IEEE AESS Radar Challenge 2025

High-Resolution FMCW Radar for Non-Destructive Testing of RAAC Structures

Phaser Pharaohs team

Kamal Khalil, Samuel Forester, Frank Podd, Tony Peyton

Project Overview

Objective:

Modify the Analog Devices CN0566 Phaser radar platform and use it for the non-destructive Testing (NDT) of Reinforced Autoclaved Aerated Concrete (RAAC) panels.

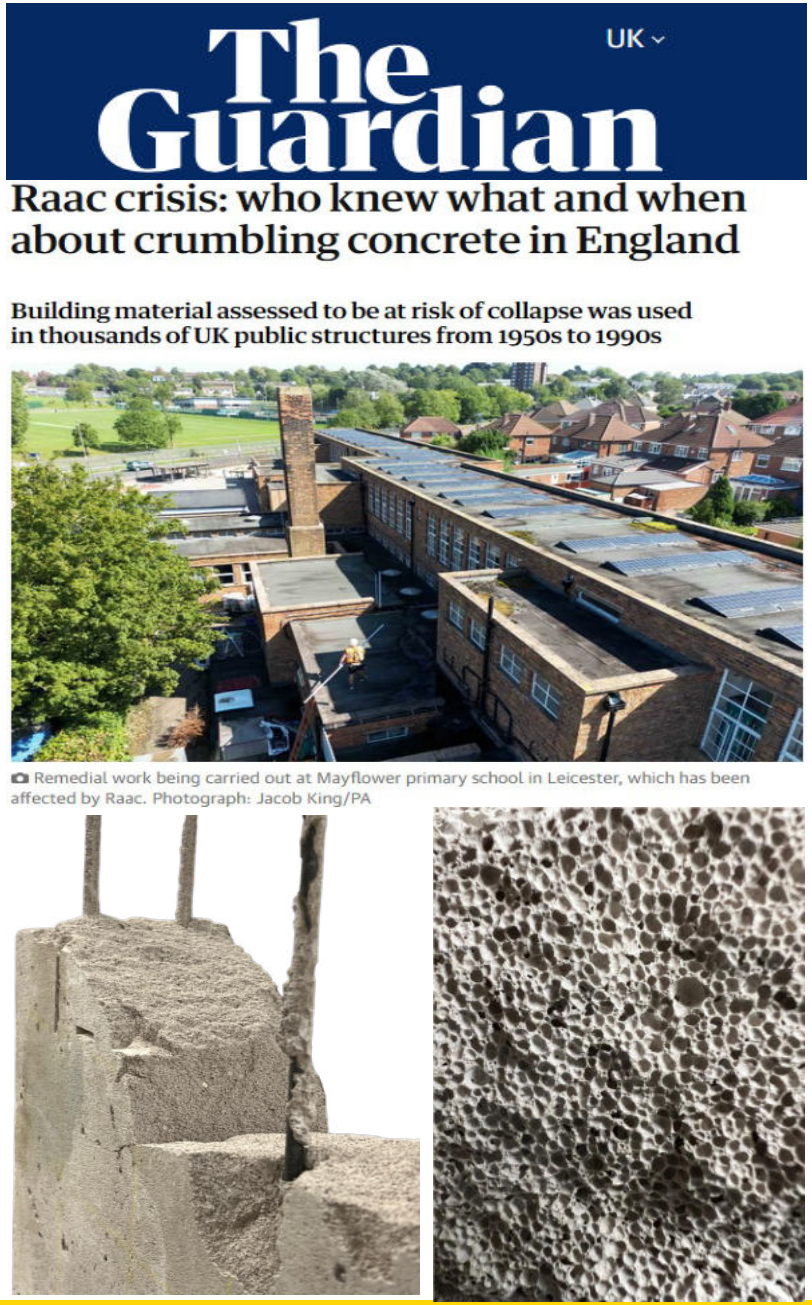
Motivation:

- RAAC is porous, absorbs moisture, and leads to **steel rebar corrosion**.
- Its **short lifespan (~30 years)** and hidden failure modes pose safety risks.
- Current inspection methods are limited or destructive.

Project Goal:

Leverage **beamforming + bandwidth expansion** to:

- Achieve **5 cm range resolution** and **fine angular resolution**
- Build a prototype system for **RAAC imaging at short range (<1 m)**



The Guardian

UK

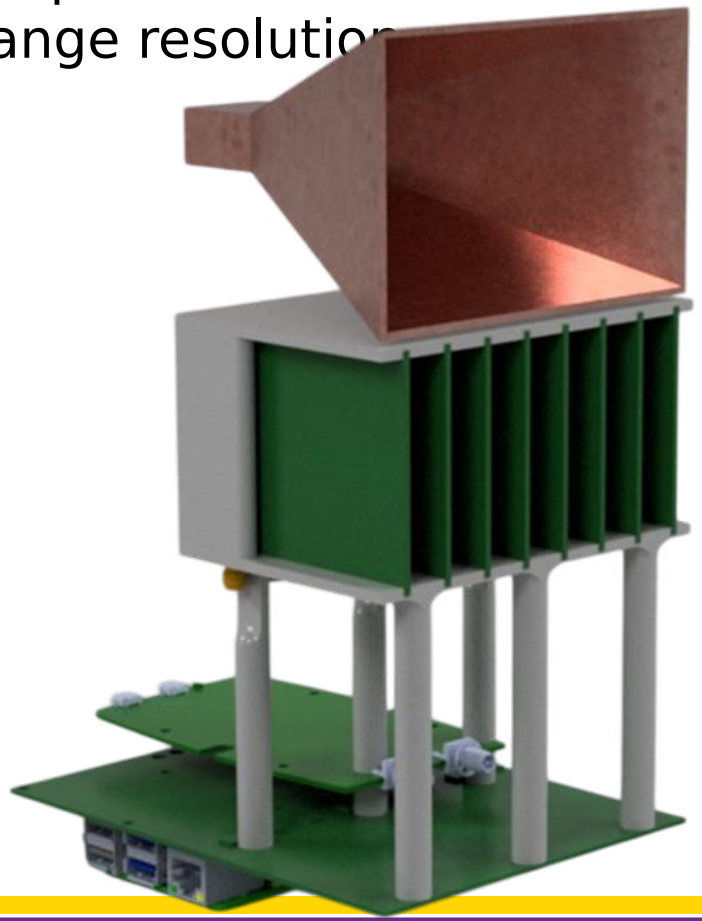
Raac crisis: who knew what and when about crumbling concrete in England

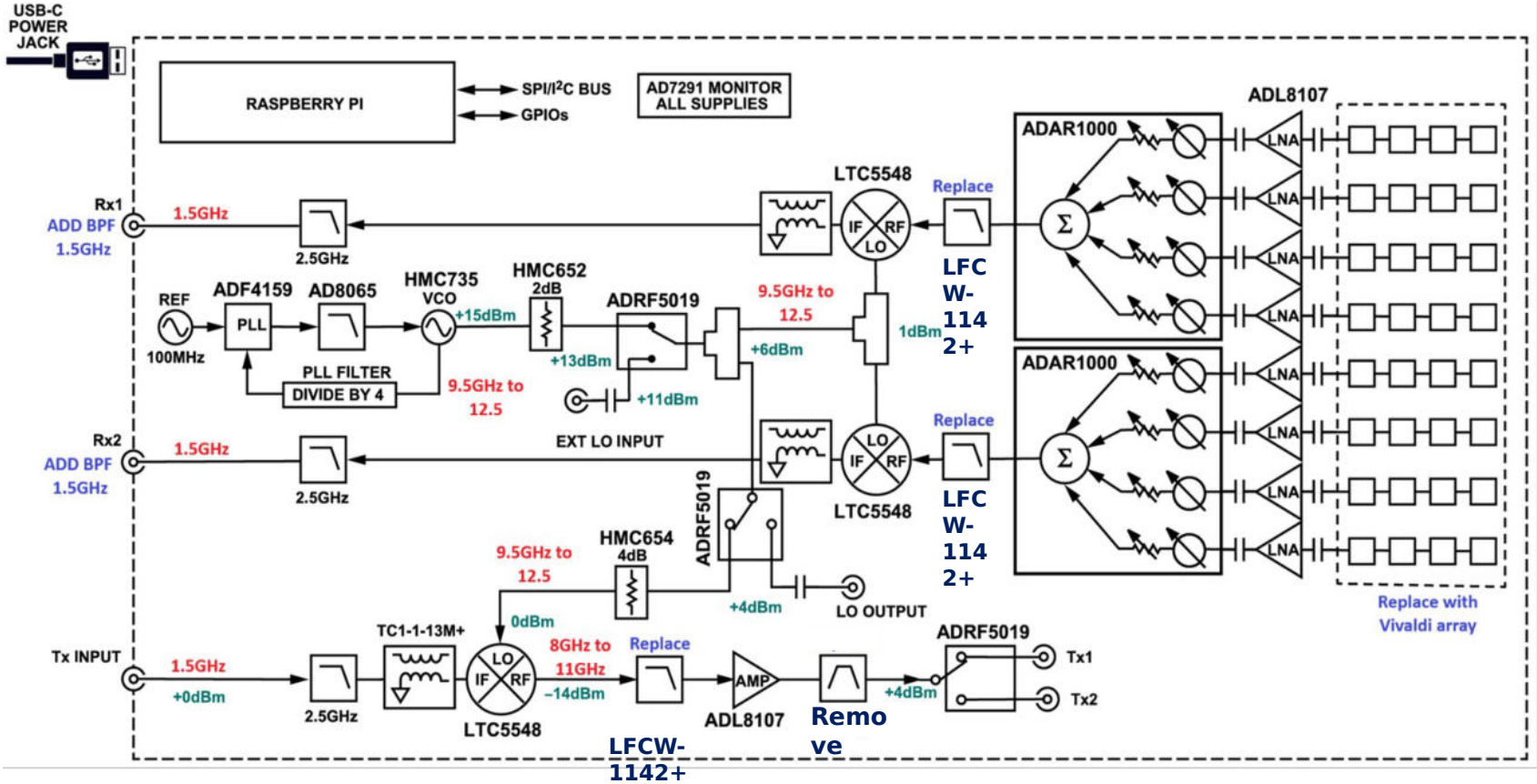
Building material assessed to be at risk of collapse was used in thousands of UK public structures from 1950s to 1990s

