Technical University of Denmark

Agency for Climate Data

# Jammertest Experience & Results

## Outline

- Experience from JT23
- Motivations for the JT24 campaign
- The Drone Defender Experiment
- Plans for research & outlook

**Lasse Lehmann,**
**Post. doc.,**
**Geodesy and Earth Observation (GEO),**
**DTU Space, Technical University of Denmark**

# JT23: Deploying cheap SDRs for detection & localization

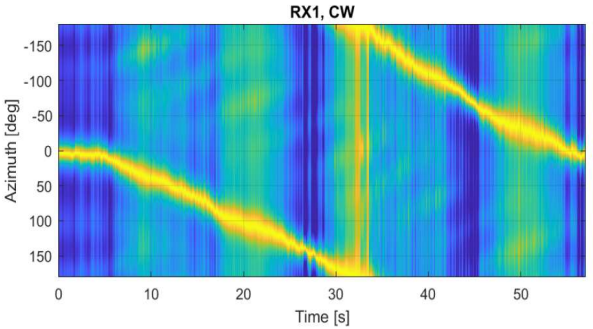
- **Use of Software-Defined Radios (SDRs)** as cheap open platforms for **jamming detection** and **localization**.

- In particular the **use of KrakenSDR as a 5-element antenna array** has been used extensively.

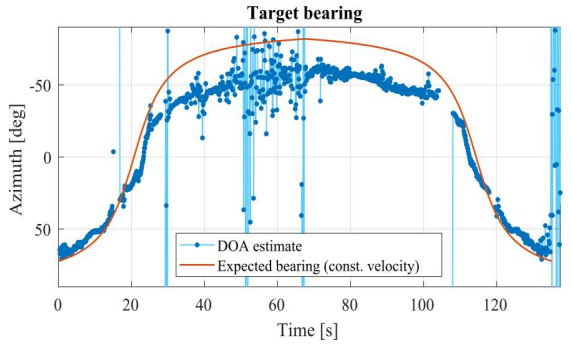
## Experiments covered in JT23 [1]:

1. Walking with jammers close to arrays.
2. Detecting passing cars
3. Localization via wardriving.

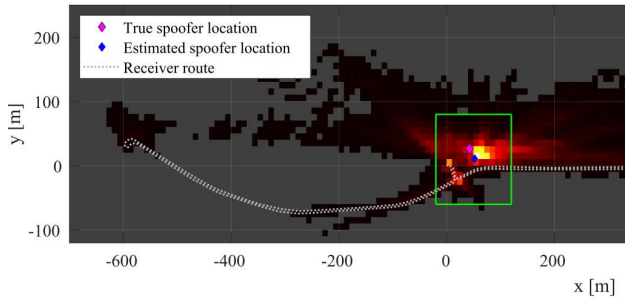
**Test 1**


**Test 2**



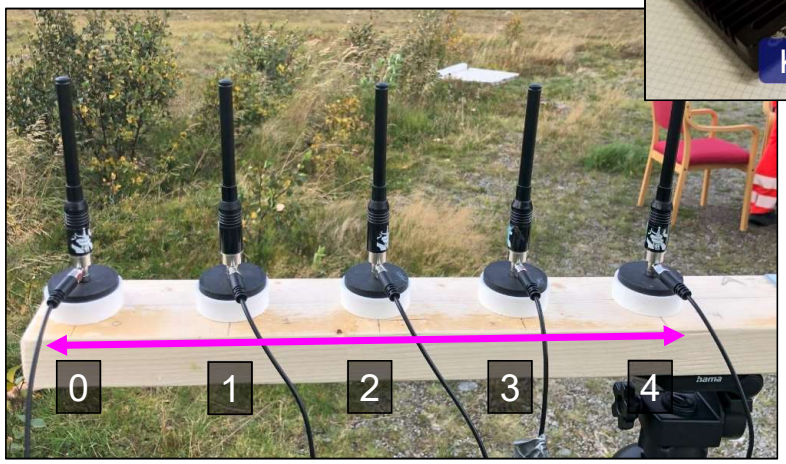

**Test 3**



# JT24: Improving upon yesteryear's results

## Test considerations

- **Still using KrakenSDR:**
  - Limited to L1 C/A processing
  - Unable to resolve wideband jamming signals
  - Limited number of antennas

