

A composite background image showing a snowy mountain range. In the foreground, there are wind turbines on a rocky outcrop. To the left, a large ship is in the water. In the distance, a city skyline is visible. An airplane is flying in the sky. The overall scene is a mix of natural and industrial elements.

NAVISP INDUSTRY DAYS ARFIDAAS PROJECT

Aiden Morrison, 23.01.2020

Today's Schedule

- ARFIDAAS is a NAVISP element 3 activity
 - "Advanced RFI Detection, Alerting and Analysis System"
 - Goal: To detect, analyze and alert site stakeholders of GNSS RFI events affecting their systems, and to centrally collect associated event data for future exploitation.
- SINTEF introduction
- The Advanced RFI Detection, Alerting and Analysis System (ARFIDAAS) project
 - Background, design, deployment, and early results
 - Future plans for ARFIDAAS
 - Time for questions

SINTEF: One of Europe's largest independent research organisations



NOK 3.2 billion
Revenues

NOK 450 MILL
International sales

Applied research, technology and innovation

Expertise from ocean space to outer space:



Renewable energy



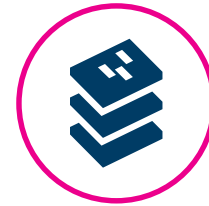
Ocean space



Industry



Buildings and
infrastructure



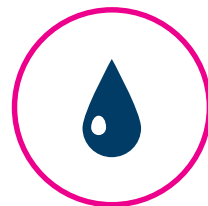
Materials



Micro-, nano- and
biotechnology



Climate and environment



Oil and gas



Health and welfare



Society



Digitalization



Mobility

GNSS disruption incidents – a growing problem

Truck driver has GPS jammer, accidentally jams Newark airport

An engineering firm worker in New Jersey has a GPS jammer so his bosses don't know where he is all the time. However, his route takes him close to Newark airport, and his jammer affects its satellite systems.

BY CHRIS MATYSZCZYK | AUGUST 11, 2013 8:08 AM PDT

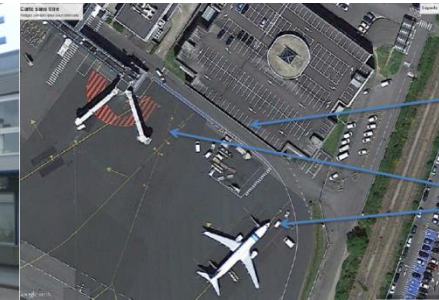


JAMMING: Piloter advares mot at GPS-signalet kan forsvinne (luftrommet fra Kirkenes til Lyngen) Trams. Foto: Privat

Pilotene mister GPS-signalet i Finnmark. Det kan knyttes til russiske øvelser

«Det er grunn til å tro at det kan relateres til militære øvelsesaktiviteter utenfor norskekysten», sier Luftfartstilsynet.

'Forgotten' GPS jammer costs motorist €2,000



CAR PARK

GATES 6 and 7

The Chirp Jammer: a GPS hit and run



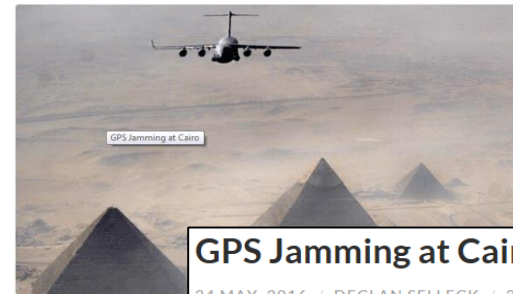
The €50 device that brought a multi-million euro project to a standstill

Aftenposten | A-magasinet | Oslo | Sport | Meninger | Bilabonnement | Meny | Norge



Luftambulansen mistet navigasjonssystemet på vei til pasient. Årsaken sto i sigarettene til en bil.

Piloten var overlatt til det han så ut vinduet for å finne veien til den kritisk syke pasienten.



GPS Jamming at Cairo

24 MAY, 2016 / DECLAN SELLECK / 3 COMMENTS

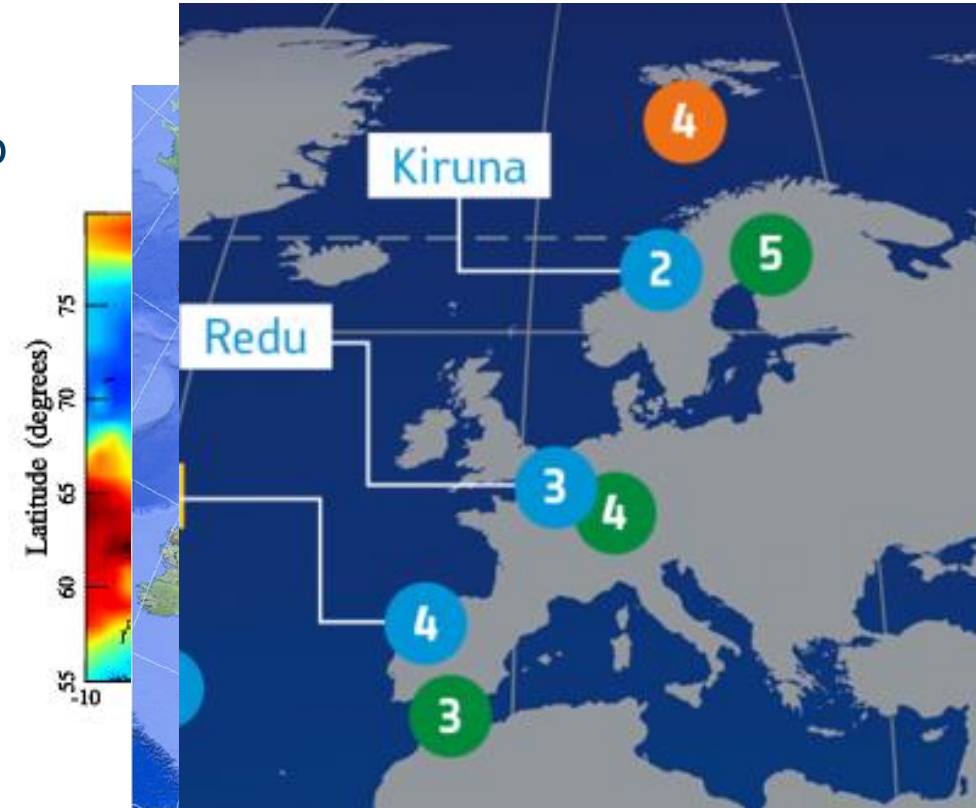


'We hacked U.S. drone': Iran claims it electronically hijacked spy aircraft's GPS and tricked aircraft into landing on its soil

By: Craig Mackenzie and Mark Duell
Updated: 10:36 EDT, 19 December 2011

Norway's GNSS interests

- All countries have an interest in the trouble-free operation of Galileo
- Norway is a small country with a substantial investment in GNSS
 - Image 1: GNSS infrastructure of the NMA
 - Supports the CPOS centimetric network RTK system
 - Not shown: dedicated Scintillation monitors
 - Image 2: seSolstorm ionospheric activity monitoring
 - Image 3: Galileo ground station on Svalbard
- Treaties clearly state an intent to defend the spectrum