Remedial work being carried out at Mayflower primary school in Leicester, which has been affected by Raac. Photograph: Jacob King/PA

Radar Architecture & Key Modifications

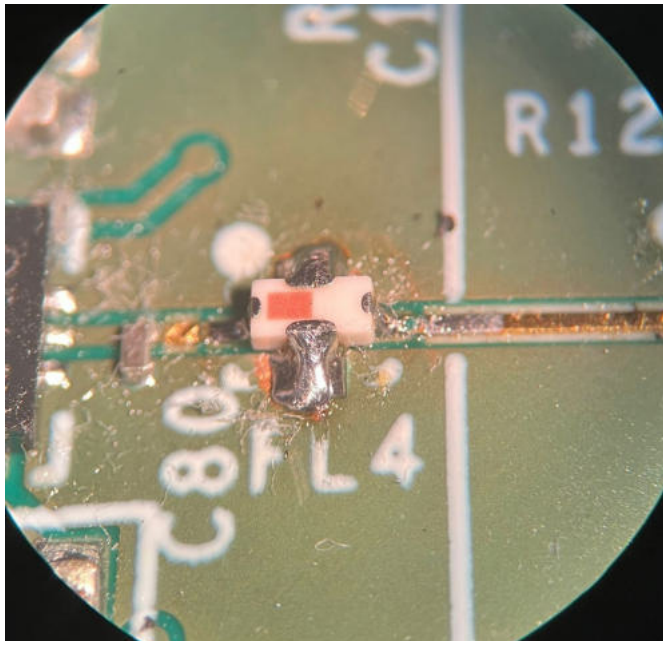
Proposed hardware modifications to expand usable BW from 500 MHz to 3 GHz → ~5 cm range resolution

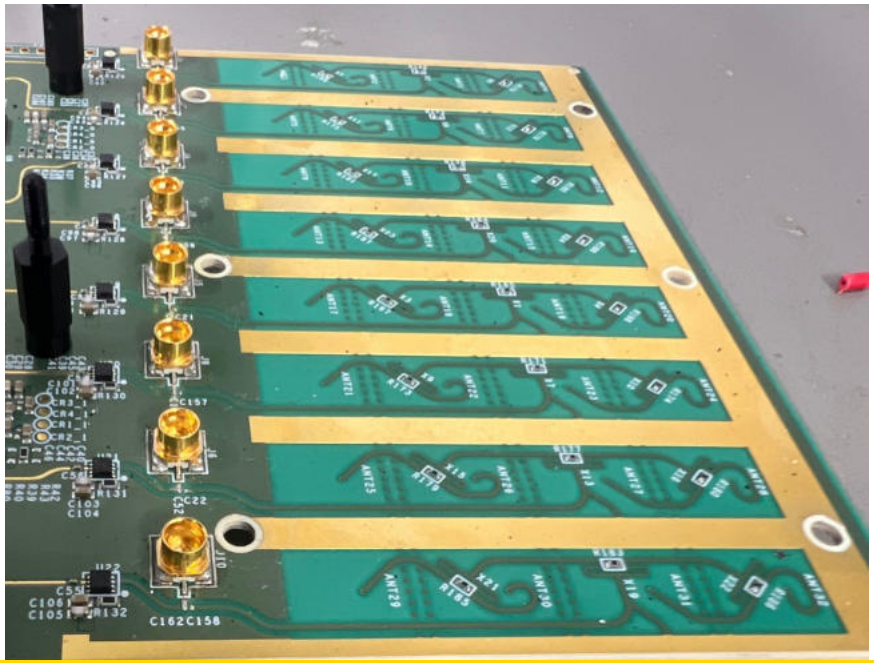


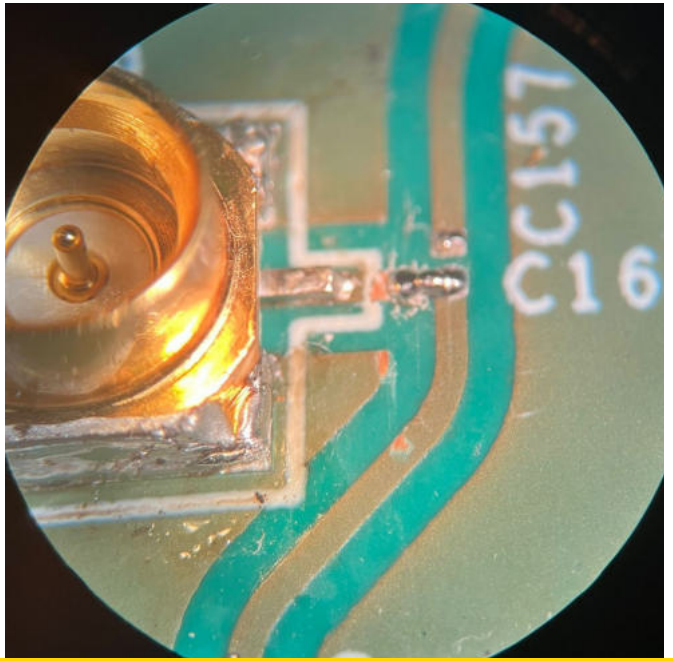


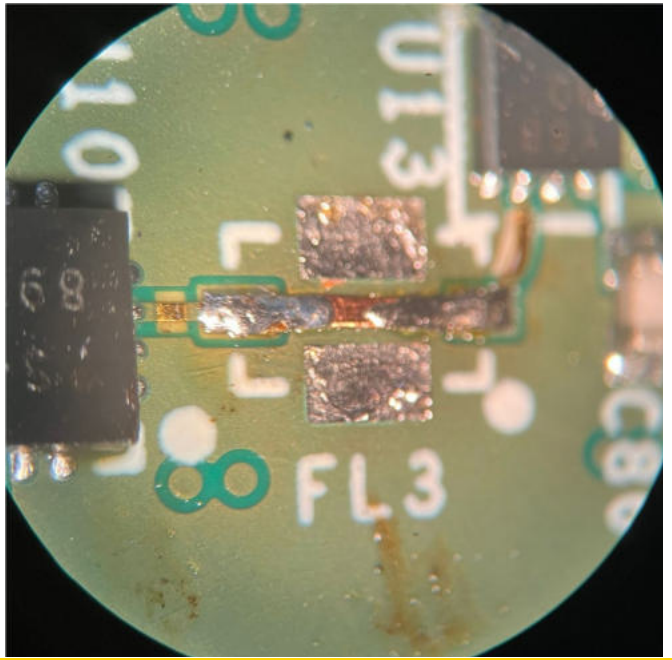
Hardware Modifications

1. Change filters to match the new operating frequency band (8-11 GHz).
2. Change the RF route to the onboard connectors.
3. Attach the RF connectors for the external antenna array.





