Benefits of GNSS software receivers for scientific applications

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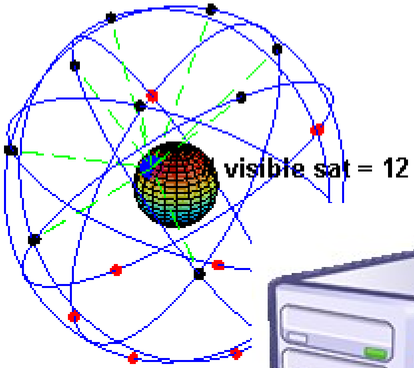
Outline

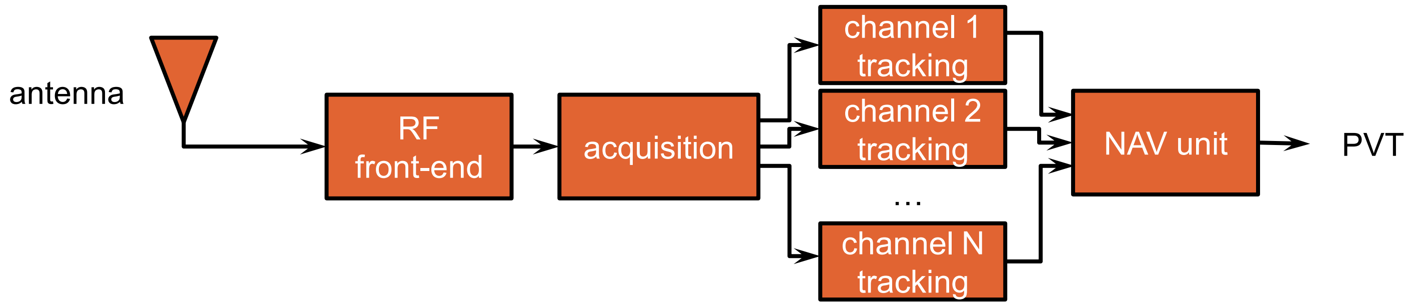
- The concept of software receivers
- An example: N-GENE GNSS software receiver
  - Advantages
  - Case studies
- Scientific applications of GNSS software receivers
  - Remote sensing and reflectometry
  - Ionospheric scintillation monitoring
    - Vietnam
    - Antarctica

Navigation satellite systems and software receivers



GNSS receivers

- GNSSs are communication systems
- Each GNSS receiver is a suboptimal implementation of a maximum likelihood estimator of the **propagation delay** of the signal
- It exploits GNSS signals characteristics:
  - CDMA code delay
  - Carrier Doppler frequency



- Traditionally **hardware** receivers

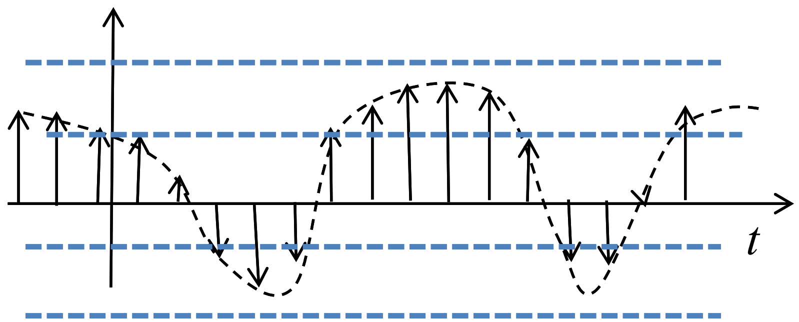
Software Defined Radio (SDR) receivers

- Ensemble of hardware and software technologies enabling reconfigurable communication architectures
- First theoretical concept: 1984
- Growing attractiveness in R&D sectors:

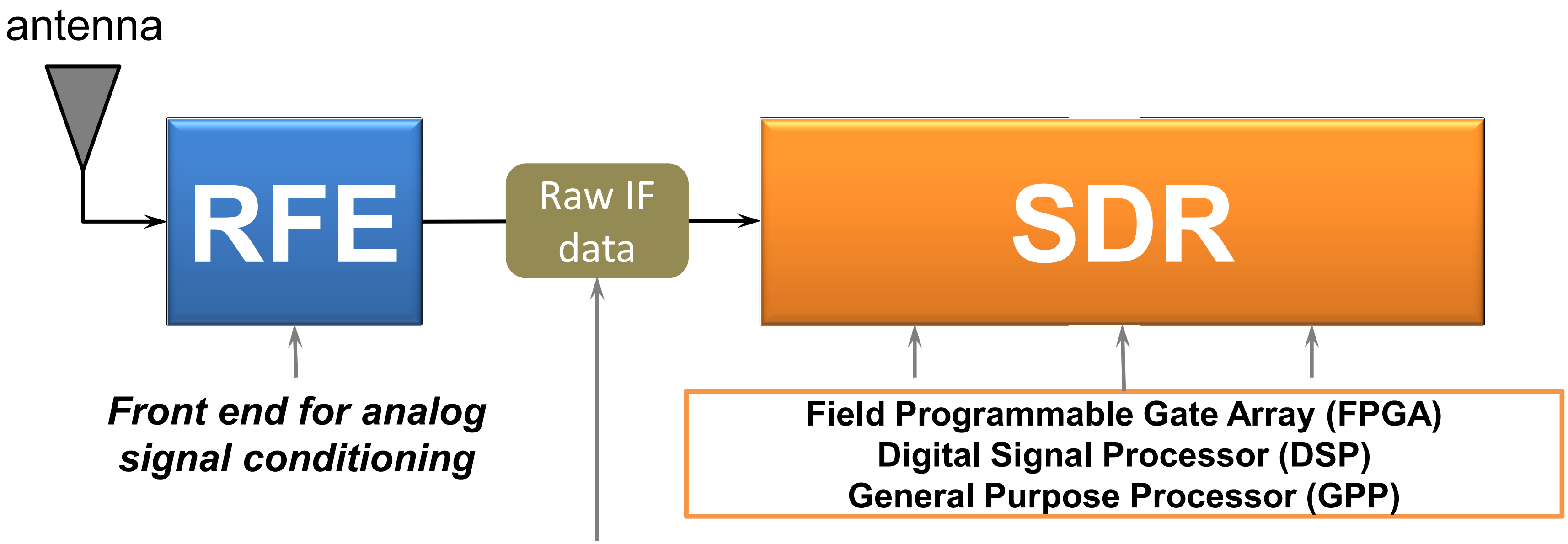
SDR	Hardware
Lower development costs	More efficient
Shorter development time	High volume markers
Easier maintainability	Strict size and power requirements
Upgradability, flexibility, re-configurability potentialities	

