Characterization of Radio Frequency Interference for GNSS Maritime Applications

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Motivation

- “90% of all trade takes place across the world’s oceans, involving over 500 million containers on 89,000 maritime vessels each year” [1]
- GNSS technology has been widely adopted and trusted (up to now)
- Shipborne GNSS navigation aids have almost not changed in last 20 years
- GNSS service reliability is of increasing concern
- Events reported but not yet a systematic, long duration campaign

Some of the so-called
Personal Privacy Devices →
(PPDs)

[1] International Chamber of Shipping

Scope

- *What?* Increase the interference awareness for GNSS services in the maritime domain
- *How?* Conduct an **international measurement campaign** and data post-processing

  Uniqueness: **Global**; **Monitoring**; **Systematic**; **long Duration**

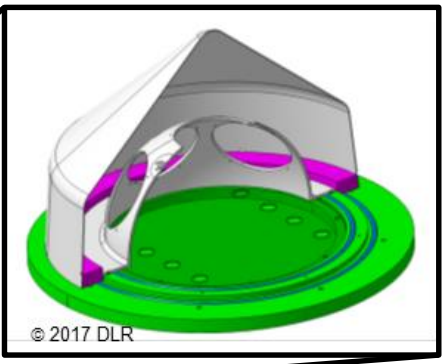
→ *We need:*

- Develop an **autonomous** system able to detect, observe and record RFI events in GNSS frequency bands
- Analyze the recorded data in “a proper way” → Develop a Methodology

Measurement Platform (i)

- Tonnage 142,292 tons
- Beam 157 ft
- Length 1200 ft
- Height 148 ft

Measurement Platform (ii)

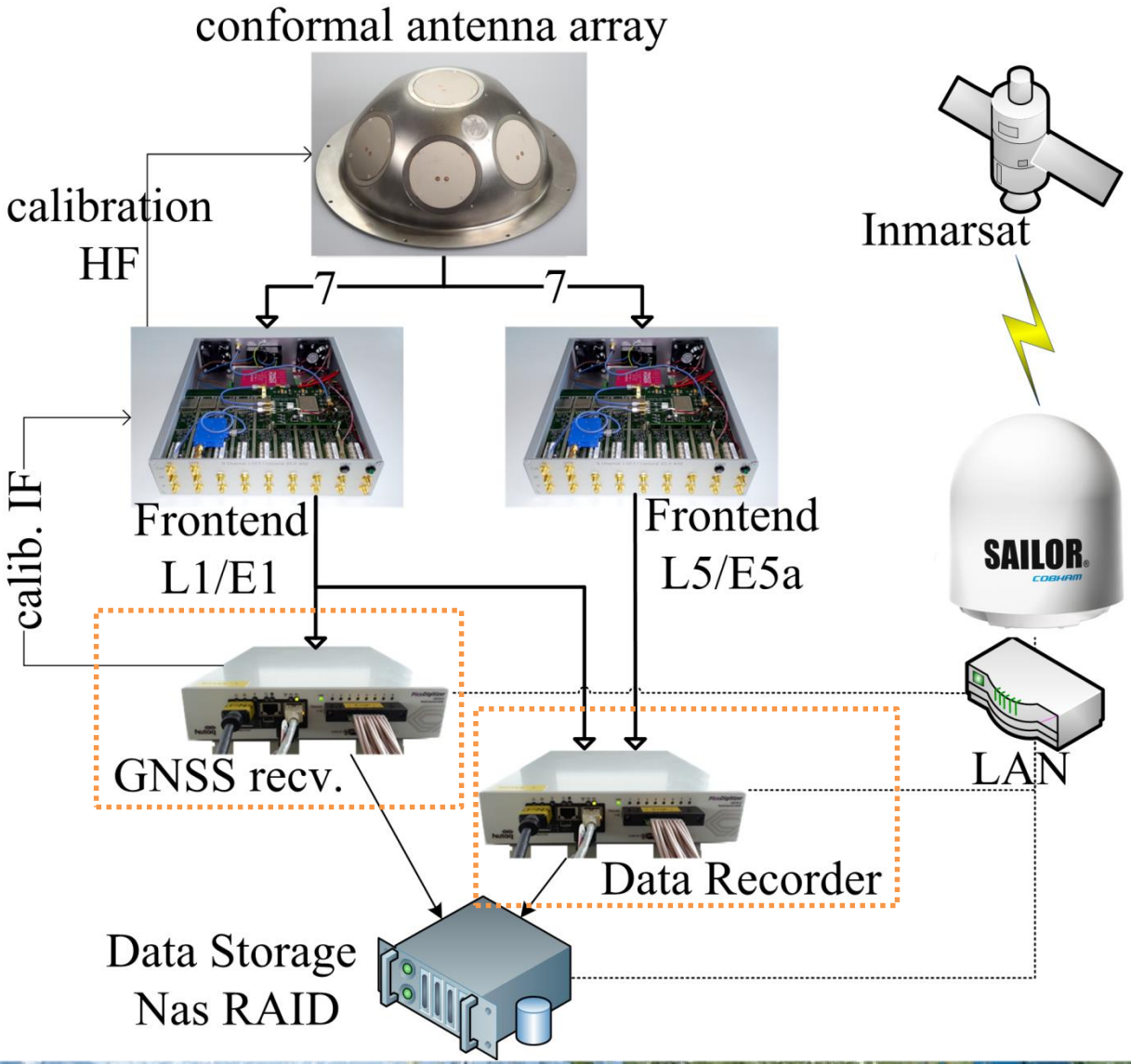


Rack
with
Subsystems

DLR

Measurement System

- 7 elements antenna array (covariance)
- Two IF bands (L1/E1 & L5/E5a)
- Snapshot Data: 30-50 ms of data @ 100 MHz
- Storage: 4 TB & satellite link 75 MB
- Calibration for DoA