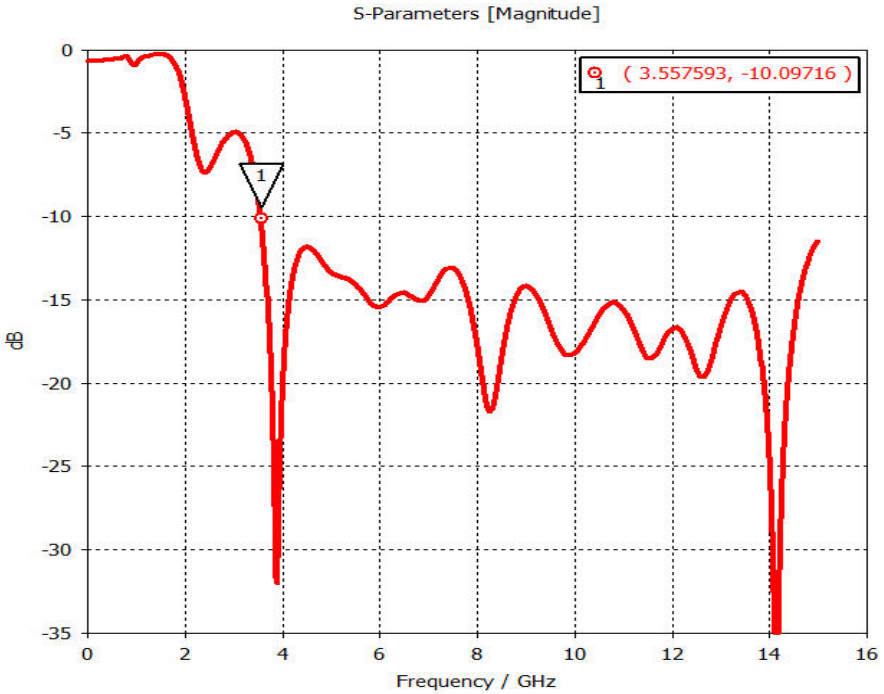


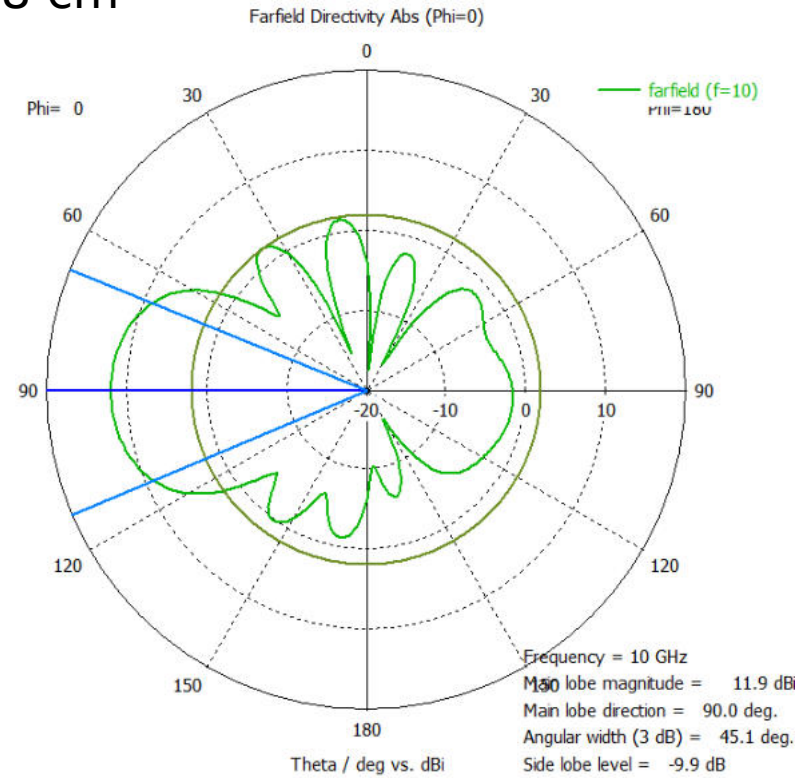


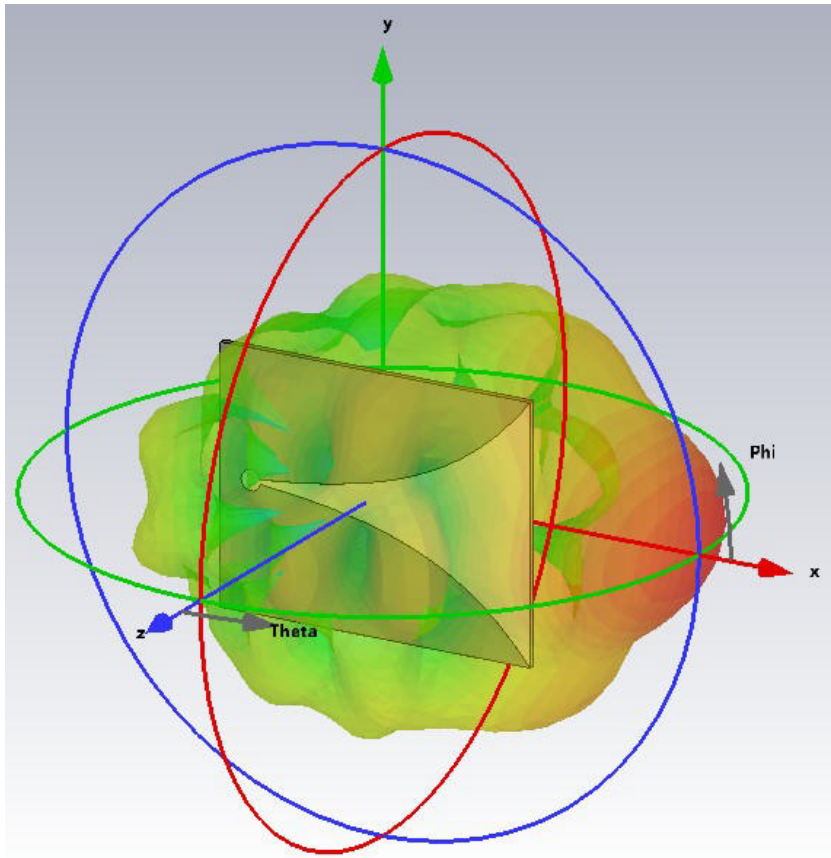
Receiving Antenna Array

Vivaldi antenna element:

- Operating between 3.5 GHz and 15 GHz
- Gain: 12 dBi @10 GHz
- Antenna dimensions: 6.2×7.8 cm
- Main side lobe level: -10 dB





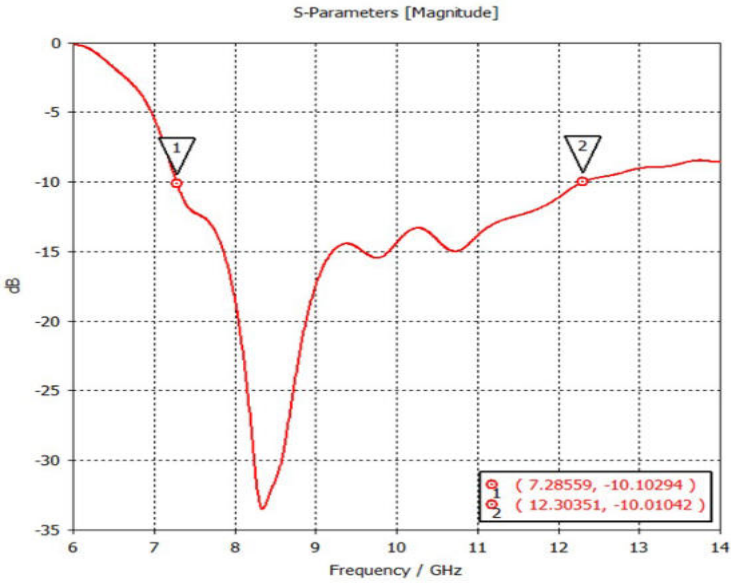


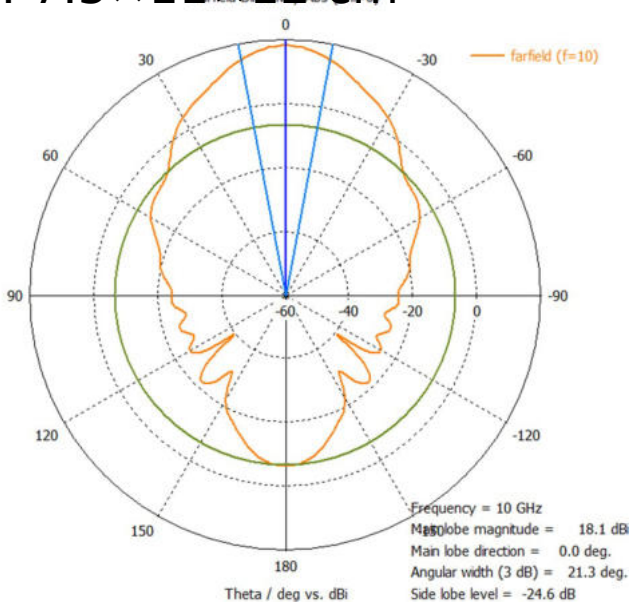
Transmitting Horn Ante

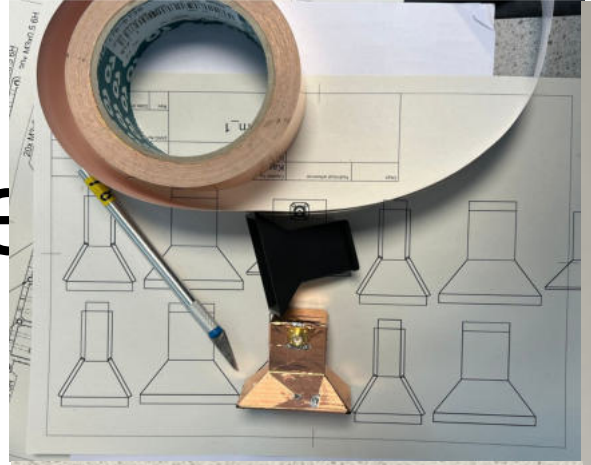
We design and fabricate two Horn antennas (Gain 18 &12 @ 10GHz)

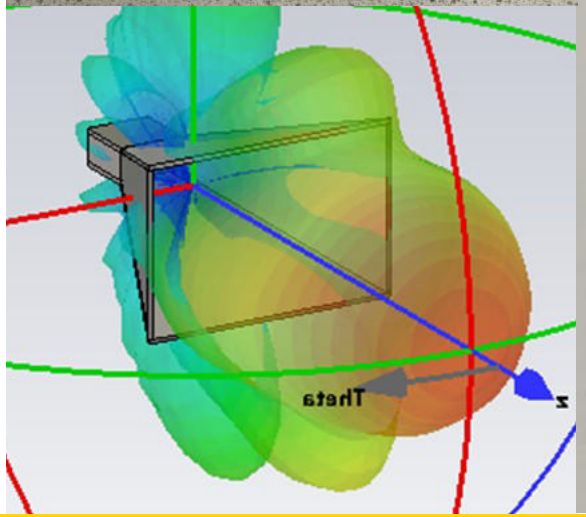
For this application, we will use the high-gain Horn

- Operating between 7.3 – 12.3 GHz
- Gain: 18 dBi @10GHz
- Main to side lobe level: -24.6 dB @10GHz
- Antenna dimensions: 7.5×11×12 cm