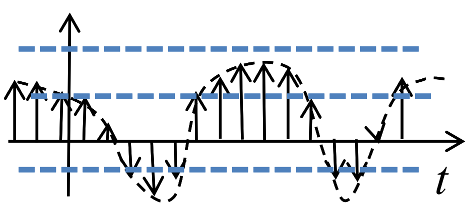
SDR and GNSS

- SDR has naturally entered the field of navigation receivers
  - GNSS popularity
  - GNSS signals characteristics
    - Small bandwidth
    - Receiver only system
    - Low data rates
  - Possibilities offered by digital domain analysis



Architecture





GBs of data!

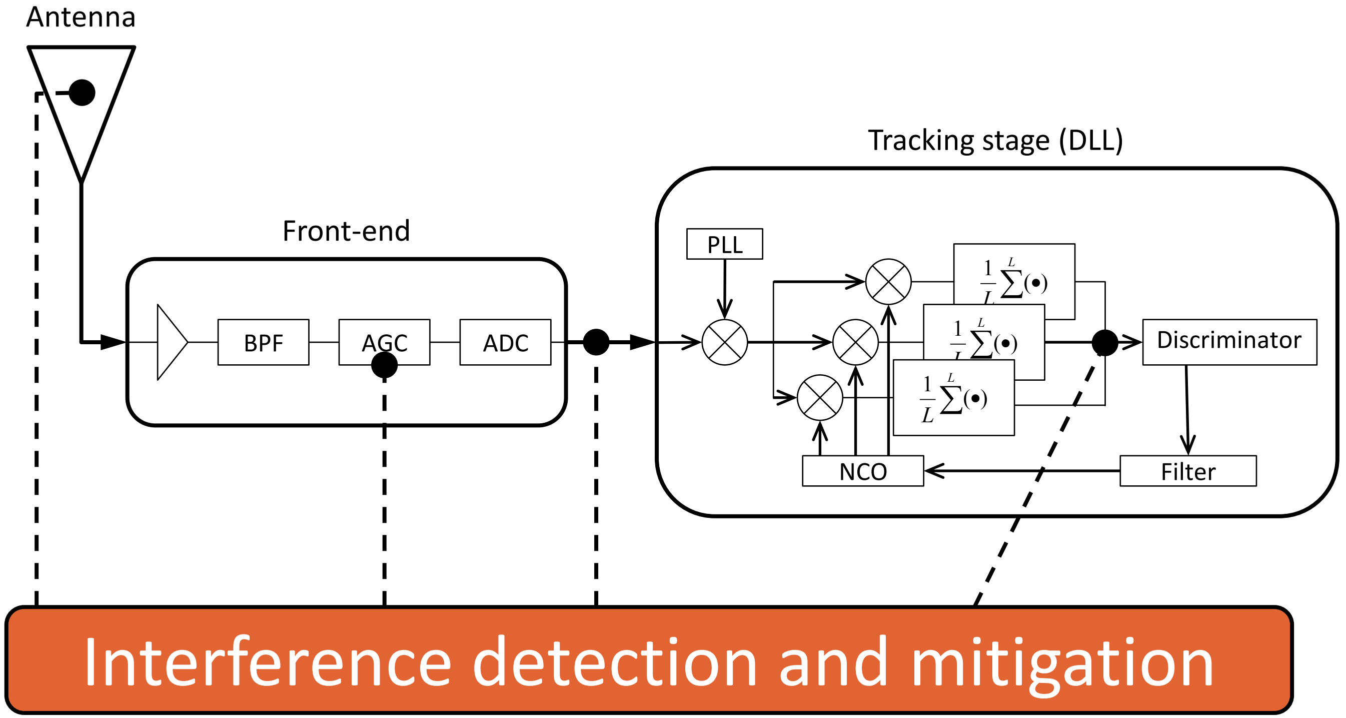
- Down-converted at IF
- Analog to digital converted (ADC)
- Sampled at a certain f_s
- Quantized
- Stored in memory as binary file

1. **Classic:** FPGA + DSP + PC
2. **Fully software:** GPP

SDR and GNSS

ACCESSIBILITY	CONFIGURABILITY	MODULARITY

- Low level processing stages, unconventional outputs



SDR and GNSS

ACCESSIBILITY	CONFIGURABILITY	MODULARITY

- Galileo first acquisition and tracking
- Galileo-only first PVT
- Galileo 5 and 6


Contact!