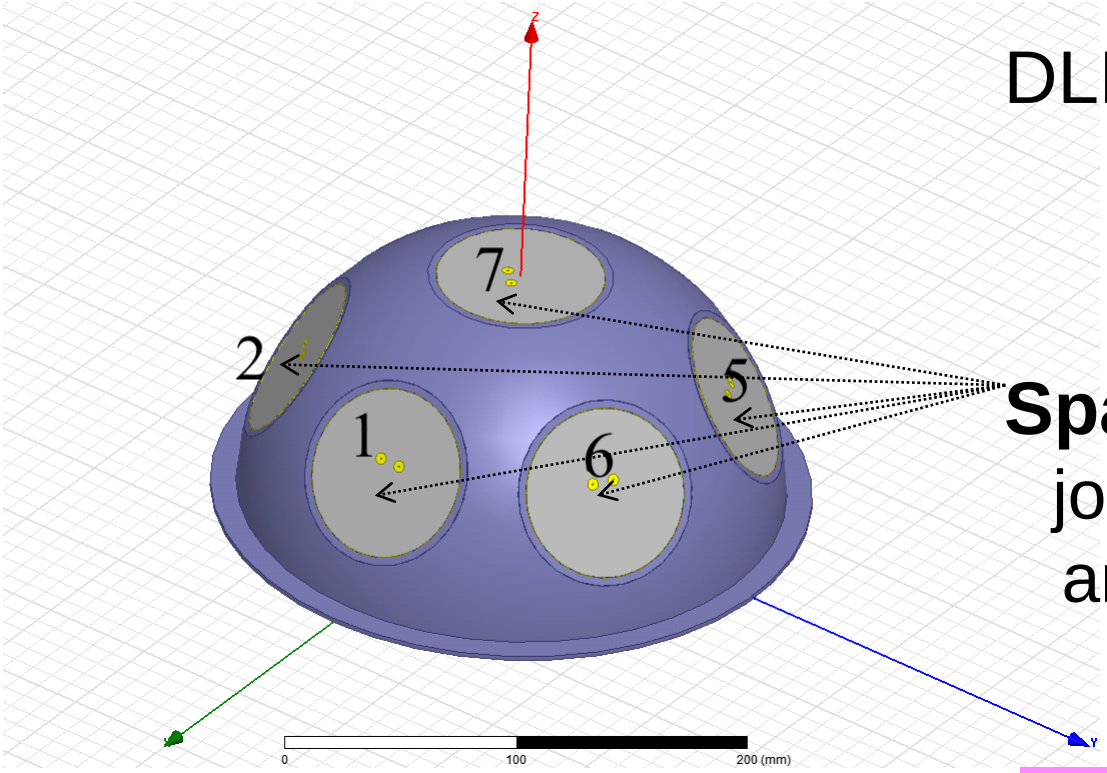
Concurrent metrics

Snapshot recorder

Received Power

from recorded

IF raw samples



DLR GNSS receiver

Spatial Covariance

joint variability of 7

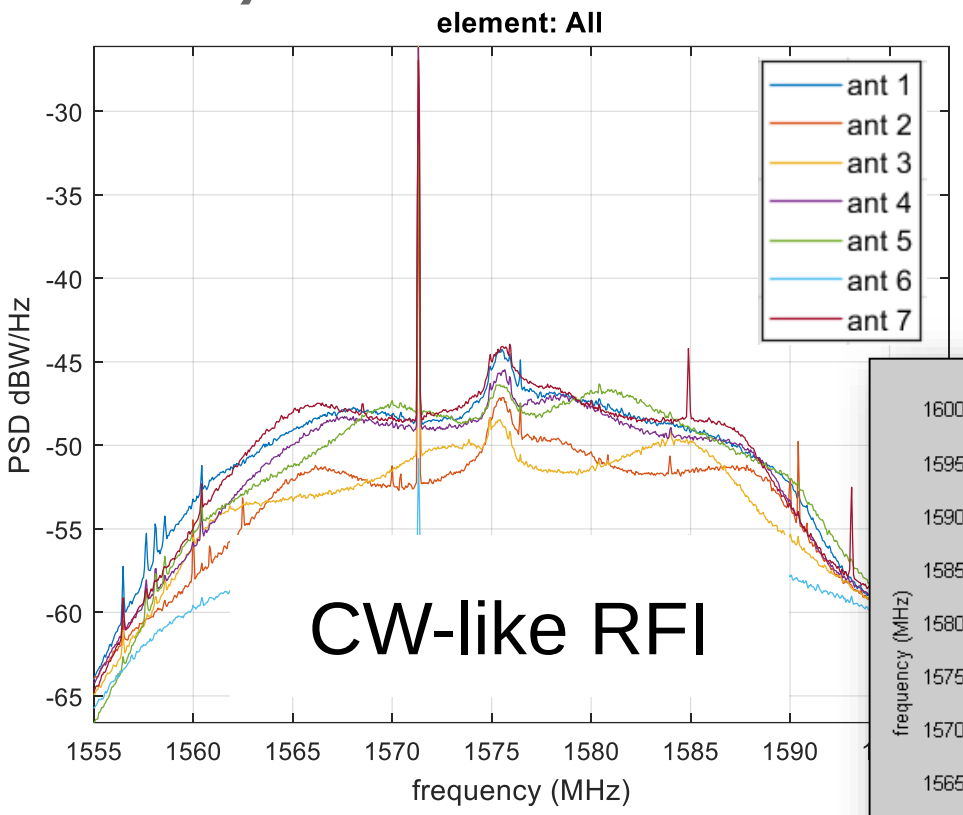