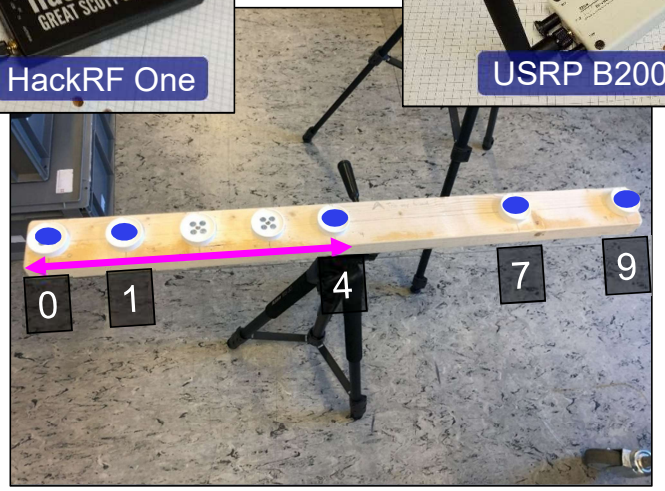




5-ULA
5-MRA (19)
X Offset in $\lambda/2$ = 9.54 cm

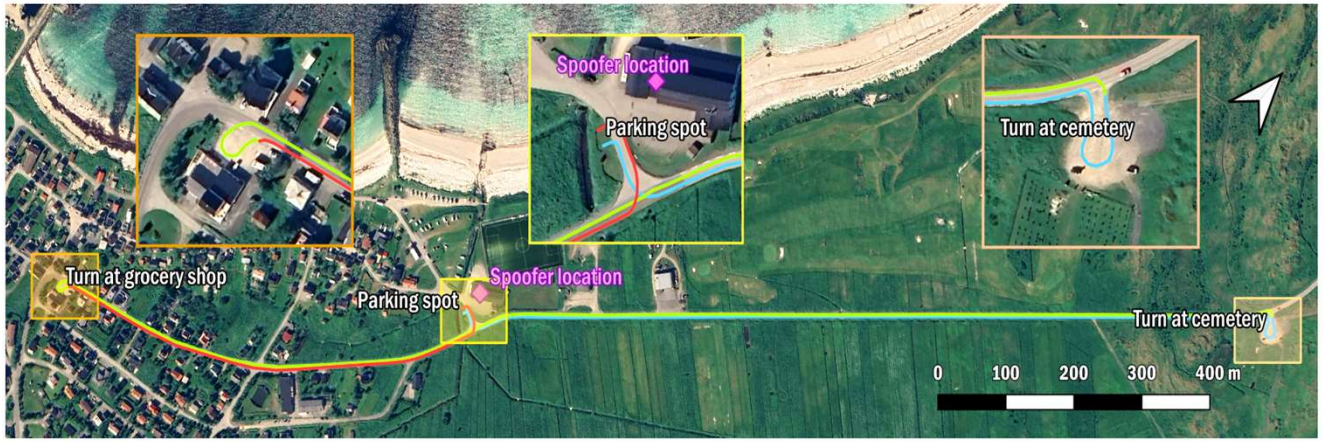
## Actions for test plans

1. Includer higher-spec SDRs for recording J&S baseband data and test GNSS proc.
2. Test the use of sparse arrays to circumvent lower number of antennas



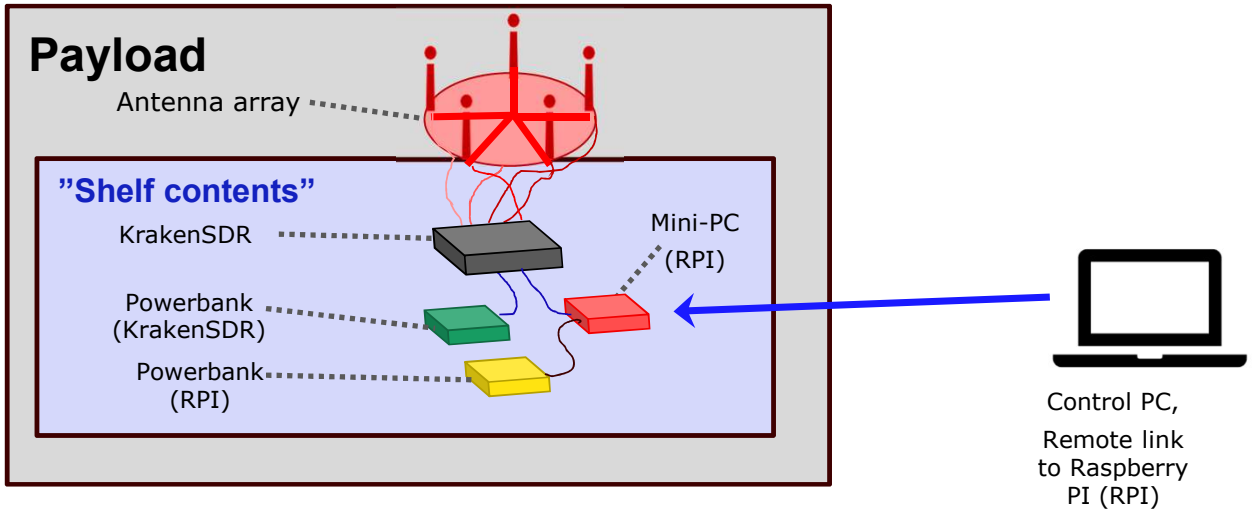


# JT24: Improving upon yesteryear's results




## Drone-based Localization

- ***Line-of-sight*** - getting above reflection sources presents a great advantage.
- ***Novelty*** – no real attention seen regarding RF-based localization.
- ***No constraint on baseline*** – a car cannot ensure good baseline for localizaiton… But a drone can.