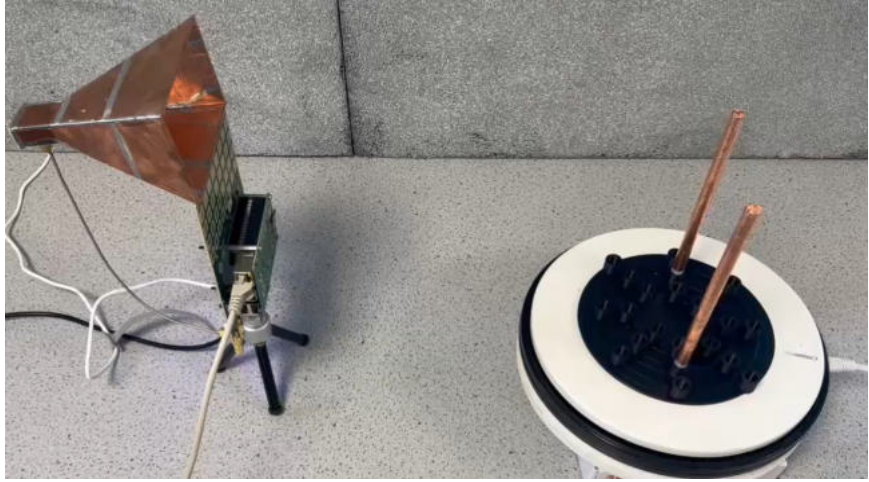






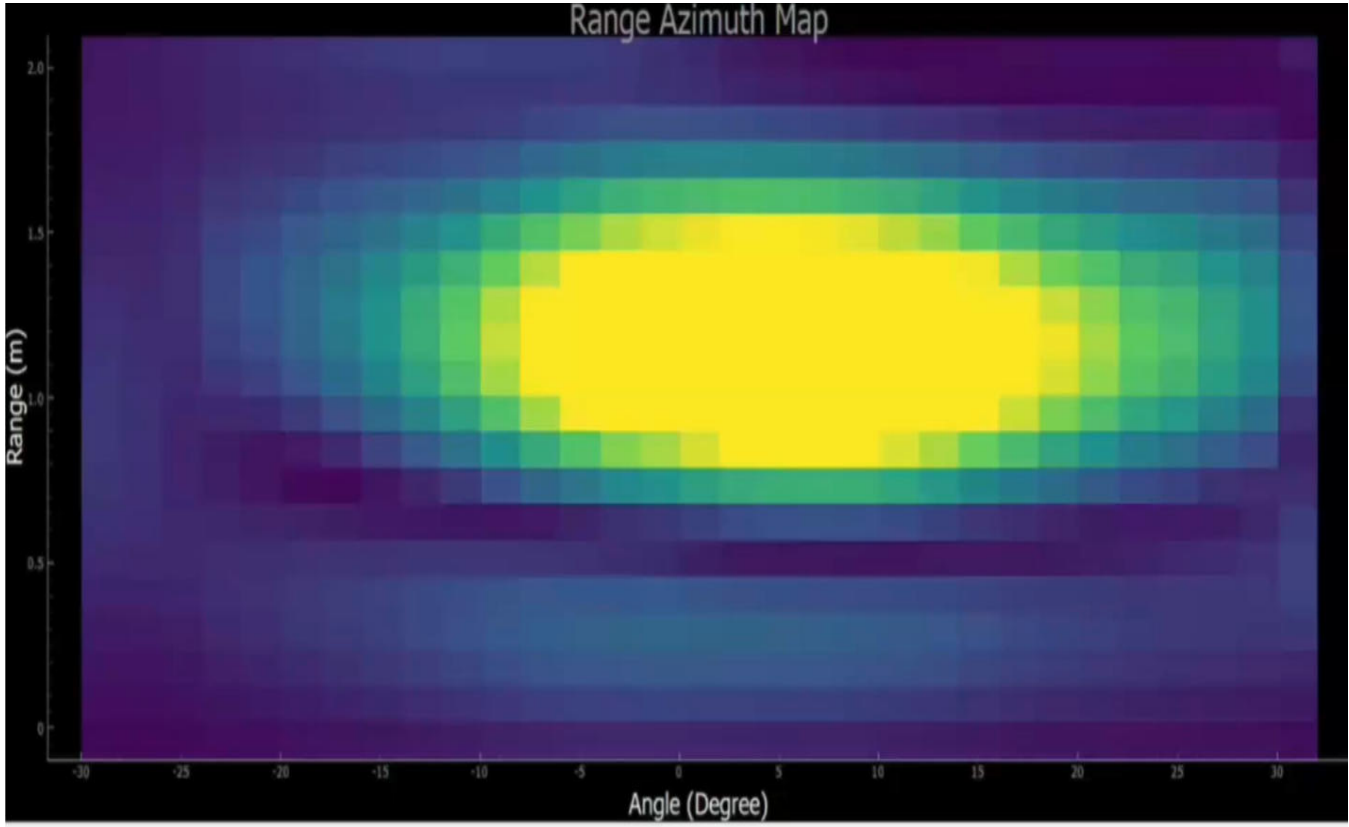
Standard Configuration

Tapered beam steering / BW 500 MHz



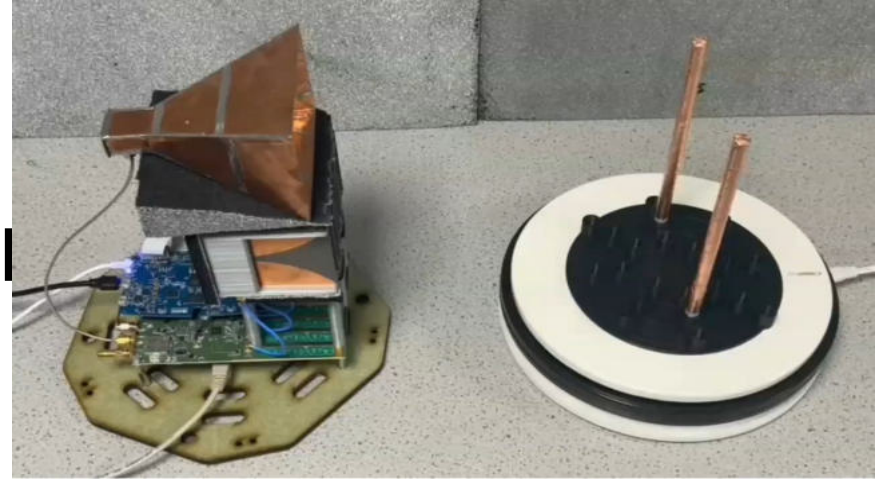
Radar:
TX: single 18 dBi Horn antenna
RX: Standard patch array
BW: 500 MHz
Fc: 10.25 GHz