antenna elements

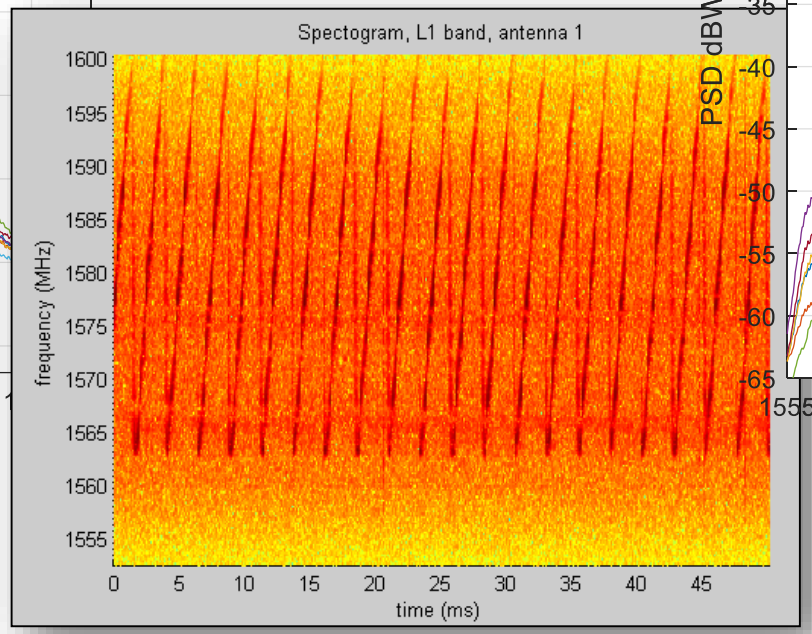
peaks in power → potential interference ← peaks in eigenvalues (λ)

Recorded Route (September ‘17 to January ’18)

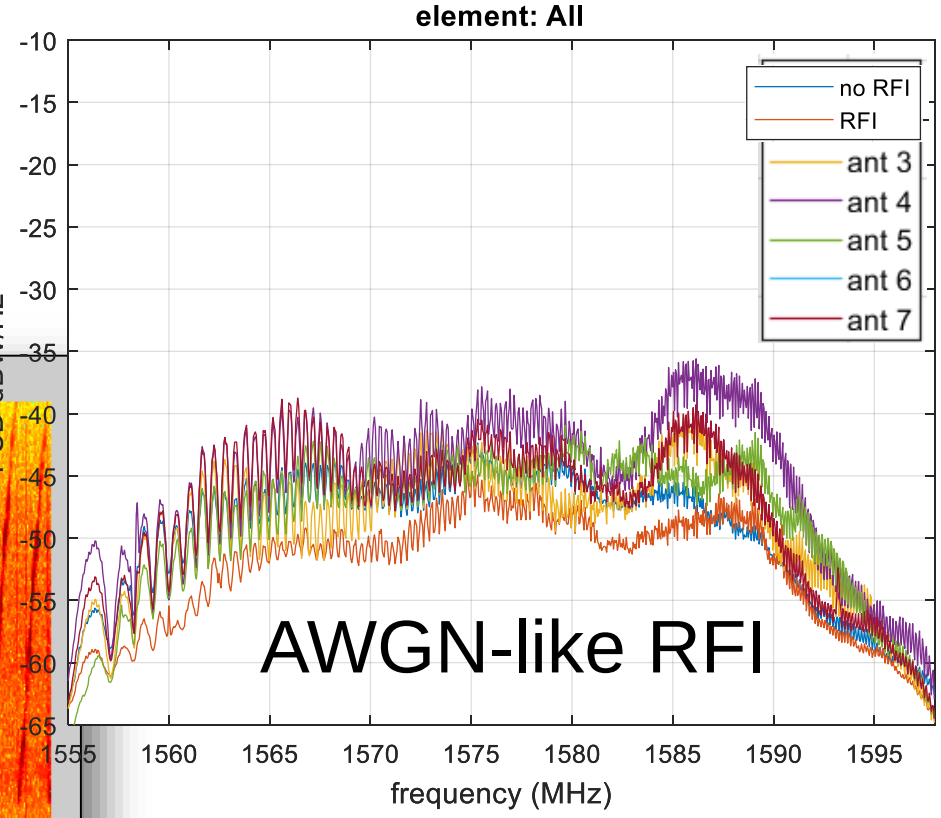
39,045 snapshots recorded!

