Using Synthetic Aperture Radar Data Dome Collections For Building Feature Analysis

Defence and Security Doctoral Symposium

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Introduction & Motivation

- Ability to gather intelligence on concealed areas/buildings is a key interest in modern military intelligence gathering.
- Defence Science and Technology Laboratory (DSTL)
  - RIBI – *Remote Intelligence of Building Interiors*.
- Current techniques involve close contact of radar against wall.

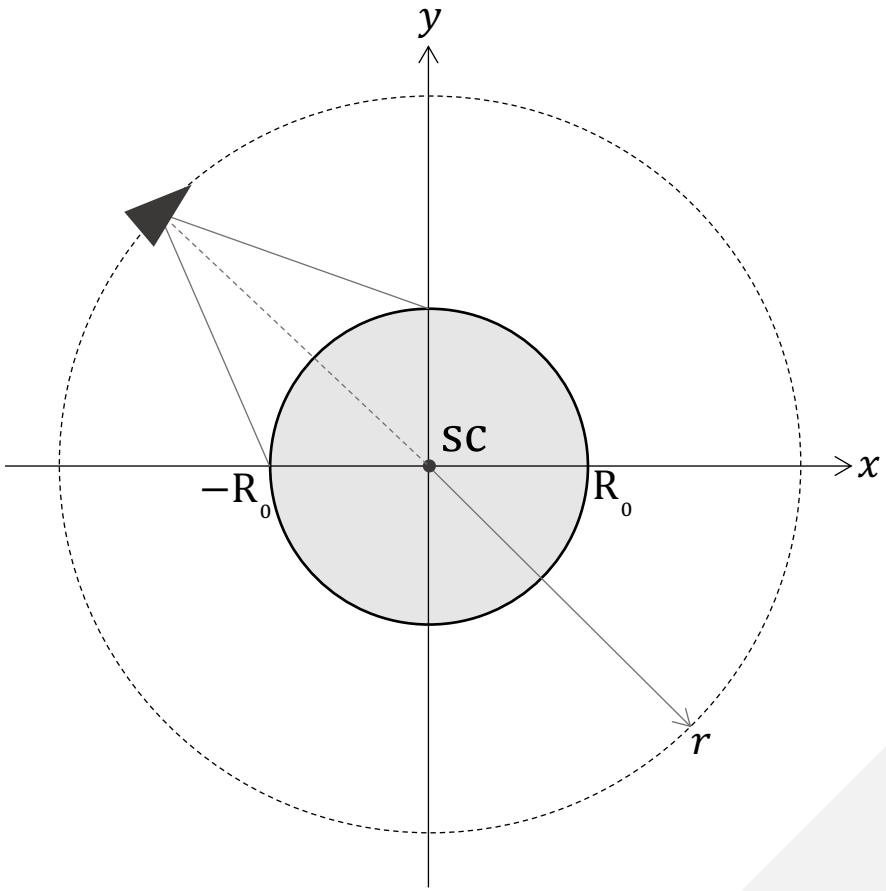
Introduction & Motivation

- Low Frequency – Synthetic Aperture Radar (LF-SAR).
- SAR is a validated technique for achieving long-range, all-weather, day-night, remote sensing of a target or area.
- Low radio frequencies achieve good sensing performance when propagating through building materials.
  - e.g. Mobile communications
  - Ideal for gathering remotely sensed data from the interiors of buildings.

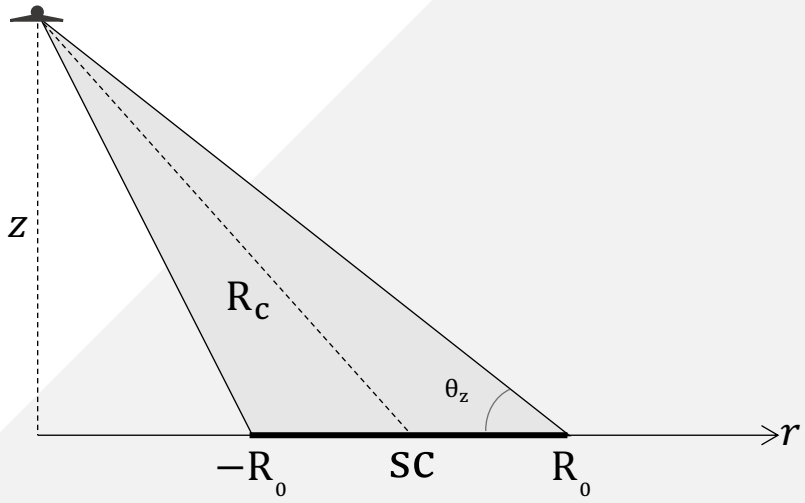
Aim

Investigate a LF airborne SAR data dome to understand the image formation requirements, difficulties, producing some preliminary results.

