GNSS Anti-jam RF-to-RF On Board Unit for ERTMS Train Control

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Outline

- ERTMS and Virtual Balise Concept
- Characterization of GNSS performance
- Jamming issue and anti-jamming filter design guidelines
- Performance analysis
- Conclusions

RadioLabs

Research Consortium

Radiolabs is involved on major international research projects with ESA, ASI, GSA and Centers of Excellence

Leader on scientific research for safety-critical geo-localization

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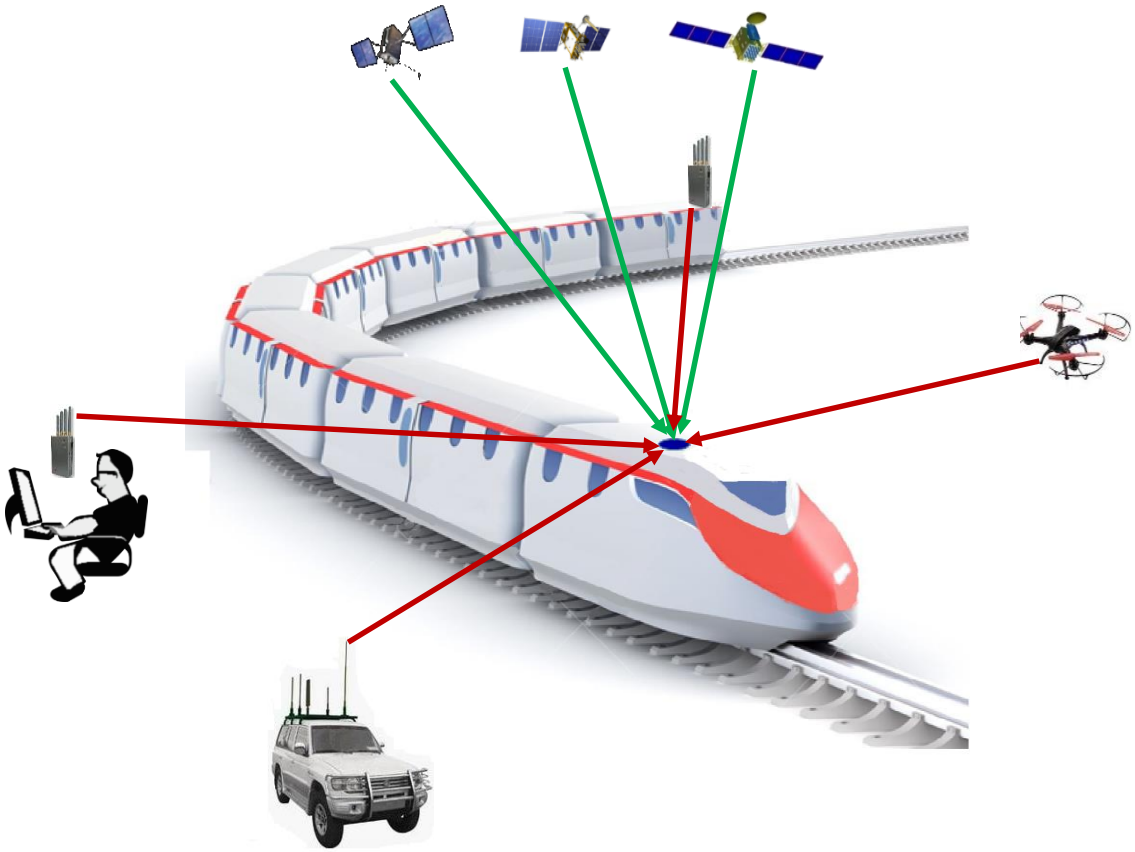
GNSS Interferences in Railway

Critical issue:
Intentional Interferences
(jamming, spoofing and meaconing)



Ref. DB4Rail project ESA

Introduction

Possible GNSS interferences must be analysed and mitigated to ensure the ERTMS can operate with GNSS positioning without degradations:

Reference scenario: ERTMS level 2 with Virtual Balise

- Evaluation of interference scenarios and identification of mitigation strategy.
- Analysis of performance for the Virtual Balise architecture

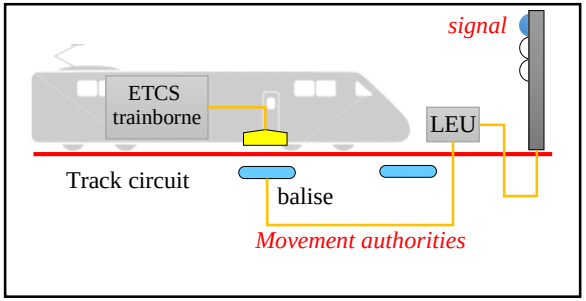
GNSS Automated Virtualized Test Environment for Rail (GATE4Rail) deals with tasks TD2.4 and TD2.6 of the Shift2Rail Multi Annual Action Plan. Particularly, its main goals are: i) achieving a realistic characterization of the environment in terms of railway and GNSS infrastrustructures able to evaluate the performances and properties of some fail-safe train positioning components in nominal and fault conditions; ii) defining a common test process framework for zero on-site testing instead of testing on-site saving effort and time.

The project "Digital Beamforming for Rail" DB4RAIL aims at designing, developing and prototyping a software digital beamforming platform for antenna array coupled with advanced GNSS signal processing techniques for high rejection of GNSS interfering signals, including jamming and spoofing, to be used for supporting the evolution of the LDS based on GNSS in ERTMS/ETCS.

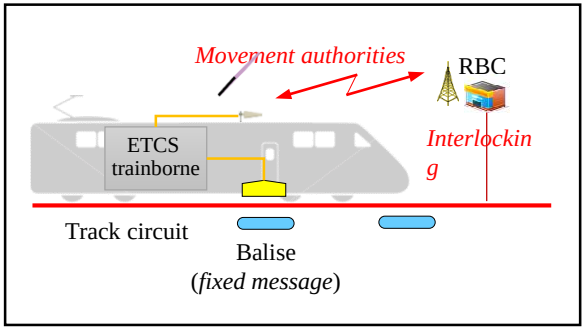
ERTMS/ETCS

The European standard for railway signaling is the ERTMS / ETCS (European Railway Traffic Management System / European Train Control System) is the standard for European railways.

Operational at the moment

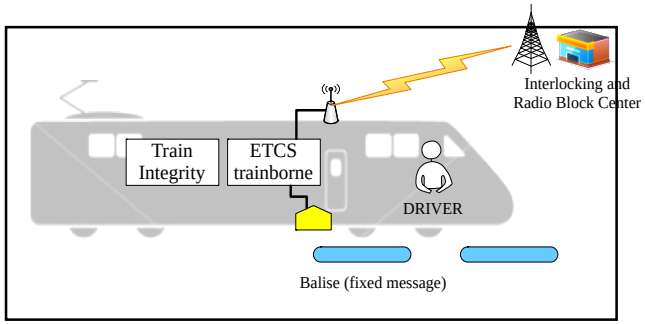


Level 1



Level 2

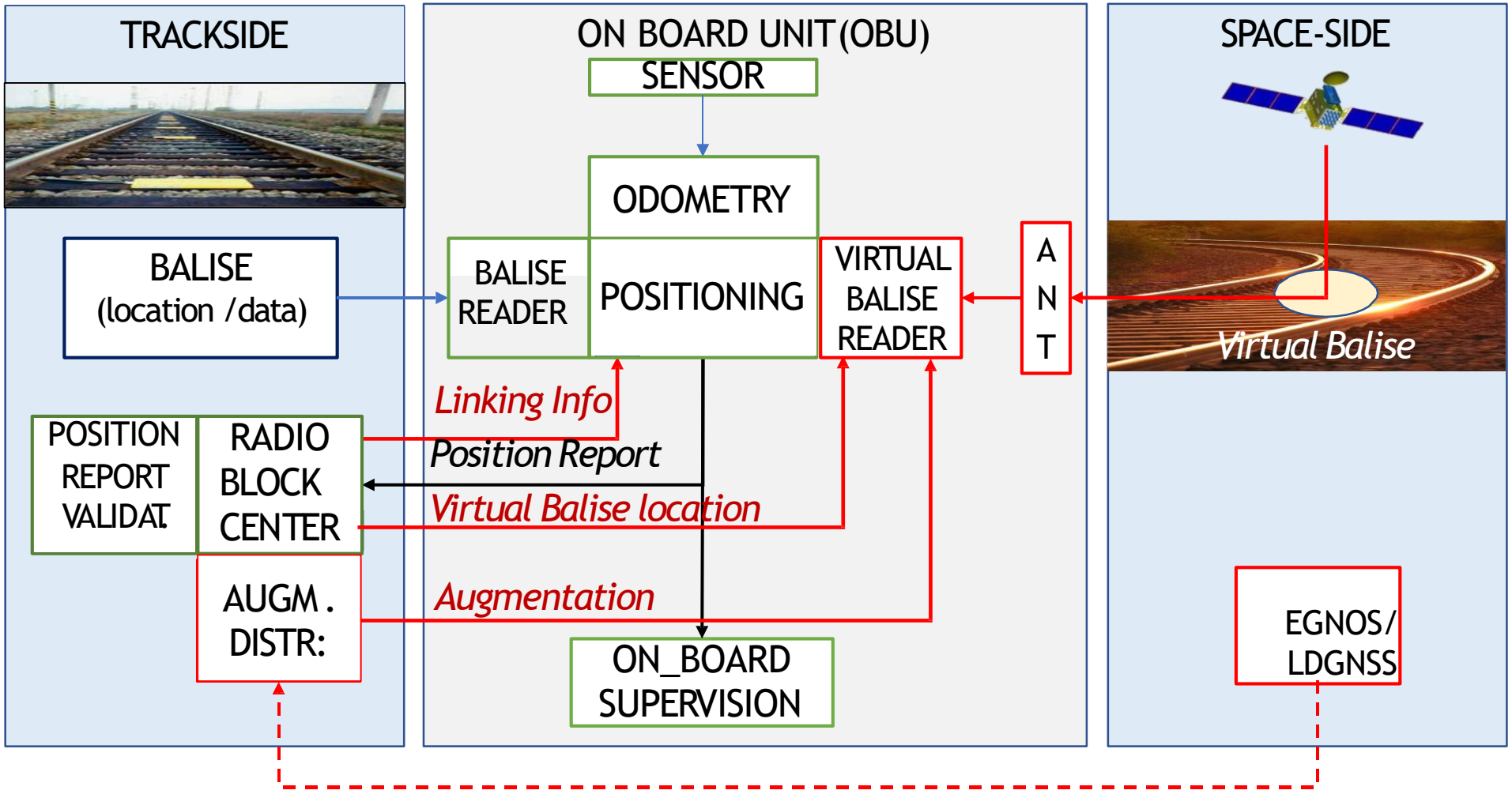
Next frontier



Level 3

Train must be able to evaluate its own position and to determine whether all the carriages are still coupled