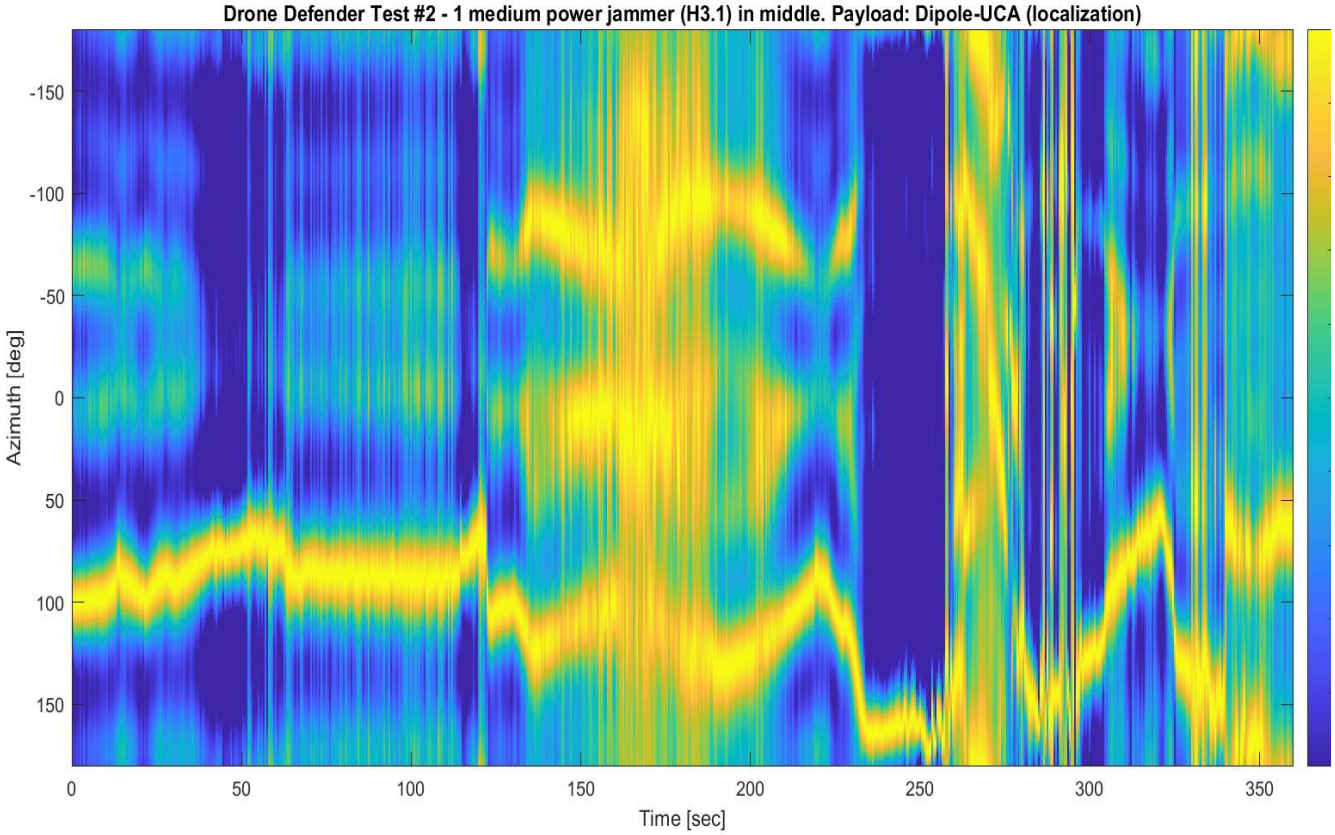


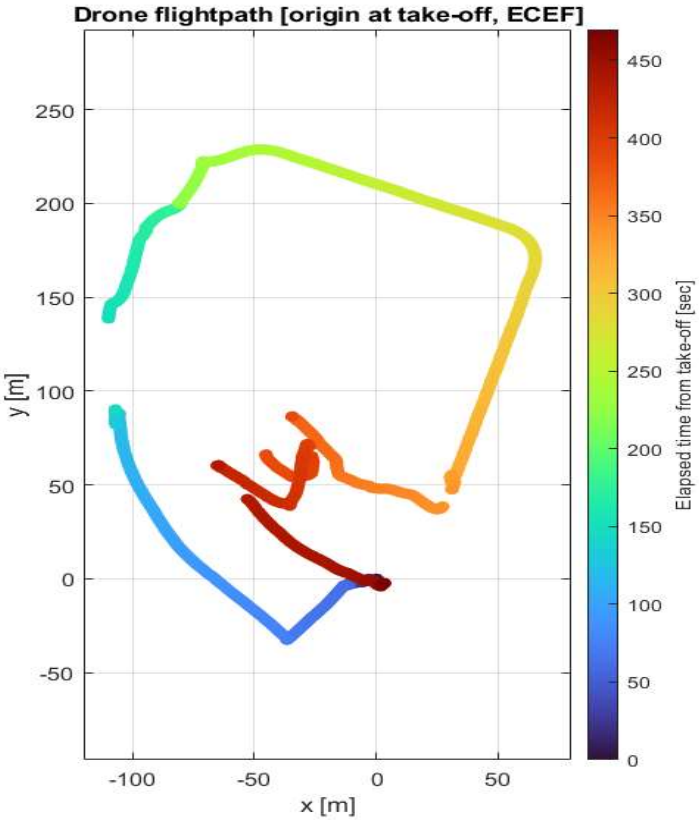
# The Drone-Defender Test


Approximate placement of jammer

- Use of KrakenSDR (5 antennas) mounted on the drone for localization.
- Medium power jammer (H3.1) for experiment.
- First large clockwise circular flight, followed by closer circle