First Acquisition and Tracking

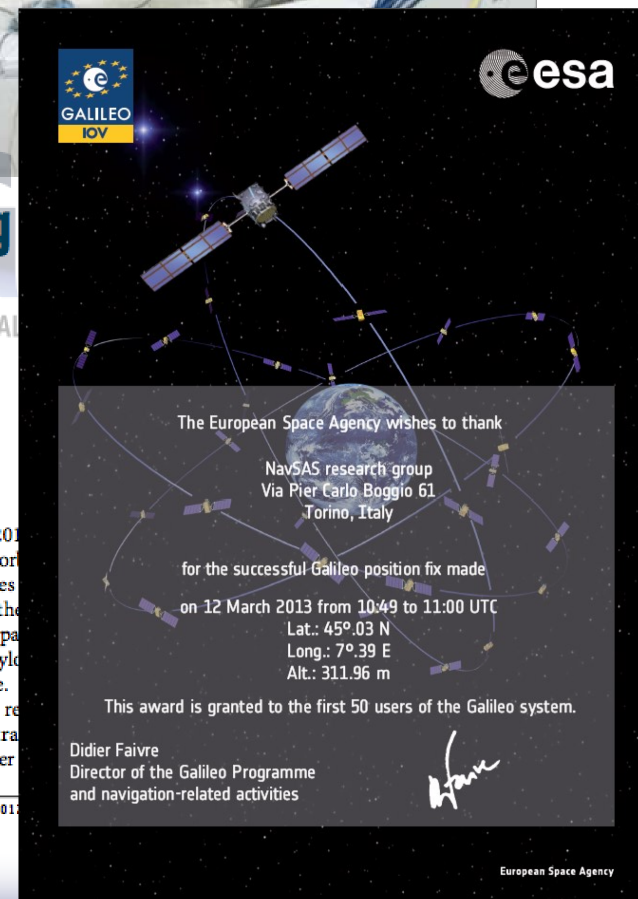
Europe's GNSS program – Galileo – entered a new phase of development with the recent launch of two in-orbit validation satellites, which comprise the first elements of the system's fully operational constellation. In this article, a team of Italian researchers present the initial results of their analysis of the Galileo signals.

NAVIGATION, SIGNAL ANALYSIS AND SIMULATION (NAVSAS) GROUP
POLITECNICO DI TORINO/ISTITUTO SUPERIORE MARIO BOELLA

On December 12, 201 the two Galileo in-or tion (IOV) satellites on October 21 — the ProtoFlight Model (PFM) spa started transmitting its paylo on the E1 band over Europe.

That same day NavSAS re were able to acquire and tra signal (Galileo Code Number

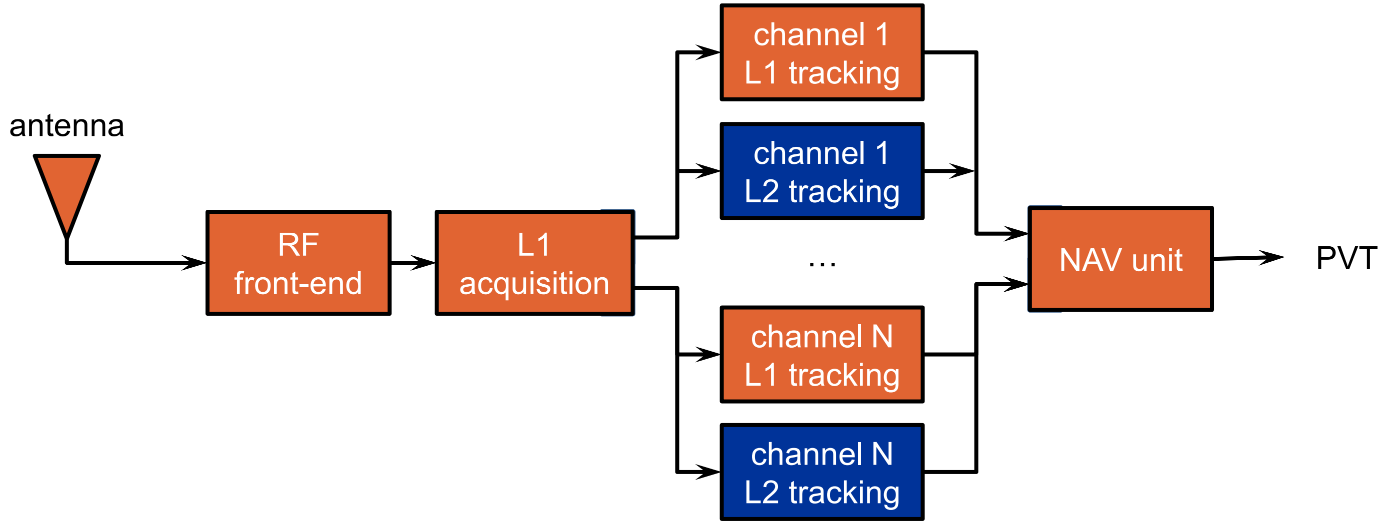
46 InsideGNSS JANUARY/FEBRUARY 201



SDR and GNSS

ACCESSIBILITY	CONFIGURABILITY	MODULARITY

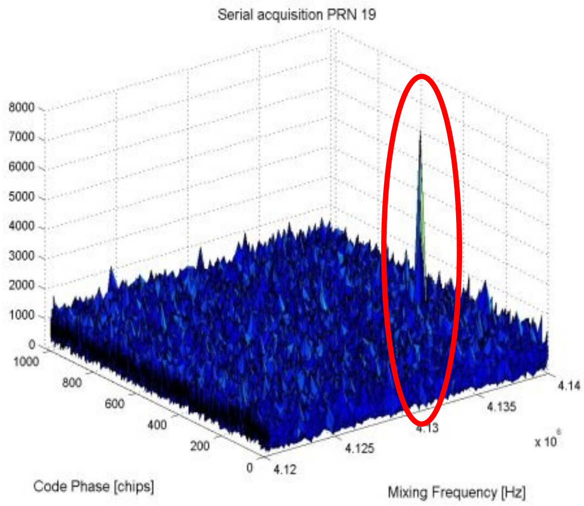
- Block structure: possibility to add new techniques
  - P(Y) codeless tracking
  - **Multiconstellation**