CW, Wideband and PPD RFIs

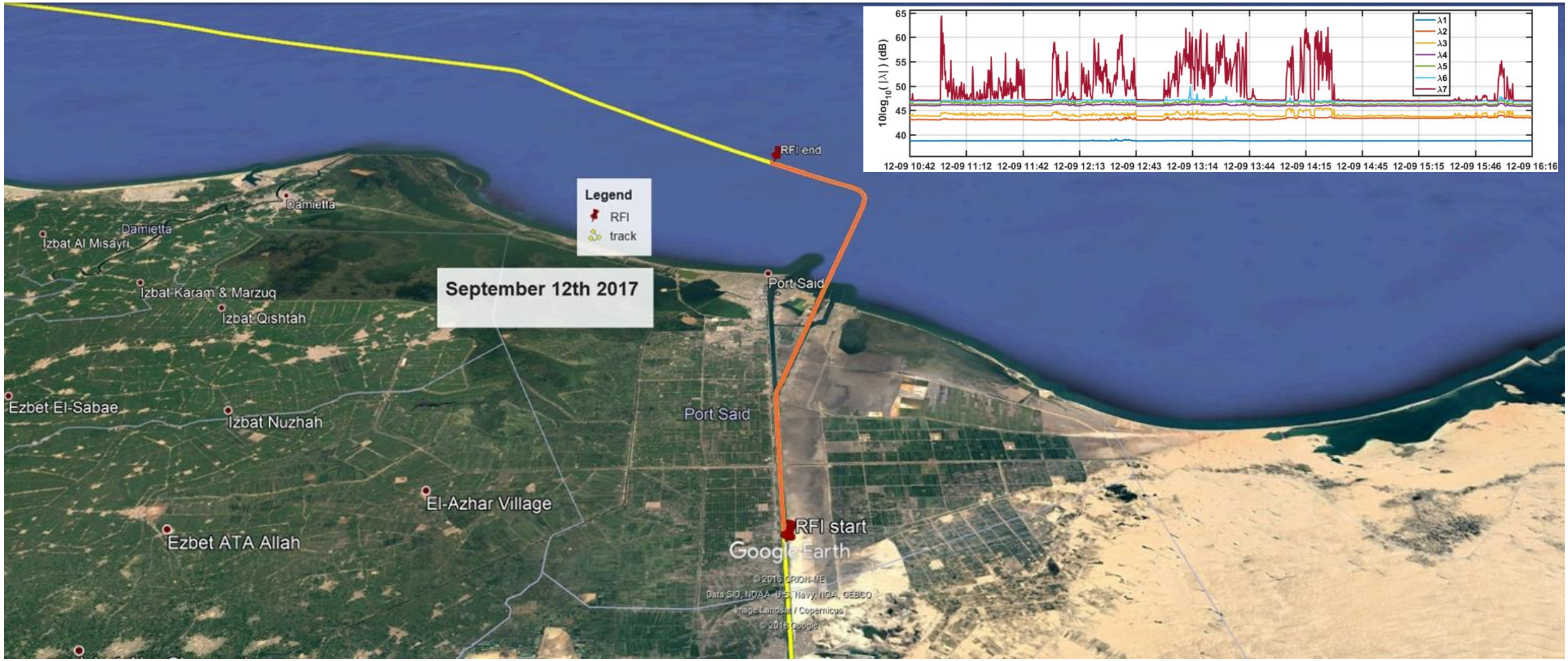




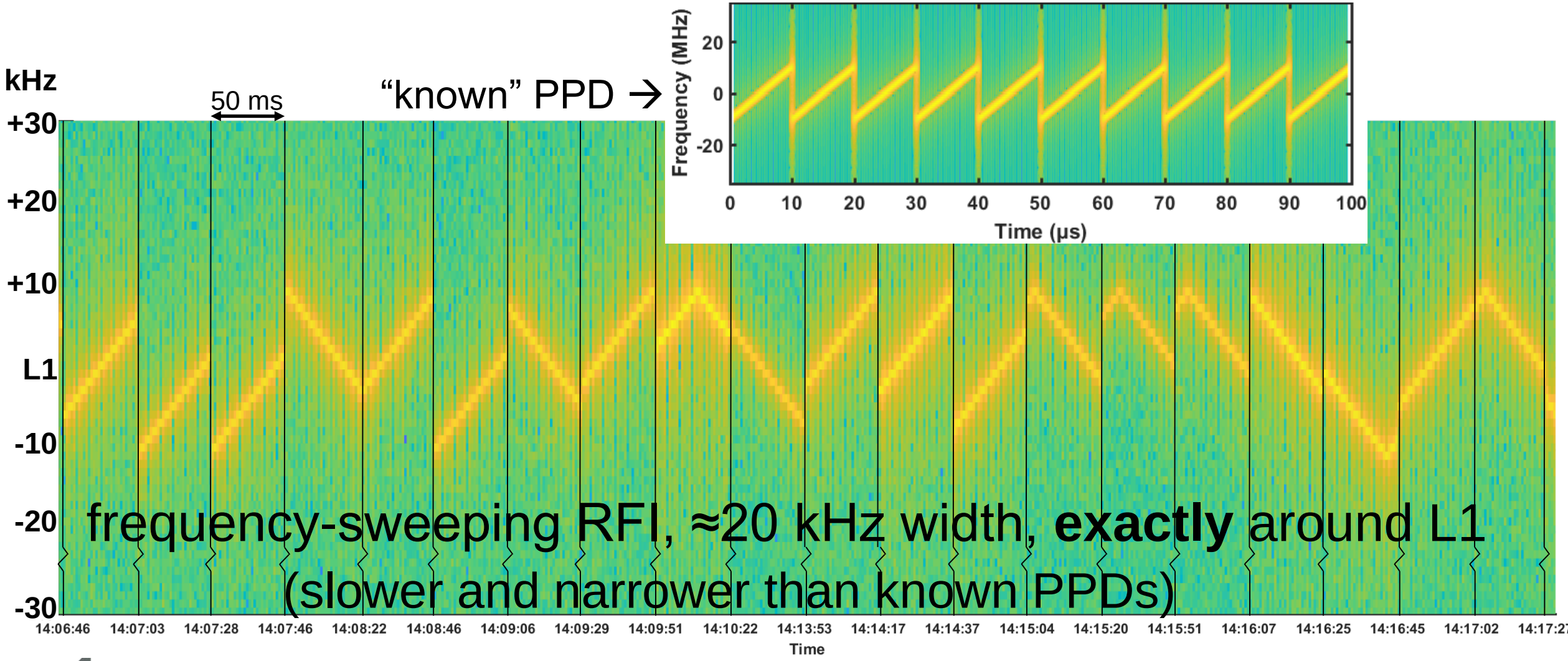
PPD



Suez Canal event (i)

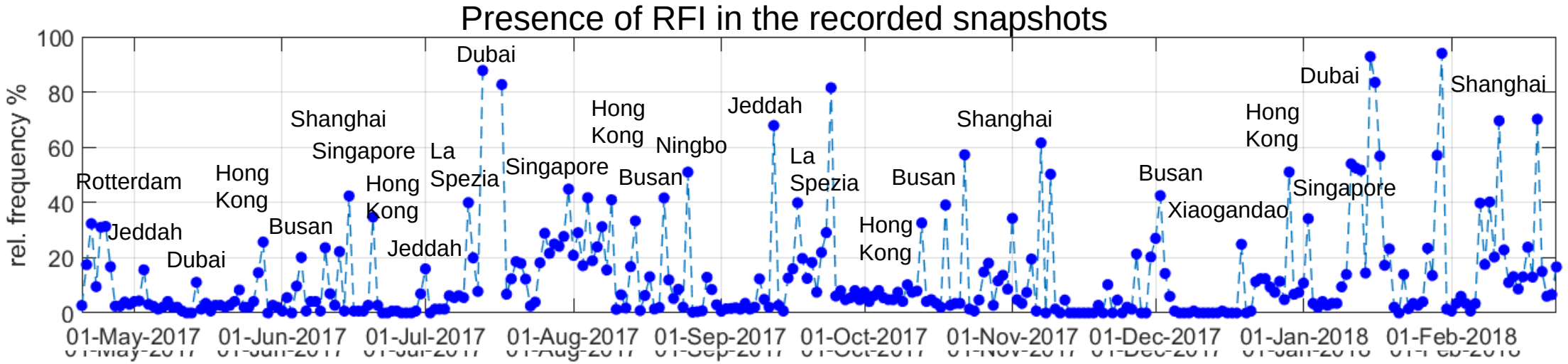


Suez Canal event (ii)



