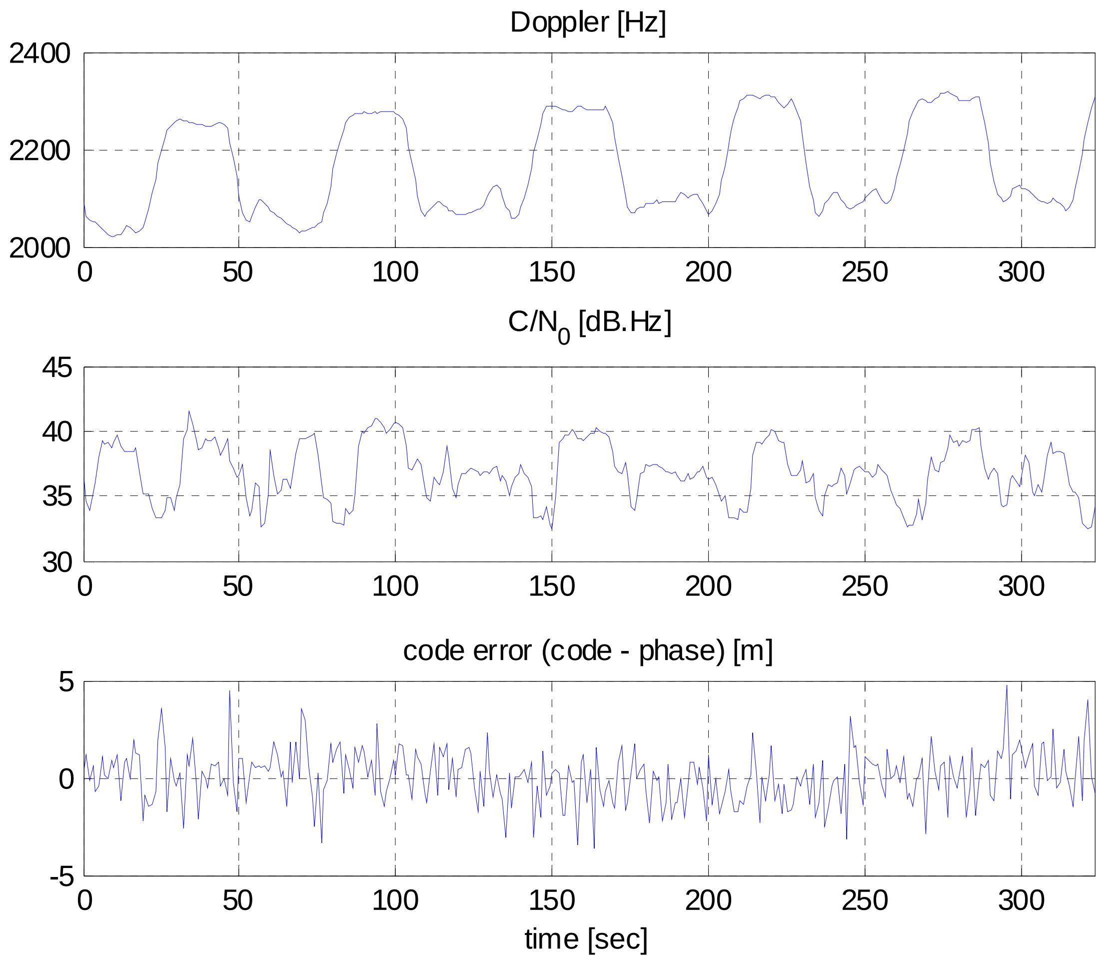
- Estimated Doppler





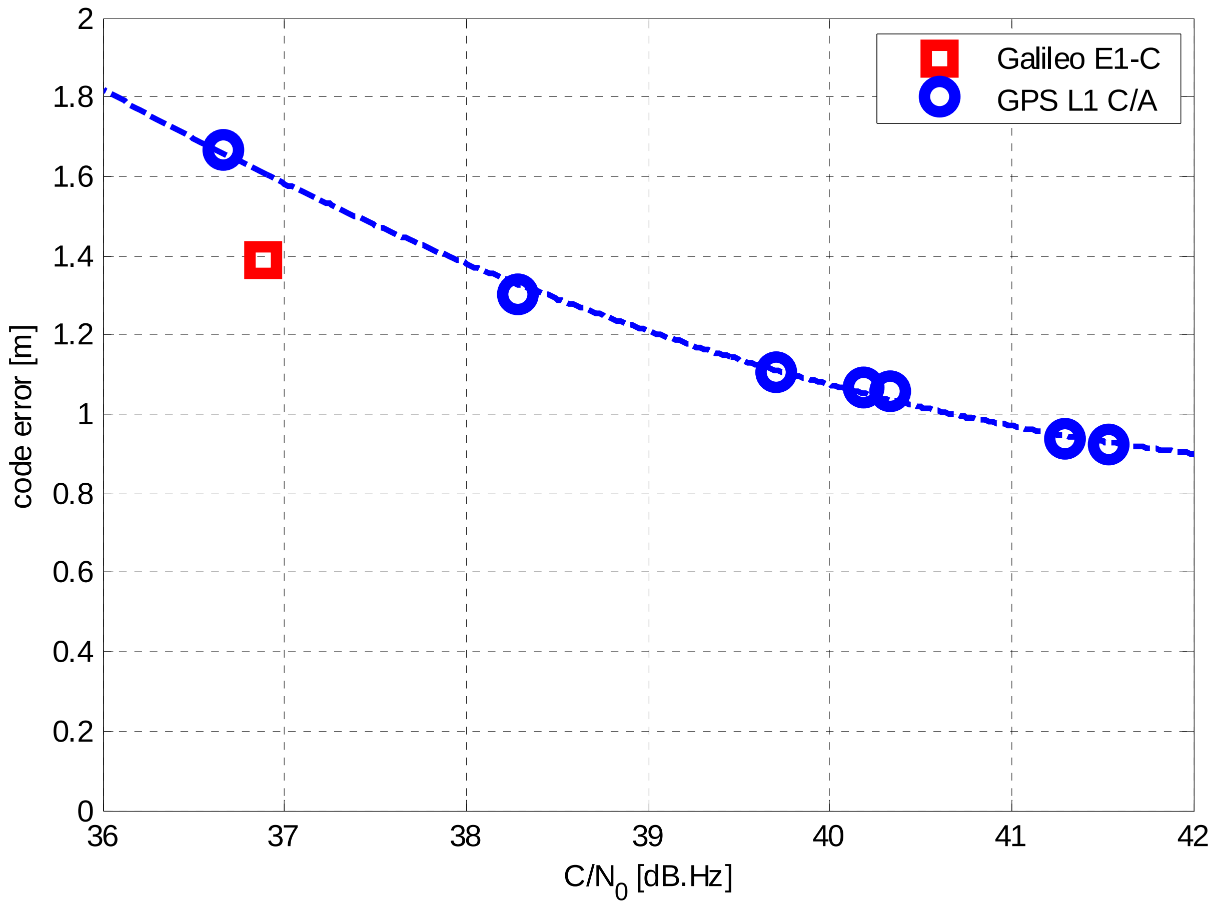
Flight Trials [cont'd]

- Galileo E1 tracking performance results



Flight Trials [cont'd]