GNSS- based Virtual Balise Concept

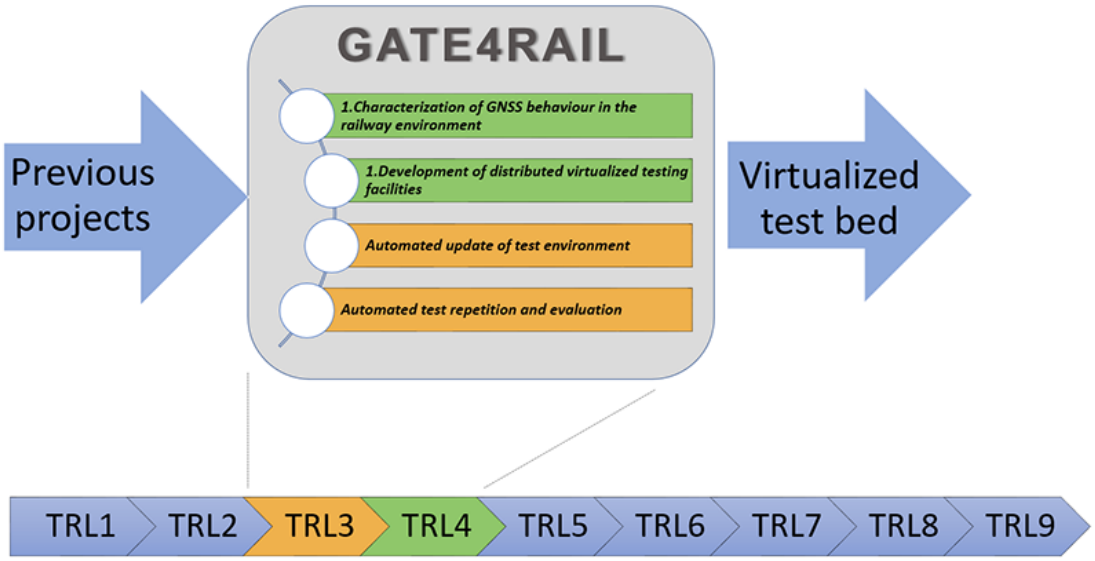


Ref. DB4Rail project ESA

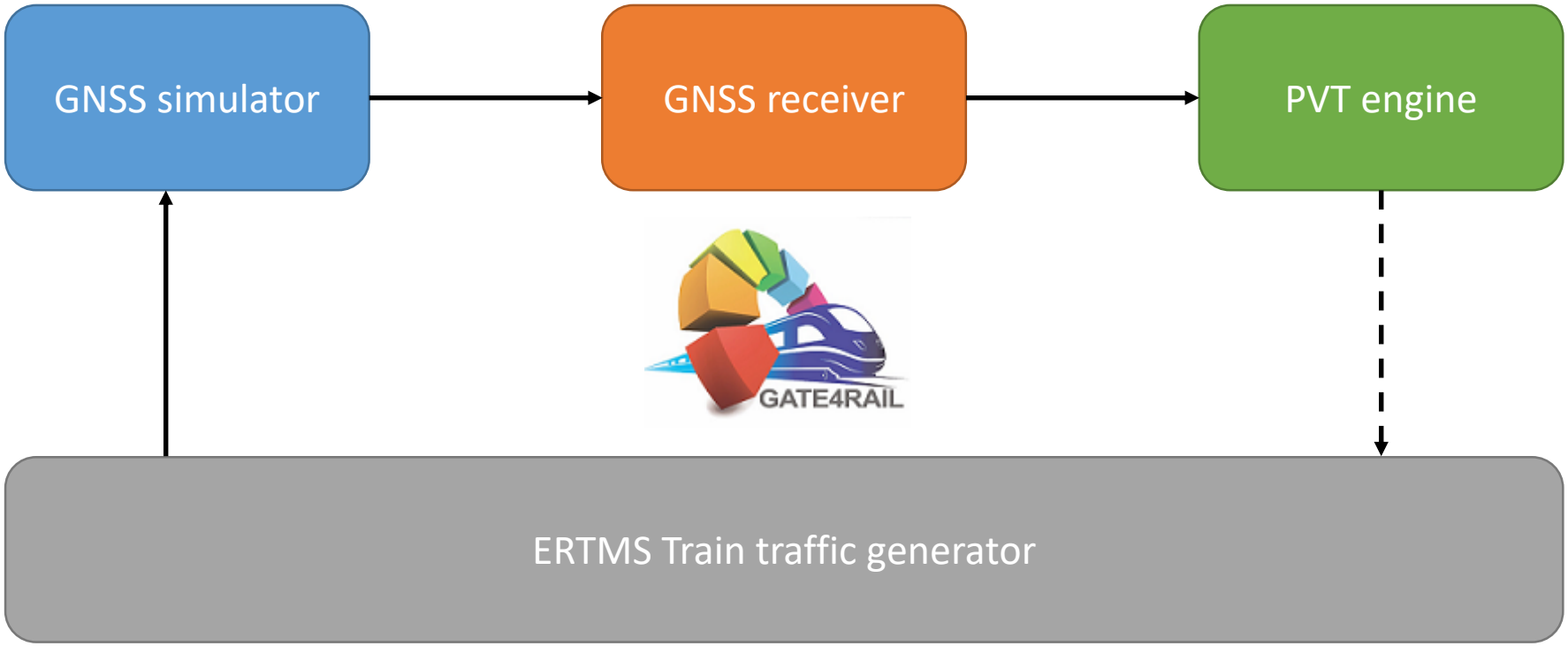
Characterisation of GNSS performance

1. Characterization of GNSS performance
2. Defining a common test process framework for zero on-site testing instead of testing on-site saving effort and time;
3. Provide a laboratory test architecture capable of simulating railway scenarios for GNSS-based ERTMS applications;

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No: 826324



Reference Architecture



Jamming, Spoofing, Meaconing

Jamming is the transmission of signals that disturb the genuine reception:

Main consequences:

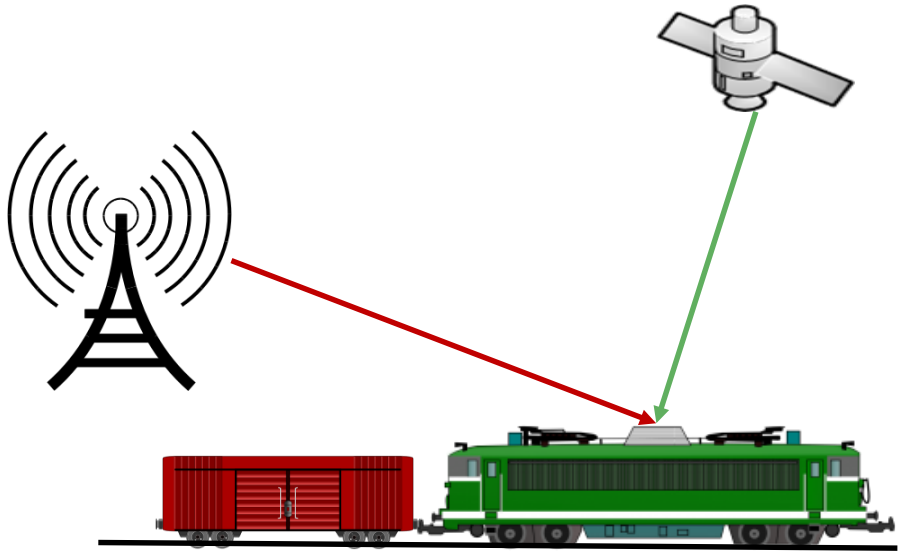
- Interference
- Denial of Service

Spoofing is the intentional transmission of fake GNSS signals to make the receiver estimate a wrong position and/or timing

Cryptography can mitigate the spoofing

Meaconing is the transmission of recorded authentic GNSS signals to make the receiver estimate a wrong position and/or timing

Also cryptographically protected signals could be affected by meaconing



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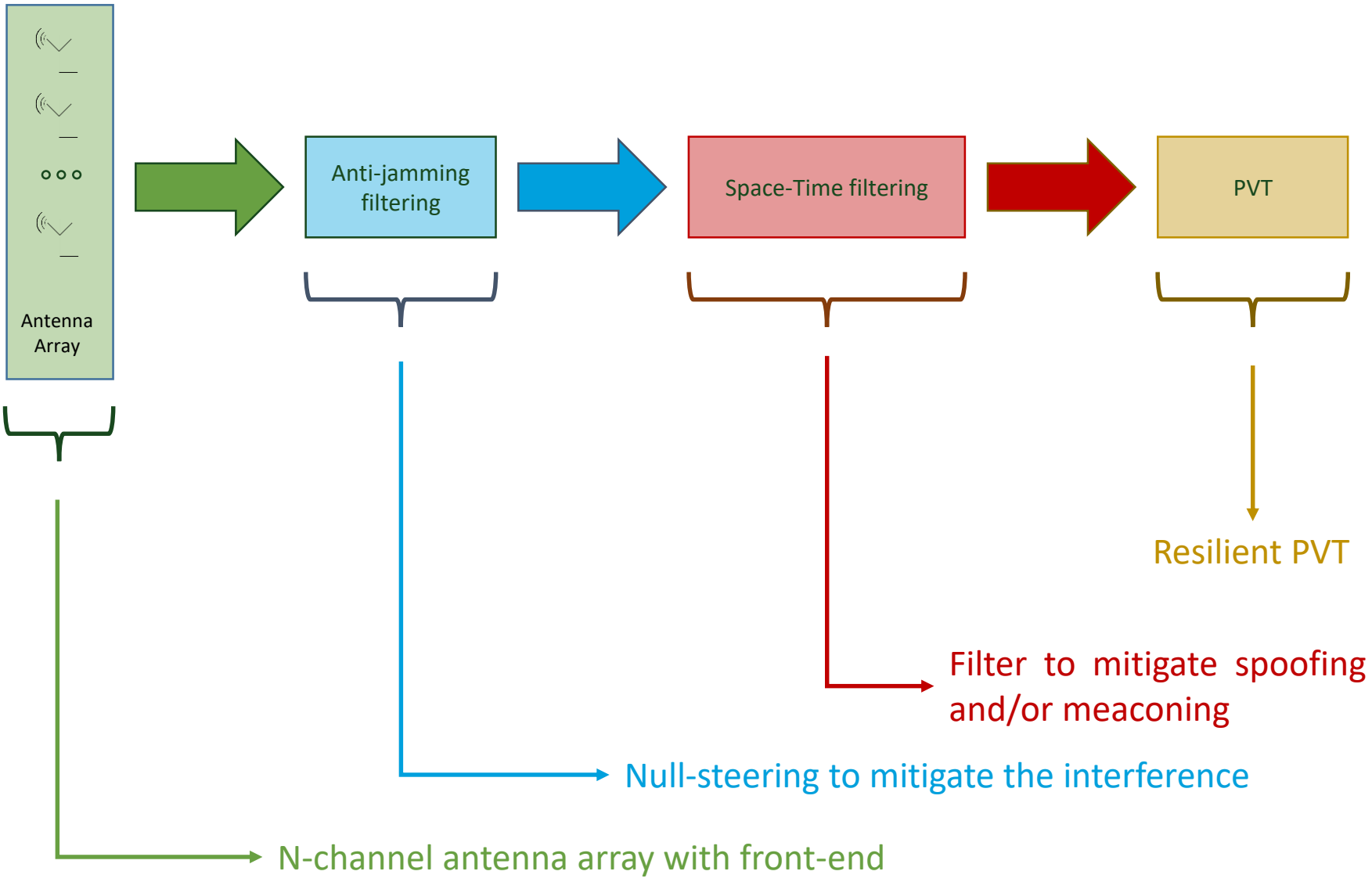
Processing scheme