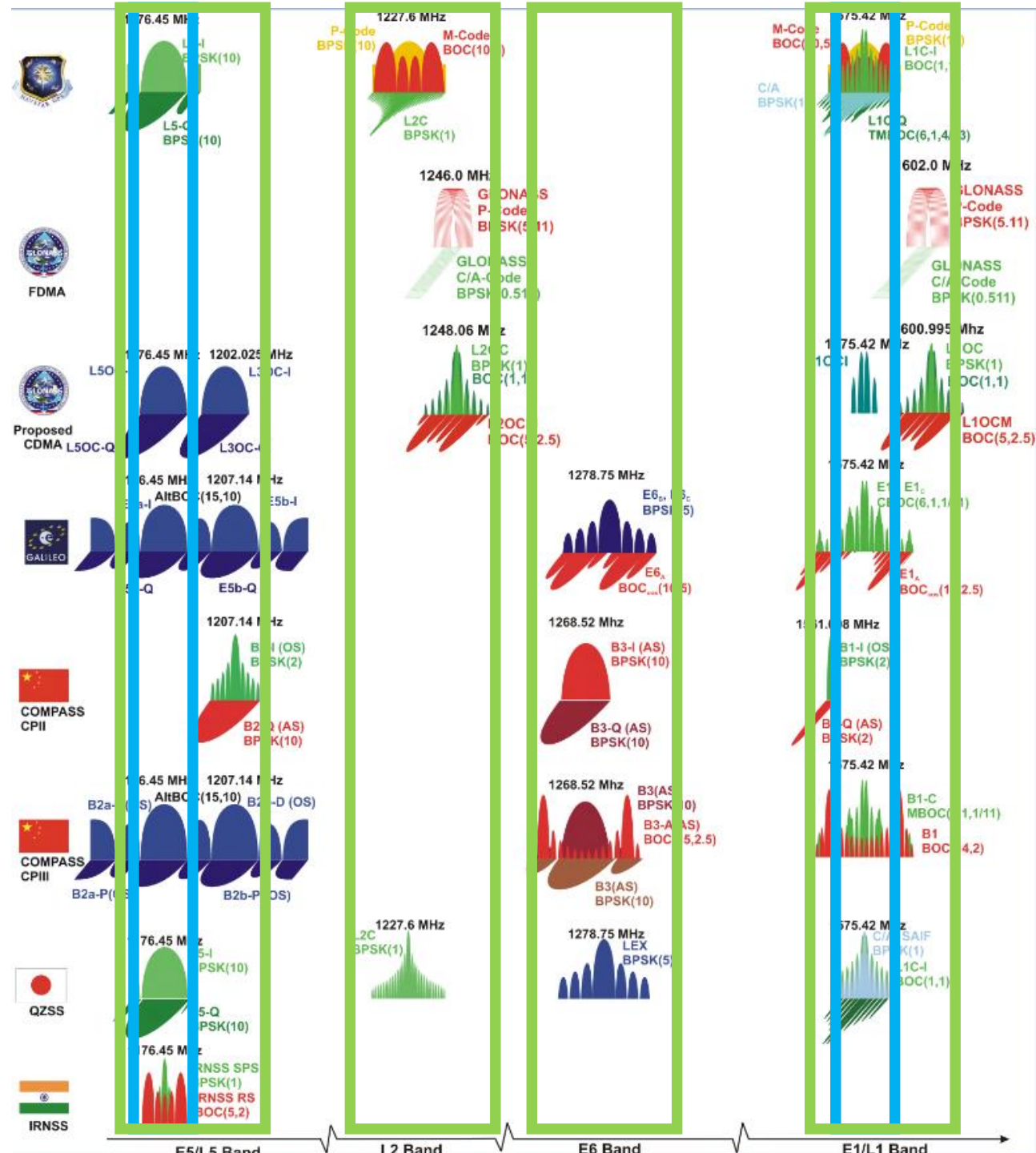


Article 4, point 3 of the **Cooperation Agreement on Satellite Navigation between the European Union and its Member States and the Kingdom of Norway** states "*the Parties recognize the importance of protecting radio navigation spectrum from disruption and interference. To this end they shall identify sources of interference*" while Article 5 point 2 clarifies that "*Norway shall take all means practicable to maintain the facilities free from local radio interference*".

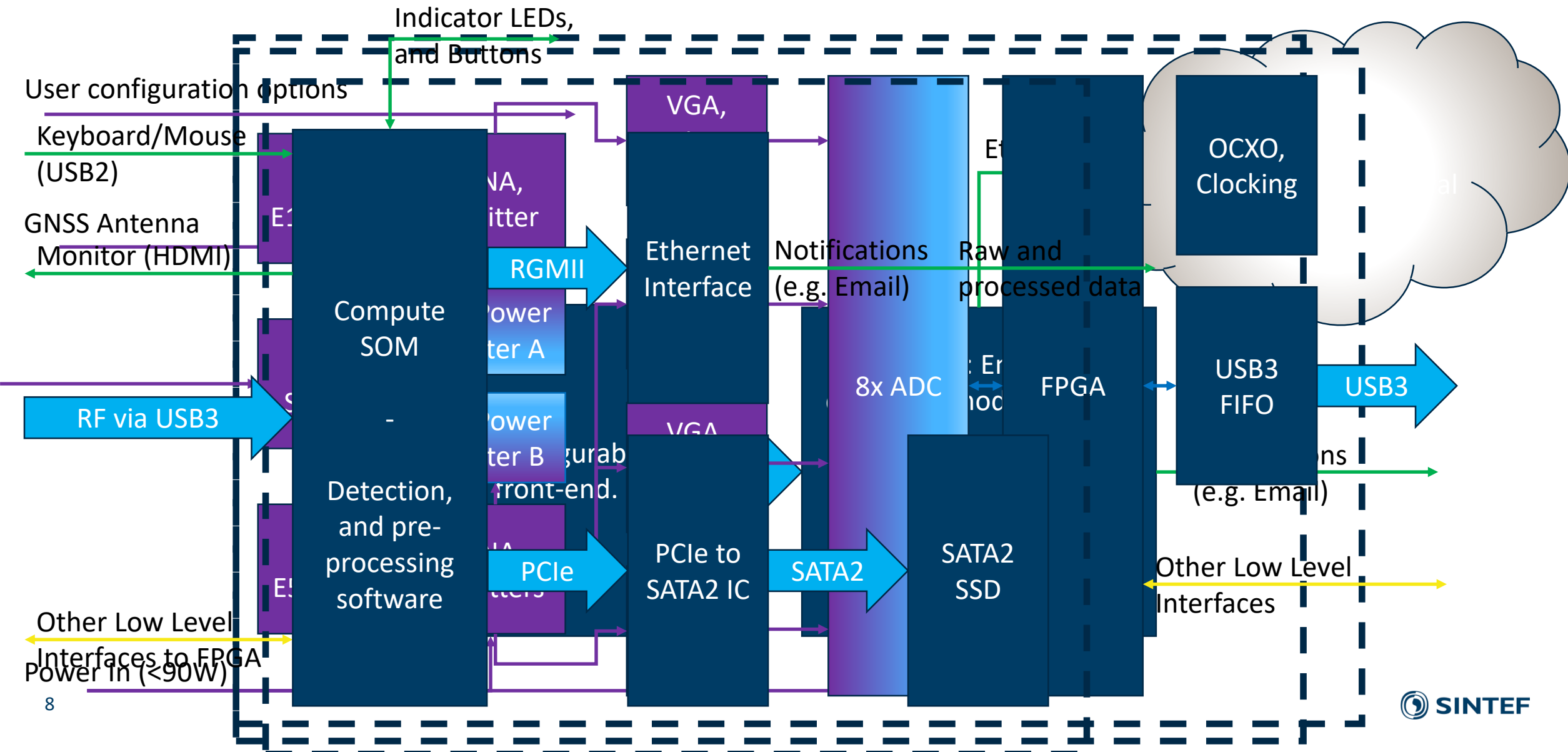
- ⁶• At some point tools are needed to turn this in to action – and there's a lot of spectrum to cover 

Monitored bands

- A chart is helpful:
- Ignoring the S-band signals, this chart shows the L-band
- Signal plans evolve over time
 - Uncertain if the GLONASS CDMA plans are still accurate
 - Most of these signals are now turned on and 'healthy'
- Our past monitor only covered L1+L5
- This system covers "everything" in the GNSS L-band



RFI Monitoring System Architecture



RFI Monitoring system unit and data products

- Results are emailed to stakeholders within 5 minutes
 - Spectral plots and generated reporting help decision making

ID: ARFIDAAS_Trondheim_2019_10_31_10_10_29

2019-10-31T10:10:29Z

Input file: Event003.DAT

Detection duration: 3.0 seconds

Analysis window: 1.0 seconds

Bandwidth: 60.0 [MHz]

Monitoring bands' center frequency: A: 1585.0 [MHz]. B: 1279.0 [MHz]. C: 1233.0 [MHz]. D: 1192.0 [MHz].

Antenna type: Novatel_704WB

Location: Norway, Trondheim, site: Trondheim, coordinates: 60N, 11E

Event origin: 0x00000811

Baseline: RF front end parameters

Avg highband power:-101.81 [dBm] at input

Avg lowband power:-89.47 [dBm] at input

Avg AGC value A: 394.90. Avg AGC value B: 397.70. Avg AGC value C: 393.60. Avg AGC value D: 409.55.

Event003: RF front end parameters

Avg highband power:-93.70 [dBm] at input

Avg lowband power:-89.50 [dBm] at input

Avg AGC value A: 463.09. Avg AGC value B: 397.41. Avg AGC value C: 393.59. Avg AGC value D: 409.57.