SAR Collection Geometries Overview



TOP

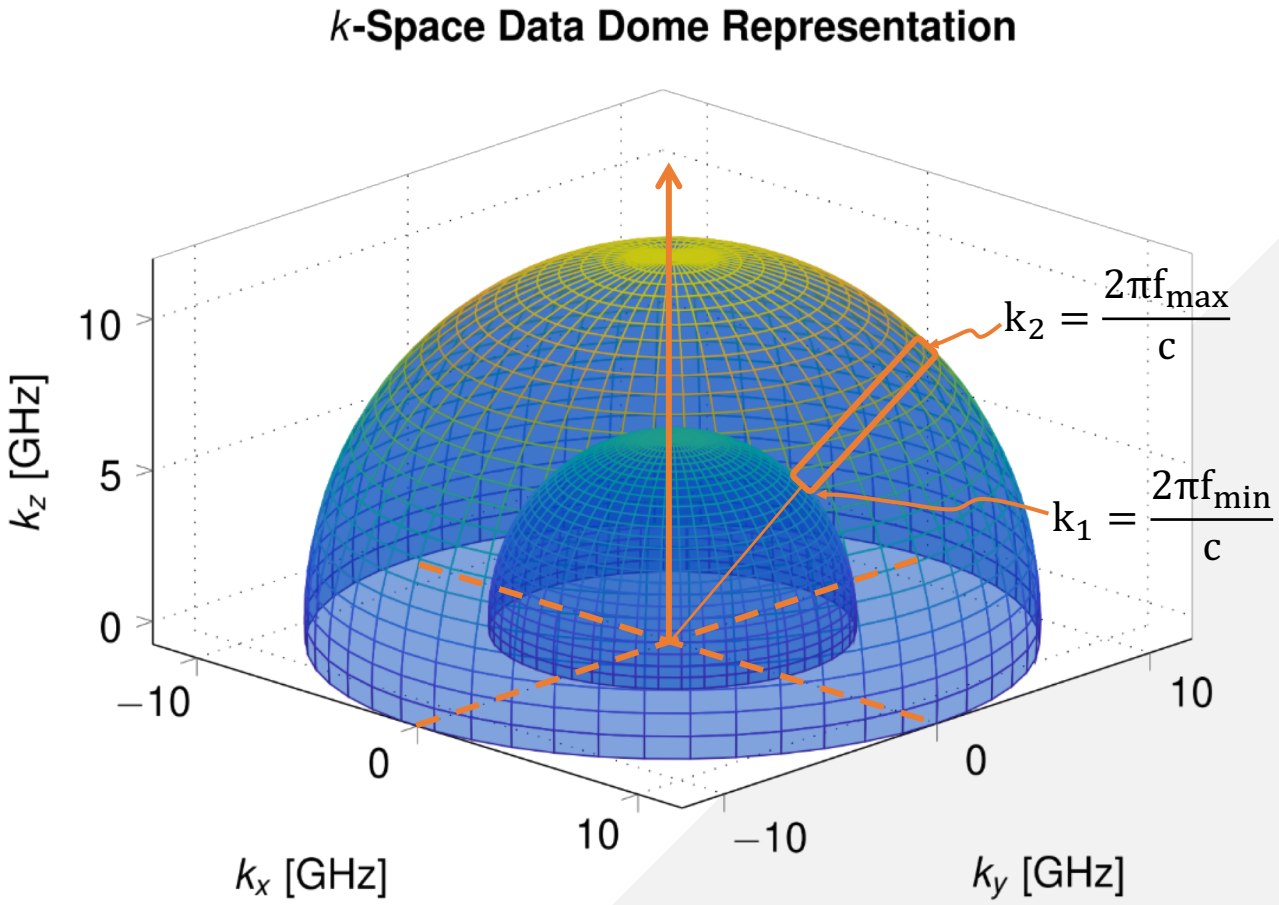


SIDE

LF-SAR Data Dome Project

- To extract the most information possible for an imaged scene, repeat measurements are necessary.
- Main difficulty for the data acquisition process:
  - Ensuring coherence between data acquisitions.
  - (Example) Coherent Change Detection (CCD) – complex subtraction of two datasets.
  - 3D acquisitions allow for *data domes* to be formed and subsequent volumetric scene analysis

Data Domes

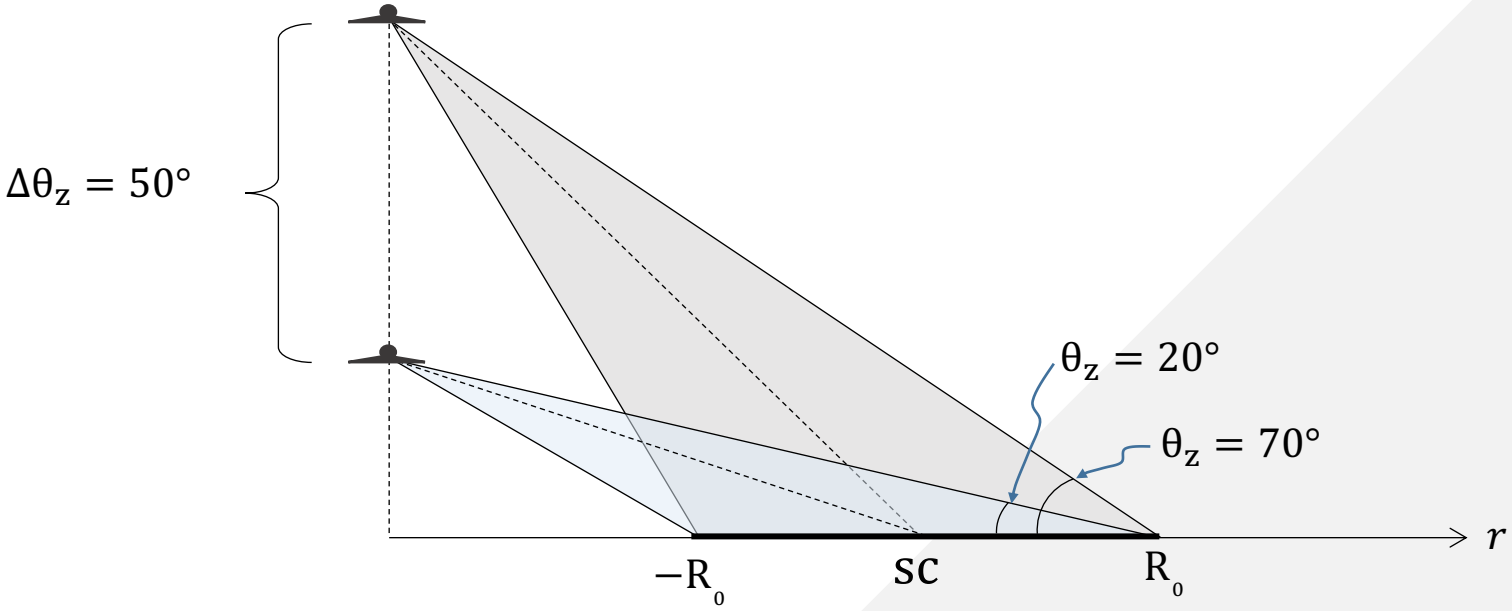


Data dome - A 3D collected dataset with measured aspect angles varying in both azimuth and elevation, that when combined coherently comprise a hemisphere of data in the k-Space (Fourier domain).

The data dome allows the investigation of any conceivable SAR geometry

LF-SAR Data Collection Trials

Measurement Details



Parameters:

- **Bandwidth: 1188 MHz**
- **Frequency Range: 200-1388 MHz**
- **Measurement Pulses: 34,000,000**
- **32 circular acquisition heights**

Theoretical Resolution:

- **Range:** $\delta_{sr} = \frac{c}{2BW} = 0.13m$
- **Elevation:** $\delta_{ecr} = \frac{\lambda_c}{2\Delta\theta_z} = 0.14m$

LF-SAR Data Collection Trials

Imaged Area

LF-SAR Data Collection Trials

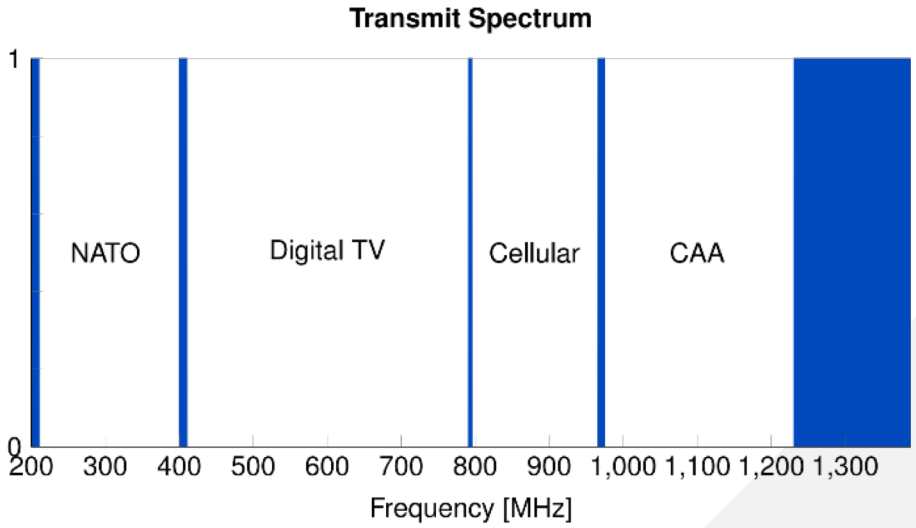
Target - The Sandilands, Arkle Lodge.