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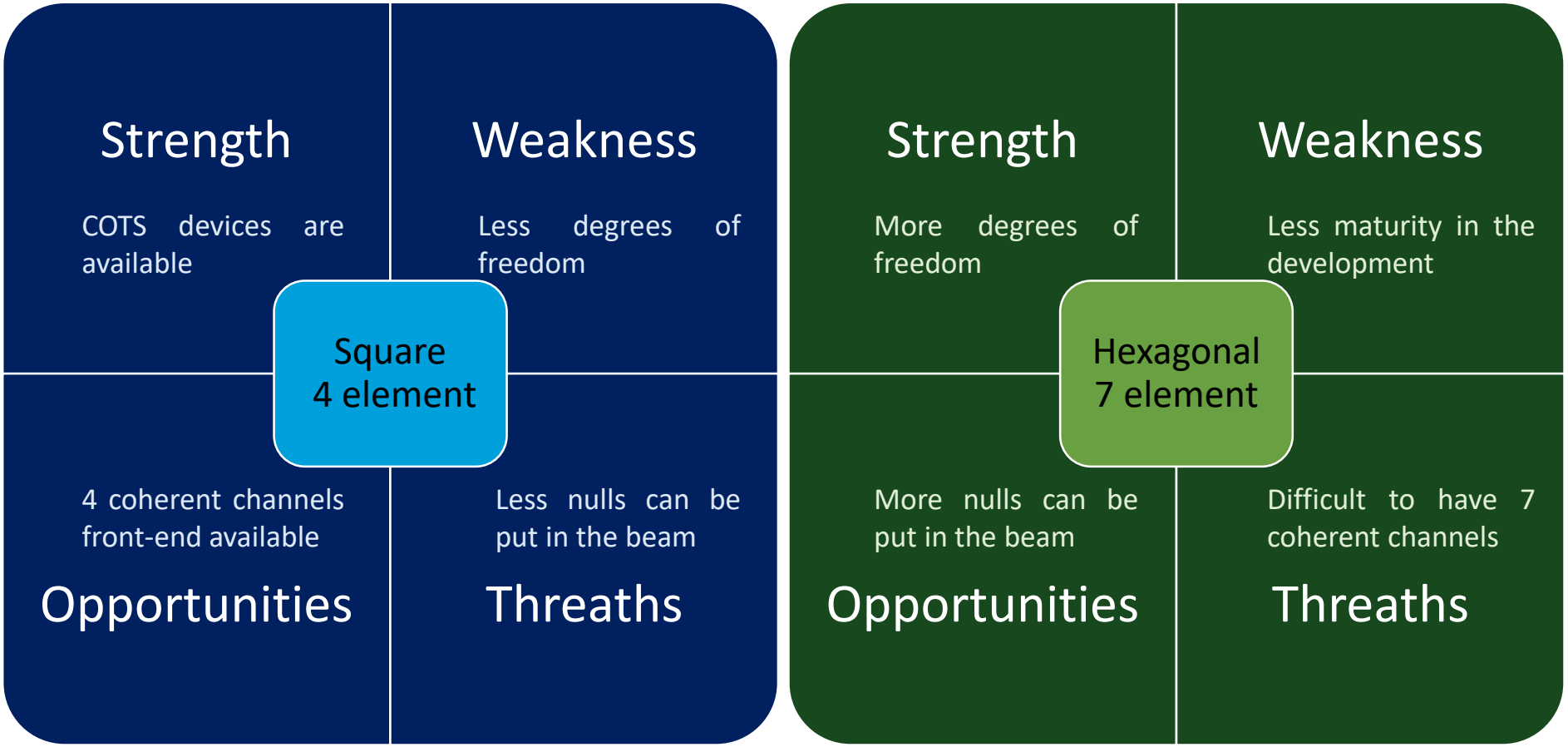
GNSS Antenna Array Design

How Many elements?
Which Shape?

SWOT Analysis



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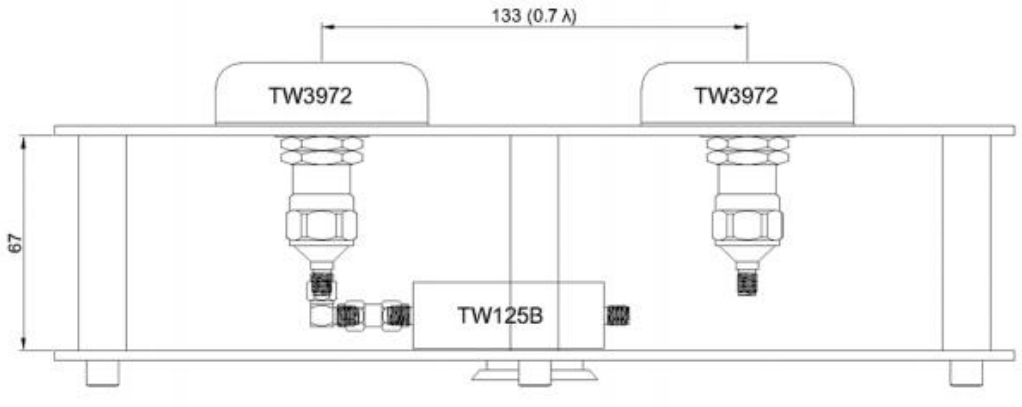
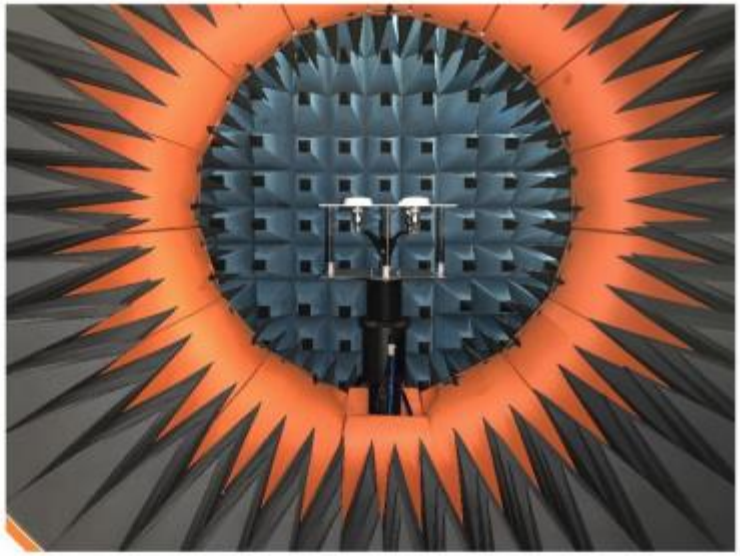
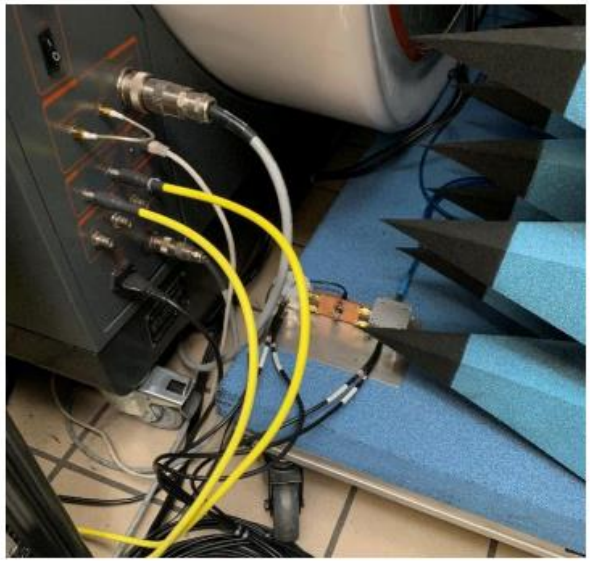
GNSS Antenna Array Development