Event003: Frequency analysis

Band A - Center frequency: 1585.0 [MHz]

Event 1: Event type: WB. Start: 1555.706 [MHz]. End: 1560.294 [MHz]. Max diff: 3.92 [dB]. Mean diff: 1.75 [dB]

Event 2: Event type: WB. Start: 1561.882 [MHz]. End: 1574.412 [MHz]. Max diff: 2.31 [dB]. Mean diff: 1.11 [dB]

Event 3: Event type: WB. Start: 1577.059 [MHz]. End: 1584.647 [MHz]. Max diff: 3.49 [dB]. Mean diff: 1.44 [dB]

Band B - Center frequency: 1279.0 [MHz]

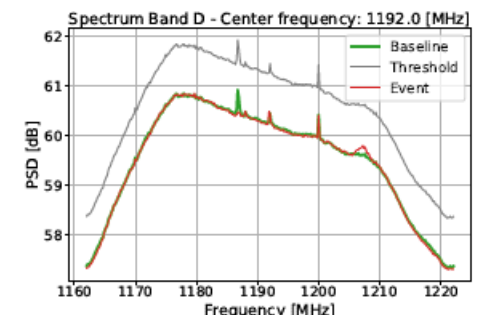
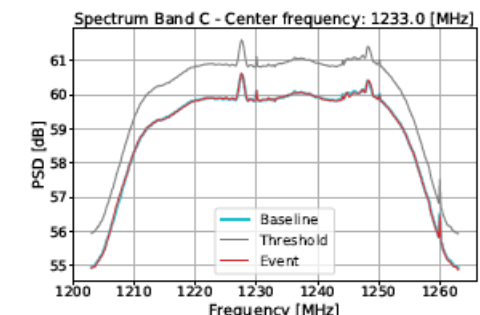
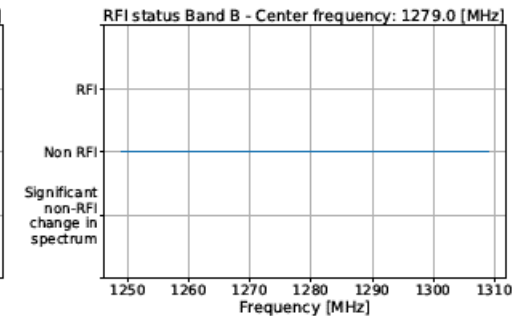
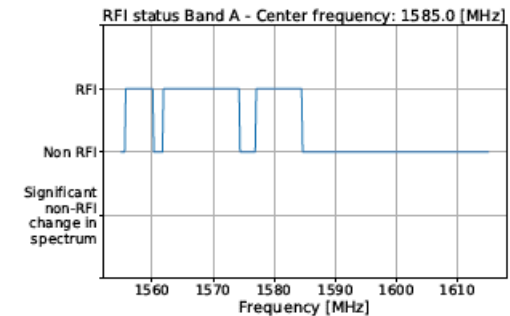
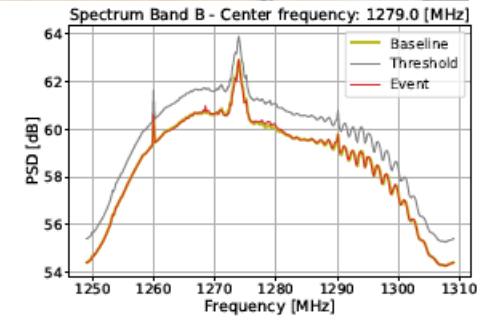
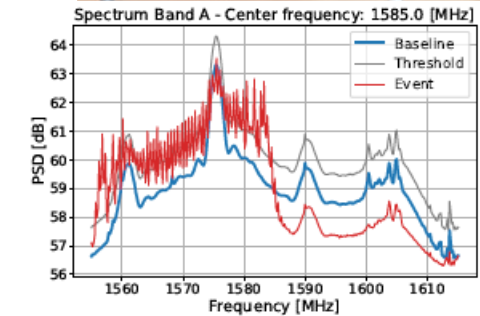
No events detected

Band C - Center frequency: 1233.0 [MHz]

No events detected

Band D - Center frequency: 1192.0 [MHz]

No events detected



Front-End deployment – 1 of 9

- Home: White Star - Now
 - SINTEF, Trondheim
 - Wave 1: Green Stars (11-13 Nov.)
 - University of Helsinki
 - ESTEC, Noordwijk
 - NLR, Amsterdam
 - Wave 2: Blue Stars (12-13 Dec.)
 - Trondheim B
 - Indra Navia, Asker
 - Wave 3: (TBD)
 - SINTEF, Oslo
 - Statens Vegvesen roadside?
- 10
- Map care of creative commons.



Front-End deployment – 2 of 9

- Trondheim – L1 ‘borrowed company vehicle’ and Radar

ID: ARFIDAAS_Trondheim_2019_10_31_10_10_29

2019-10-31T10:10:29Z

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Band B - Center frequency: 1279.0 [MHz]

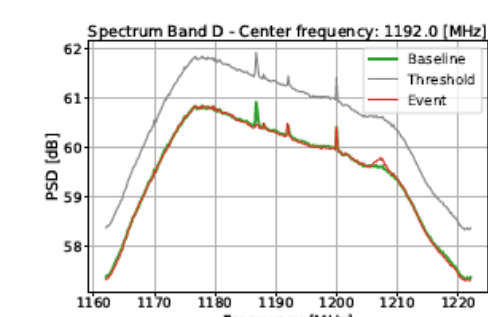
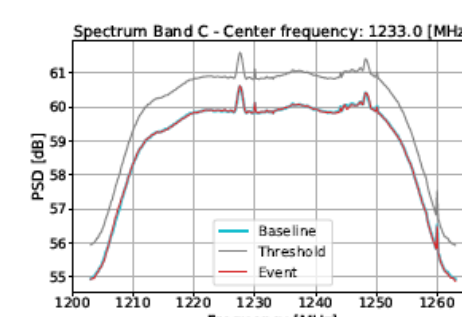
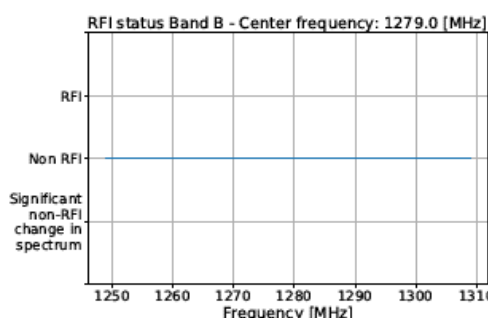
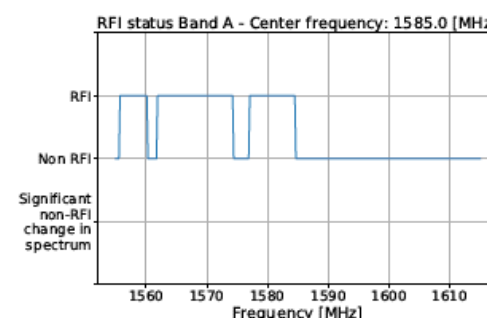
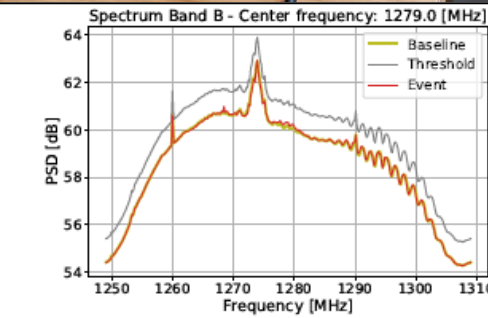
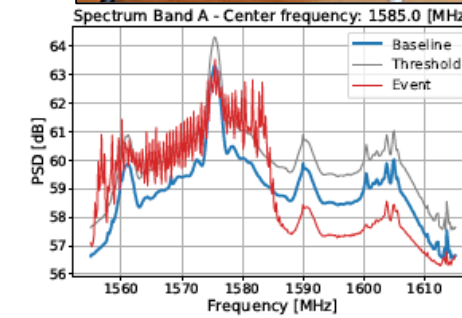
No events detected

Band C - Center frequency: 1233.0 [MHz]

No events detected

Band D - Center frequency: 1192.0 [MHz]