Target:
Range ~30 cm
Separation = ~10 cm



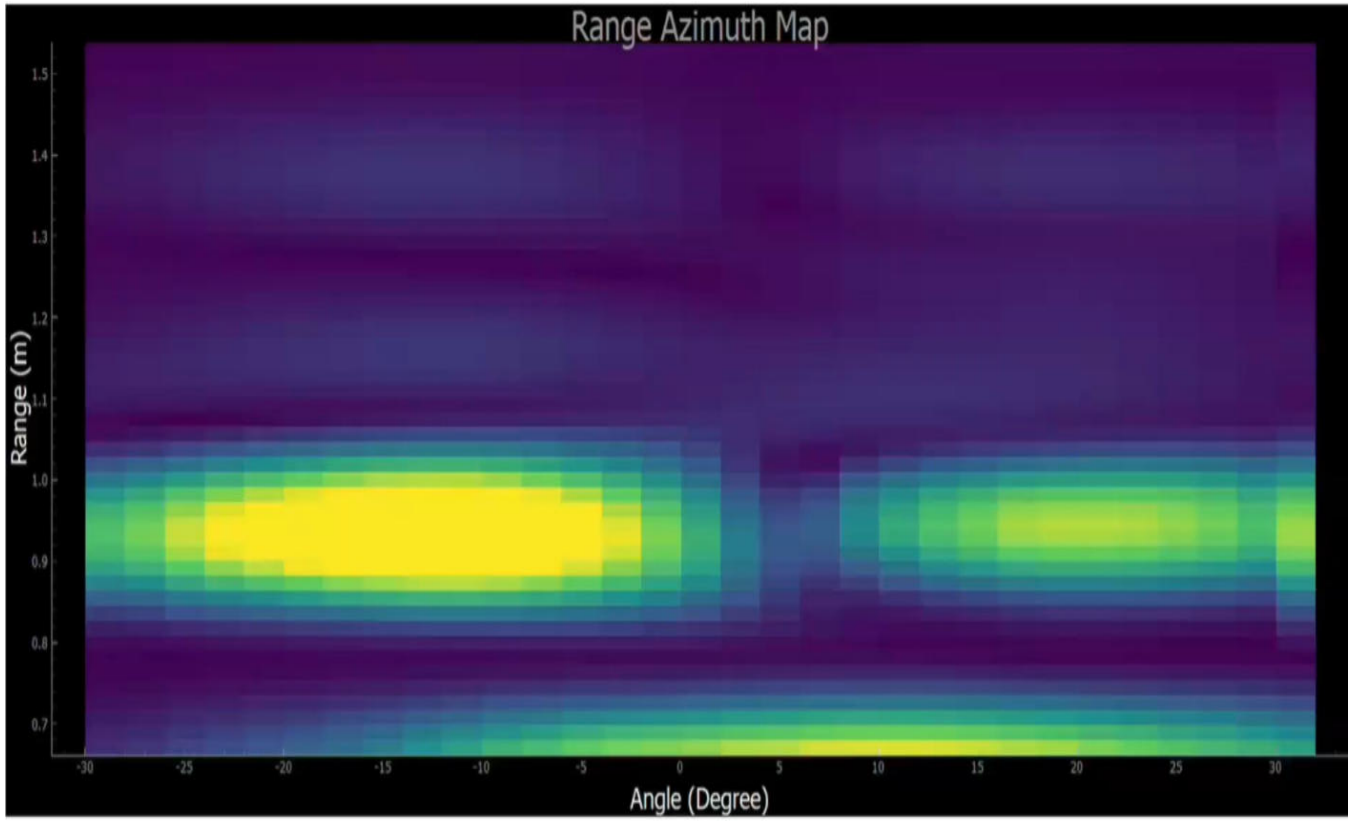
High Range Resolution Configu

Tapered beam steering / BW 3000 MHz

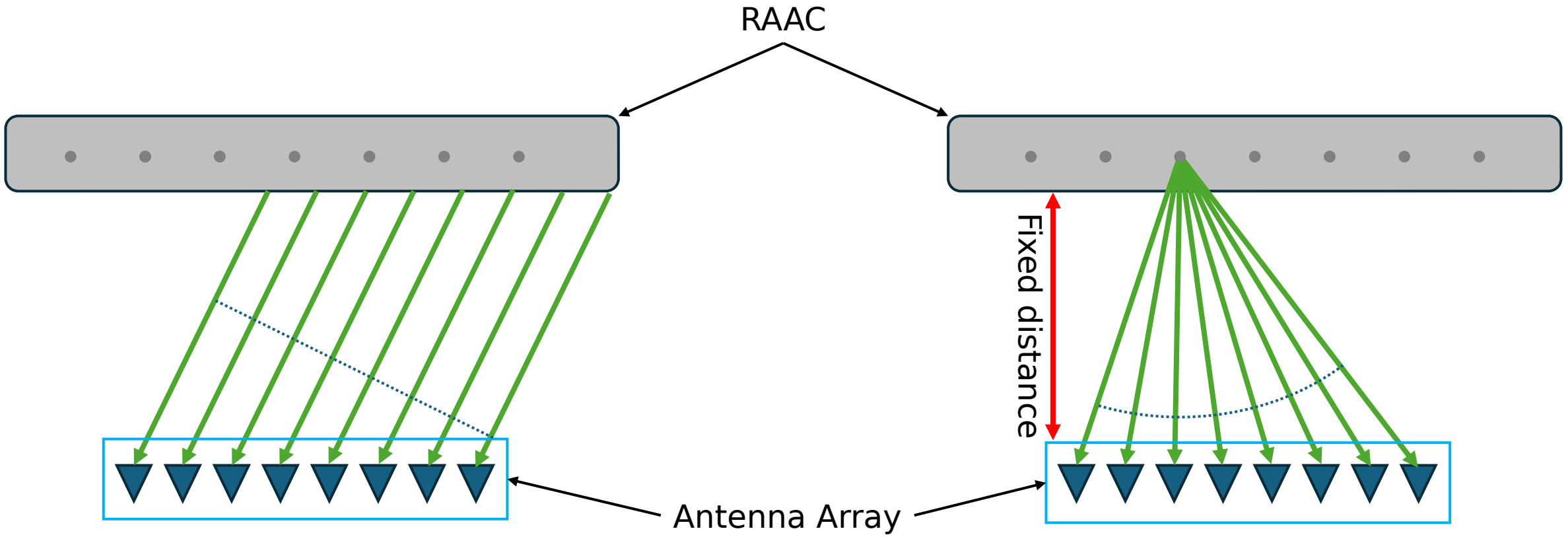


Radar:
TX: single 18 dBi Horn antenna
RX: 8-element 12dBi Vivaldi array
BW: 3000 MHz
Fc: 9.5 GHz

Target:
Range ~30 cm
Separation = ~ 10 cm

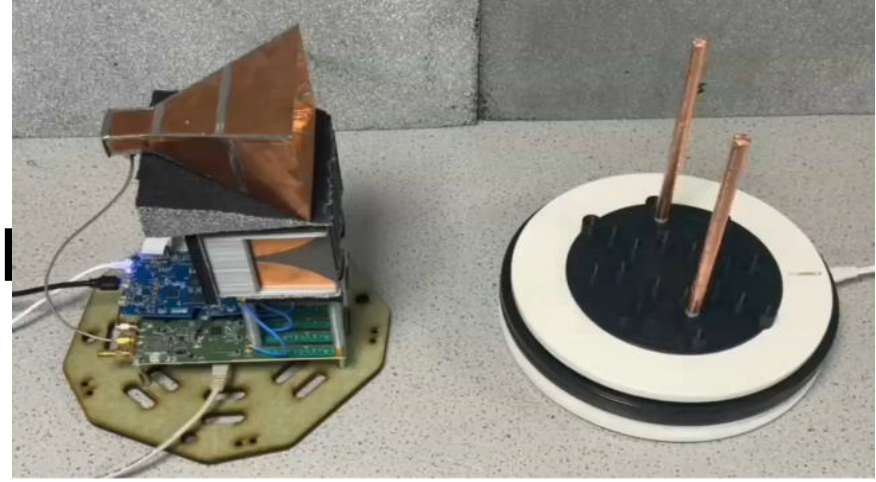


Near-field focused beamforming adapted for spherical wave geometry for sub-meter imaging of RAAC panels



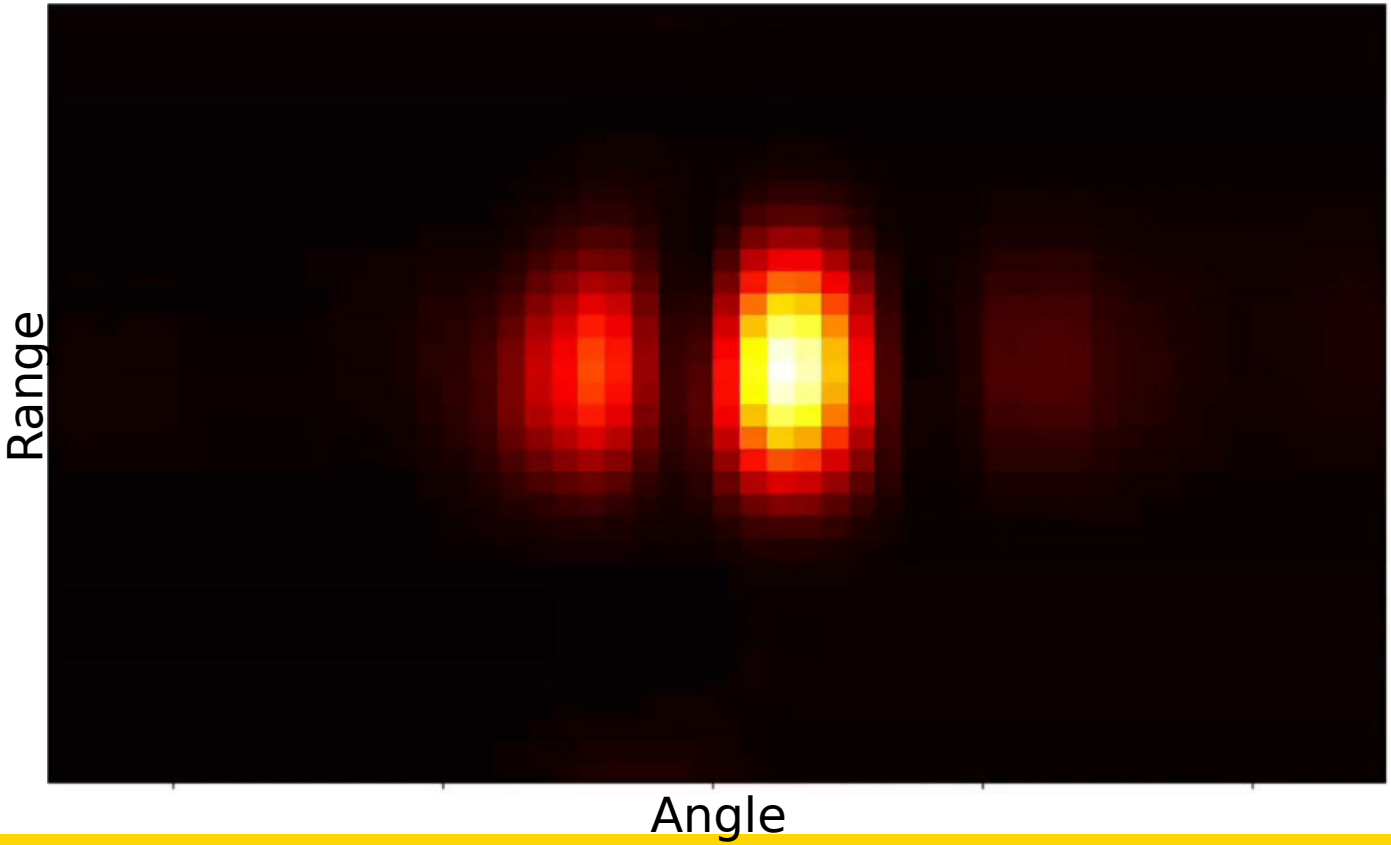
High Range Resolution Configu

Focused beam steering / BW 3000 MHz



Radar:
TX: single 18 dBi Horn antenna
RX: 8-element 12dBi Vivaldi array
BW: 3000 MHz
Fc: 9.5 GHz