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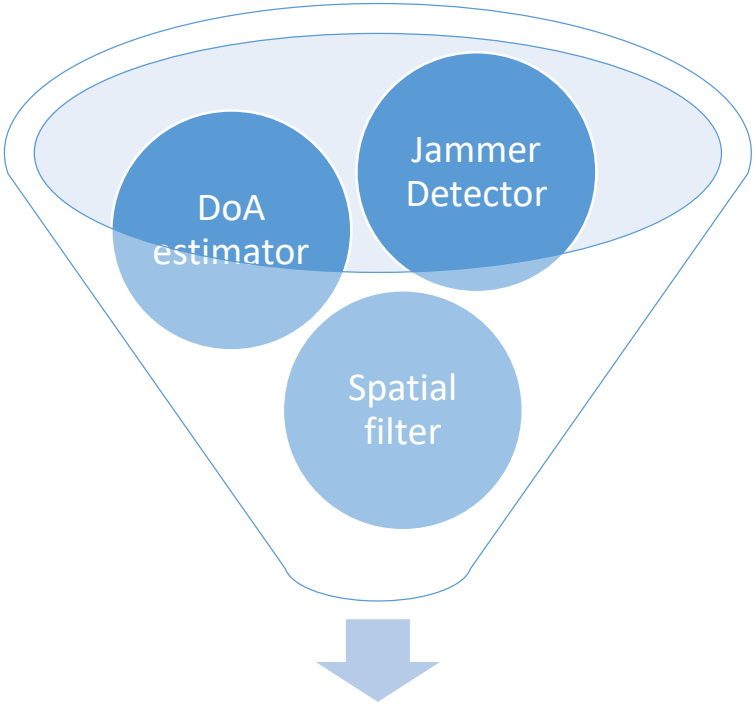
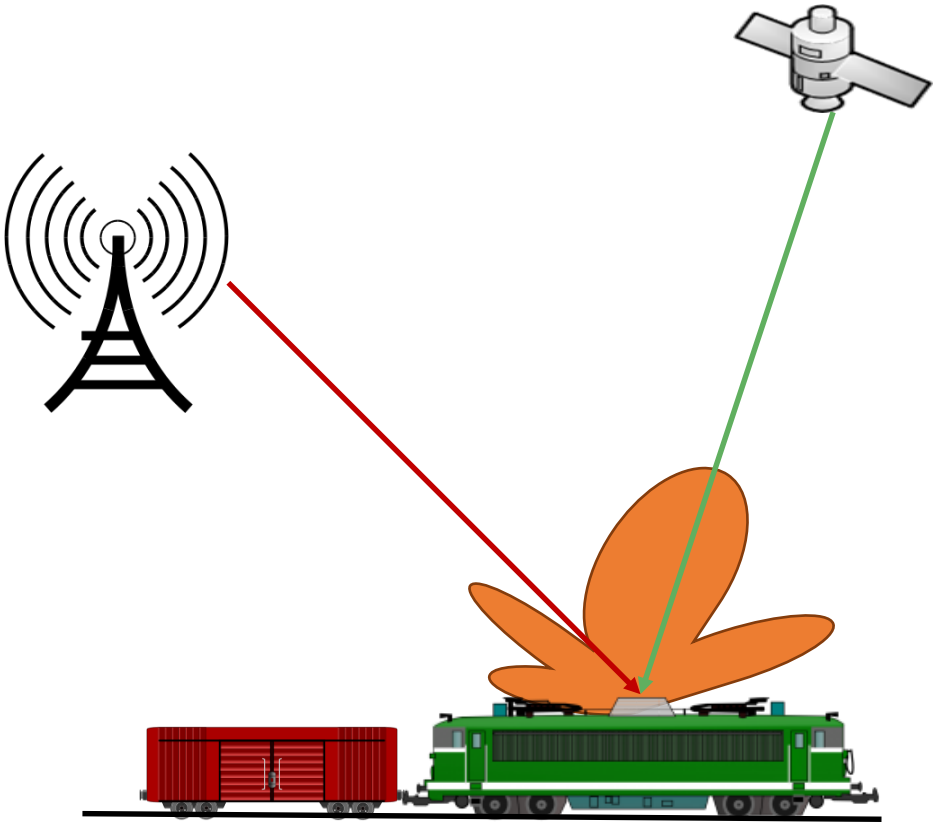
Anti-jamming filtering



Anti-jamming filter

Jamming mitigation process can be decomposed in 3 steps.



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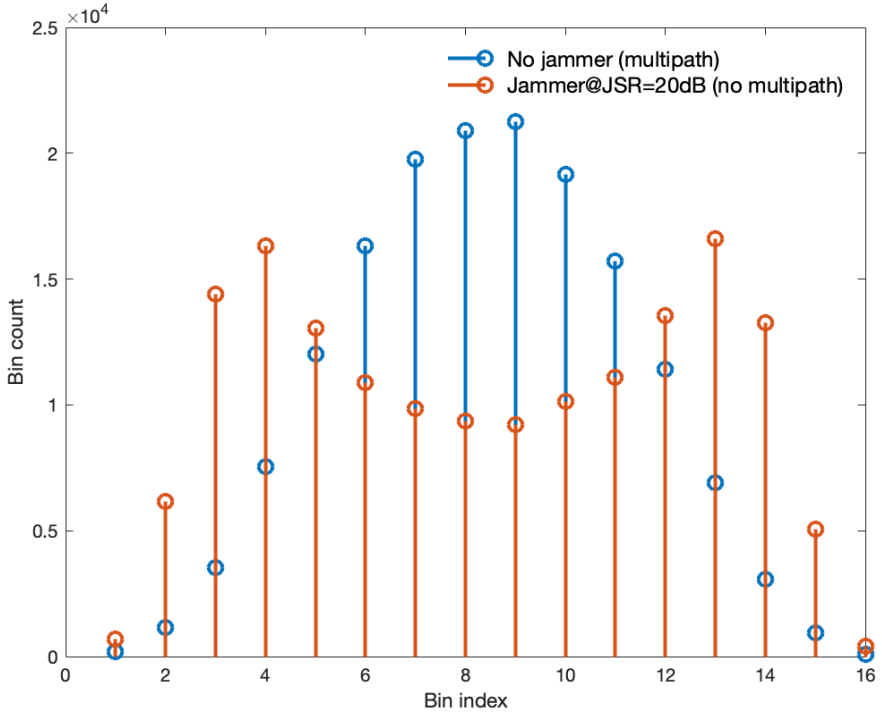
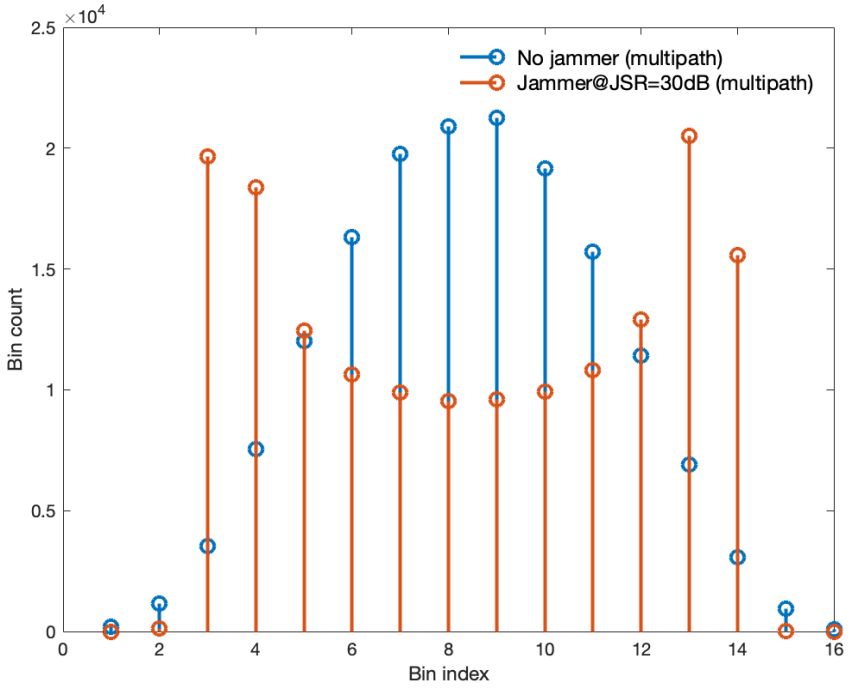
Hystogram comparison

The jammer presence can be detected by accounting for the hystograms



J/S = 20dB



J/S = 30dB

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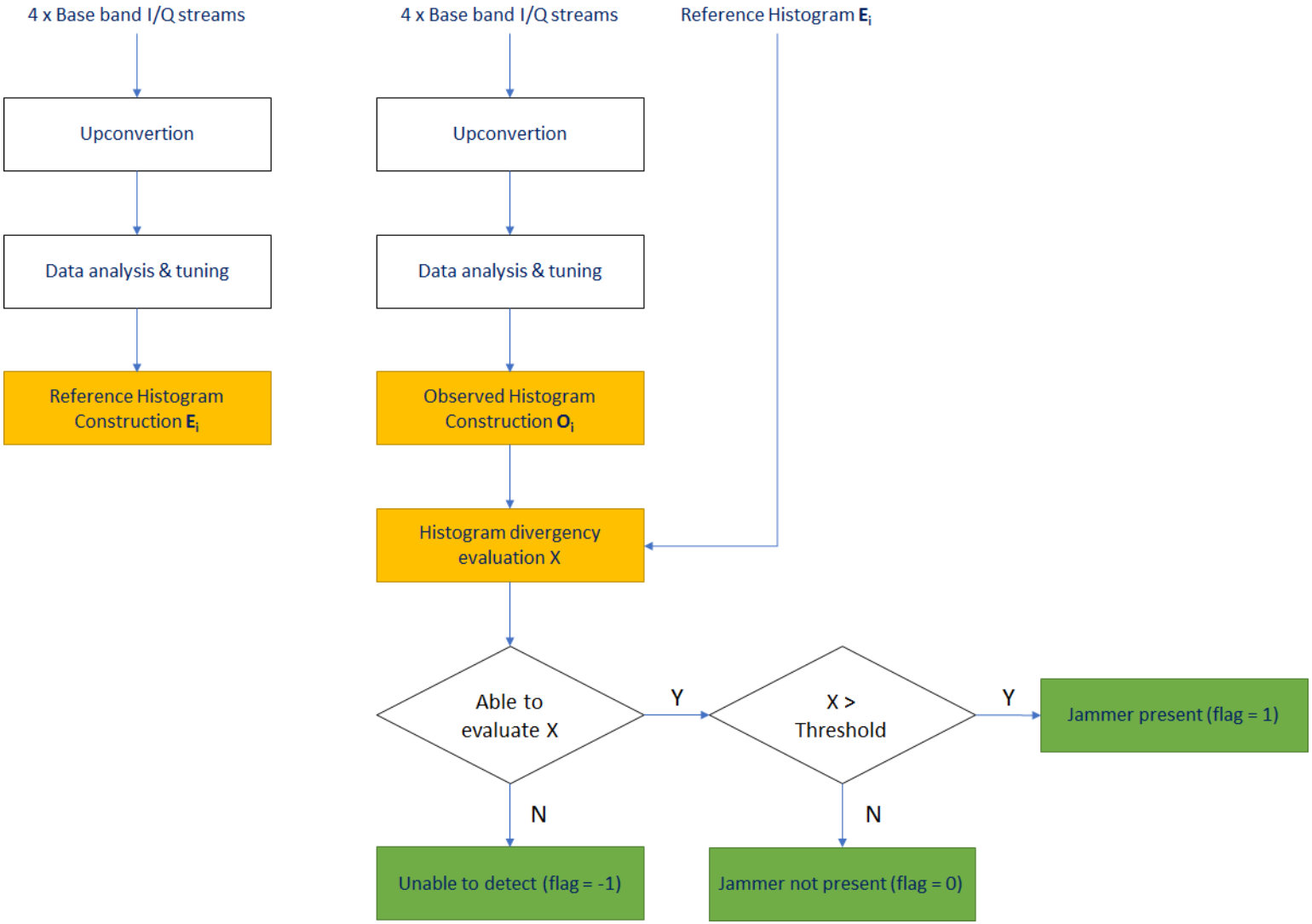
Jamming Detection