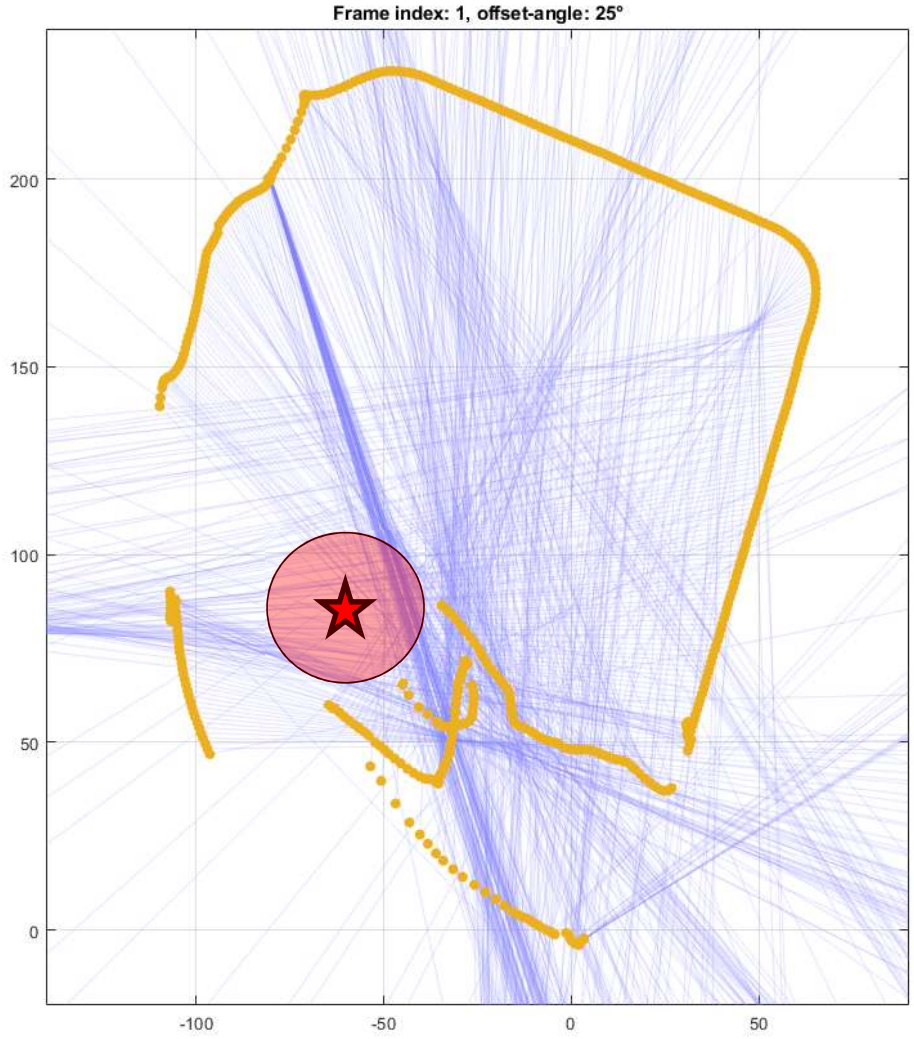
# The Drone-Defender Test




- Difficult to make sense of the DOA estimates in isolation → DOA angles change with platform orientation.
- GNSS still available on drone for most of the flight – outages coincide with overflights around the jammer.

# The Drone-Defender Test




## Lines of Bearing (LOB)

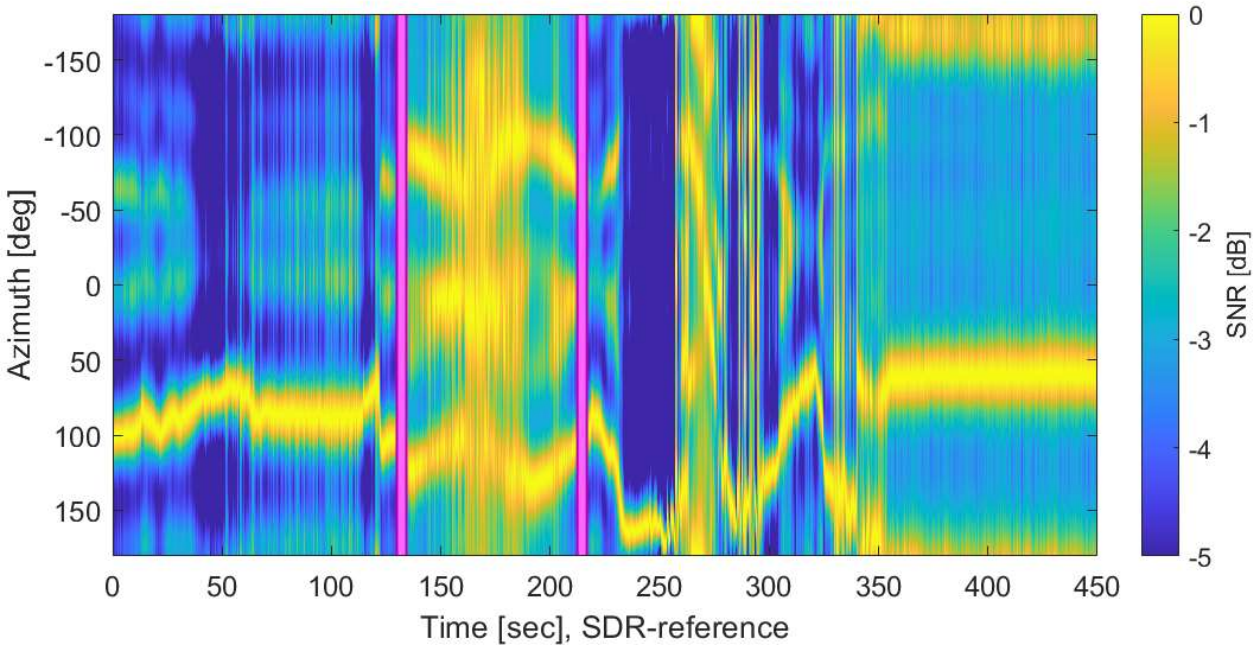
Plotting semi-transparent lines for most probable DOA to each time-point in the drone data.