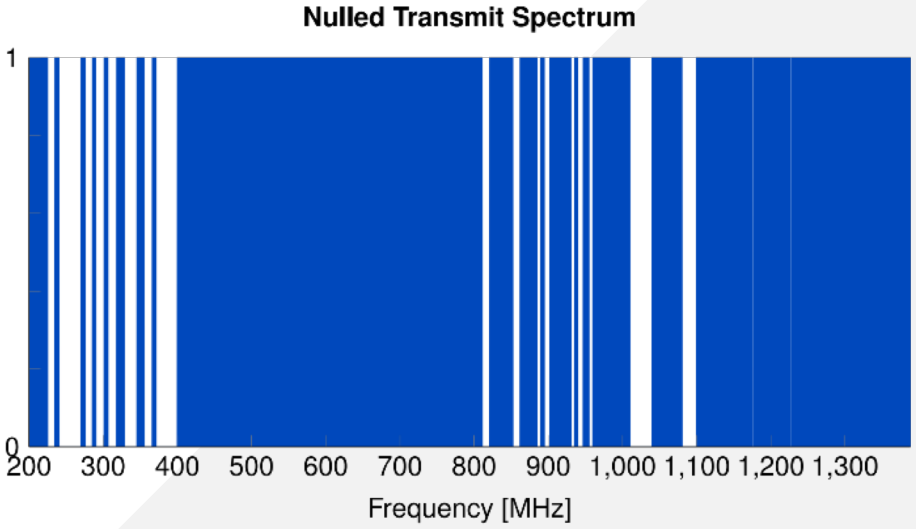
Located at Country Retreat Lodges holiday site in Mablethorpe, Lincolnshire

LF-SAR Data Collection Trials

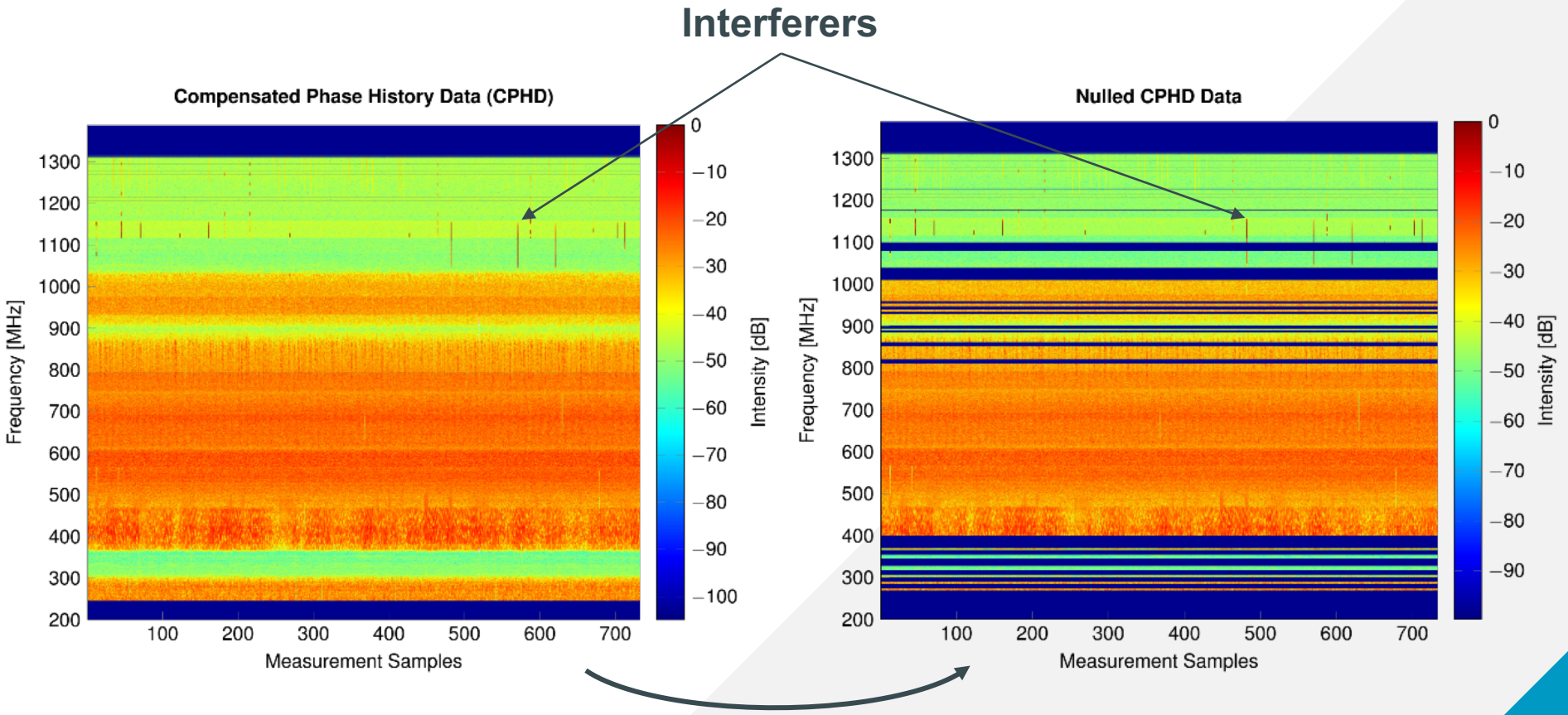
Calibration Targets

Difficulties of Operating at Low Radio Frequencies





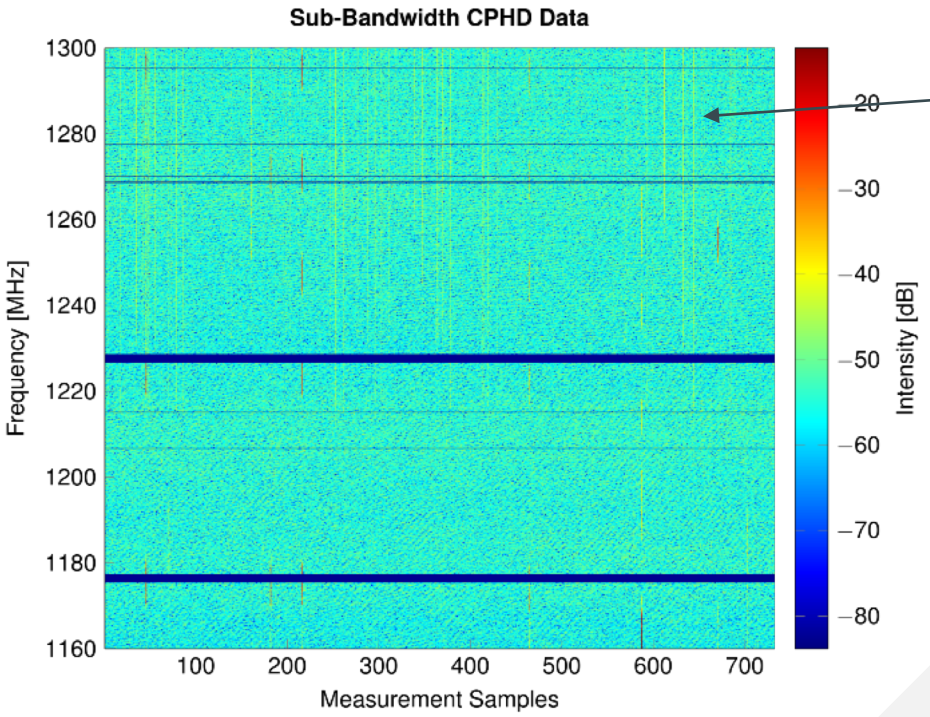
Difficulties of Operating at Low Radio Frequencies



Interferes – Result of radio frequency interference (RFI). Operate across entire bandwidth. Higher frequency has reduced RFI.

