Low frequency SAR data-dome collection with the Bright Sapphire II instrument

Specialists' meeting on Remote Intelligence of Building Interiors

DEFENCE AND SPACE

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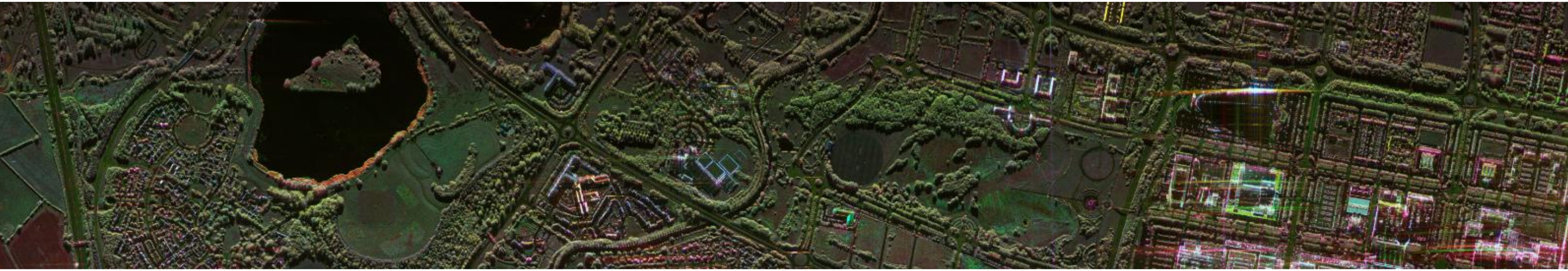
Low Frequency Airborne SAR

Justification and potential

Airborne SAR

Airborne SAR is a useful method to gather ISTAR information. Multiple airborne campaigns have proven the advantages of such systems, which include:

- Remote stand-off
- All weather, day-night sensing capability
- Height information and 3D tomography (with adequate acquisitions)
- Multi-frequency system
- Potential for customisation
- Flexibility on operation



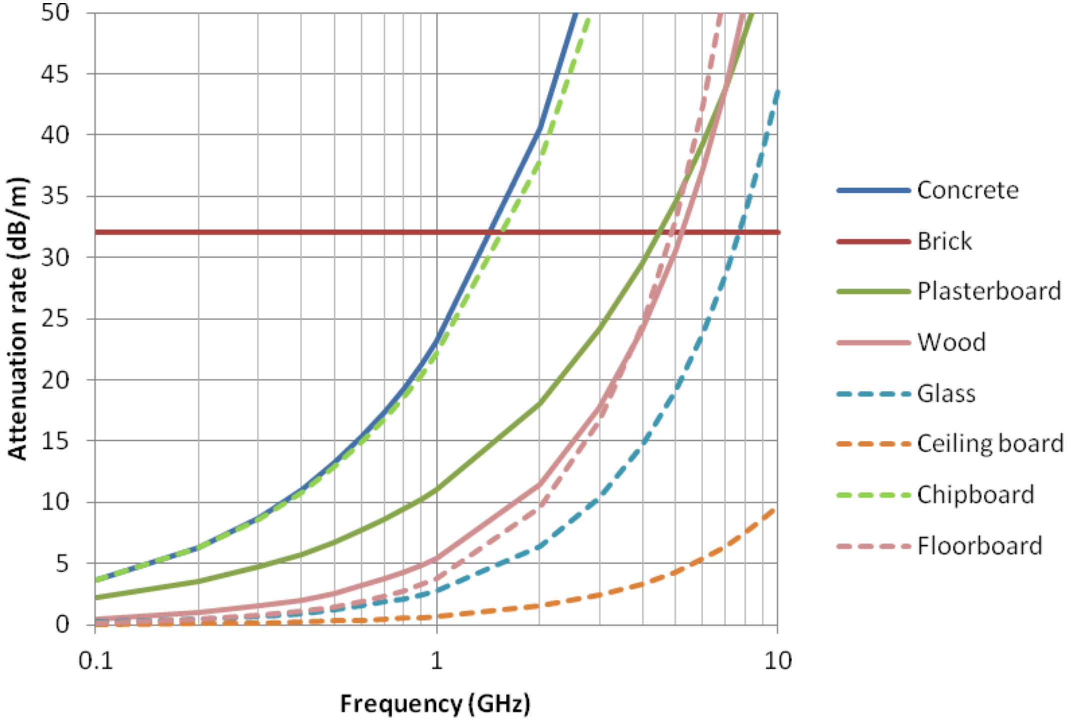
X-band fully polarimetric SAR image, Milton Keynes

Low Frequency RF

The use of low frequency RF for communications applications requiring building penetration is well established, with very common examples such as mobile and Wi-Fi.