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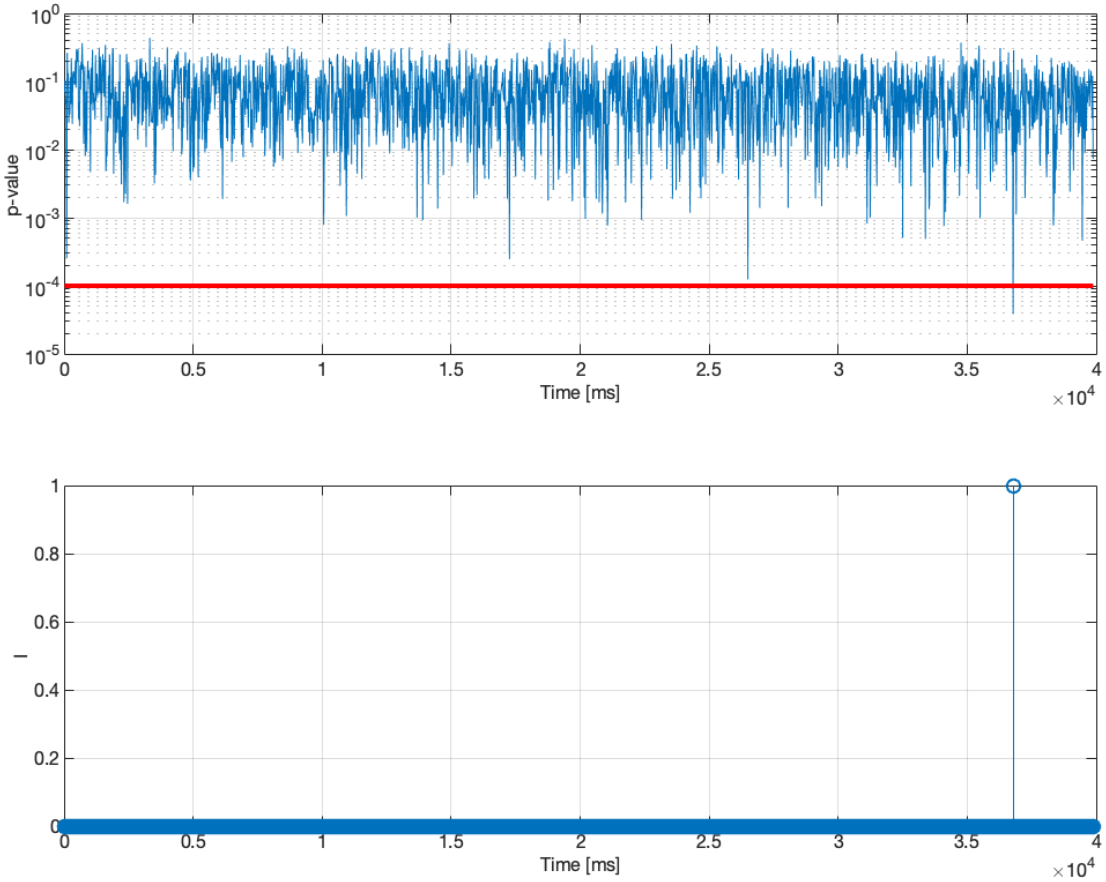
The p-value testing



The jammer detector algorithm has been calibrated by using GNSS signals in absence of any jammer signals, and the following parameters have been chosen:

- Detection period = 20 ms
- Number of bins = 16
- Level of significance = 10-4.

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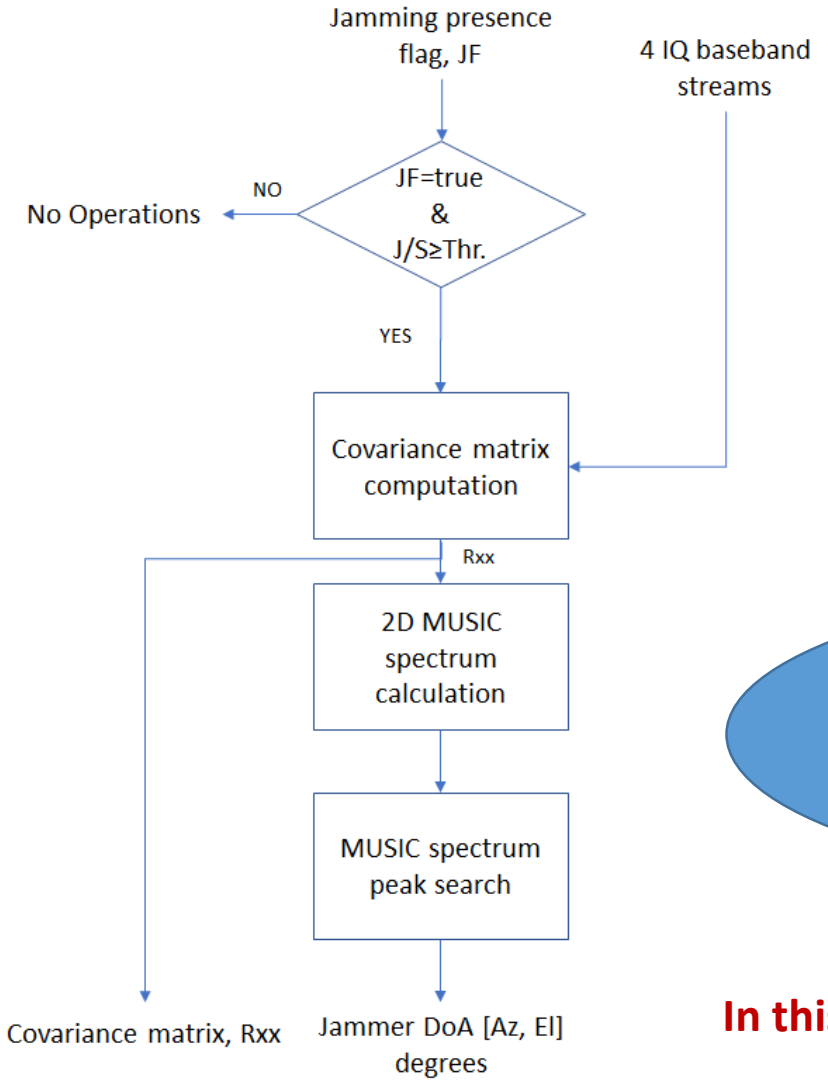
Jamming DoA estimation and mitigation



Different approaches can be followed:

- Power minimization
- Null Steering
- Capon beamforming

The choice depends on a trade-off among performance and complexity

In this work we have implemented the Null-Steering

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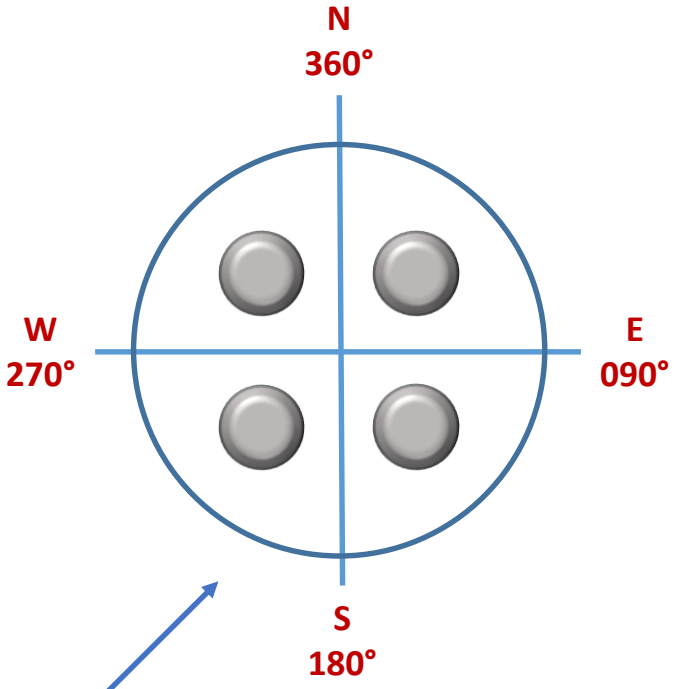
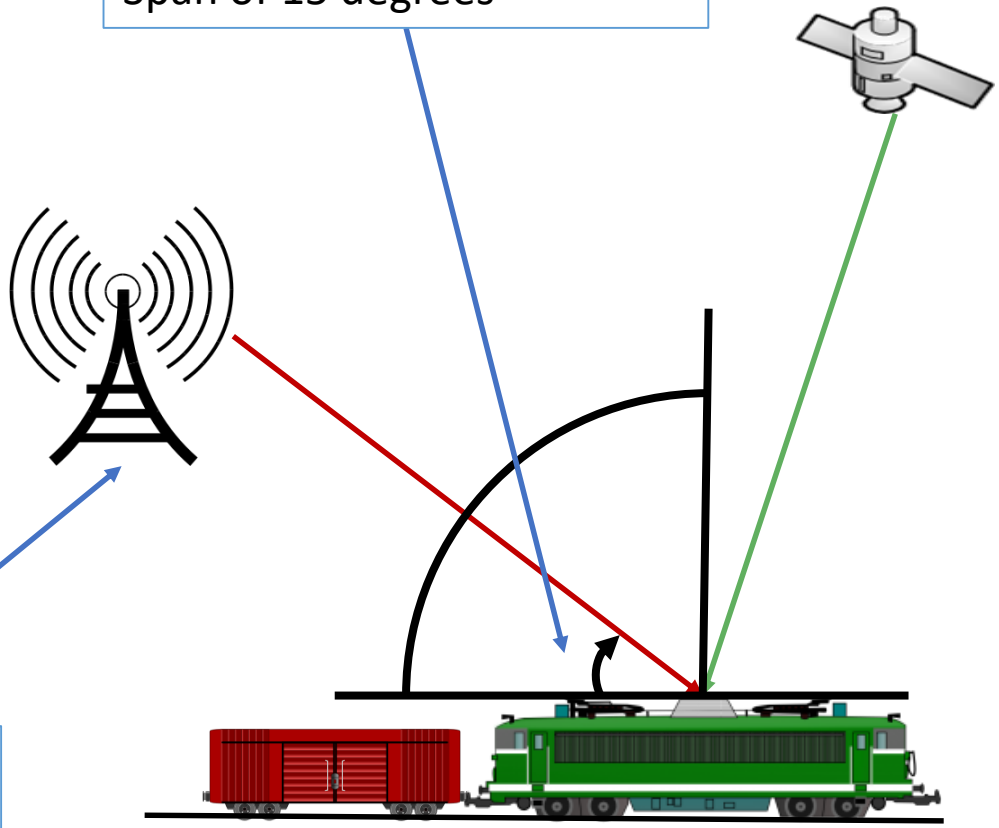
Simulation results: assumptions