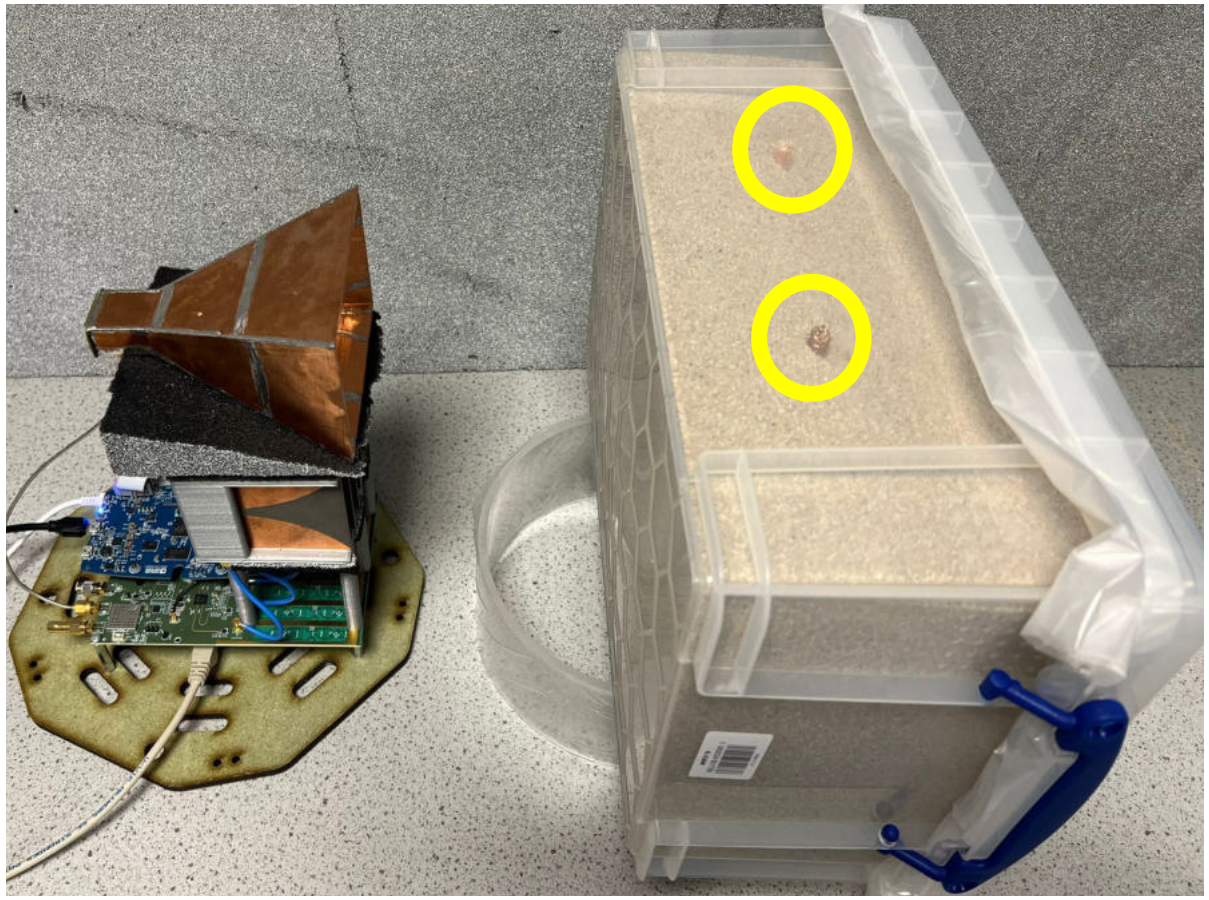
Target:
Range ~30 cm
Separation = ~ 7 cm