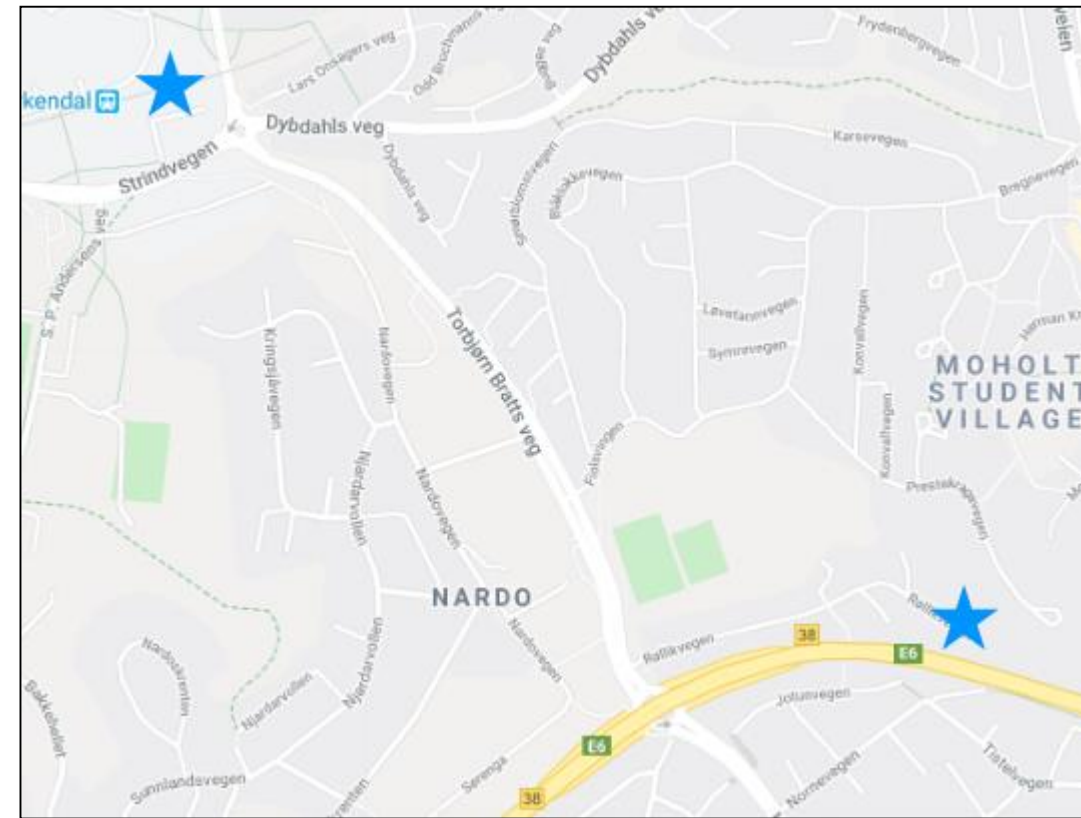
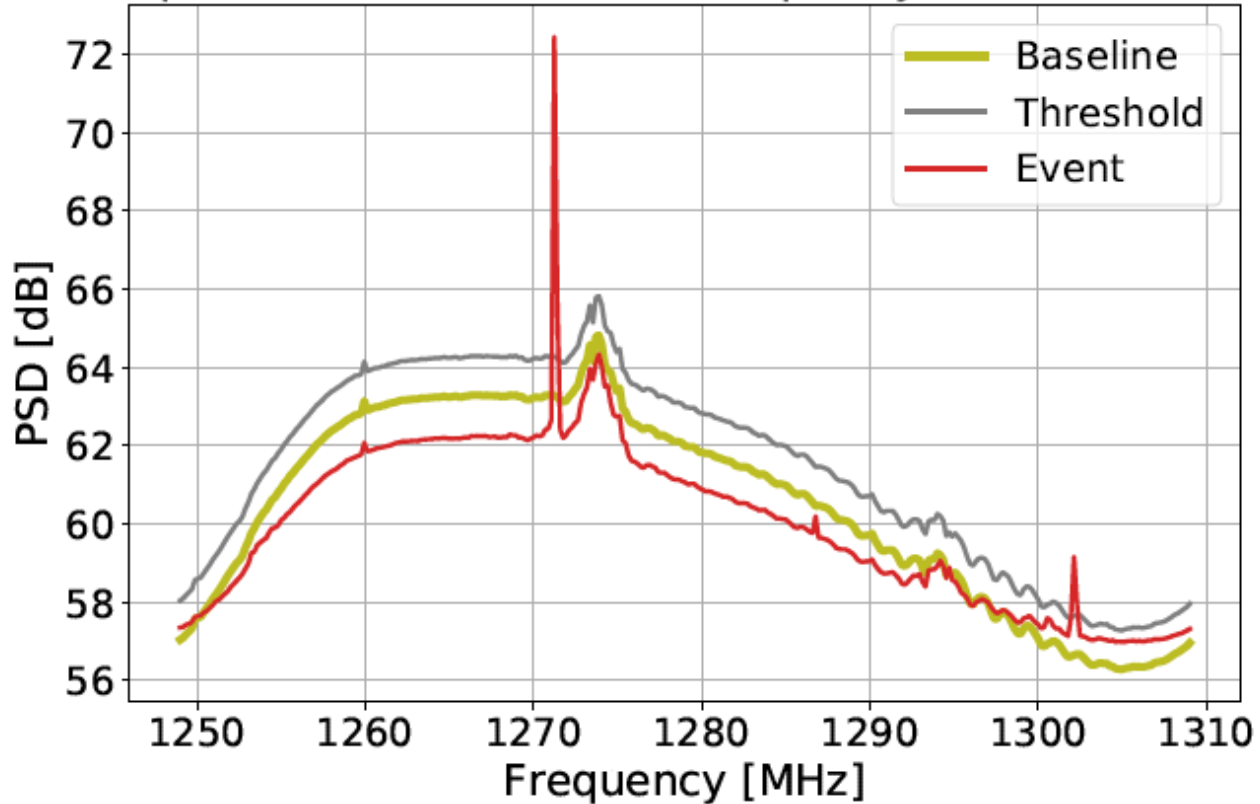
No events detected



Front-End deployment – 3 of 9

- Trondheim B
 - Direct view of a major highway with on/off ramps
 - Many events detected in only a few days
 - B6 tone in addition to the Radar
 - Intermittent L2 events – had to disable L2 detection

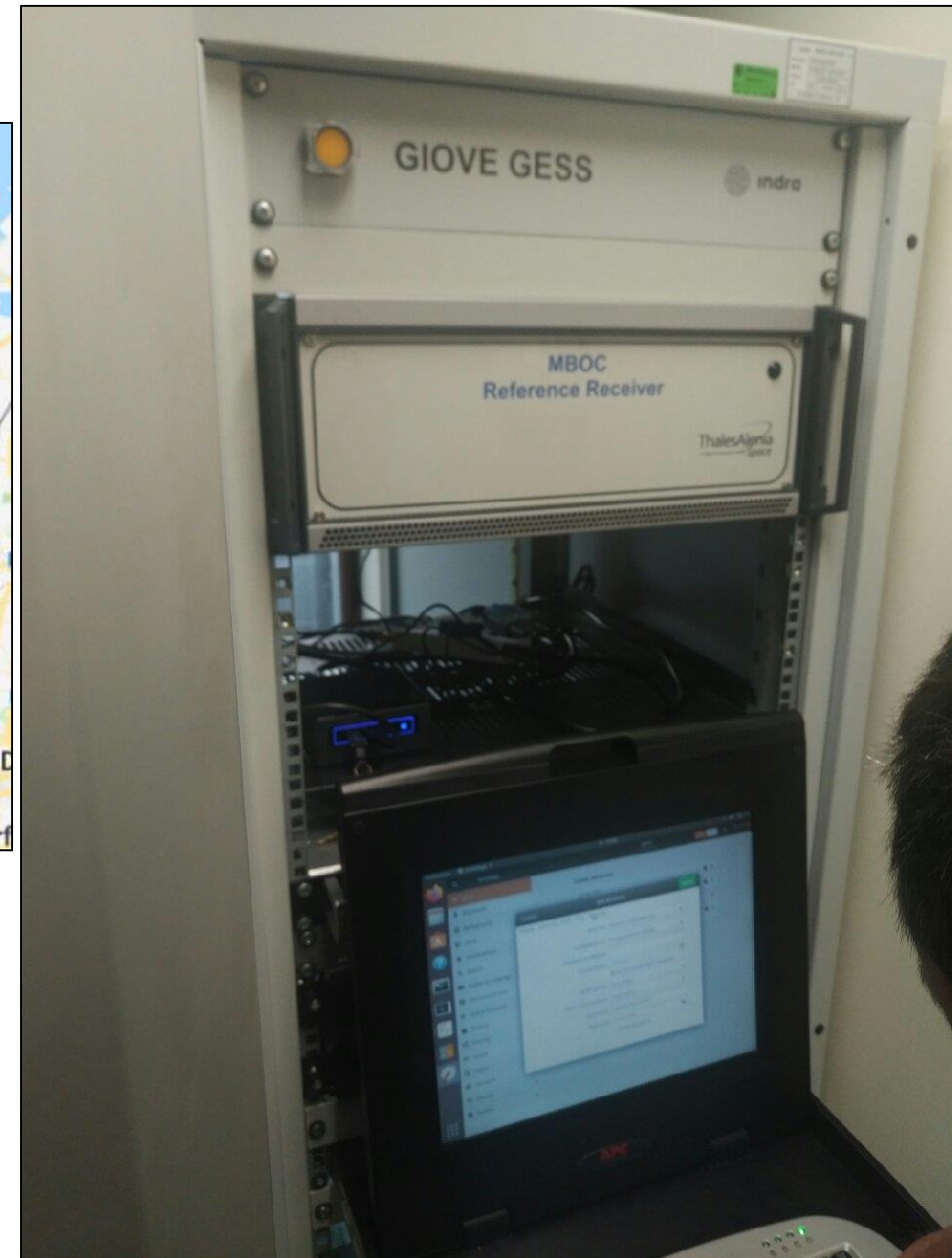
Spectrum Band B - Center frequency: 1279.0 [MHz]



- Just use GLONASS (™)?