Azimuth angle:
Fixed 180 degrees

Elevation angle:
Range from 10 to 70 degrees
Span of 15 degrees

JSR:
Fixed 20 dB



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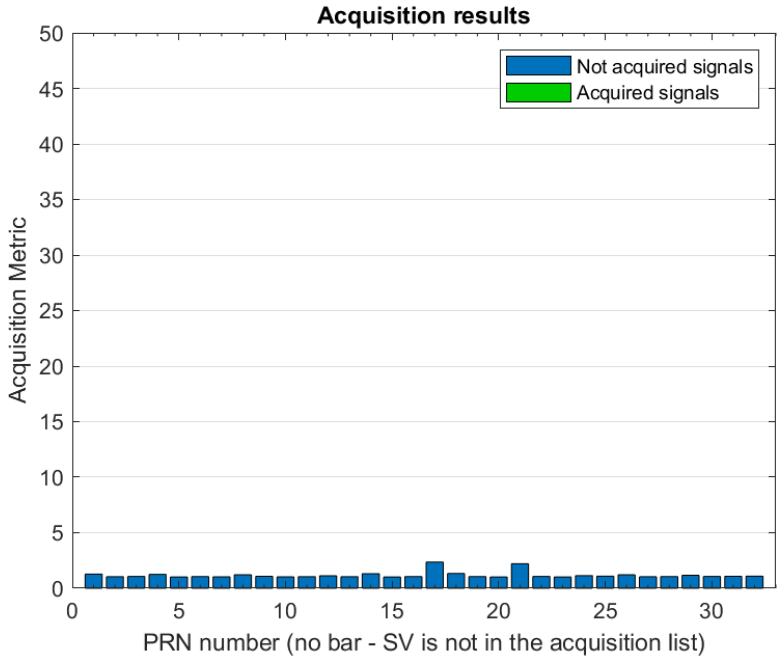
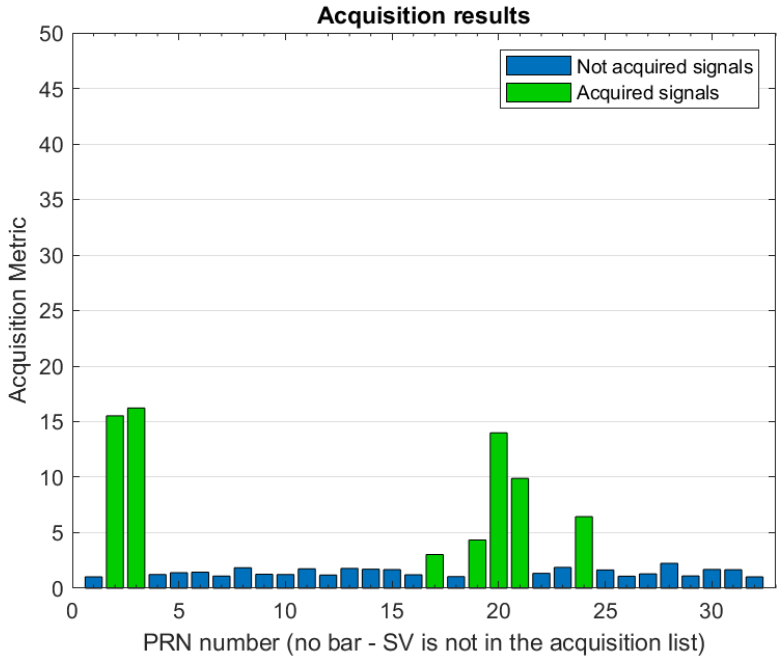
Acquisition results (1)

Scenario - J/S = 20 dB, Jammer [Azimuth = 180°, Elevation = 10°]



Antenna 1



Null-steering

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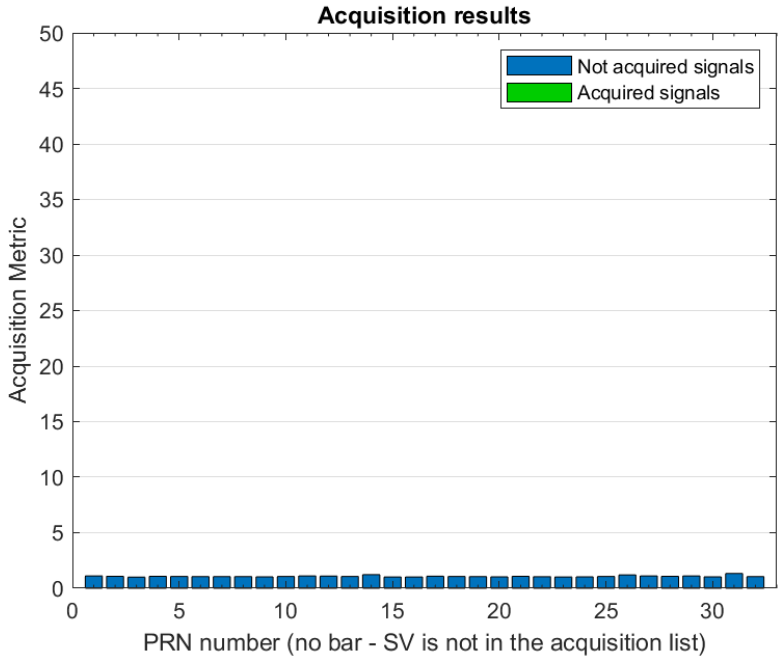
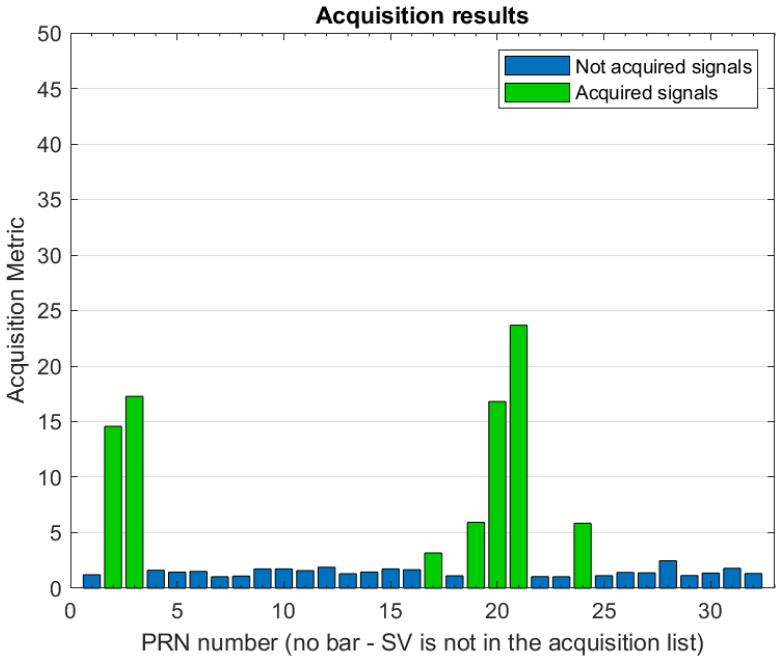
Acquisition results (2)

Scenario - J/S = 20 dB, Jammer [Azimuth = 180°, Elevation = 25°]