The attenuation rate of building penetration depends on:

- Signal frequency
- Building construction and materials
- Penetration angle



Calculated attenuation rates of building materials.
Source: OFCOM report on "Building Materials and Propagation"

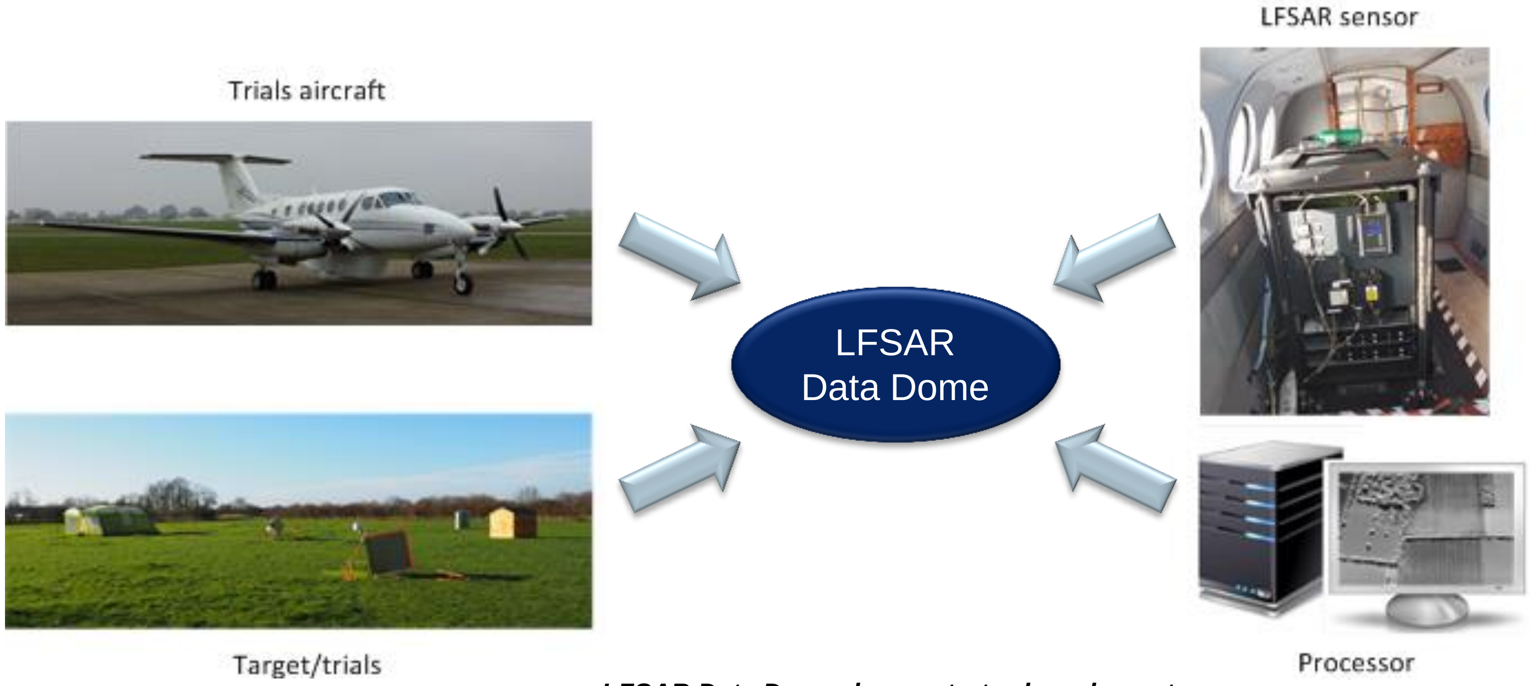
LF SAR

Low frequency SAR is a solution to seeing inside buildings and facilities to detect activity or occupancy.

An airborne demonstrator campaign has been performed to prove the potential capabilities of LF SAR.

The key elements of the demonstration programme is:

- Development of Bright Sapphire II LF SAR sensor
- Integration of the sensor onto the trials aircraft
- Planning and undertaking of trials to acquire data
- Conversion of raw data to CPHD format to enable exploitation.