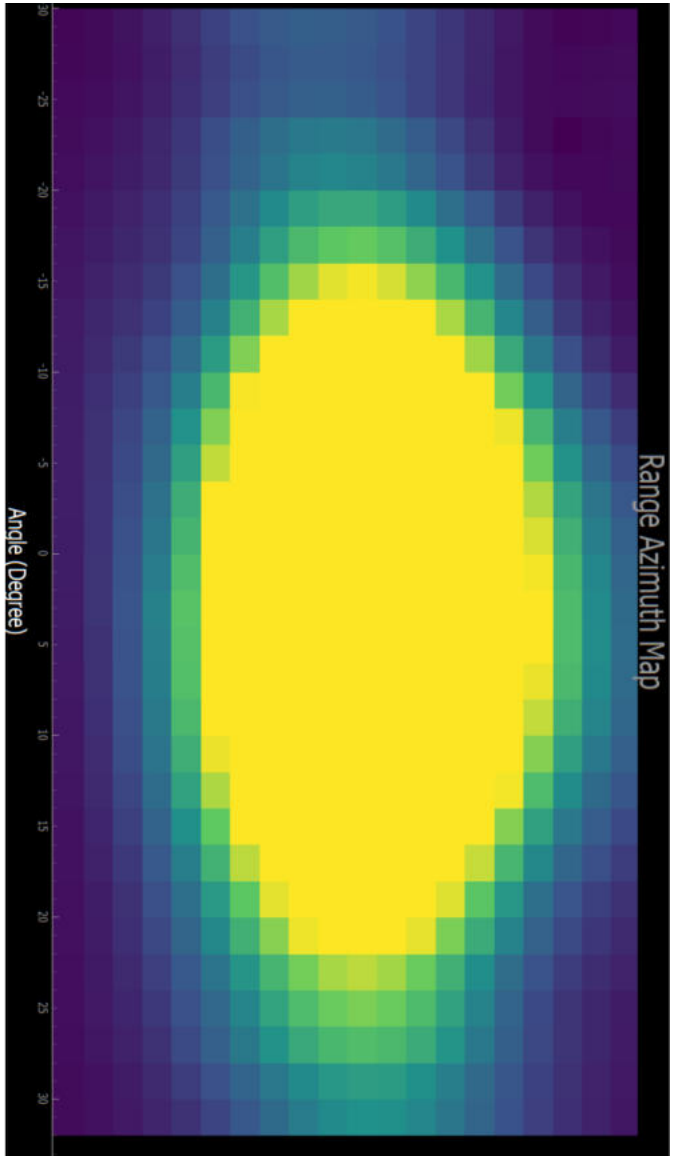


MANCHESTER 1824

Inspecting a Sandbox with Two Metal

Tapered beam steering / BW 500 MHz

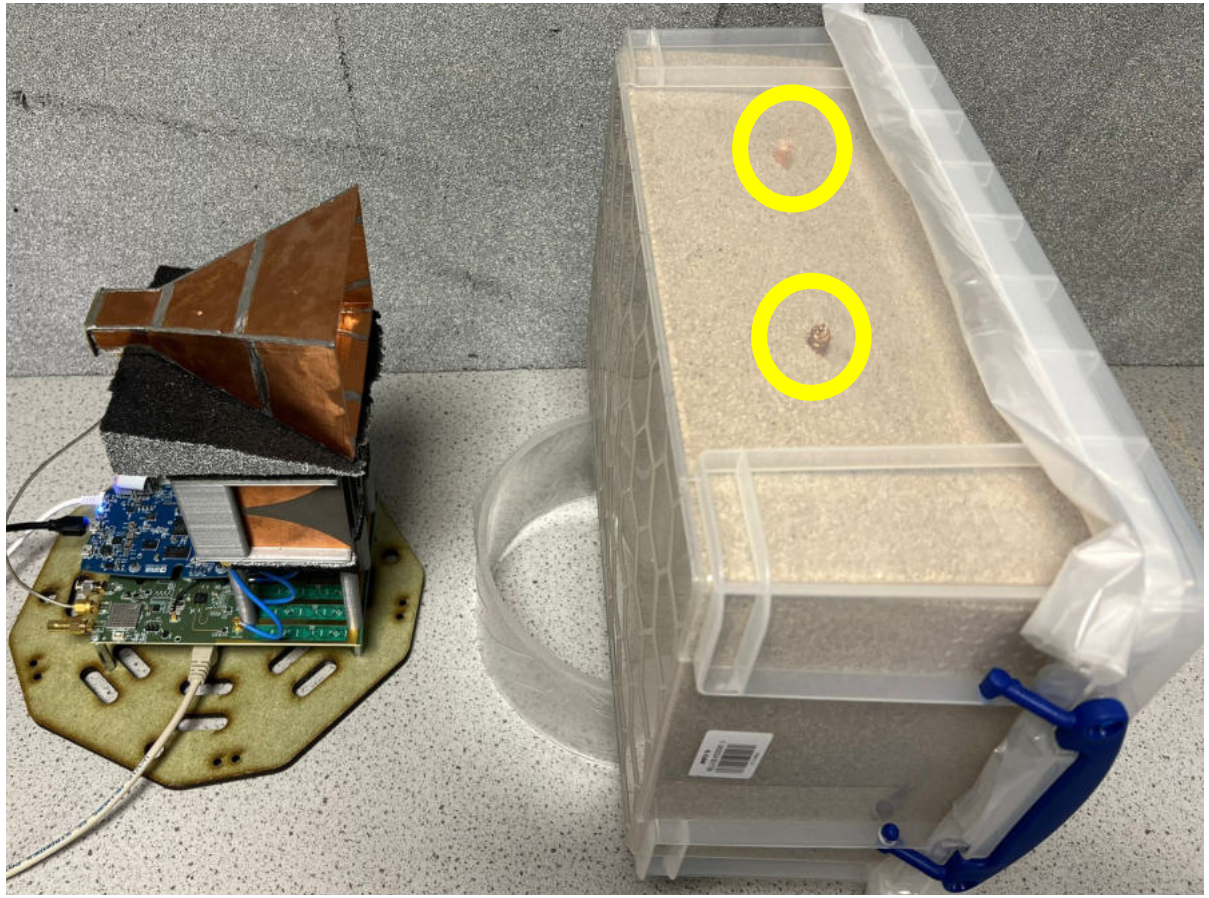


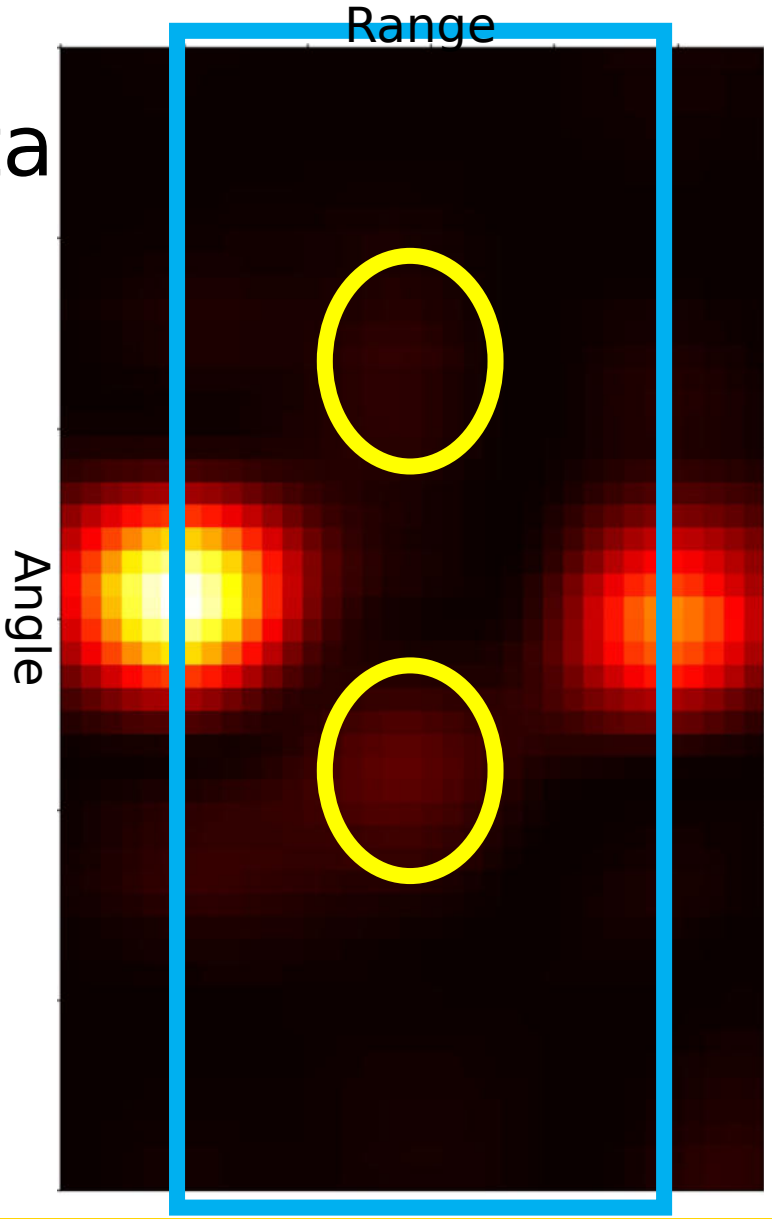


MANCHESTER 1824

Inspecting a Sandbox with Two Meta

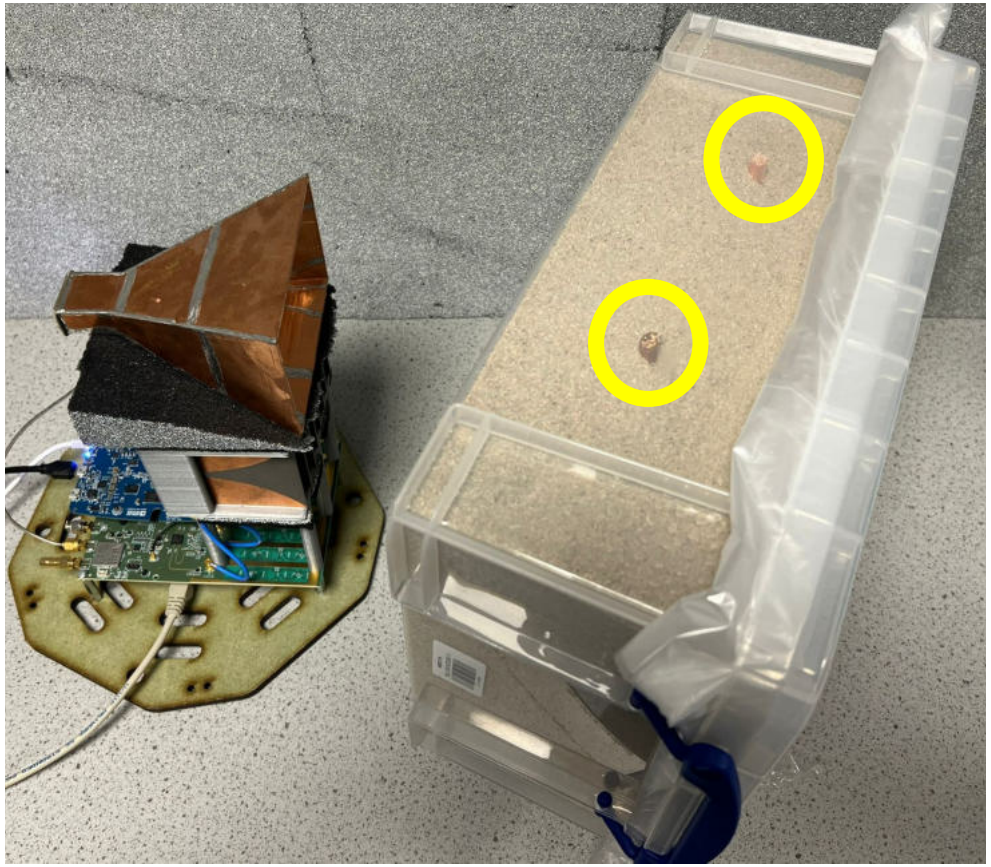
Focused beam steering / BW 3000 MHz

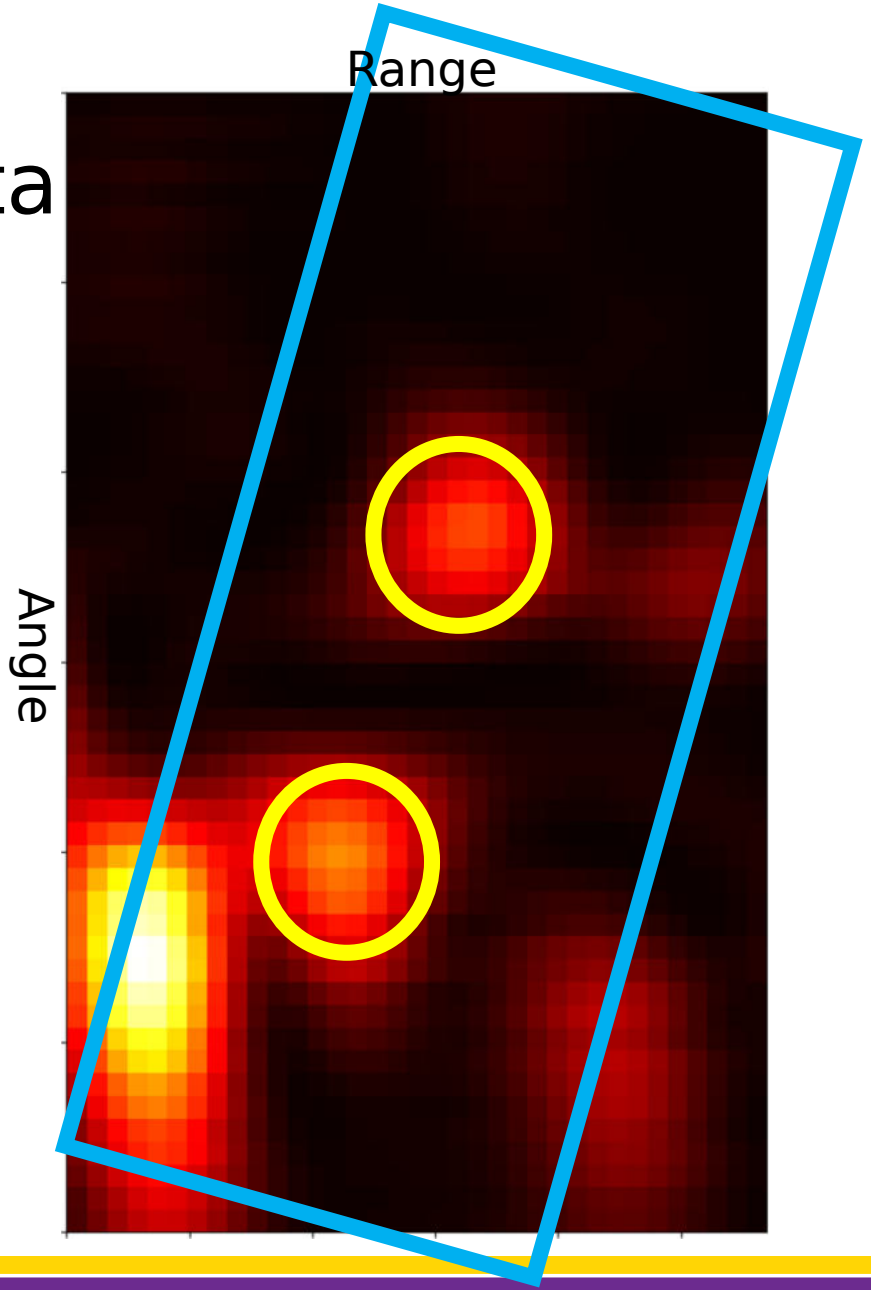




Inspecting a Sandbox with Two Meta

Focused beam steering / BW 3000 MHz

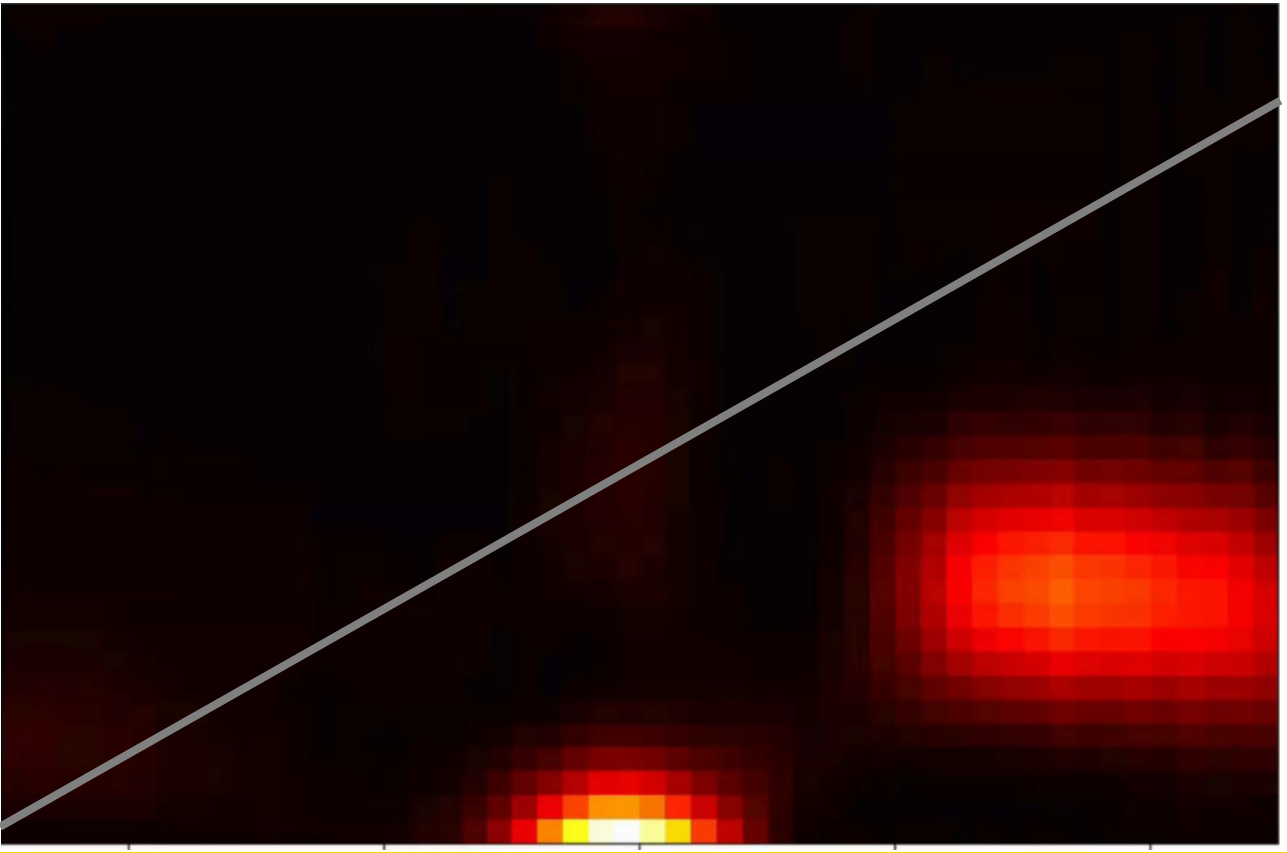


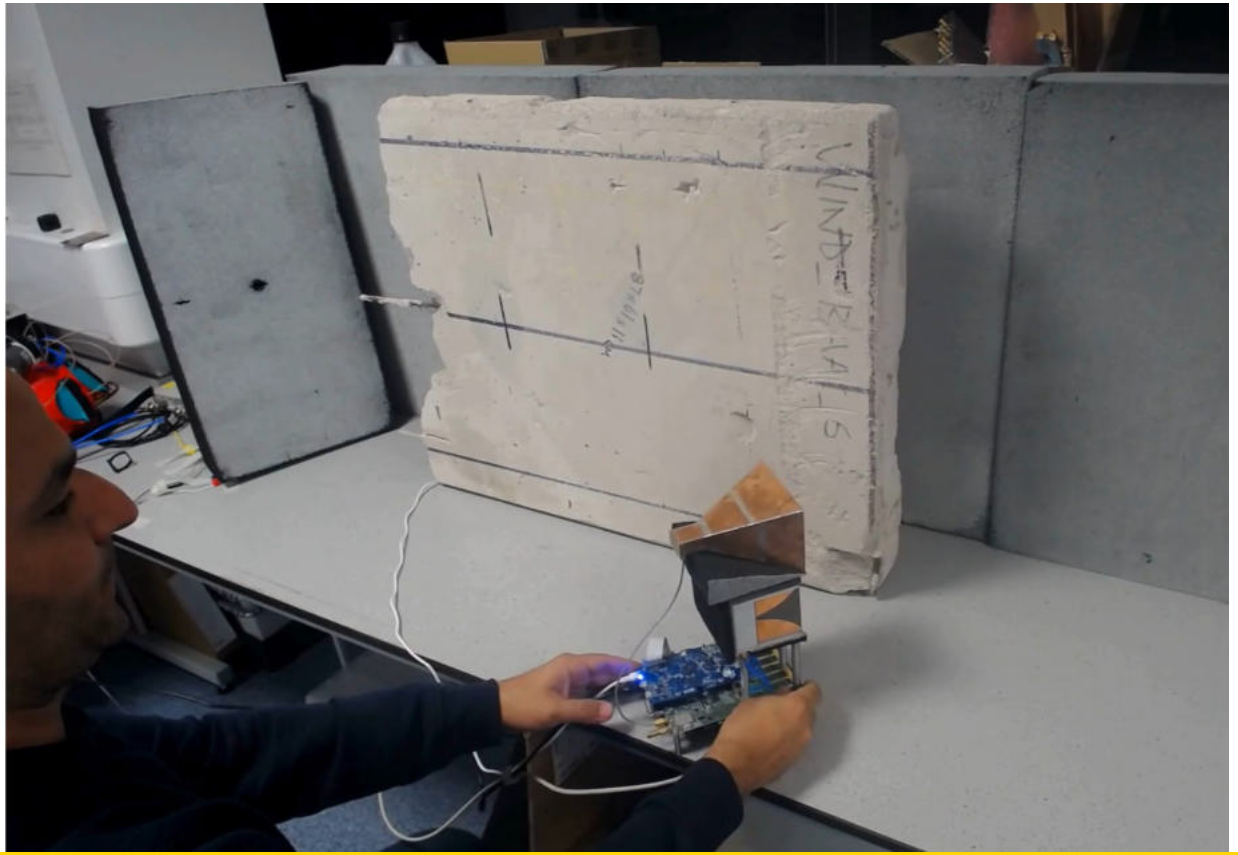


MANCHESTER 1824

Inspecting Steel Reinforcement of a RAAC Sample

Focused beam steering / BW 3000 MHz





Conclusion

Performance Enhancement