Preliminary Image Processing

Identifying RF Interferers



Interferers

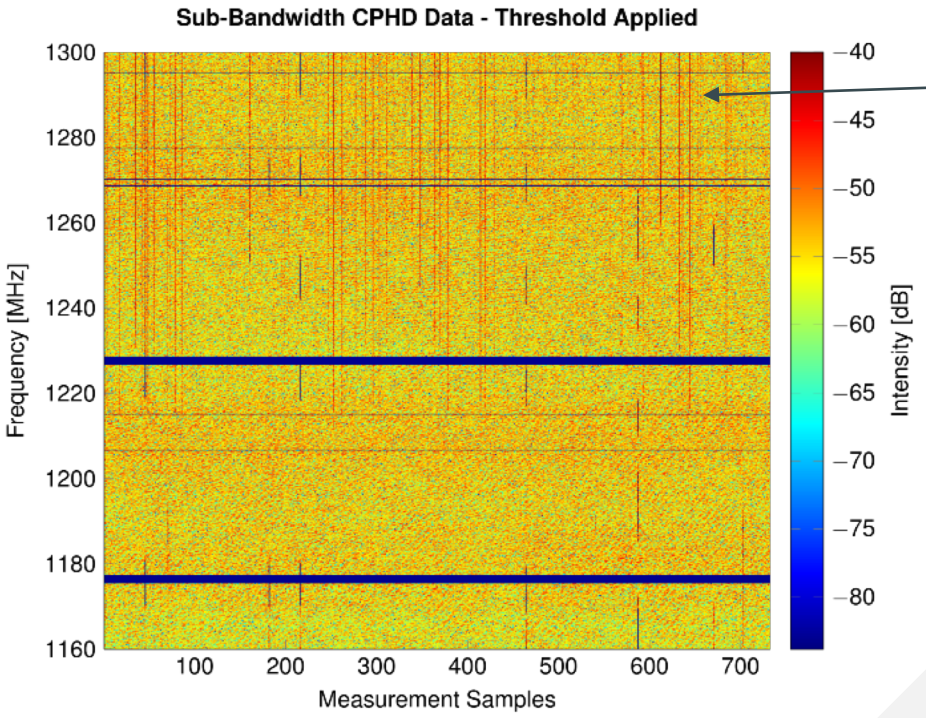
Sub Frequency Range : 1160-1300 MHz

Sub Bandwidth : 140 MHz

Range Resolution: $\delta_{sr} = \frac{c}{2BW} = 1.07m$

Preliminary Image Processing

RF Interference Reduction – Absolute Threshold



Interferers

Absolute Intensity Threshold:

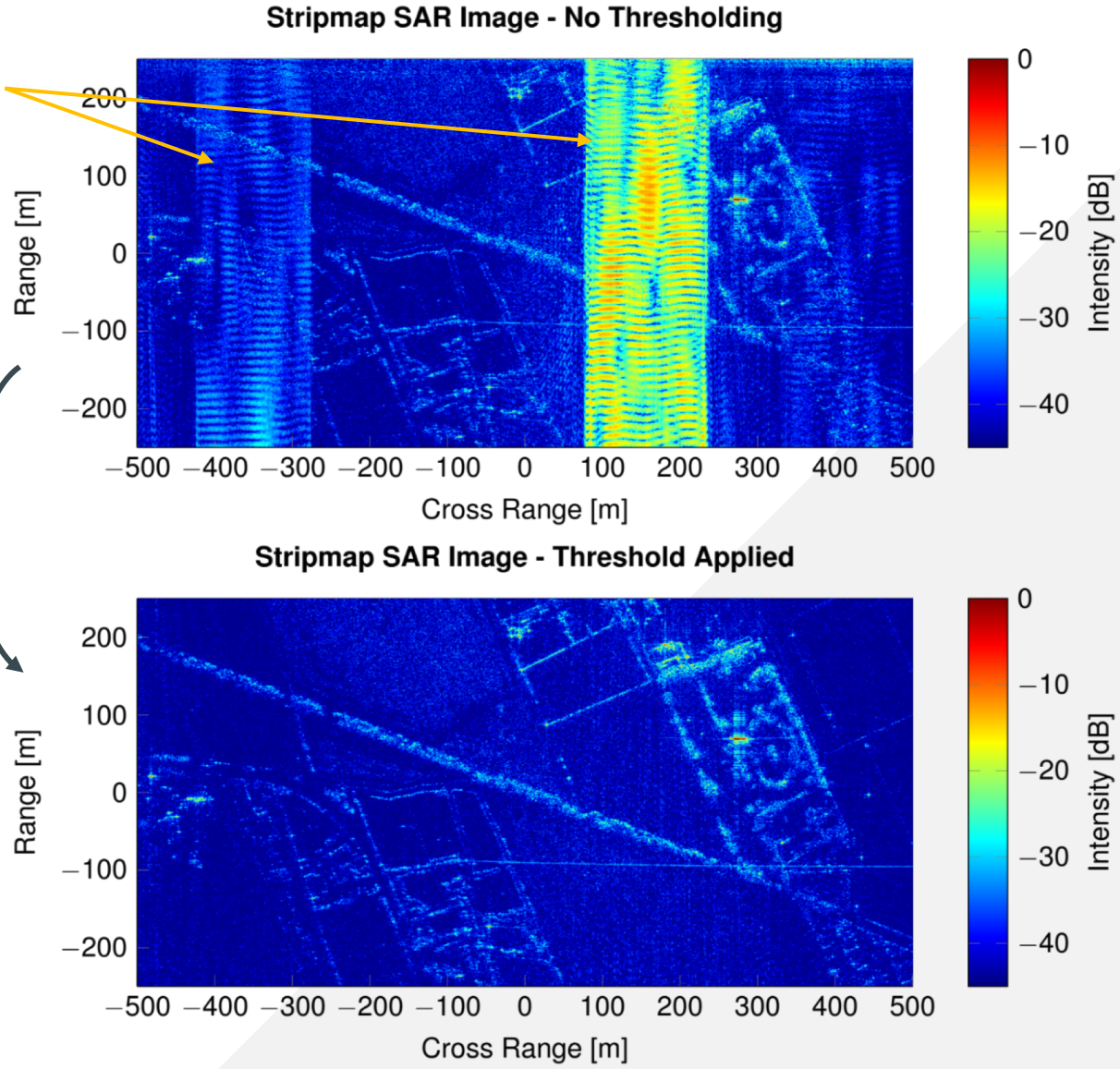
1. **Calculate the absolute values of the CPHD data.**
2. **If abs values > 0.01 then set these CPHD phase data values to 0.**