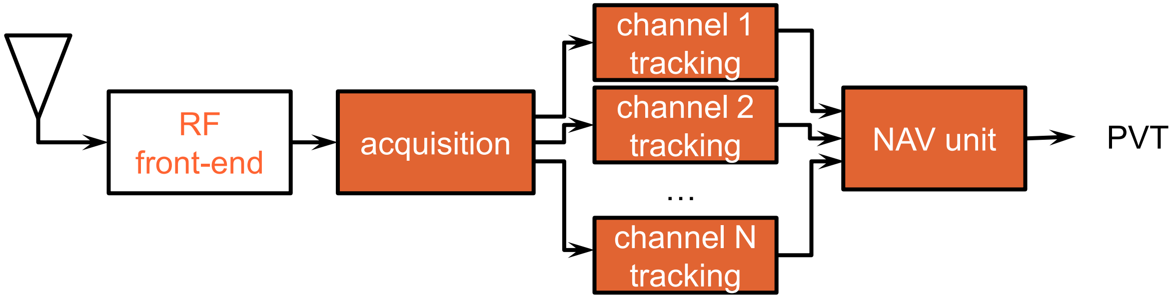


N-GENE

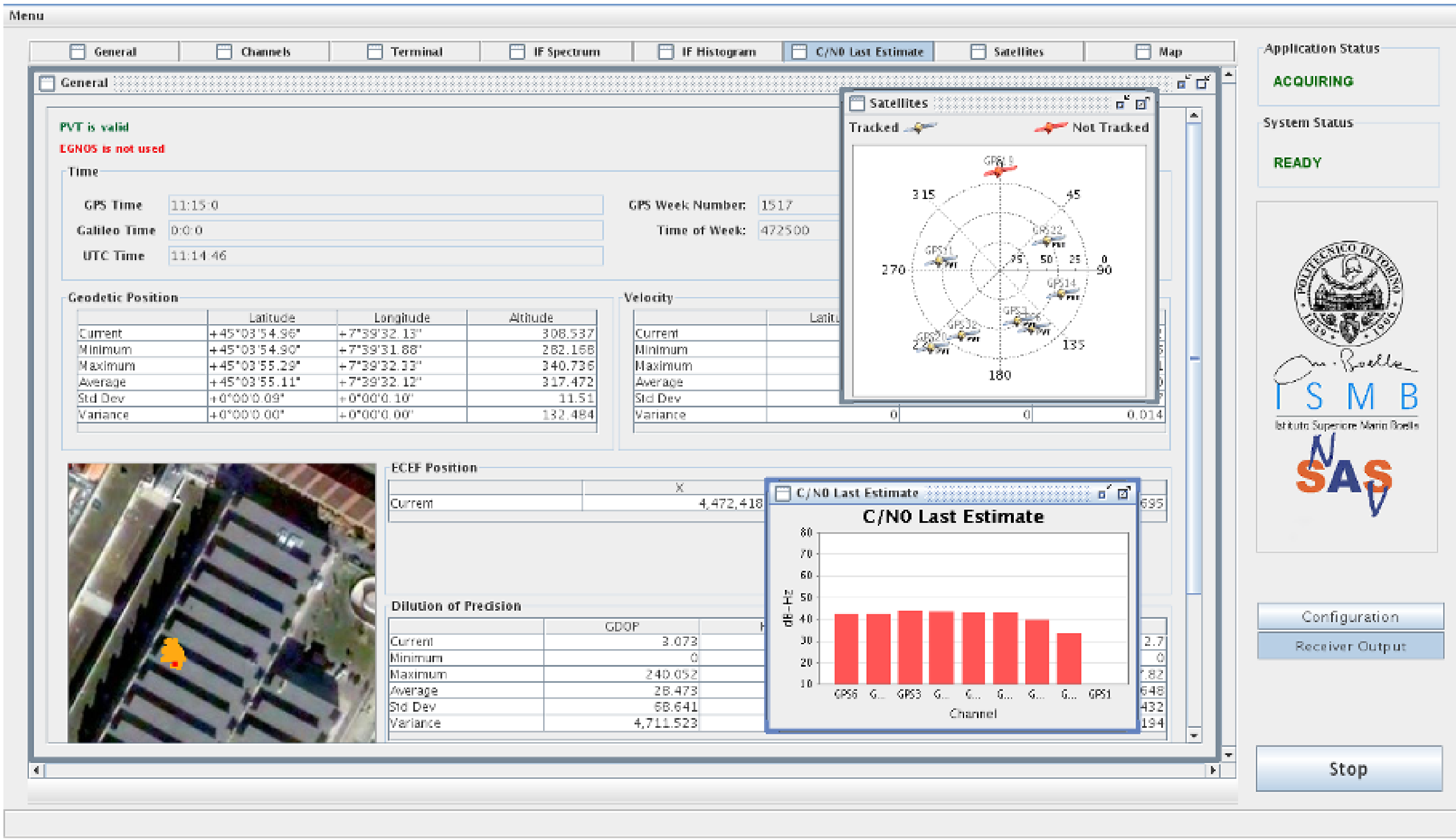
N-GENE fully software receiver

- Real time
- GPS L1 C/A, Galileo E1 OS, EGNOS
- Code measurements + carrier smoothing
- Standard PC Intel x86 processor, with Linux OS
- Process the output of a RFE through USB