frequency-sweeping RFI, ≈20 kHz width, **exactly** around L1
(slower and narrower than known PPDs)

Detected RFI events

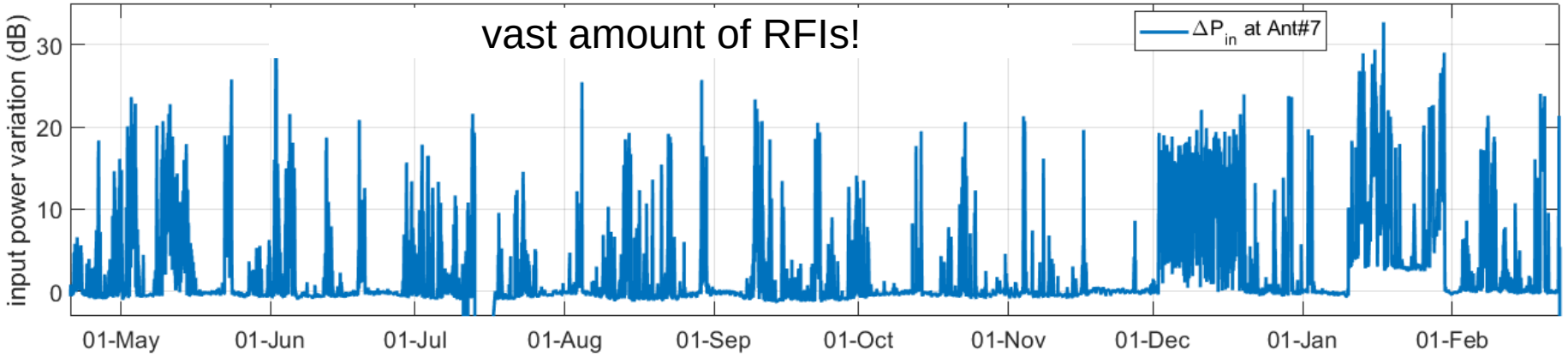


- At certain **locations** at **different visit times** events were detected
  → threat is consistent!