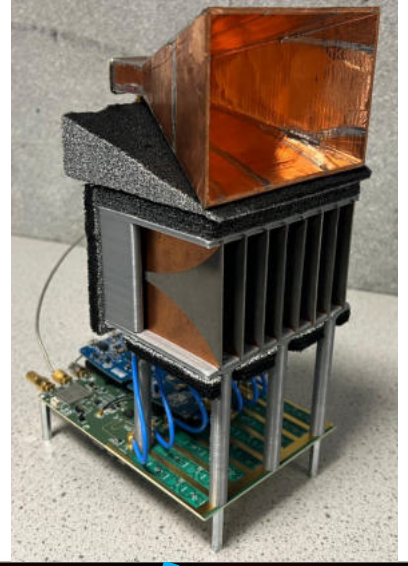
- ✓ Expanded bandwidth from **500 MHz → 3 GHz → 6x resolution improvement**
- ✓ Achieved **5 cm range resolution** and resolved **7 cm target separations**

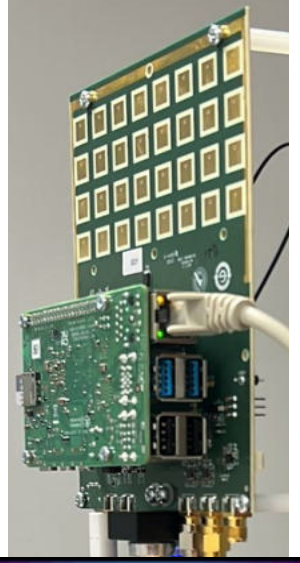
Proven Feasibility

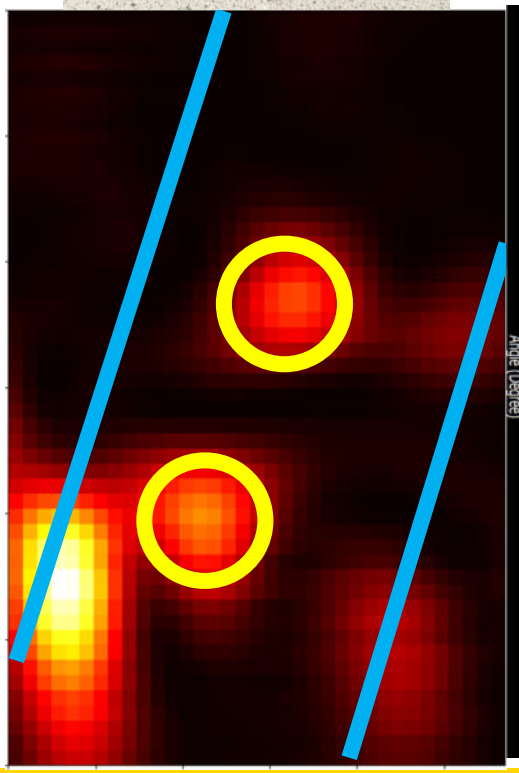
- ✓ Custom Horn + Vivaldi antennas for optimised short-range imaging.
- ✓ Focused beam steering demonstrated on RAAC samples & testbed

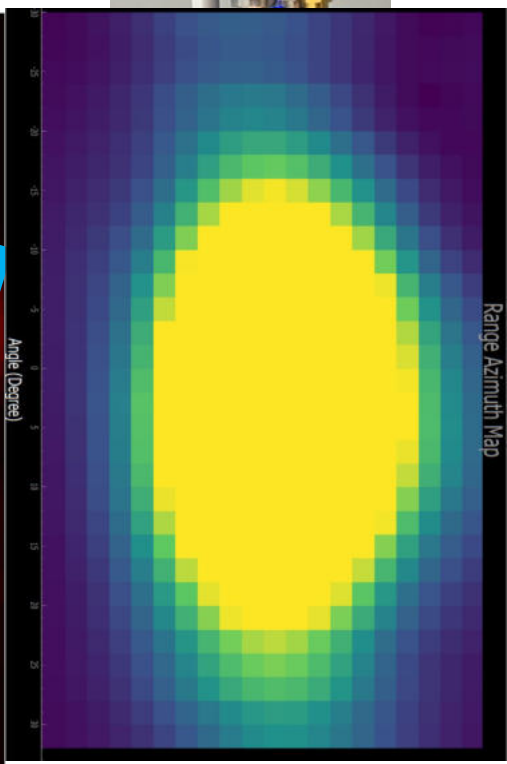
Transformative Impact

- ✓ Non-destructive, high-resolution inspection
- ✓ Scalable to bridges, tunnels, and aerospace composites.









Future Work

Combine antenna array + translational motion → reconstruct 3D high-resolution images of RAAC reinforcement.