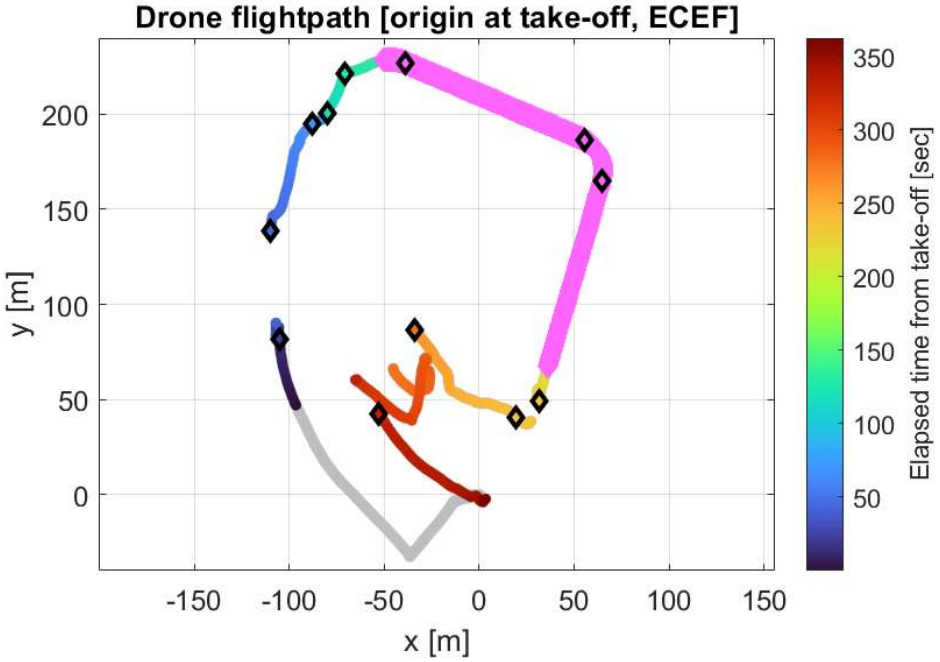
Few observations to be made:

- ✔ We are getting fixes within the field confined by the flightpath of the drone
- ÷ Large spread in LOBs
- ✔ However, yet to implement UAS-attitude compensation for DOA estimates & yet to obtain final fix for jammer position.

- Long time spent in North Western corner hovering, hence strong indicator here.