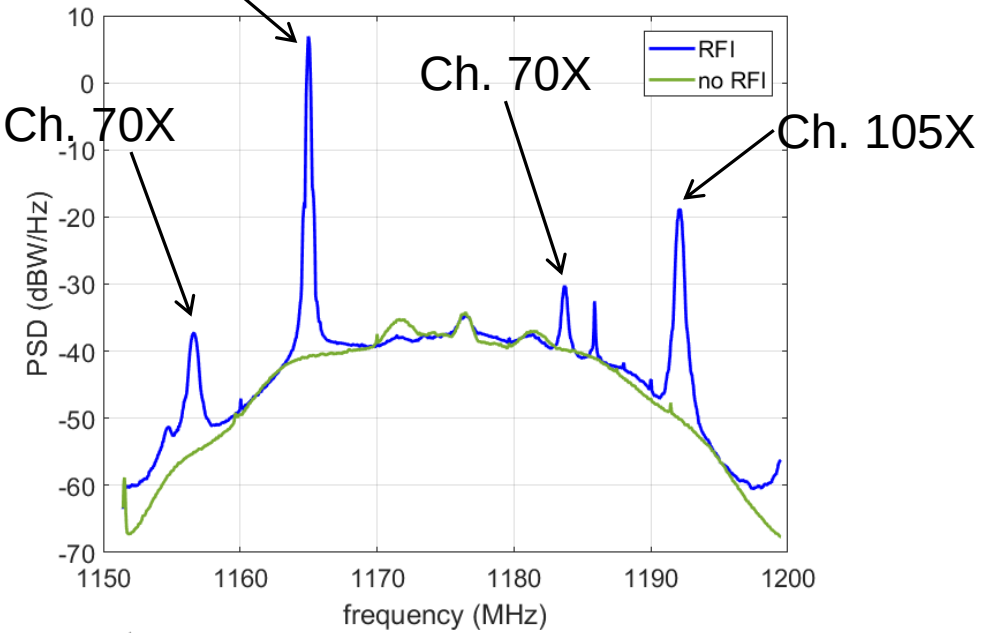
- Harbours (coasts) are the most critical

- Events are also detected in open sea

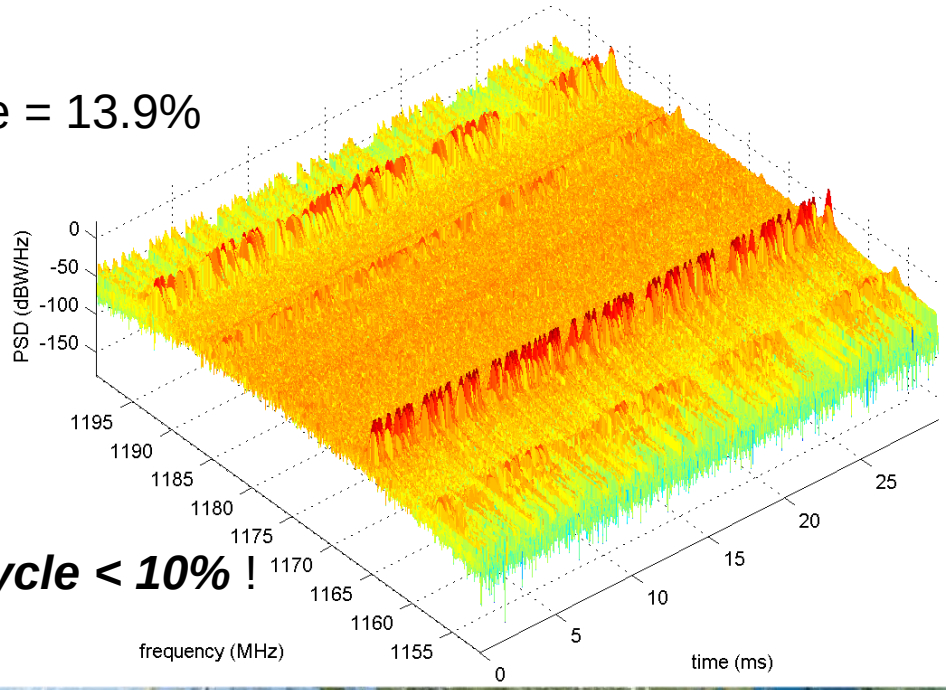
What about L5/E5a?



DME Ch. 78X



Observed duty cycle = 13.9%



pulse-blanker duty cycle < 10% !

Conclusions & Outlook

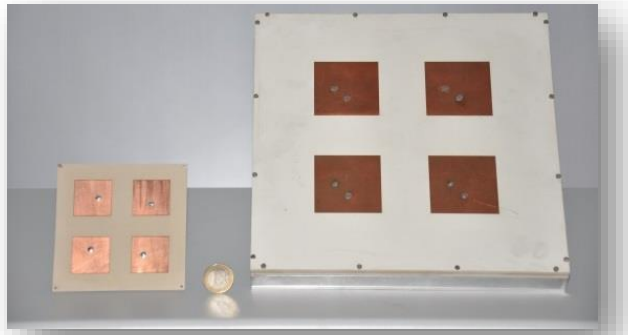
High resolution **raw** and **GNSS** data belonging to the **maritime domain** recorded during a period of 11 months

many **non expected** RFIs detected in L1/E1 (NAV reserved) & L5/E5a bands →

- GNSS **time & position** service is unreliable and
- cannot be **completely trusted** anymore
- **harbours** are specially **sensitive** → **receivers** should deal with it!