Antenna 1

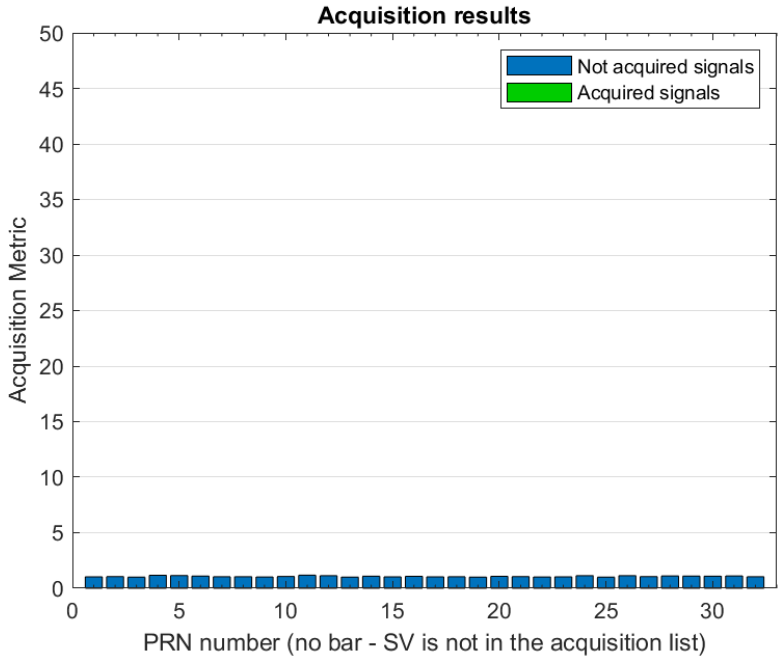


Null-steering

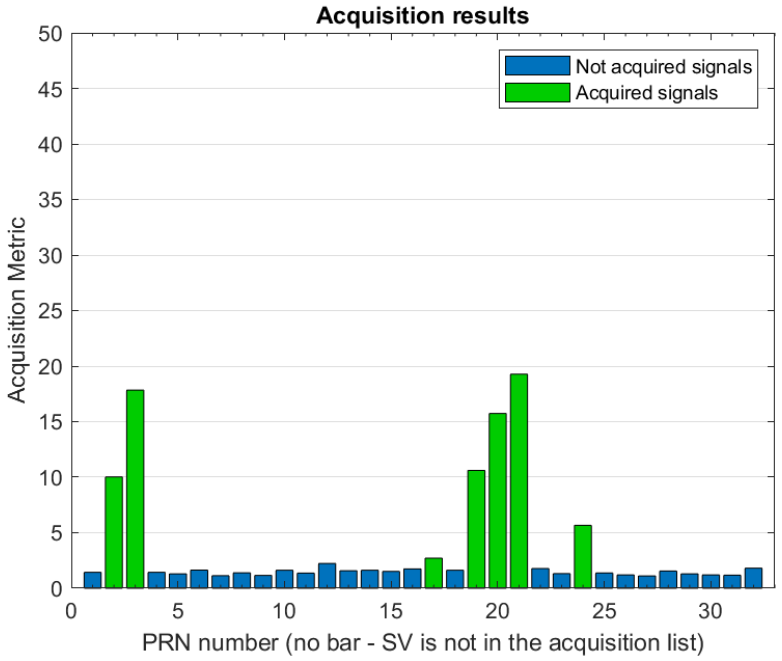
Ref. DB4Rail project ESA

Acquisition results (3)

Scenario - J/S = 20 dB, Jammer [Azimuth = 180°, Elevation = 40°]



Antenna 1

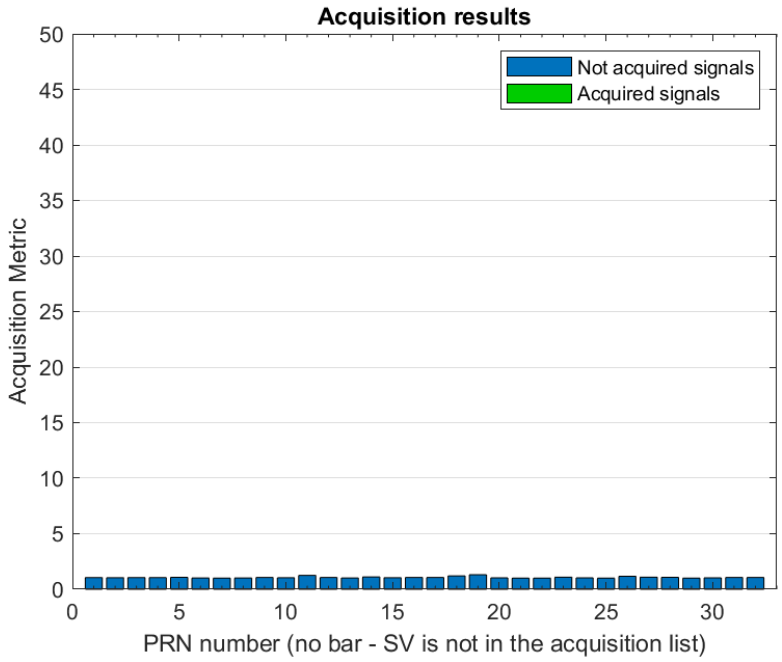


Null-steering

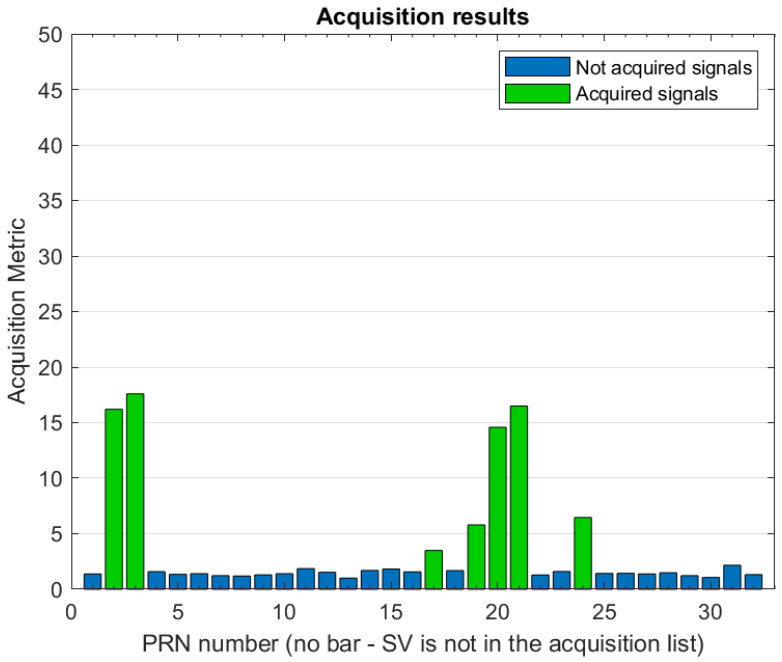
Ref. DB4Rail project ESA

Acquisition results (4)

Scenario - J/S = 20 dB, Jammer [Azimuth = 180°, Elevation = 55°]



Antenna 1

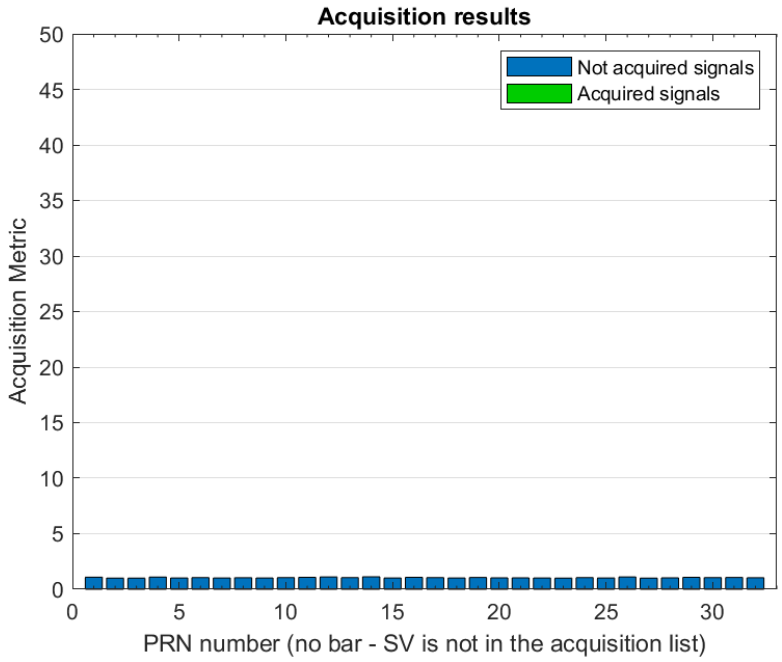


Null-steering

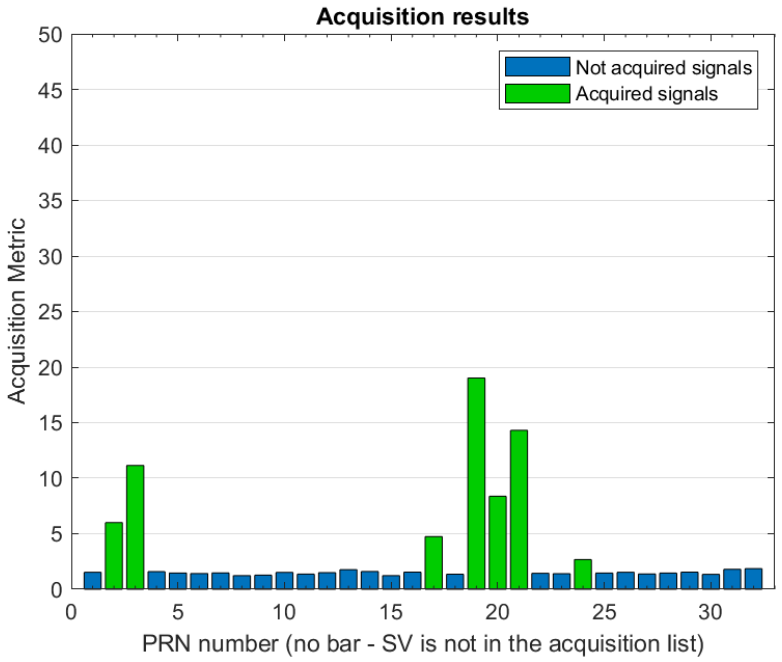
Ref. DB4Rail project ESA

Acquisition results (5)

Scenario - J/S = 20 dB, Jammer [Azimuth = 180°, Elevation = 70°]