# The Drone-Defender Test

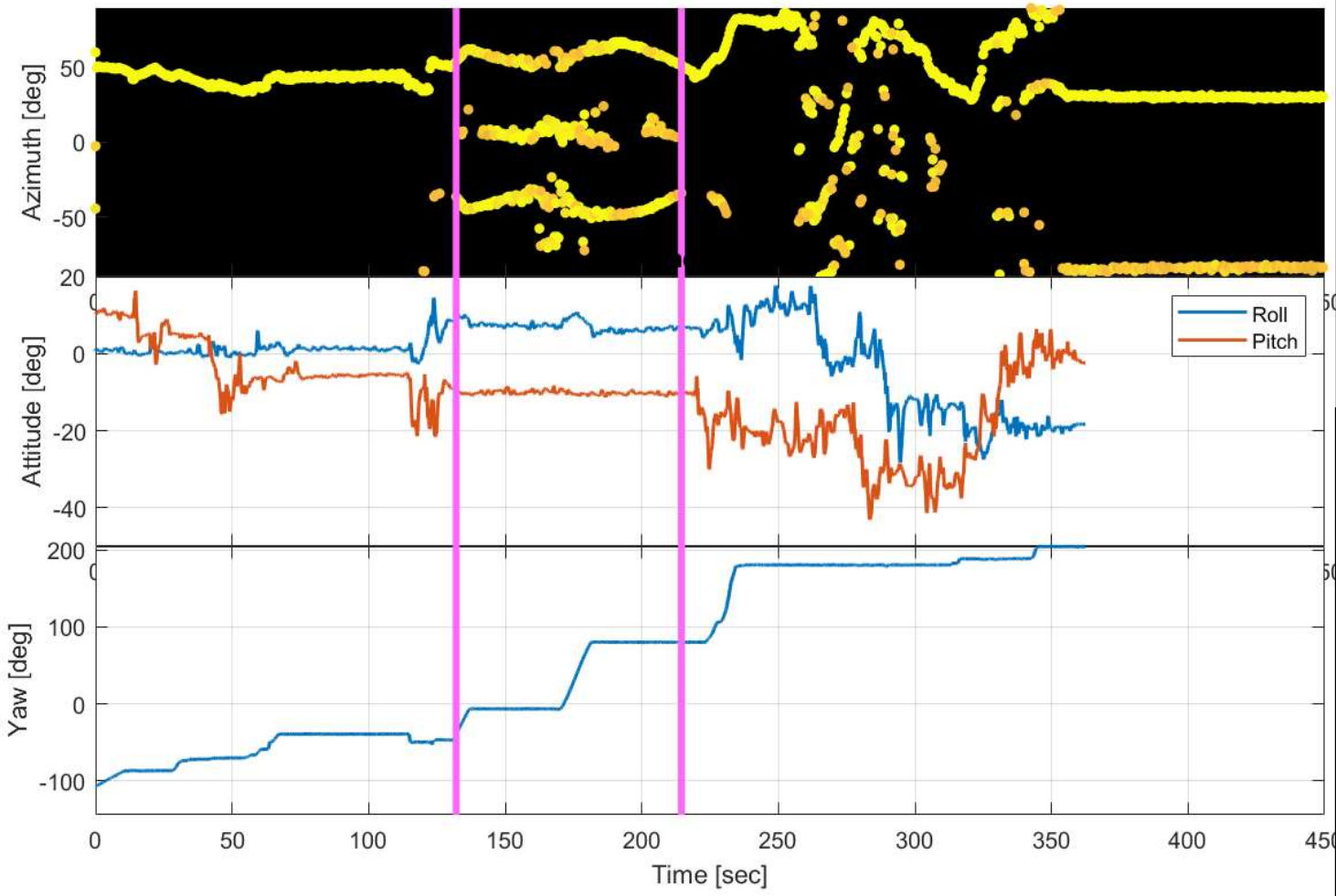


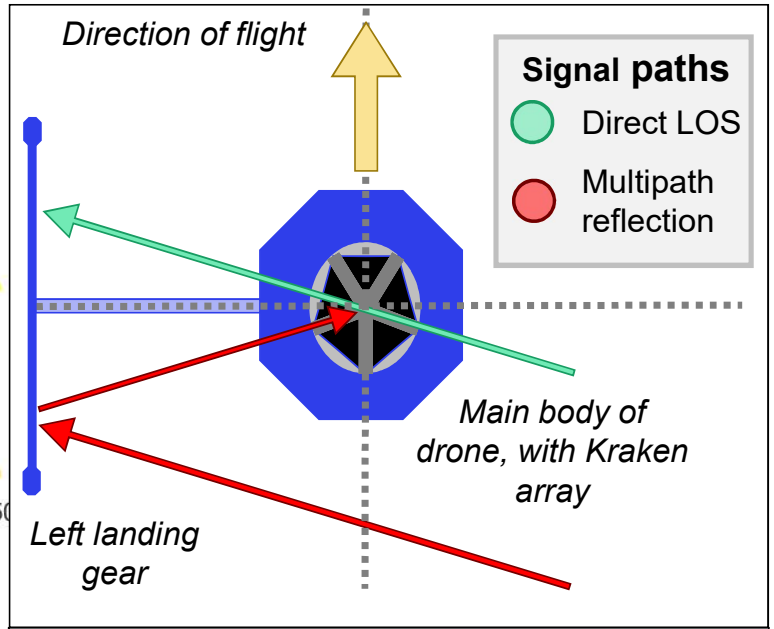




## Multipath reflections affecting DOA estimates

- Note time interval of 132-214 sec – this coincides with the timeframe during which we get multiple viable DOA estimates (left) and the time frame where the road is followed (right).
- Clearly this is associated with the setup. True bearing to jammer also present, but clearly something associated with the flightpath

# The Drone-Defender Test

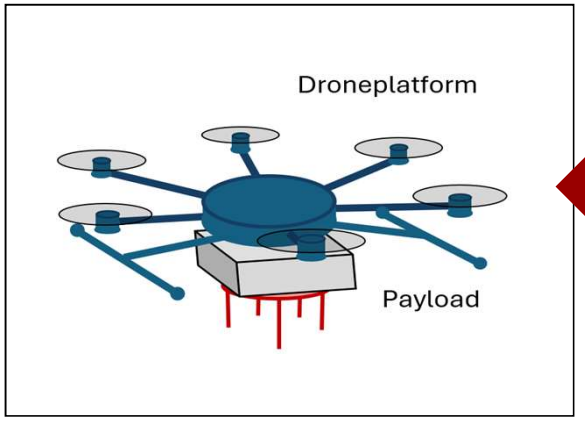


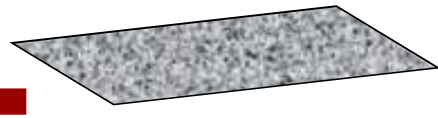




# Plans for research & Outlook

## Future Drone Trials

- ***Control the reflections*** – installing a proper ground plane running the span of the drone.
- ***Free-band for more time*** – use of amateur radio band to test setup more from home.

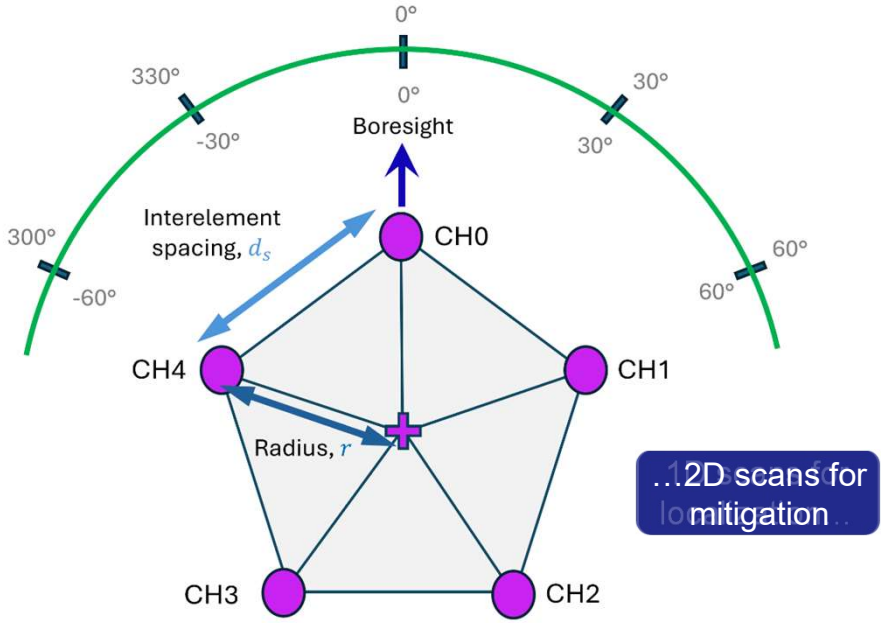


*Introduce groundplane spanned btw. Payload and landing gear (chickenwire)*


## Use of GNSS antennas

- ***Mitigation is a logical next step*** – array techniques such as null steering to suppress interference. .
- ***Nontrivial calibration for 2D BF*** – KrakenSDR is not without flaws…



# References

## Publications from research group on jammertest

*Only [1] yet published of the ongoing studies:*


- [1] Lehmann, L; Larsen, S. R.; Olesen, D. H., (2024) *Real-world Jammer Localization using a Low-cost Array-based Software-Defined Radio,* for ION GNSS+ 2024.
- [2] Lehmann, L; Larsen, S. R.; Elsholm, B. B., Olesen, D. H., (2024) *Real-world Jammer and Spoofer Localization using a Low-cost Array-based Software-Defined Radio* , for Journal of the Institute of Navigation. (Pending review)
- [3] Lehmann, L; Larsen, S. R.; Elsholm, B. B., Olesen, D. H., (2025) *Array-based GNSS Jamming Mitigation using a Low-cost Software-Defined Radio,* for ION GNSS+ 2024 (Submitted)