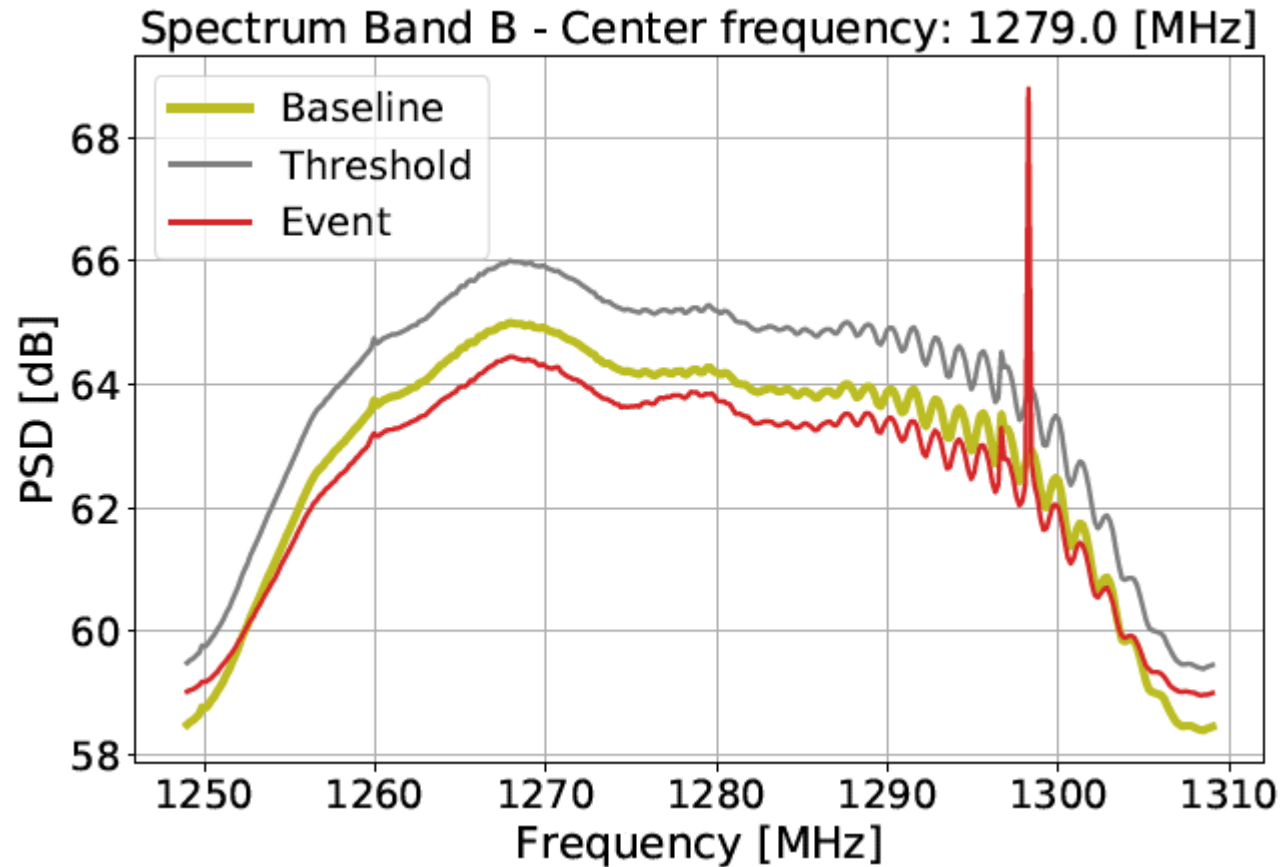
Front-End deployment – 4 of 9

- ESTEC
- Netherlands near Leiden
 - Noordwijk
- We don't expect many events
 - Campus back from highway
 - No large roads nearby
- Why deploy here? Because we have noticed events here before
 - In the SESAR RFI monitoring project we captured at least two
 - One was pulsed nearband power
 - The other we believe was a taxi or delivery vehicle w/jammer



Front-End deployment – 5 of 9

- Even in a well protected campus, distant from roads E6 is 'busy'
 - Likely not a threat to E6, but still a 'noisy neighbor'

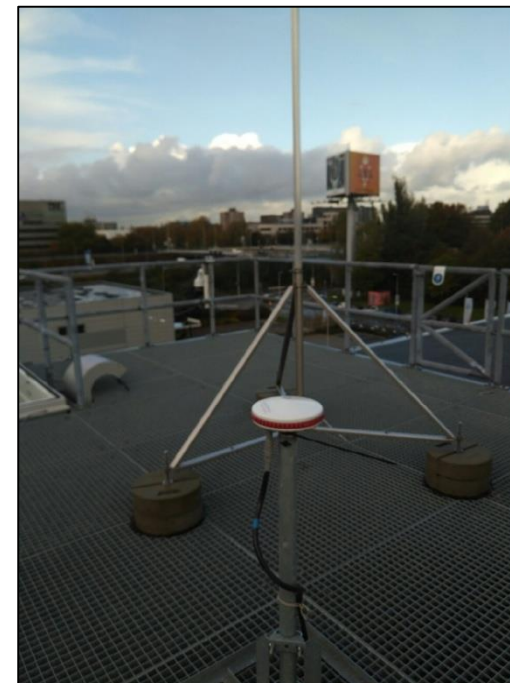
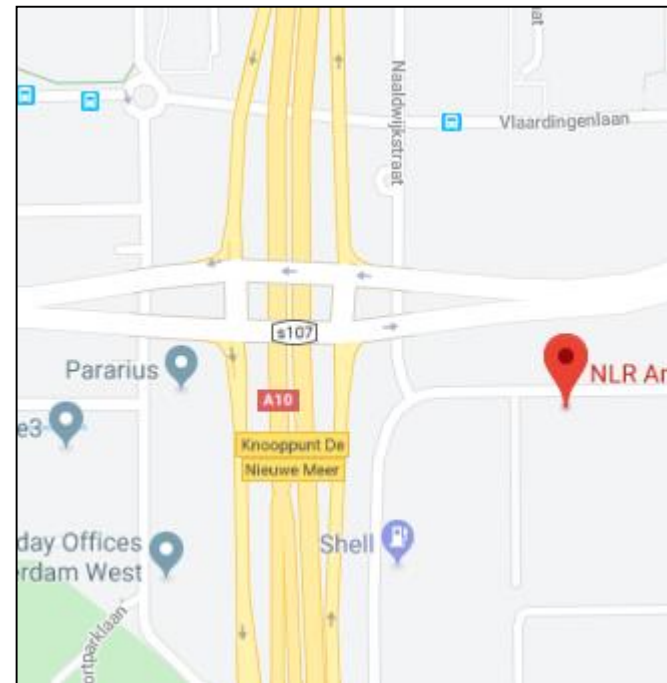


- Some locations have both jammers and 'noisy neighbors'

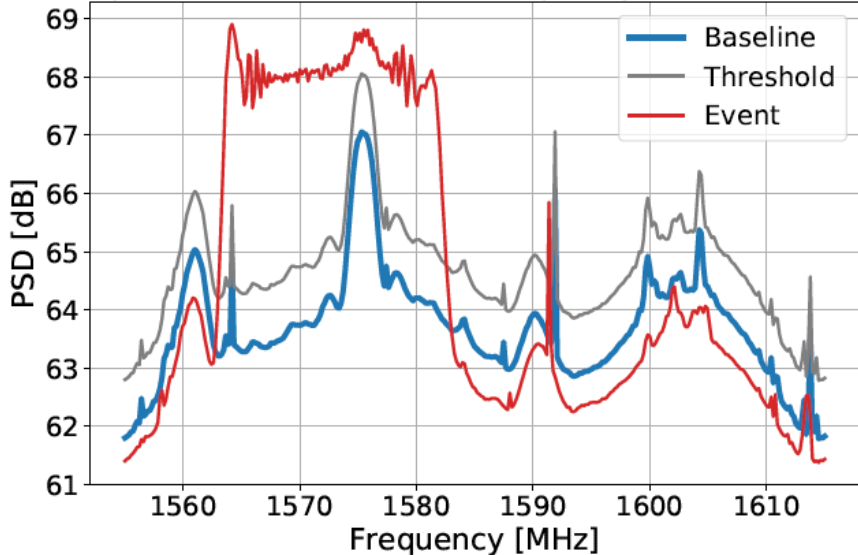


Front-End deployment – 6 of 9

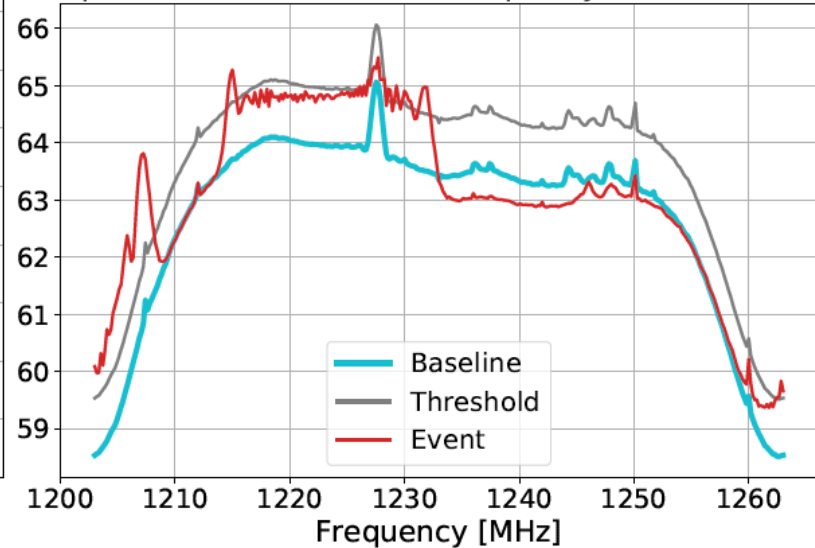
- NLR
- Office located next to a very busy highway
- Known occurrences of RFI based on past investigations
- Instances of triple frequency jamming observed
 - L1+E1, L2, E5B (If we look closely, L5+E5a too?)
 - Juse use GLONASS^(TM)?
 - However, once again E6 hides a problem