Antenna 1

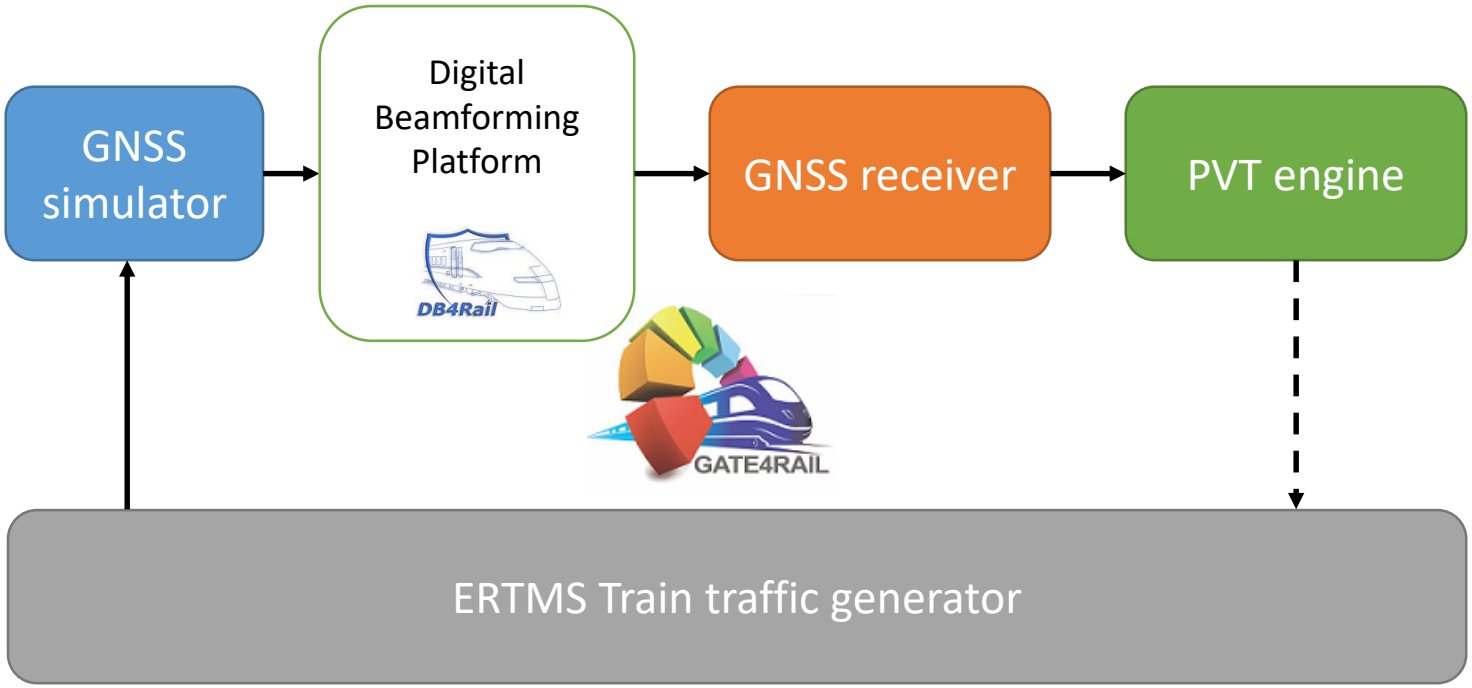


Null-steering

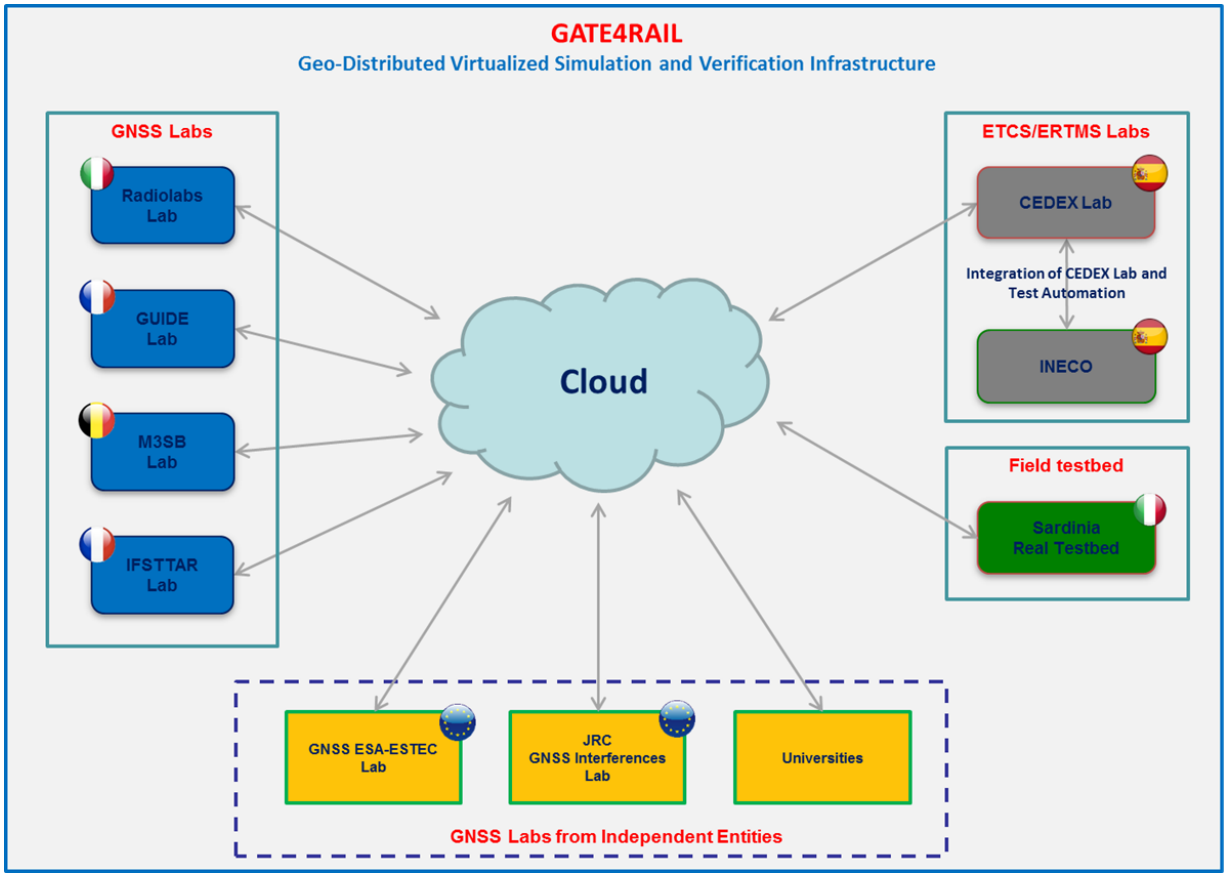
Ref. DB4Rail project ESA

Overall solution

The anti-jamming mitigation platform developed in the ESA GSTP 6.2 DB4Rail project can be integrated in the GATE4Rail test-bed architecture to create a **unified test-bed architecture** to test the system resilience to RF interference and jamming.



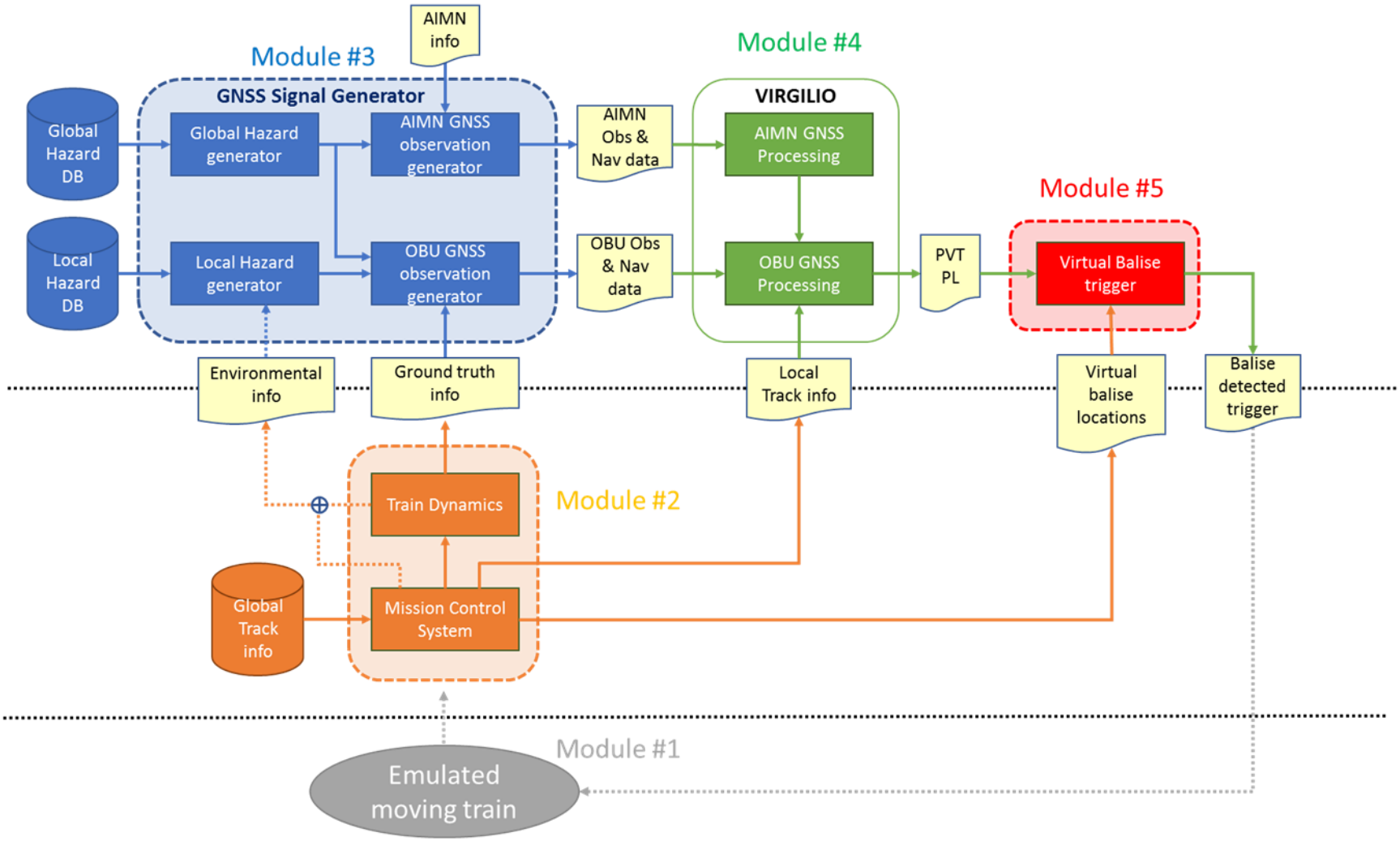
Gate4Rail Geo-Distributed Lab Concept



GATE4Rail architecture for simulating railway scenarios for GNSS-based ERTMS applications by integrating different simulation blocks and by defining their interfaces in order to cover the global simulation chain

The GATE4Rail proposal addresses the topic S2R-OC-IP2-02-2018 - Modern methodologies and verifications for GNSS in Railways and virtual test environment.

Gate4Rail Architecture



Conclusions

- GNSS positioning for the ERTMS system needs a characterisation of RF signals including those that can be affected by interferences. Our approach is to create a unified test-bed architecture to test the system resilience to RF interference and jamming by exploiting:

  - the GNSS Anti-jam RF-to-RF On Board Unit optimized for ERTMS Train Control (**DB4Rail)**
  - the distributed test-facility to evaluate the GNSS performance with a zero-on-site testing approach (**Gate4Rail**)

- Jamming can impact primarily on the ERTMS system availability and the antenna array solution of the **DB4Rail project** can be used to mitigate such a threat

- **GATE4Rail** platform is ideal to test also the system anti-jamming capability in a controlled environment that otherwise would require severe constraints and high costs.

Gate4Rail project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No: 826324

www.gate4rail.eu

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