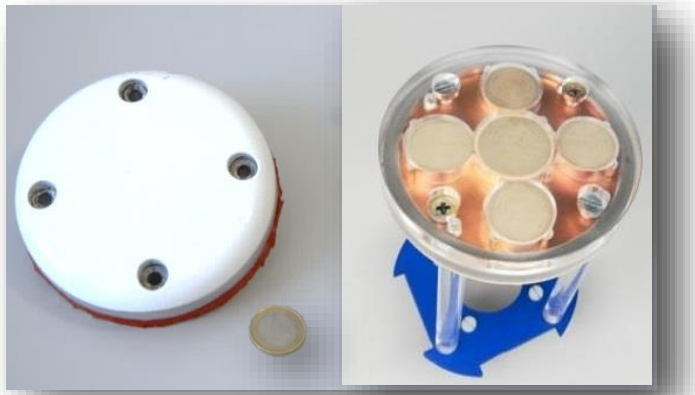
Keep looking at the data
Threat model is required in order to aware manufactures and users

DLR's solution: antenna array systems



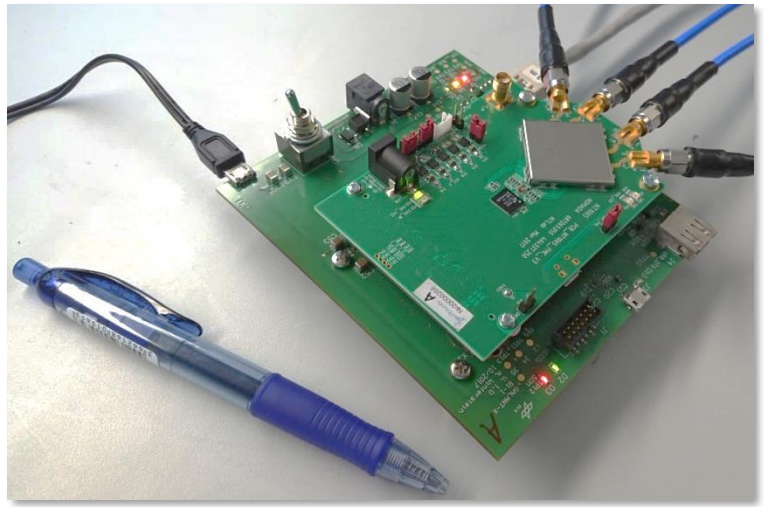
GNSS E1/E5 standard and miniaturized

Conformal antenna array



Miniaturized array and Receiver (ARINC form-factor)