## Acknowledgements


| | |
|---|---|
| Casper Jepsen (KDS) | (JT23&24) Planning & conduct |
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| Søren R. Larsen (DTU Space) | (JT23) Research, planning & conduct |
| Alexander R. Vesterhauge (DTU Space) | (JT24) Drone payload & pilot (and photography) |
| Benjamin B. Elsholm (DTU Space) | (JT24) Remote link to KrakenSDR & characterization thereof |

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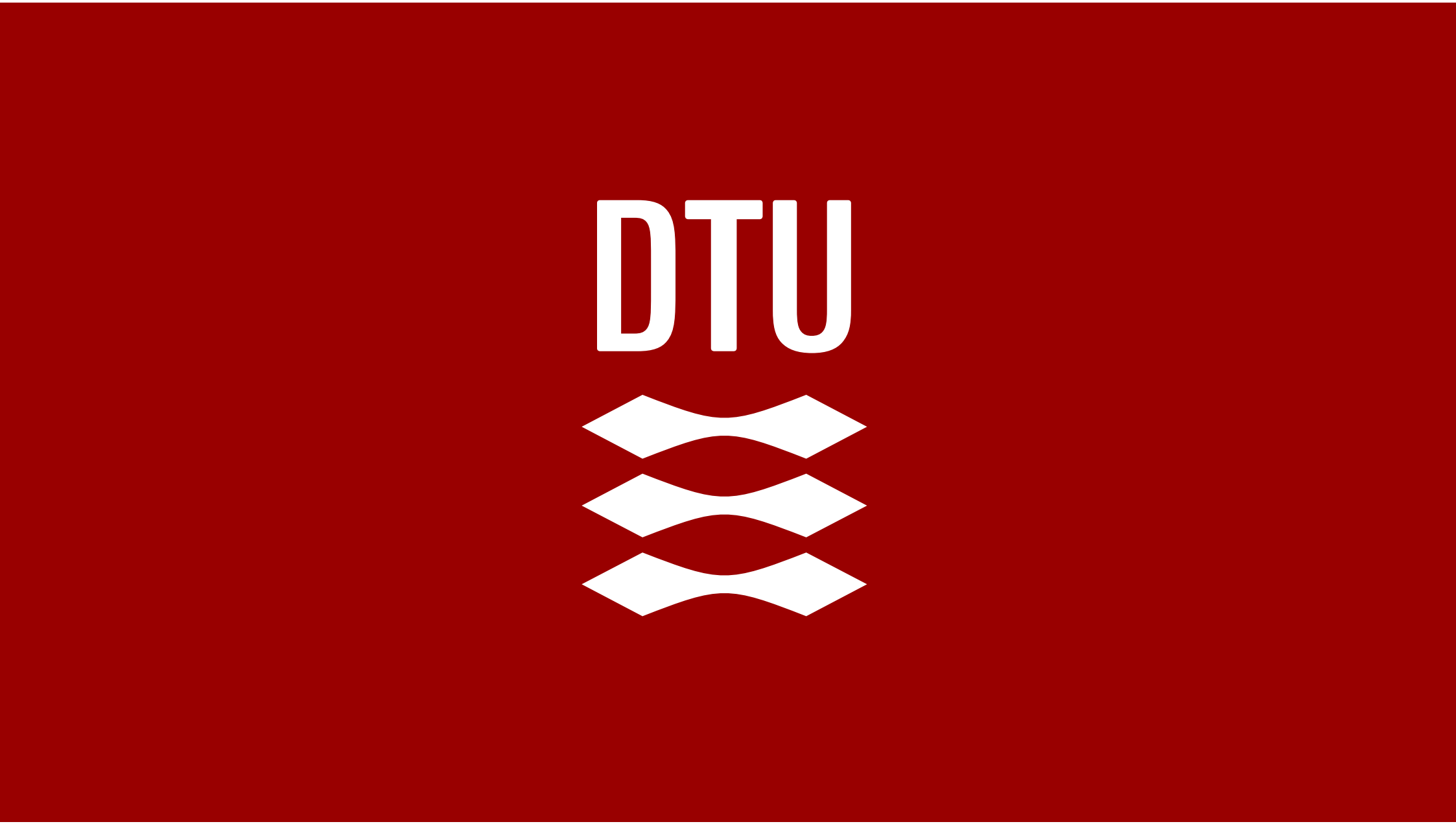
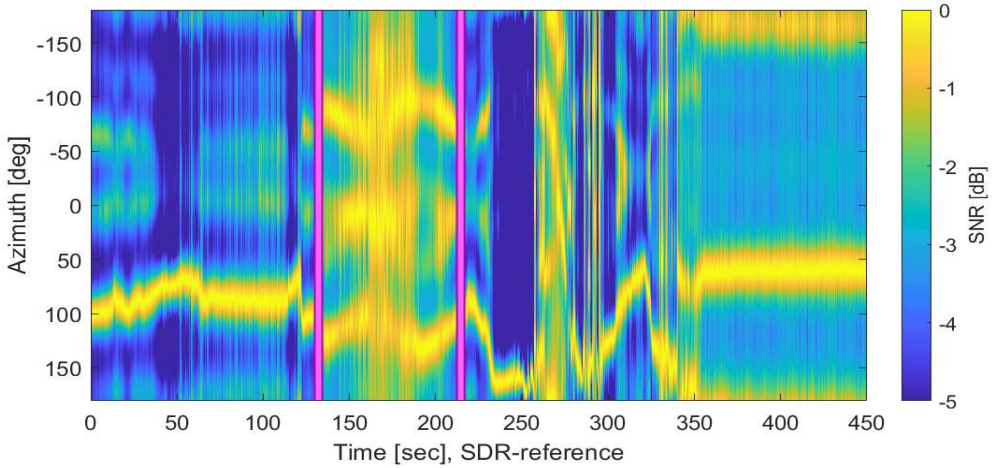
# Thank you for your attention!