Preliminary Image Processing

Linear Acquisition – Stripmap SAR Processing

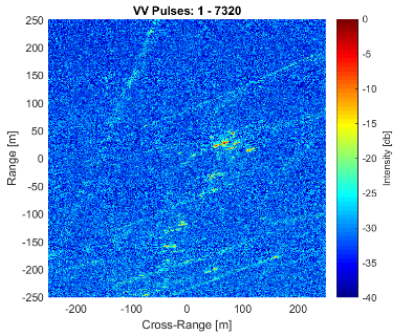
RFI

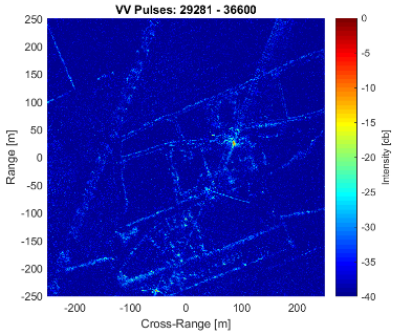
RFI Reduced

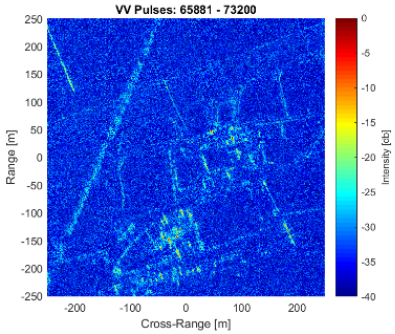


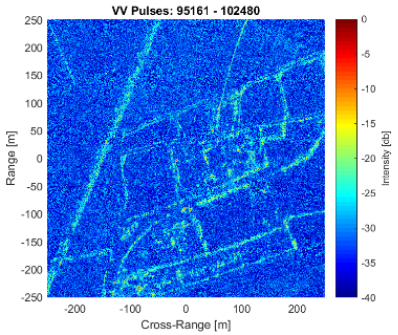
Preliminary Image Processing

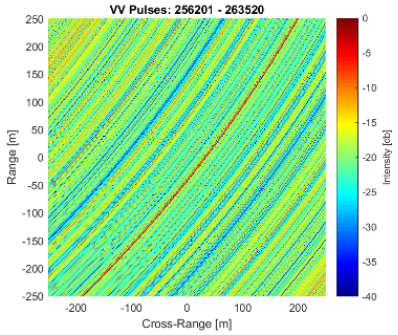
Circular Acquisition – CSAR

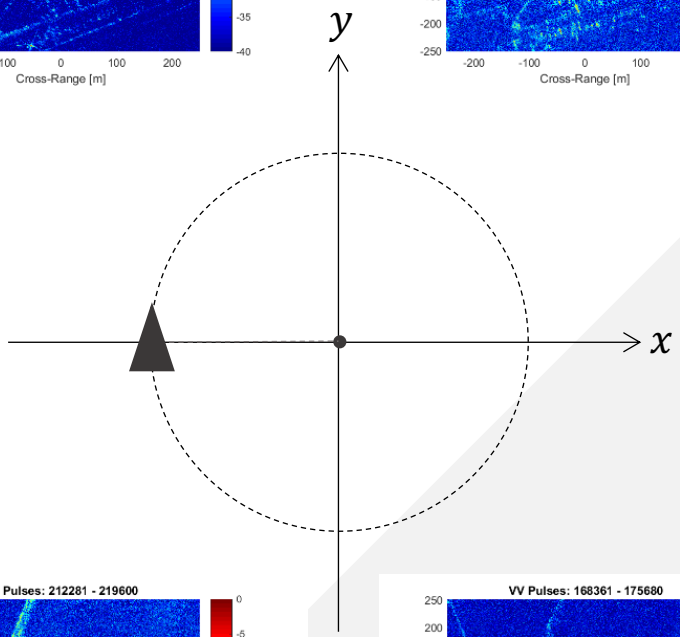


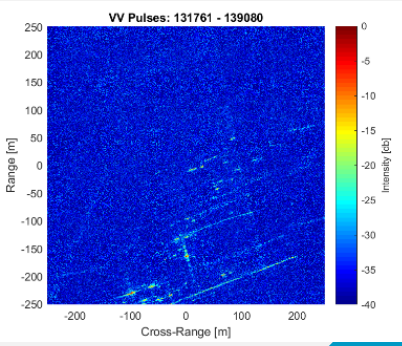


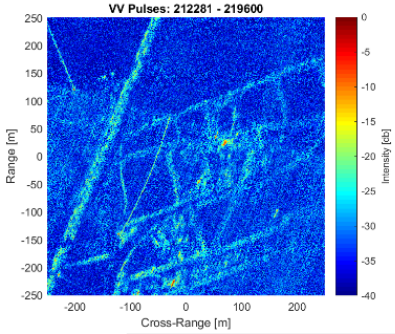












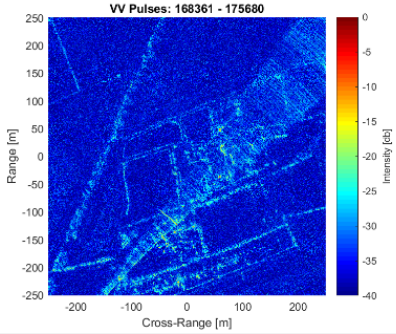
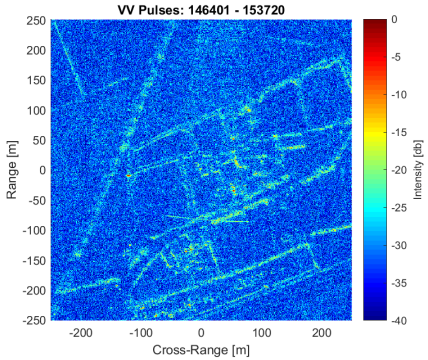
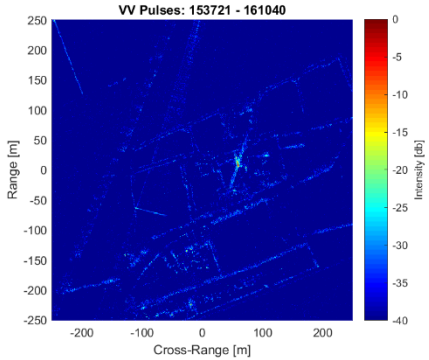
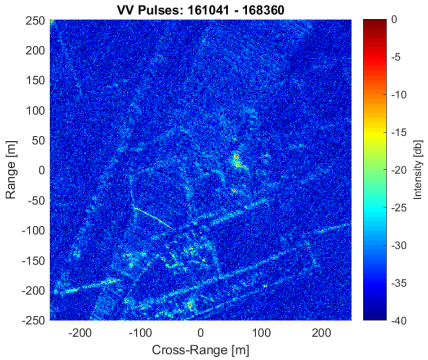