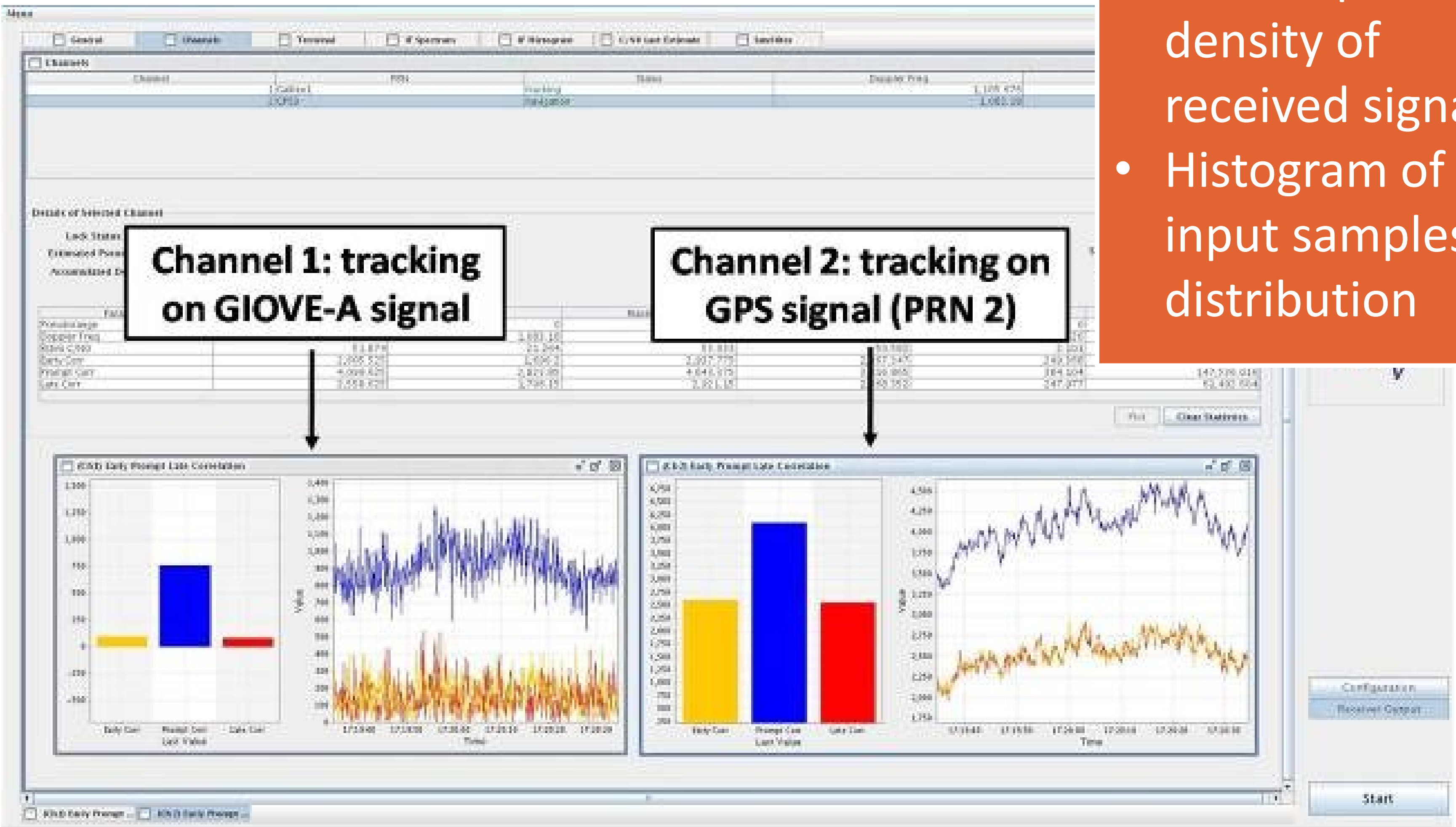




Navigation display output



Unconventional outputs

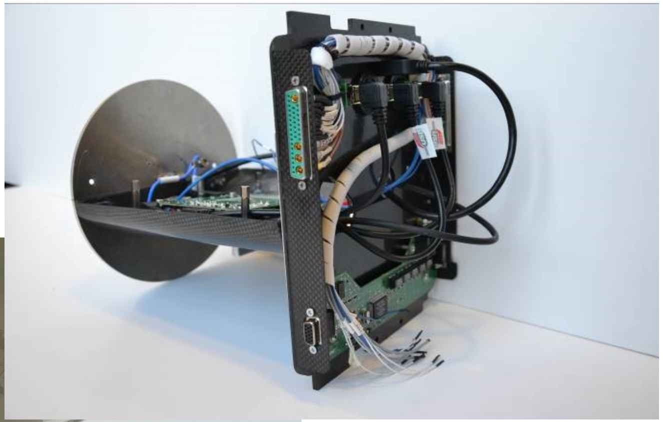


- Power spectral density of received signal
- Histogram of input samples distribution

Real time and post-processing

- Real time processing of GNSS data from antenna
  - Requirements on sampling frequency
- Post-processing of stored raw samples
    - Repeatability, comparison
    - Useful for testing and prototyping
    - Working tool

Scientific applications: remote sensing and reflectometry



Remote sensing and reflectometry

- Earth surface monitoring
- **Ocean** remote sensing:
  - sea-water monitoring (altimetry, wind detection)
  - sea-ice monitoring (topography and thickness)
- **Land** remote sensing:
  - water bacins detection
  - soil moisture measurements
  - snow monitoring

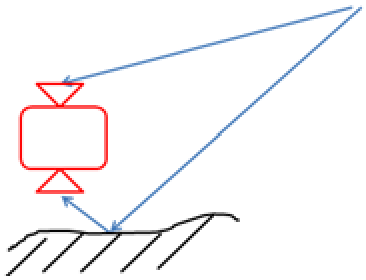




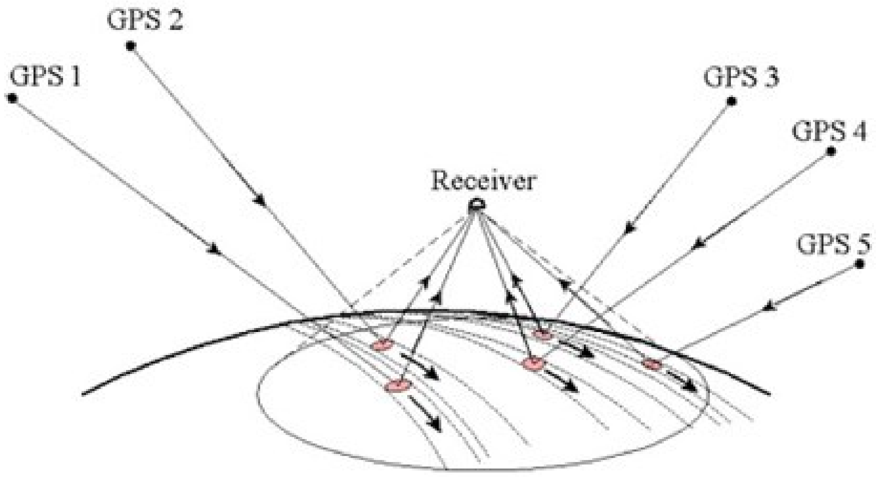


GNSS and reflectometry

- GNSS signals reflected from Earth's surface
  - A spacecraft in low earth orbit or an Unmanned Aerial Vehicle (UAV) can simultaneously collect **direct** and **reflected** signal transmitted from the visible satellites