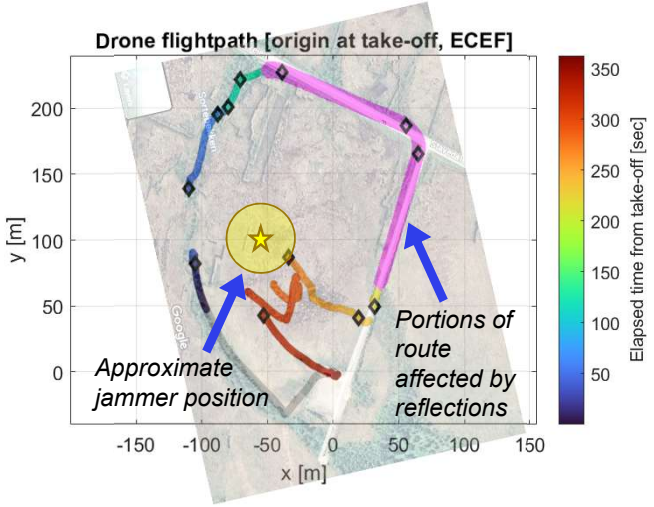

DTU

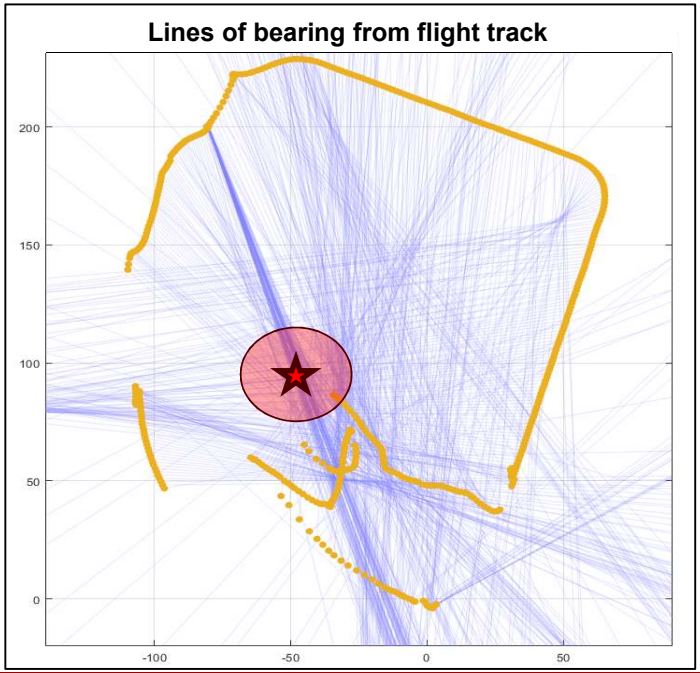
# Single jammer, Drone Defender




*DOA trace from KrakenSDR. Distinct trace from jammer, but interval sees mirrored traces (magenta interval)→ reflection axis fixed to drone; we get reflections from the drone*

*Kraken array mounted underneath drone chassey*




- **Premise:**
  - A single jammer (PPD) set around 100 m away from reference at Grunvattn. Use of different PPDs between tests.
- **Conduct:**
  - KrakenSDR array mounted underneath drone to test localization. Drone was flown in large ”rectangle” around the jammer, then commenced a sharp
- **Results:**
  - Clear multipath (onboard reflection). Coarse localization <seems> to be possible.

# Single jammer, Drone Attacker

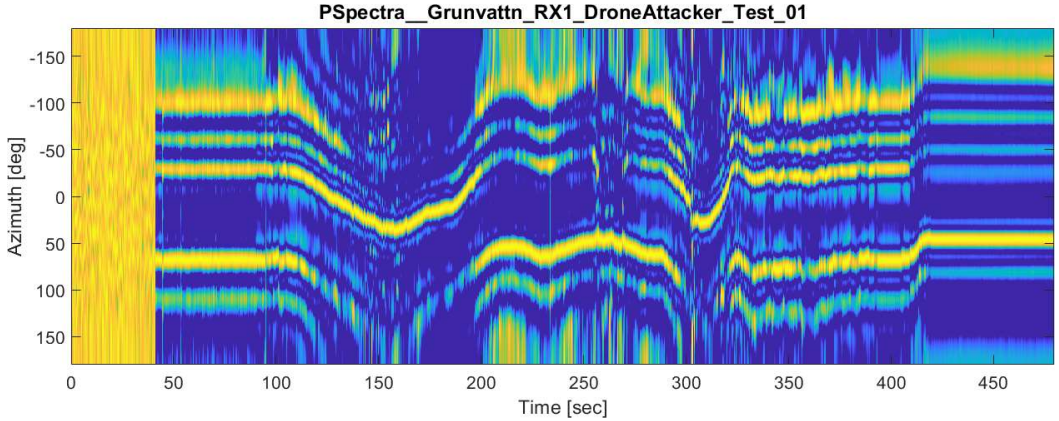
*Jammer underneath drone chassey*

*Ground-based arrays observed from drone POV.*

*1st array: linear dipole antennas (ULA: Uniform Linear Array)*

*2nd array: circular, patch antennas (UCA: Uniform Circular Array)*

- **Premise:**
  - High-power jammer mounted onto drone and flown in similar pattern as defender tests.
- **Conduct:**
  - 2 KrakenSDRs deployed at previous jammer location in field. One for localization (ULA) one for GNSS (patches).
- **Results:**
  - Localization as expected for ULA array. Need to establish flightpath from GoPro. Patch antennas pending.




*DOA trace from ULA-array. Distinct trace from jammer, but observe multiple traces that follow the same relative changes in DOA → multipath from ground plays a role*