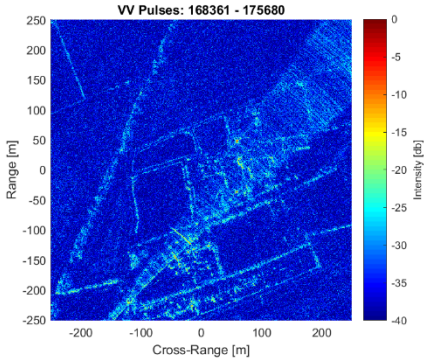
Image Summation – VV Polarisation

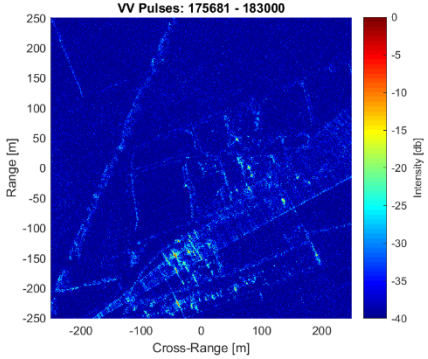
Pulses: 146401 - 226920

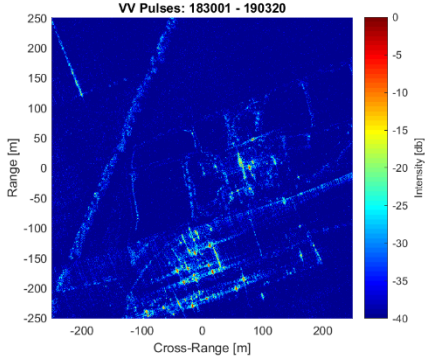


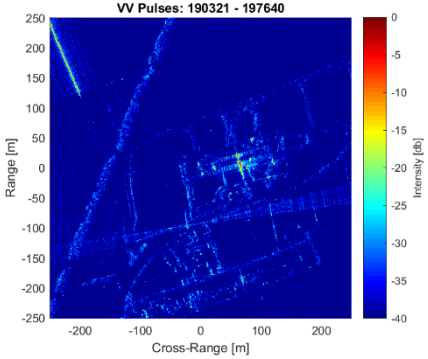


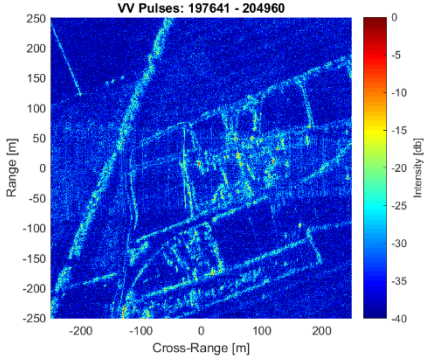


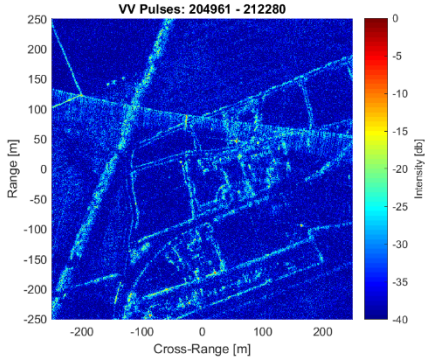












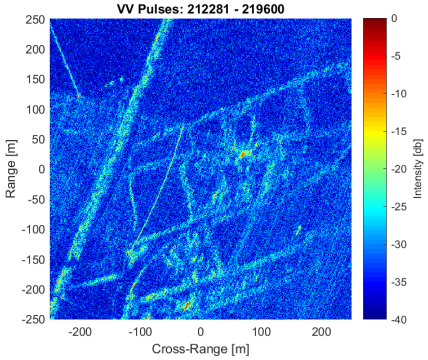
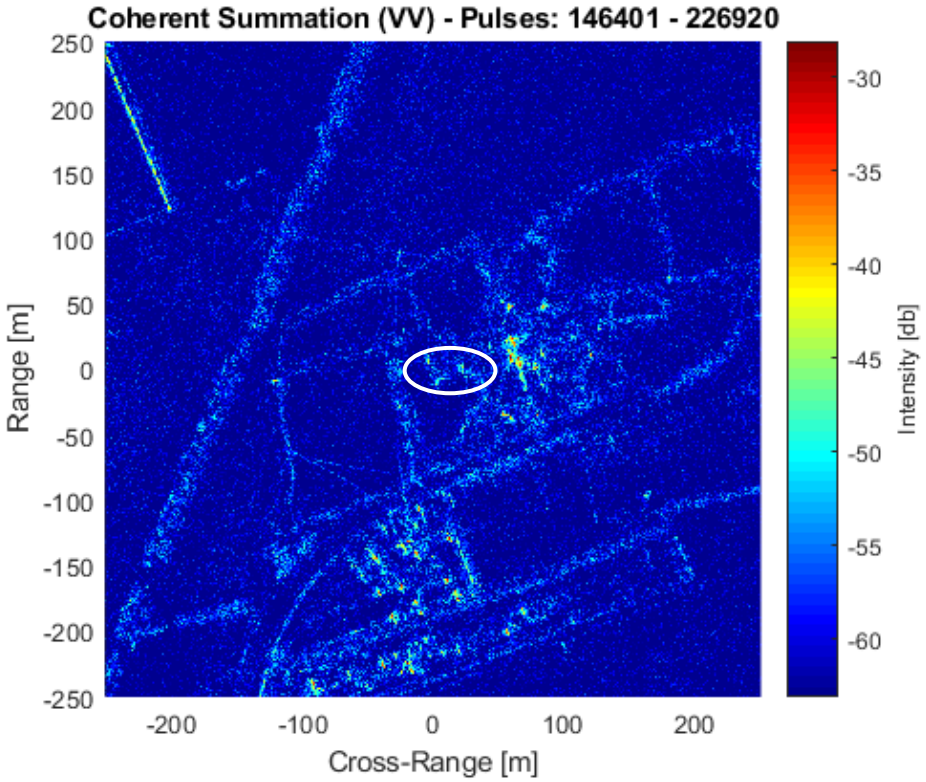
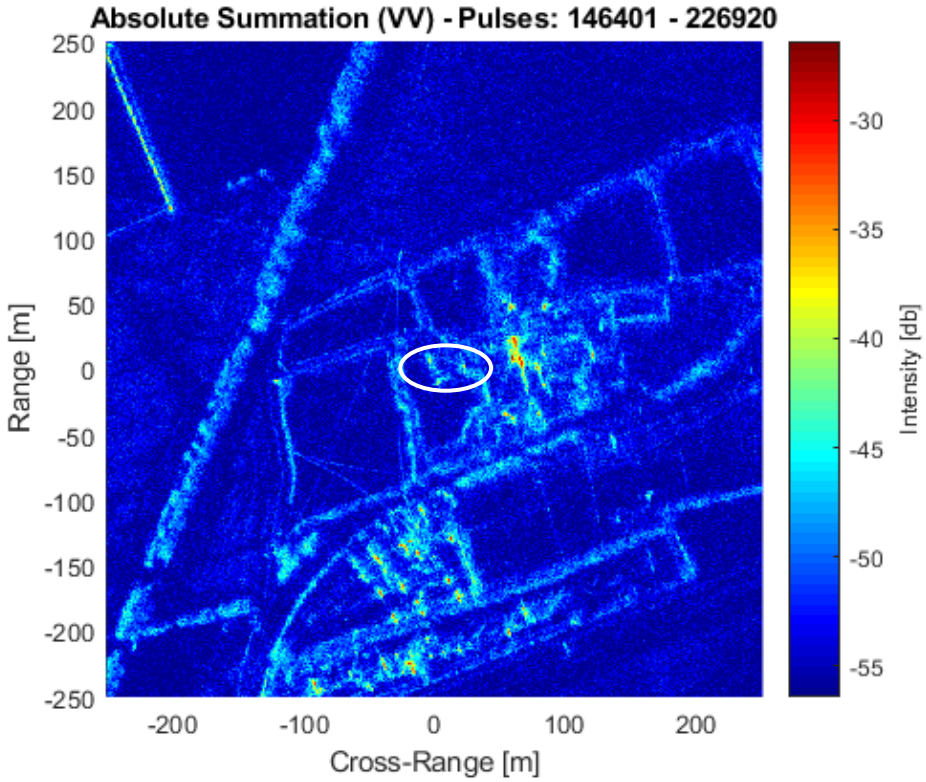