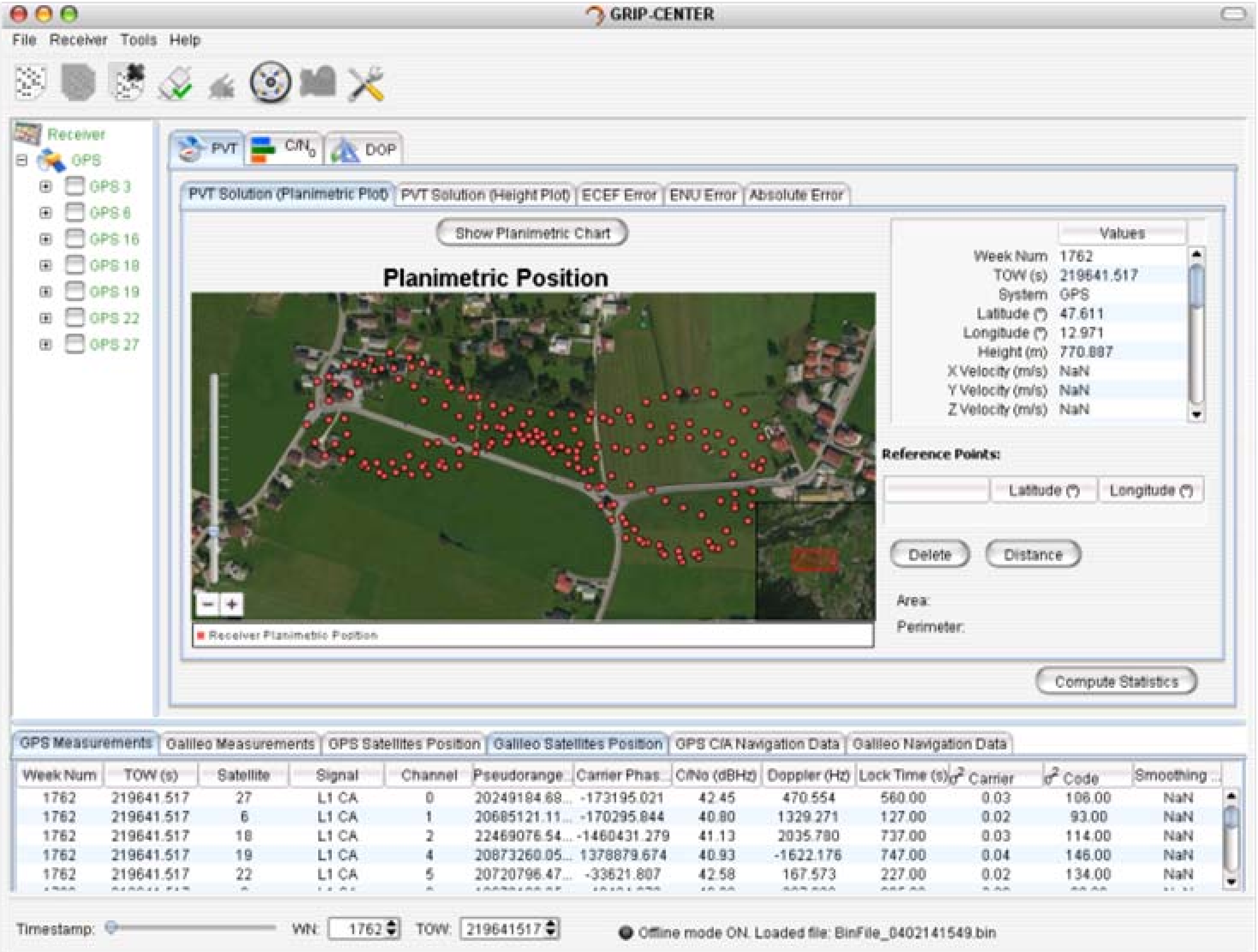
- Code Error vs. C/N_0 for GPS L1 and Galileo E1



Flight Trials [cont'd]

- As expected, the higher the C/N_0, the lower the code error.
- Code error for Galileo E1
  - Lower than for GPS L1 C/A signals (for similar elevation angles and C/N_0) but...
  - Not as low as expected, possibly due to
    - *The low pre-correlation bandwidth (4 MHz), which does not enable the full potential E1 signals;*
    - *Sub-optimal receiver parameters due to last minute modifications (larger PLL bandwidth, use of a 2nd order DLL, and different correlator spacing)*

Flight Trials [cont'd]



Conclusions

Conclusions

- DEIMOS and ISEL developed a **low-cost experimental GNSS receiver for L1/E1 signals**
  - Targeted for use as a non-critical redundant sensor for space missions
  - Also applicable to terrestrial applications

- **Field test campaign** (including the processing of GPS L1 C/A and Galileo E1 signals in static and airborne scenarios) **produced promising results**
  - Although indicating that further tuning is required for Galileo E1 signal processing (to be done in future activities)

ACKNOWLEDGMENTS

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Questions?

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Thank you for your attention