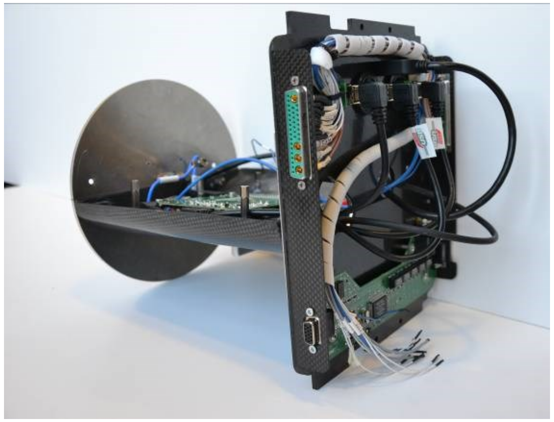
- GNSS bistatic radar, ASIS/FPGA custom receiver
  - too heavy and bulky for UAVs
- GPS scatterometer
  - light and compact
  - SDR approach

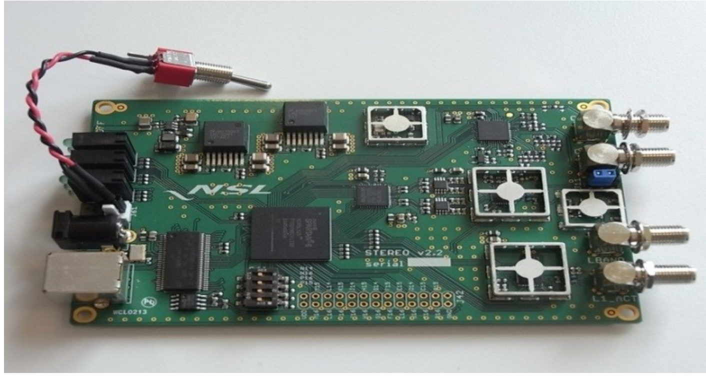


The SMAT project

"Development of a system for territory monitoring, based on sensors on board UAVs, for preventing and controlling a wide range of events (floods, fires, landslides, traffic, urban situations, pollution and crops)"

- Monitoring of the **presence of water** by using GNSS signals





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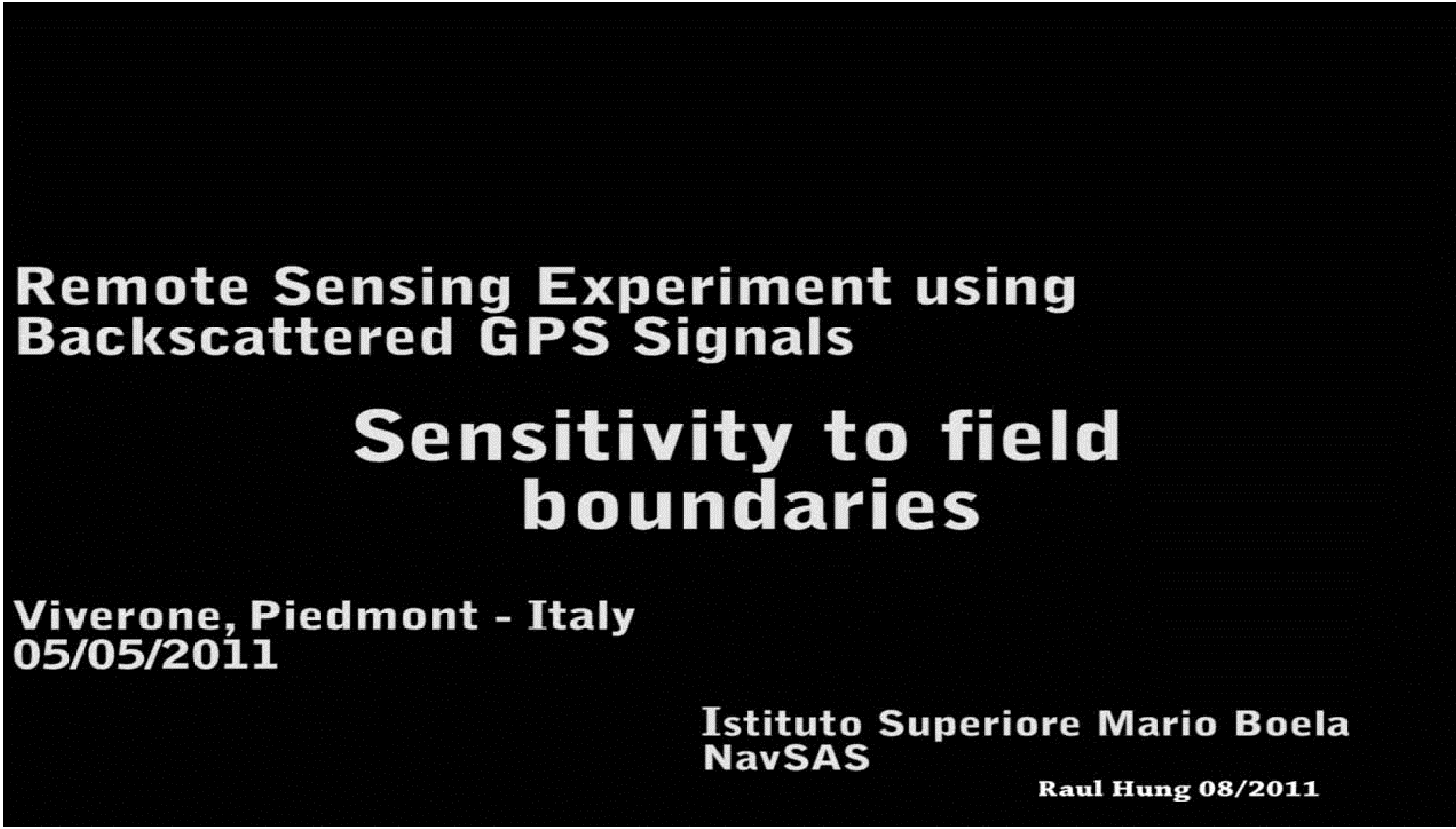
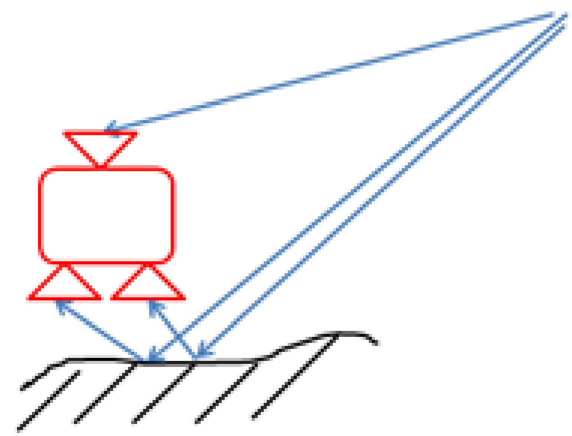
SMATF2