Image Summation – VV Polarisation



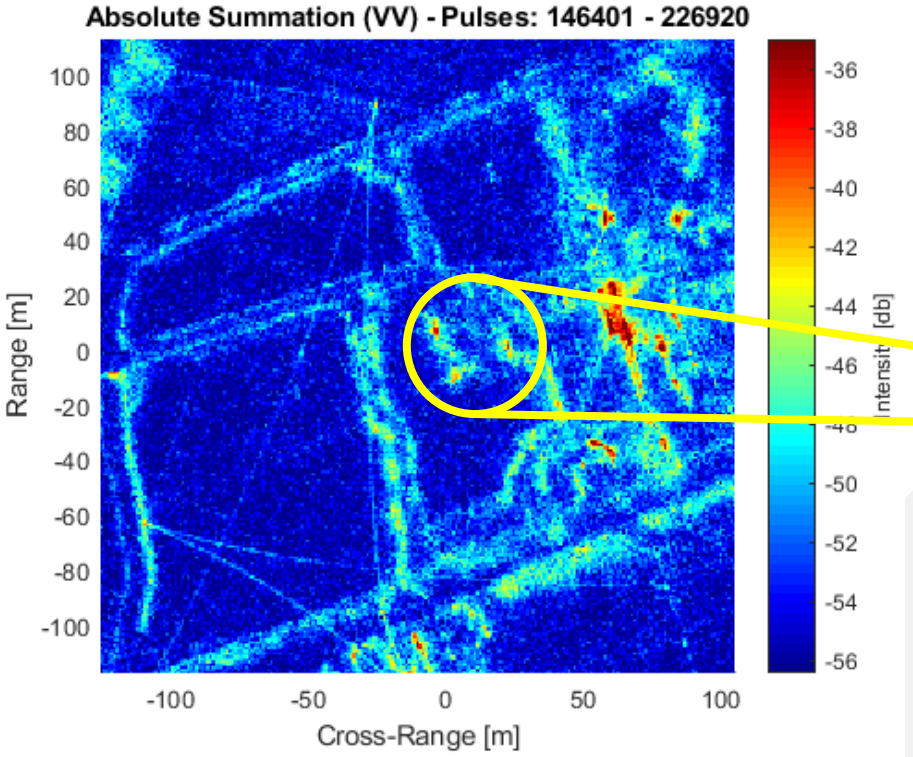
Coherent Image Sum

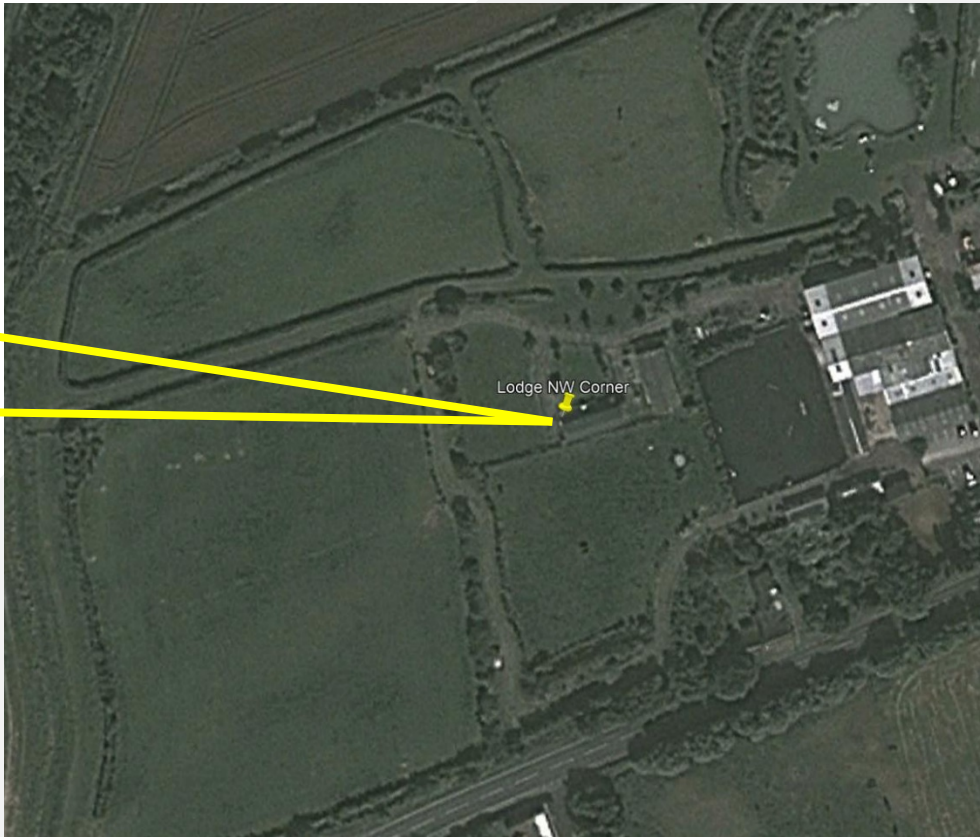


Incoherent Image Sum

Image Summation – VV Polarisation

- LF-SAR has been able to completely penetrate the lodge, and reveal signatures inside.
- The high intensity signatures are believed to be the calibration targets.





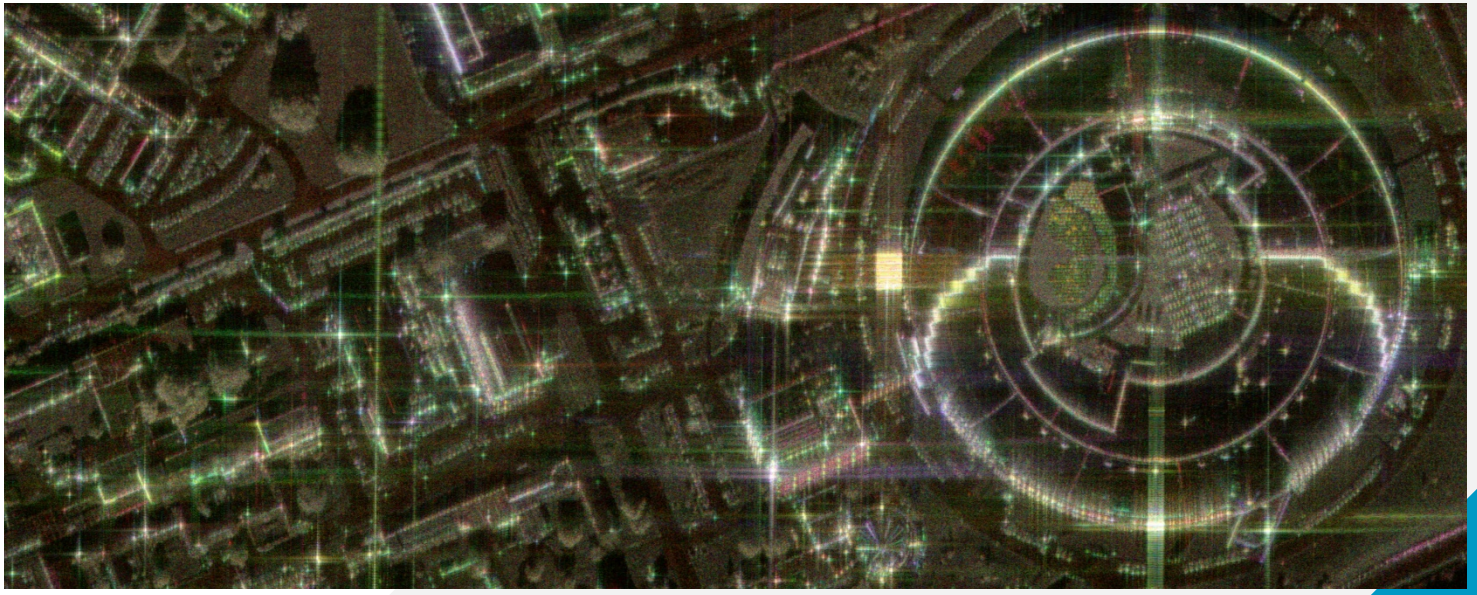
https://www.google.com/intl/en_uk/earth/desktop/