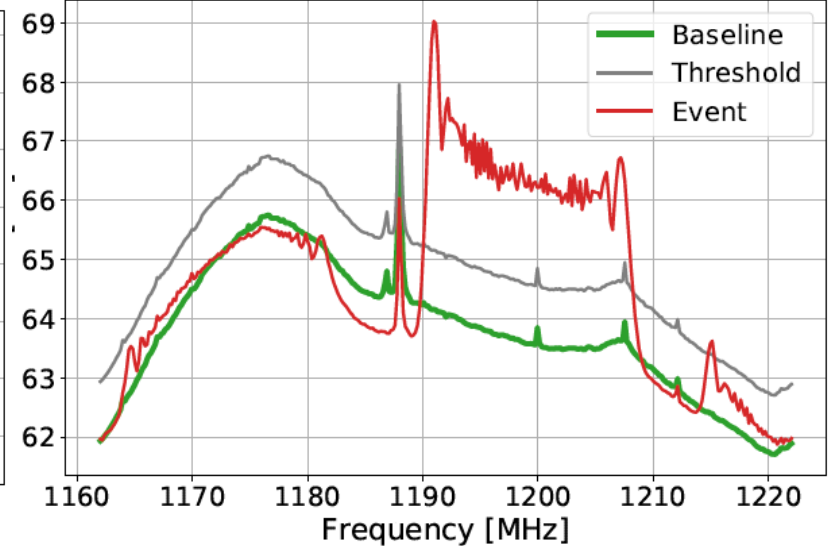
Spectrum Band A - Center frequency: 1585.0 [MHz]



Spectrum Band C - Center frequency: 1233.0 [MHz]



Spectrum Band D - Center frequency: 1192.0 [MHz]

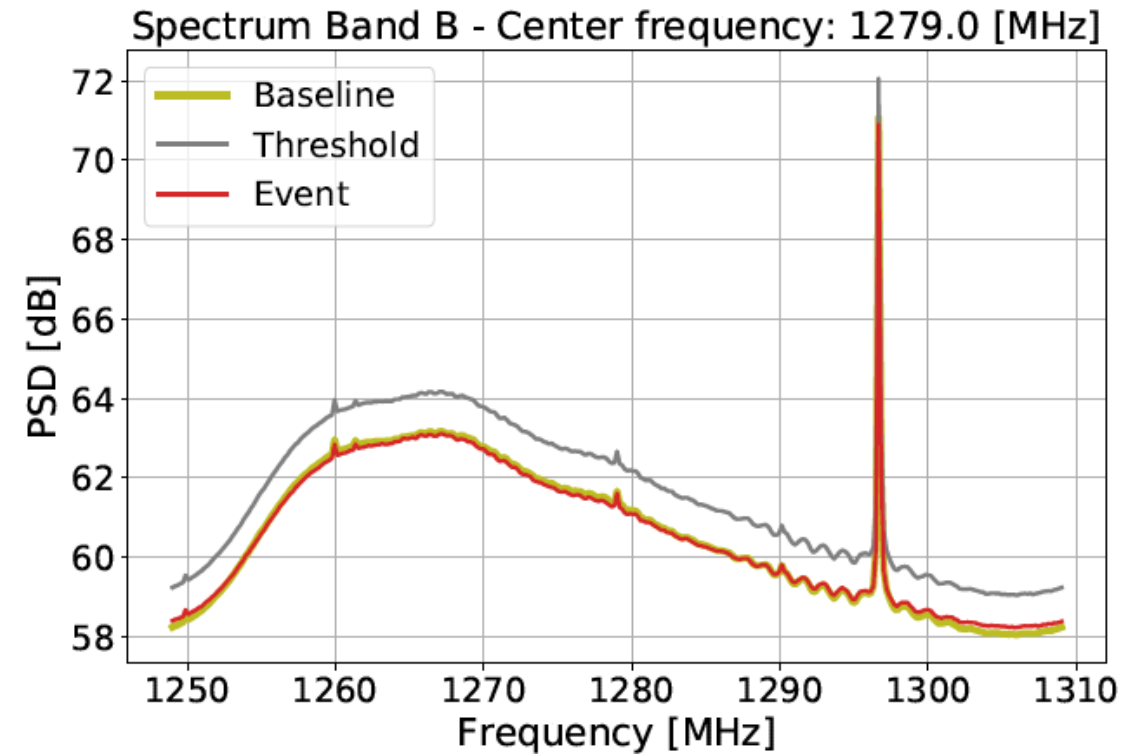


Front-End deployment – 7 of 9

- NLR Jammer 1296 MHz
- The antenna does not support E6
 - Also in the roll-off region of the SAW filter
 - Strong enough to punch through
 - Intermittent
- Turns out 1296 MHz is or was legal for amateur radio
 - <http://www.pa0ply.nl/1296.htm>
 - A 300 Watt amplifier through a 28 dB gain dish...

Station outfit:

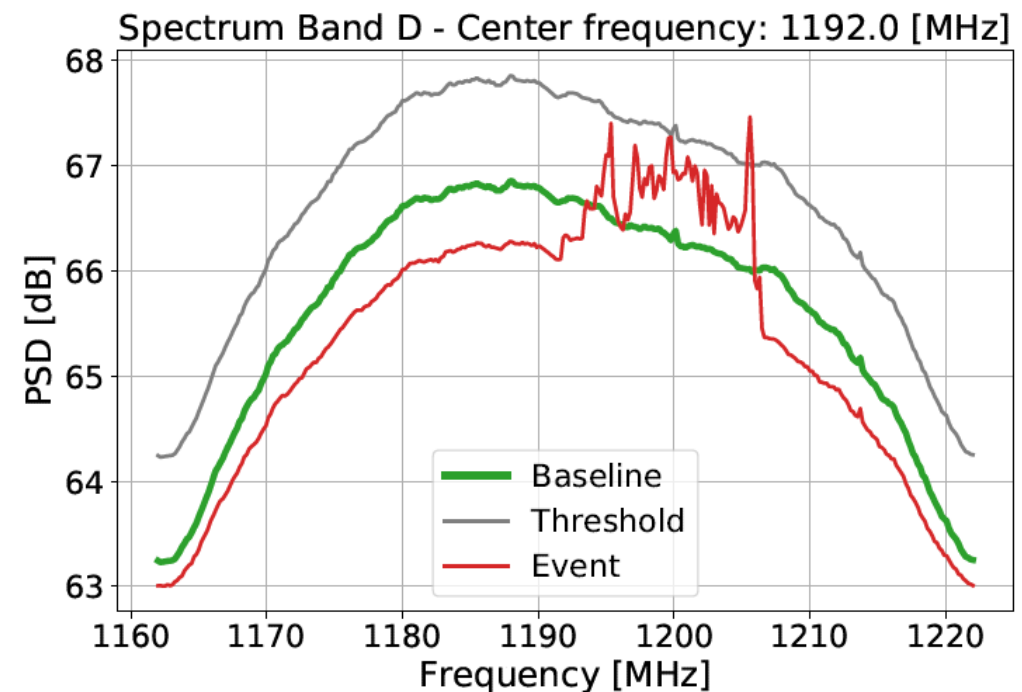
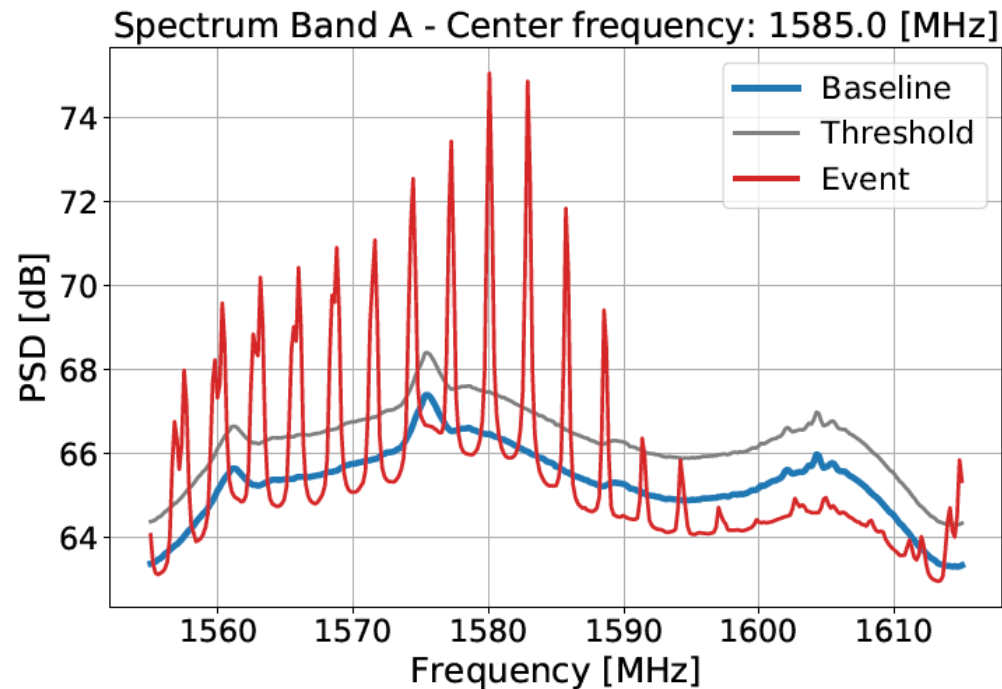
- Transceiver: TS-2000X
- Preamp: VHF Design - 0.3dB
- Final amplifier: 300Watt SSPA (DF9IC)
- Antenna system: 3m solid dish, Andrews prime focus - 28dBi / Septumfeed modified for f/D 0.32
- Control system: VK5DJ - Stand alone interface



Front-End deployment – 8 of 9



- Indra Navia AS Asker(Oslo suburb)
- 200m distant from a busy highway and local rail station
 - Engineers here have wondered if their roof mounted antennas were experiencing jamming
 - We were skeptical due to the distance to the highway



17

- We were wrong...