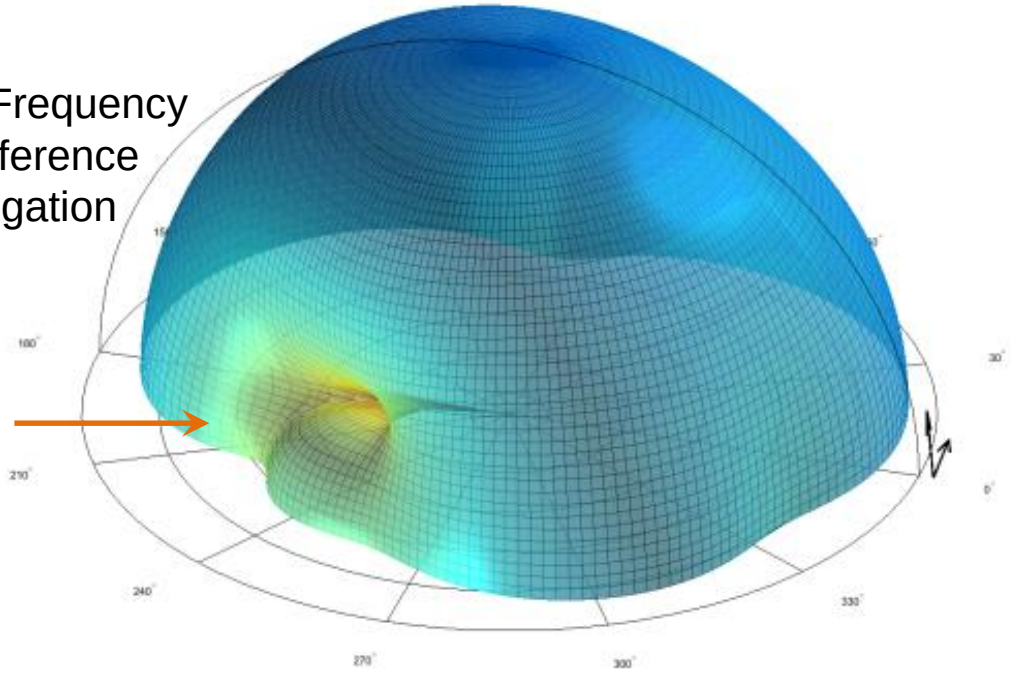
DLR GALANT Multi-Antenna Receiver



DLR's solution: antenna array systems

Desired reception pattern

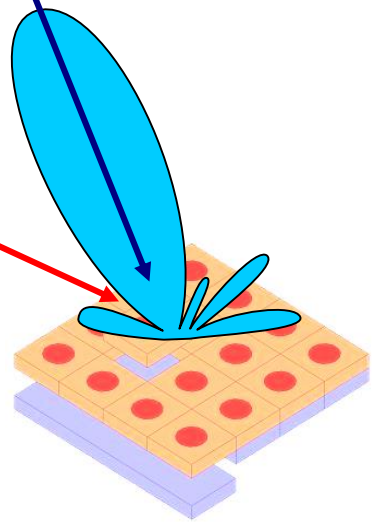
Radio Frequency Interference Mitigation

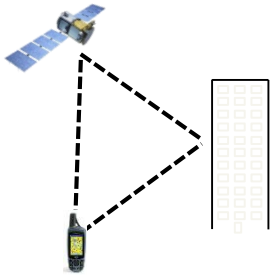


Spatial zero to mitigate unwanted signal

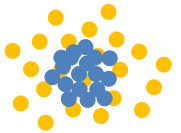
Signal of Interest

Unwanted signal

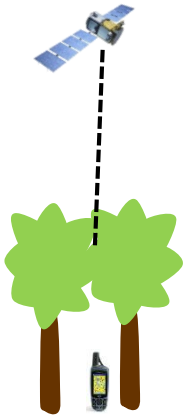




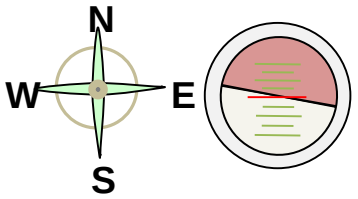
Multipath Mitigation



Better Accuracy



Improved Availability



Attitude Determination

DLR's Baltic Jamming Testbed 2016

GNSS antennas

Jamming equipment

Antennas

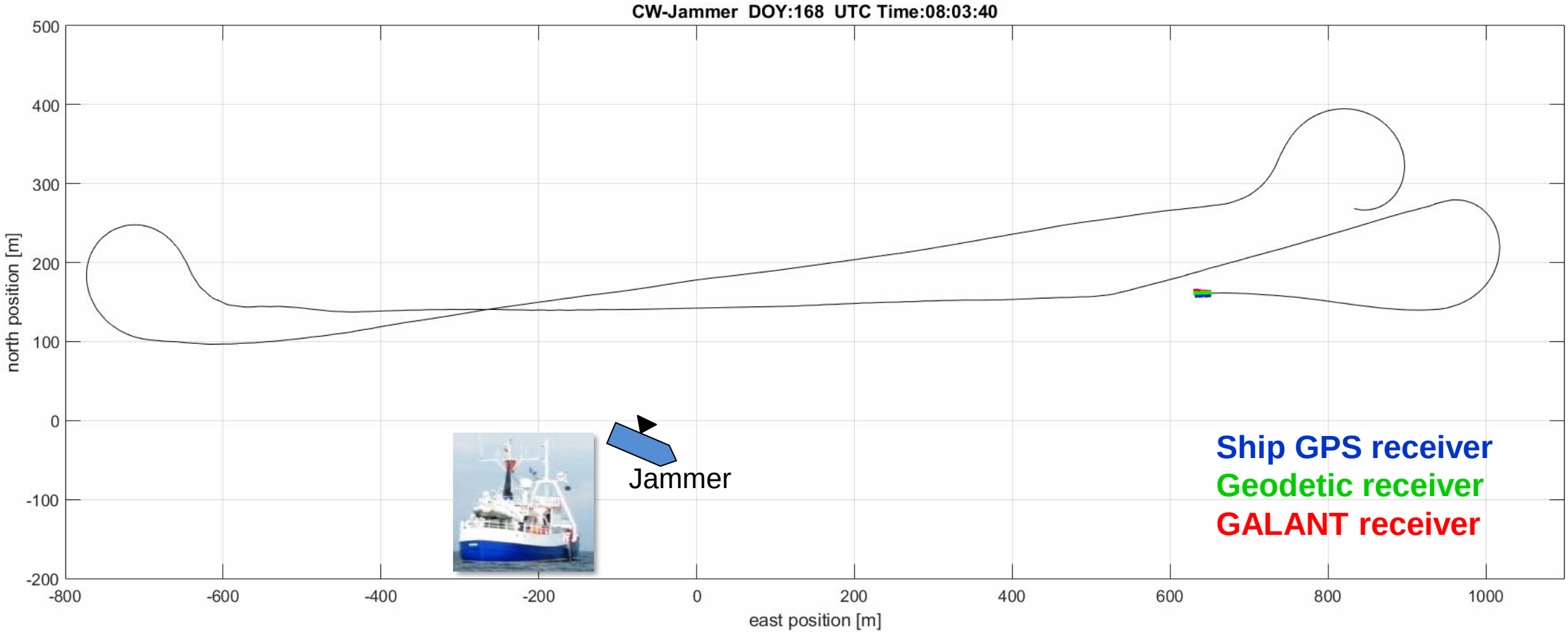
WIND PROTECTOR

Baltic Diver II

THEO FISCHER

GALANT hardware

DLR's Baltic Jamming Testbed 2016



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Thank You!

Q&A