Conclusion

- The practical usage of LF-SAR has been discussed.
  - LF-SAR data dome project.
- The main difficulties affecting the usage LF-SAR have been shown.
  - Radio frequency interference.
- Basic RF interference removal has been implemented.
  - Absolute intensity threshold.
  - Its effectiveness has been shown.
- Preliminary CSAR results have been produced, including coherent and incoherent summations.

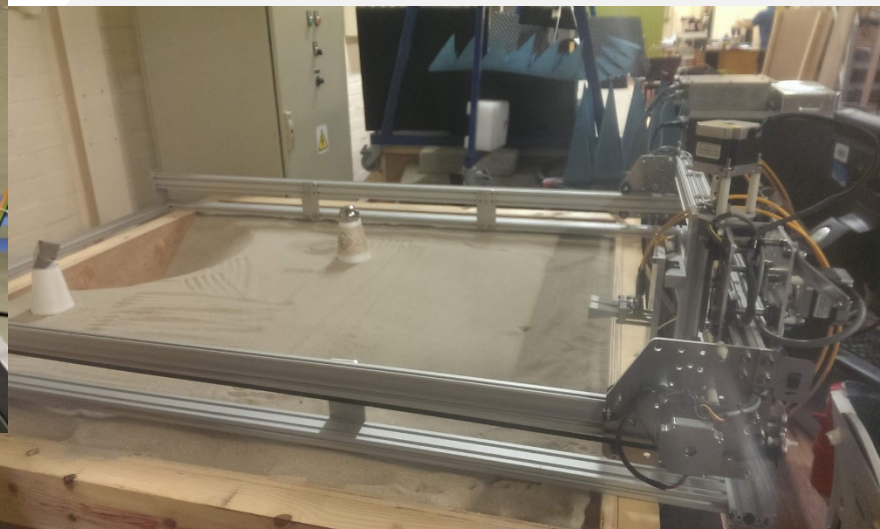
Future Work

- Improve RFI mitigation techniques.
- Use more of the complete CPHD frequency bandwidth, producing results of a higher resolution.
- Investigate all polarisations.
  - Develop novel signal processing techniques for exploiting how the polarisations can be used together.



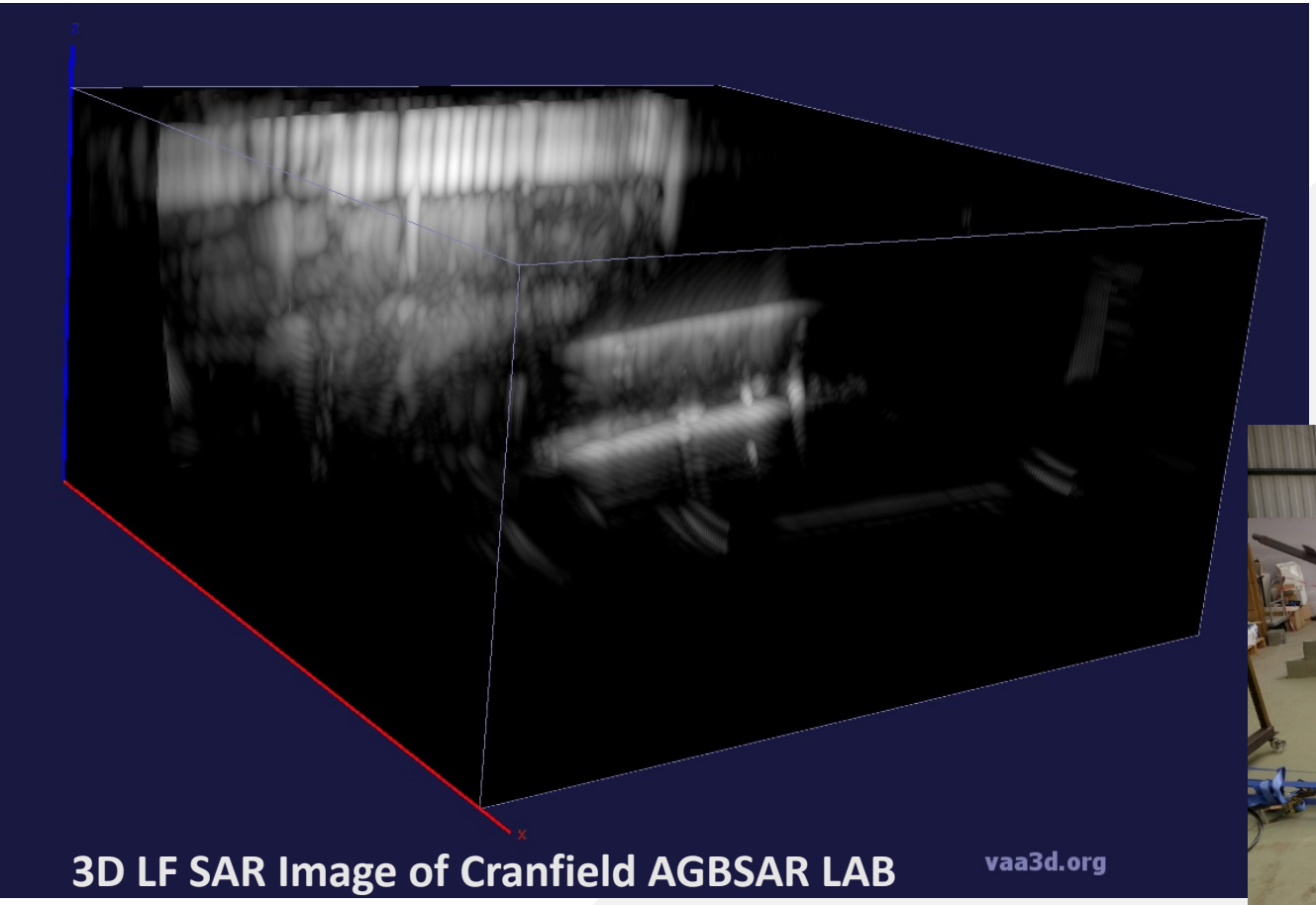
Future Work

- Cranfield's AGBSAR laboratory allows for 3D SAR experimental data to be collected in support of the RIBI project.



Future Work

- **Process multiple CSAR acquisitions collected at different elevations, producing volumetric 3D SAR images of the target lodge and building to be formed.**



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