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)

Satellite Comm. Antenna

Conformal Antenna Array

Rack with Subsystems

48 m (157 ft)

45 m (148 ft)
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

Received Power
from recorded IF raw samples

Spatial Covariance
joint variability of 7 antenna elements

peaks in power

potential interference

peaks in eigenvalues (\lambda)

Snapshot recorder

DLR GNSS receiver
Recorded Route (September ‘17 to January ’18)

39,045 snapshots recorded!
CW, Wideband and PPD RFIs

CW-like RFI

AWGN-like RFI

PPD
Suez Canal event (i)
Suez Canal event (ii)

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

vast amount of RFIs!

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

- Miniaturized array and Receiver (ARINC form-factor)
- Conformal antenna array
- GNSS E1/E5 standard and miniaturized
- DLR GALANT Multi-Antenna Receiver

DLR GALANT Multi-Antenna Receiver

Miniaturized array and Receiver (ARINC form-factor)

Conformal antenna array

GNSS E1/E5 standard and miniaturized
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
- Improved Availability
- Better Accuracy
- Attitude Determination

Better Accuracy

Improved Availability
DLR’s Baltic Jamming Testbed 2016

- **GNSS antennas**
- **Baltic Diver II**
- **GALANT hardware**
- **WIND PROTECTOR**
- **THEO FISCHER**

**Jamming equipment**
**Antennas**
Thank You!

Q&A