Front-End deployment – 9 of 9

- Helsinki



- Future deployment sites

More road-side locations

- Discussion with Norwegian Public Roads Administration.
 - SINTEF monitors will be co-located with monitoring equipment deployed by Nkom?
 - High bandwidth network connections, power and proximity make the sites ideal



Patterødkrysset
(Busiest intersection in Norway)



E8 Kilpisjärvi-Skibotn
Road used for autonomous testing

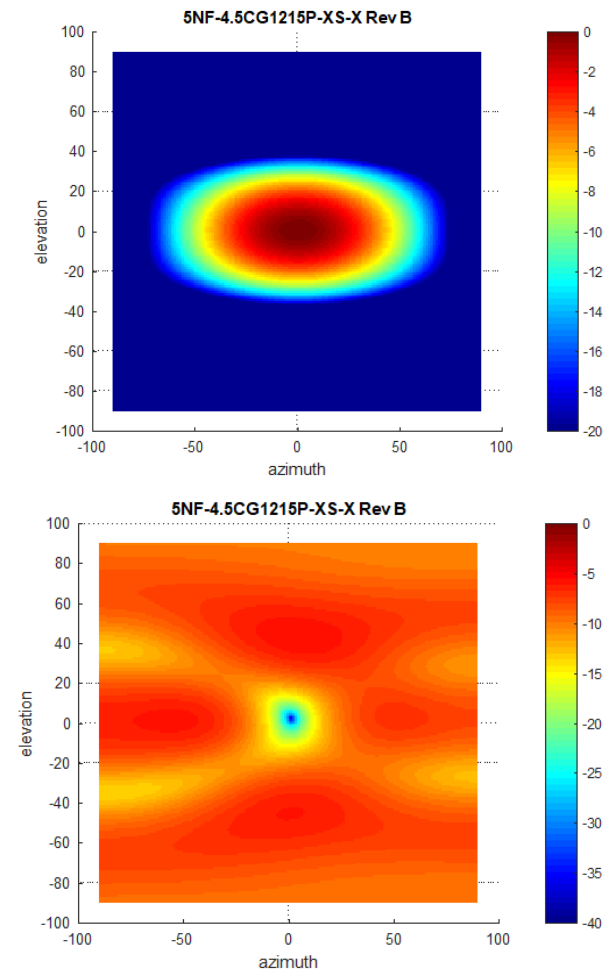


Data Availability

- We dedicated time and effort to ensuring we were meeting minimum standards of STRIKE3 compatibility
 - STRIKE3 was an international RFI monitoring activity which concluded at the end of 2018
 - While only GPS+Galileo L1/E1 coverage was mandatory, it is still the largest database of GNSS RFI events that we are aware of
 - The value of data scales with the amount available, so ideally we would contribute directly to the STRIKE3 database
 - Unfortunately all outreach to Nottingham scientific failed (they are a company and not paid to help us out)
 - We will be maintaining the database of our captured events (up to 20 TB provisioned) for a period of 2 years past the end of the ARFIDAAS project, and will provide copies to interested researchers
 - Mail us drives to populate, or sign up for an Amazon Web Services account – downloader pays for access
- Near future...

Source localization

- We are of the opinion that detecting and characterizing is great, but localizing is better
 - Light weight, compact and drone borne would be best
 - Our goal is to have frequency agile L-band source localization for testing within 2020
- The challenge will be keeping it compact and light enough to be carried by small drones
 - And not running afoul of ITAR restrictions dealing with GNSS receivers that have null steering
- The images show what can be done with a 5 element antenna array
 - Top plot is a steered lobe along the boresight, the bottom plot is a steered null
 - Obviously the null has much better resolution in terms of localizing the source of the signal
- The tentative plan is to statically define a pattern of gains and nulls
 - Calculate both simultaneously using digital beamforming techniques
 - Use the gain lobes for coarse search (maximize power in the central lobe) then use the nulls for fine steering
 - We think we can achieve 3-5 degrees of resolution while avoiding problems with export control (TBD)



Future plans – 1 of 3

- SINTEF is a research institute, so commercialization usually takes one of three routes
- In order of prevalence:
 - 1) Creation of a spin-off company
 - 2) Partnership with an existing industry player
 - 3) Partnership with a government body
- Examples

Future plans – 2 of 3

- SINTEF is a research institute, so commercialization usually takes one of three routes
 - 1) Creation of a spin-off company – Gas Secure

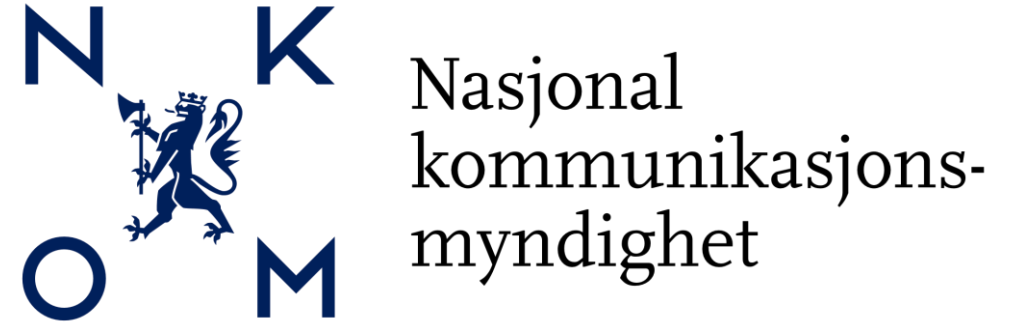
The GS01 is a hydrocarbon gas detector that operates truly wireless. Based on innovative MEMS technology the GS01 enables battery-powered gas detection with wireless communication in demanding industrial applications. The GS01 creates value for the customer with better flexibility during installation, reliable «infrared» operation and its calibration-free design. GasSecure has developed the GS01 in compliance with IEC 61508:2010. –gassecure.com



GAS
SECURE
A Dräger Company

Future plans – 3 of 3

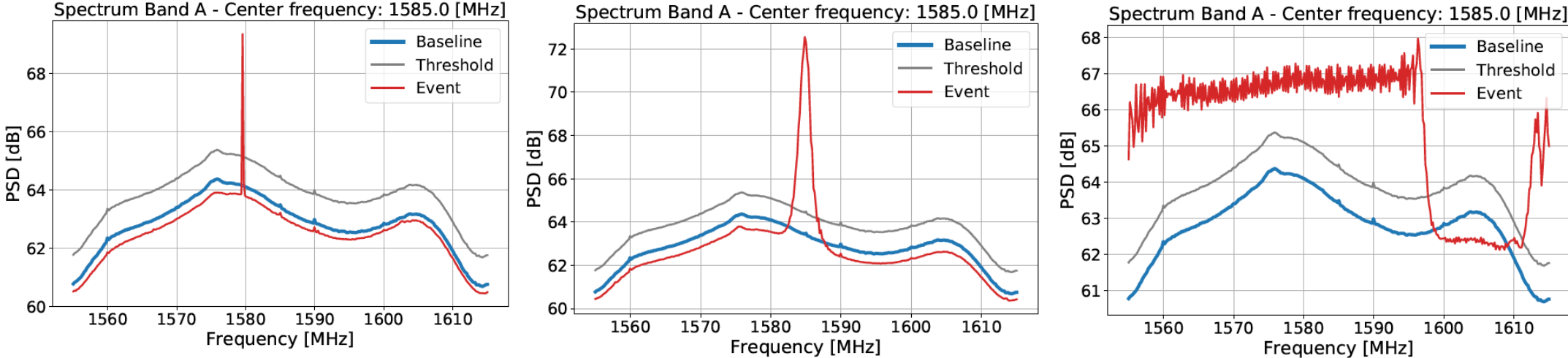
- SINTEF is a research institute, so commercialization usually takes one of three routes
 - 2) Partnership with an existing industry player
 - 3) Partnership with a government body
- NKOM: Norwegian Communications Authority
 - In Norway the National Spectrum Management Authority is partially funded by fines
 - Right now they operate on a system of reporting followed by sending an inspection vehicle
 - Three of these vans service the nation
 - If the source is not persistent when they arrive, no source can be located, no fine issued
 - We are actively discussing how best to solve this problem
 - Obviously I'm advocating for technology related to ARFIDAAS