Example: rice fields



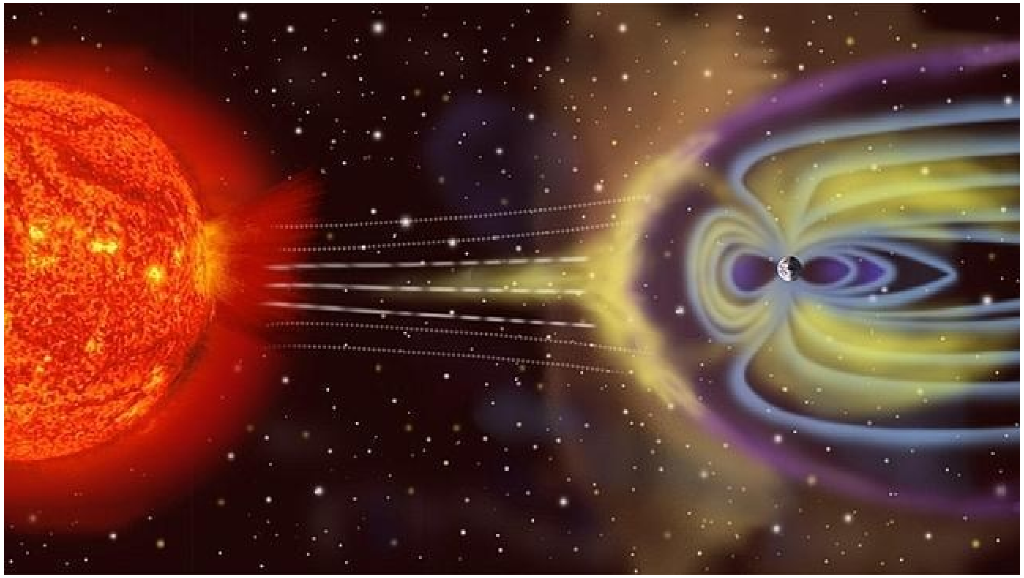
Advanced monitoring: soil moisture retrieval

- 1 up-looking antenna: direct signal
- 2 down-looking antennas:
  dual polarization
  RHCP/LHCP



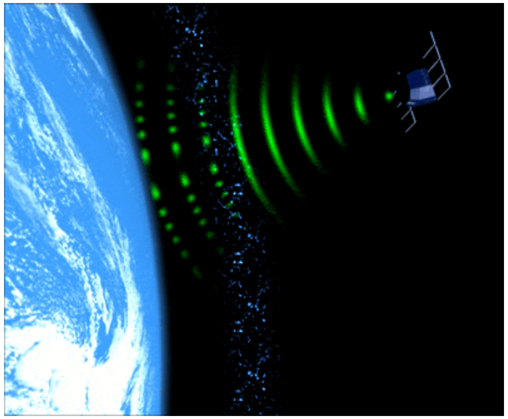
- 2 possibilities:
  - Storing of raw IF data for post-processing
  - Real time processing and storing of correlation results

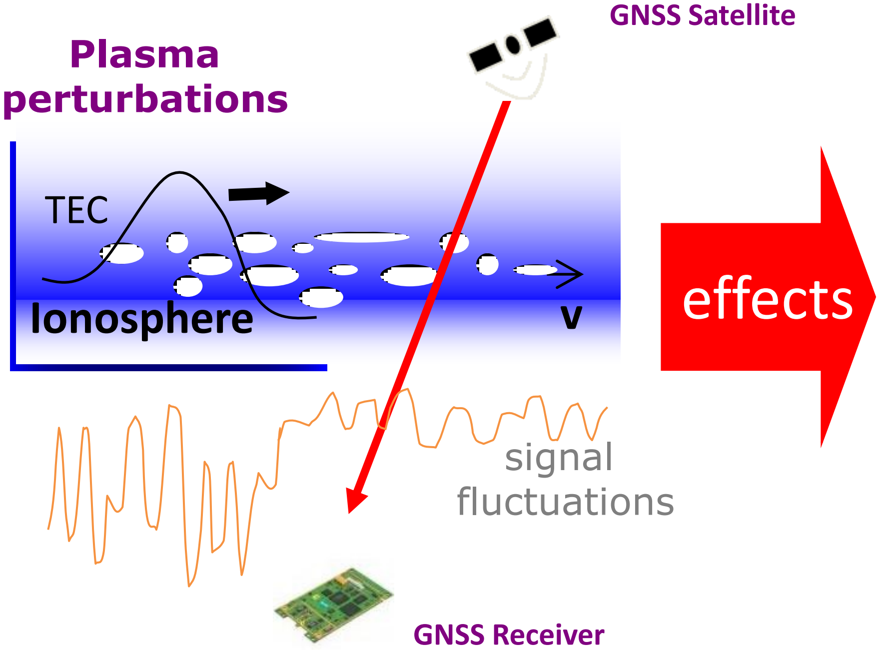
Scientific applications: ionospheric scintillation monitoring