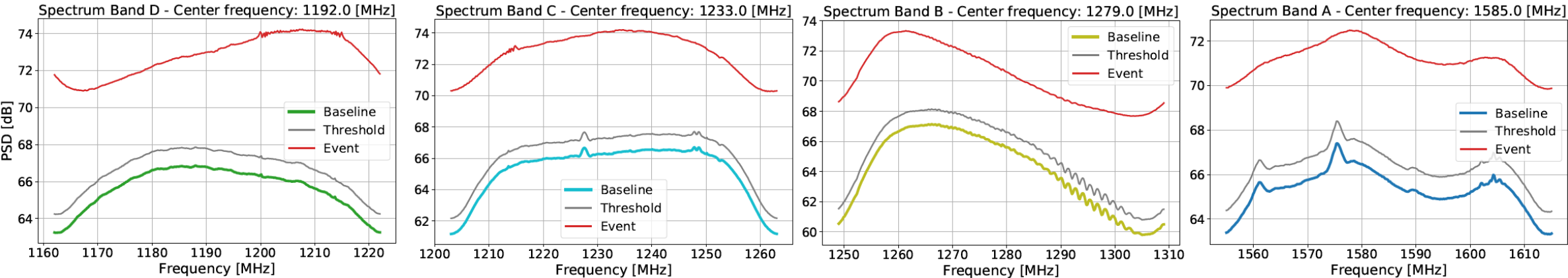
Summary of NAVISP benefit to SINTEF

- The NAVISP program has allowed SINTEF to develop an important tool for the support of national exploitation and protection of GNSS signals
 - Tighter working relationship with national spectrum management authorities
 - Technical growth towards the localization of sources
 - International visibility with respect to hosting and data production

Anecdotal observations

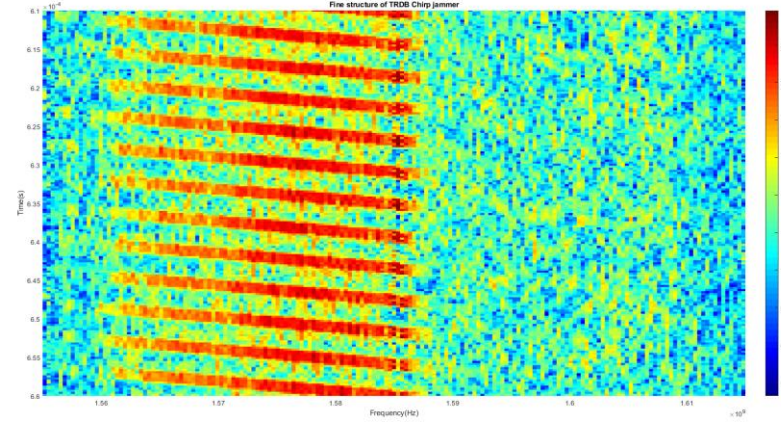
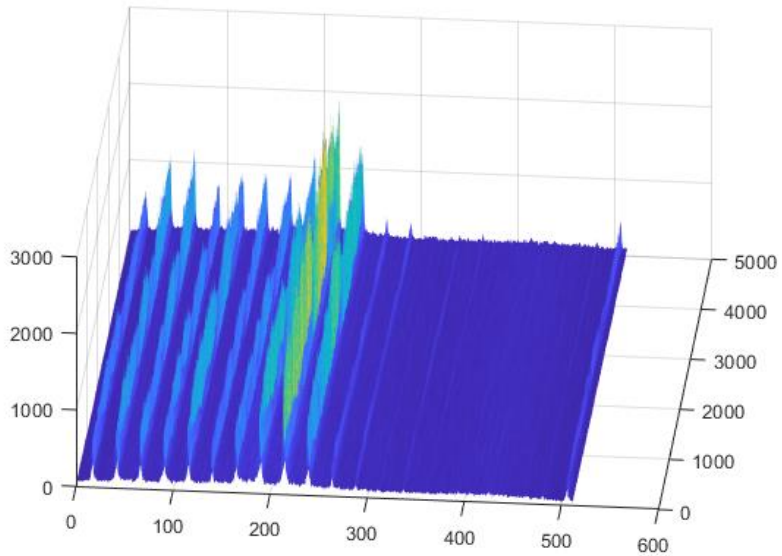
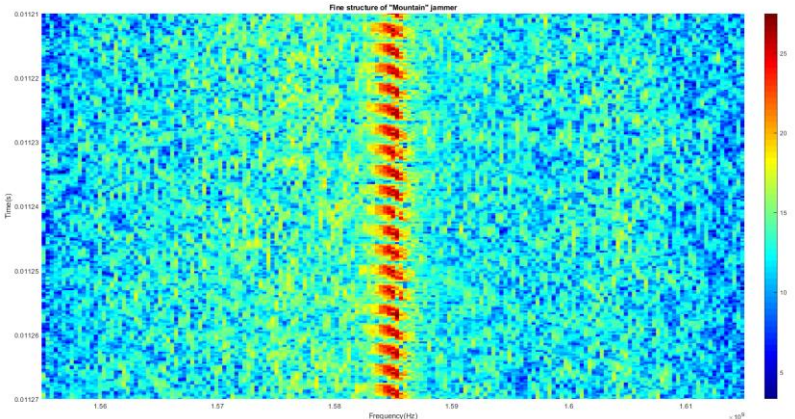
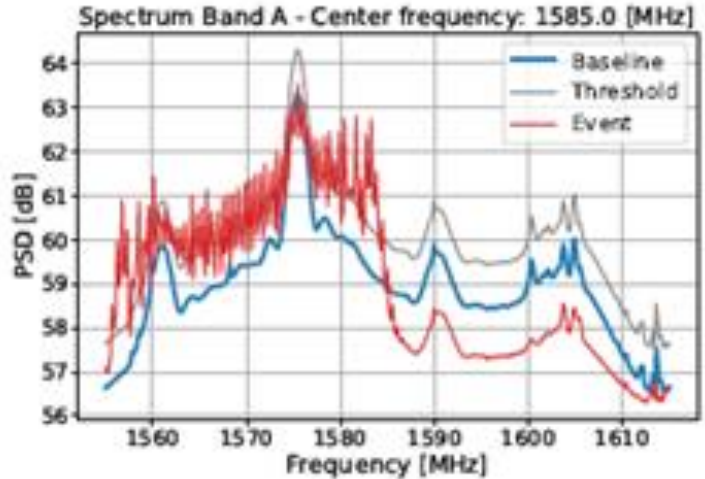
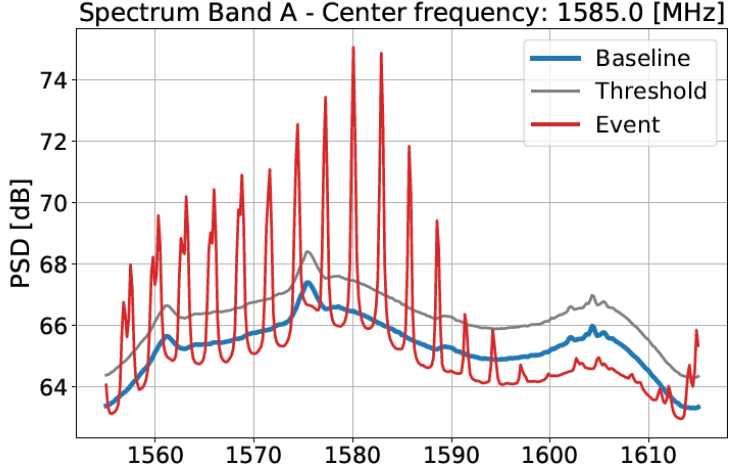
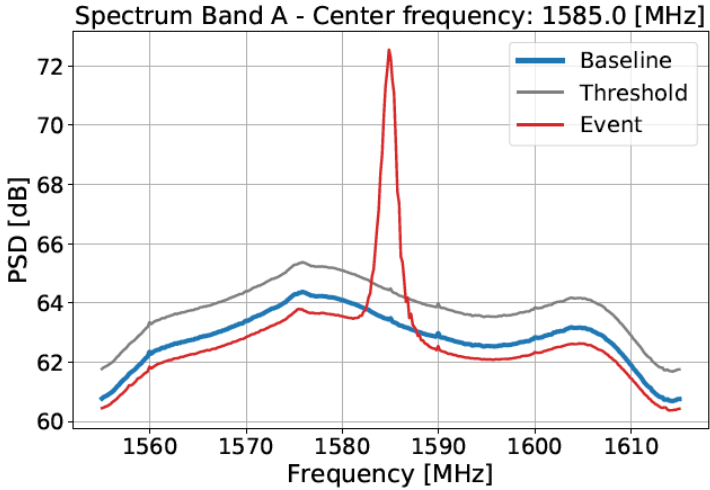


- Above: RFI in the wild within a 24 hour period at one site
- Below: An active USB3 device operating near an antenna



Questions? – Aiden.Morrison@sintef.no

- Future: Identification of individual jammers via fine-grained time-frequency fingerprint?





Teknologi for et bedre samfunn