Ionospheric Scintillations

- Rapid fluctuations in the received signal amplitude and phase, originating from a scattering effect in the ionosphere due irregular electron concentration
- Intensity depends on solar and geomagnetic activity, seasons, time, signal frequency and latitude

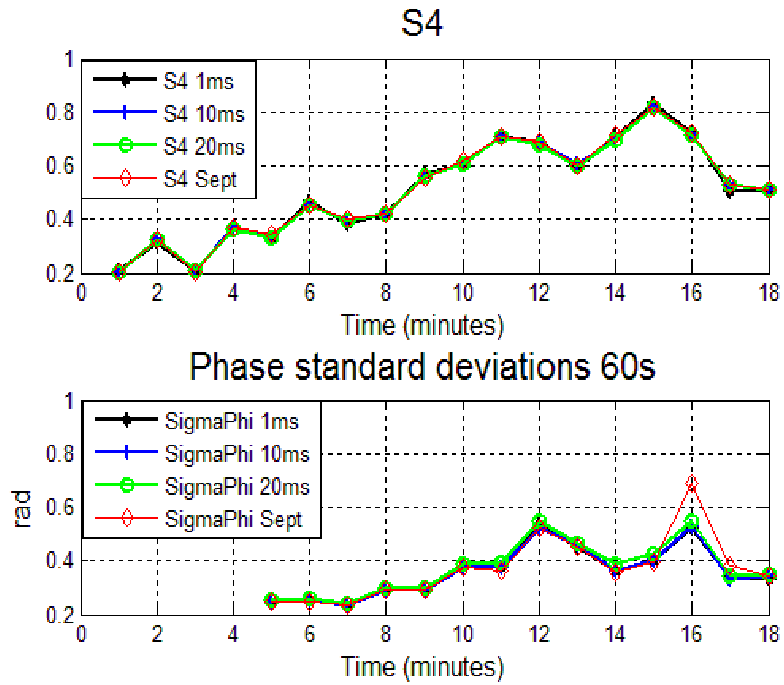




- C/N_0 degradation
- Pseudorange and carrier phase measurement noise increases
- Cycle slips
- Loss of lock
- Degradation of positioning accuracy
- Loss of positioning availability

Ionosphere and GNSS SDR

- SDR receivers allow to have access to **pre-correlation** sections and **unconventional** outputs
  - effects of scintillation along the whole processing chain
  - computation of scintillation indices
- **Configurability** and modularity:
  - test with different configurations and architectures
  - dynamic adjustments of the receiver parameters to mitigate the scintillation effect
  - easy implementation of advanced signal processing algorithms on raw signal samples



Vietnam: NAVIS center

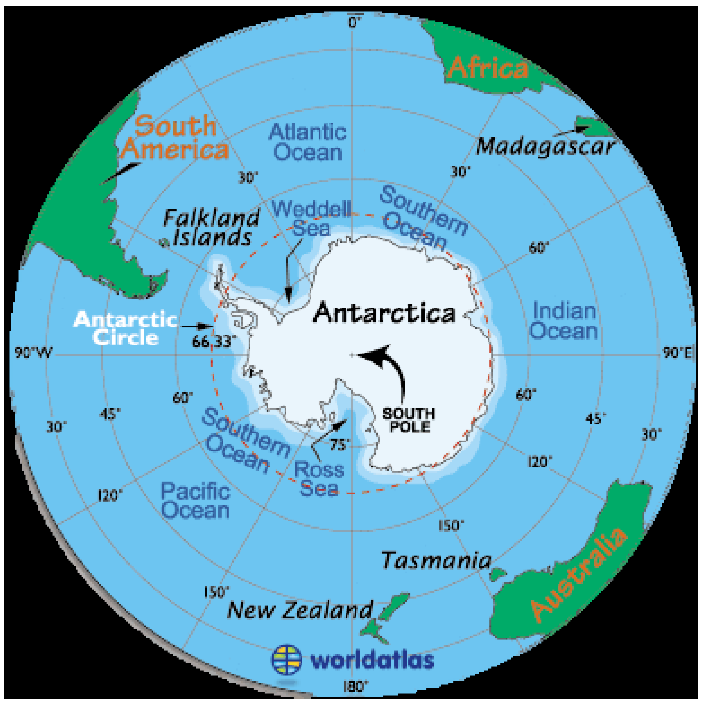
- International collaboration center
- Monitoring station set-up in cooperation with ESA and EC-JRC

- Single frequency (L1)
- Samples collected after sunset on a daily basis
- Raw data storage (1 day of data = 178 GB)
- Professional receiver used for benchmarking

NAVIS Centre
Hanoi University of Science and Technology

Antarctica

*“**DemoGRAPE** is a demonstrator, to provide on selected case studies an empirical assessment of the delay and of the corruption induced by the ionosphere on satellite signals in the Antarctic regions”*



- Dual band (L1+L2, E1+E5) fully software receiver (dynamic switching)
- Configurability: 2 bytes quantization to better represent the signal
- Accessibility: unconventional outputs

2 installations

- Sanae-IV
  (SANSA, South Africa)
- EACF (INPE, Brazil)

http://www.demogrape.net

DEMOGRAPE

Conclusions

- Advantages of SDR receivers vs hardware dedicated platforms
  - modularity, flexibility, re-configurability, accessibility, …
- Advantages of fully software receivers in GNSS
  - Engineering applications
    - Signal quality monitoring
  - Scientific applications
    - Remote sensing and reflectometry
    - Ionospheric monitoring

Visit: **www.navsas.eu**
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