LFSAR Data Dome demonstrator key elements

LFSAR Data Dome

Trials and instrument overview

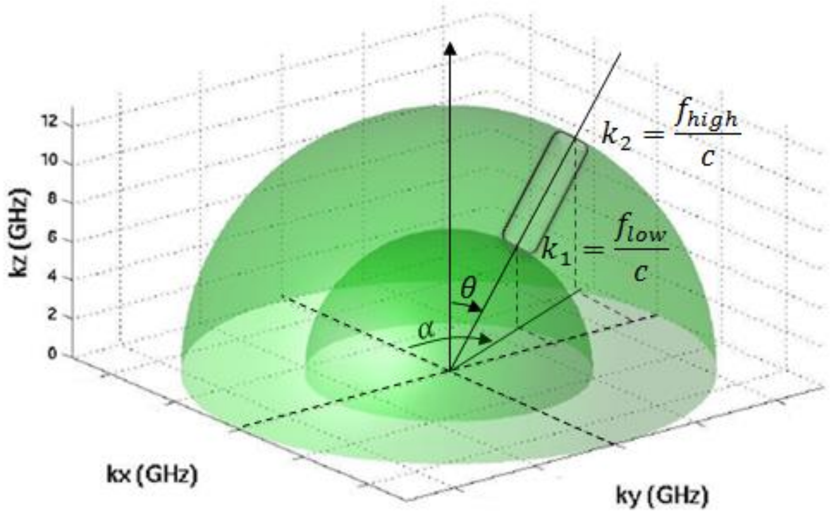
Trials

The trial objective is to collect data in such a way that it can be coherently combined to form a ‘Data-Dome’.

Data-Dome refers to a collected dataset that covers a hemisphere over the target area defined in ‘k-space’. The data-dome collection enables tomographic and volumetric information to be extracted about the building.

To achieve the objective, circular acquisitions were used to image over 360° of azimuth (α) and 20-70° range of incidence angles (θ), with a height separation adequate to avoid height ambiguities during tomographic combination.

Linear acquisitions were added to the trials to verify instrument performance and to be able to fly closer to the target for enhanced signal-to-noise ratio.



Data Dome representation in k-space

Targets

Data collected over a range of different target types (tent, wooden shed, plastic Shed, wooden lodge, brick buildings) to explore the capability of penetration of buildings of a range of material and construction types that cannot be penetrated by other sensors (optical, infrared).

For each building structure, calibration targets were placed inside and outside the building to assess the potential for building penetration.

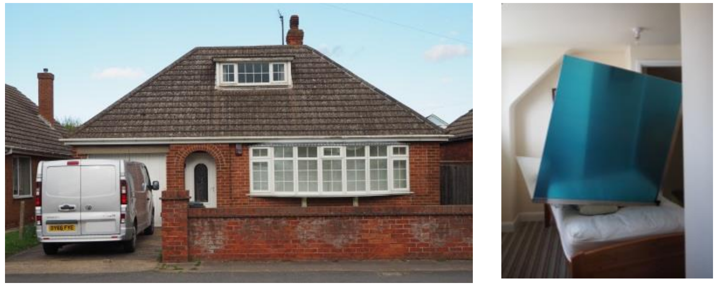
Ground truth was performed in each target to identify internal features.

Some examples of imaged targets:

DD6 Brick Building-Sports Facility (left) with internal targets (Right)

DD7 Wooden Scandinavian Lodges (left) with internal targets (Right)

DD1, DD2 Tent, Wooden Shed, Plastic Shed and calibration targets (internal and external)



DD17 Two storey Brick Building-Residential (left) with internal targets (Right)

Sensor

The Bright Sapphire II sensor is capable of operating at low frequencies with a large bandwidth (200-1300 MHz), which can offer a slant range resolution of 12cm, uncommon at such low frequencies.

The sensor took the key elements of the original Bright Sapphire replacing the Front End Electronics, implementing a more compact antenna and doing the necessary modifications and upgrades to the Back End.

The system is capable of also transmitting low-band (UHF, VHF, P, L-band), S-band and X-band simultaneously with additional aircraft installation.

Bright Sapphire II instrument top-level architecture

Parameter	Value
Centre frequency	750MHz
Bandwidth	1.1GHz
Polarisation	Quad polarisation
HPA peak transmit power	80W
Tx Duty Cycle (max)	CW (10W)
Rx Duty Cycle (max)	20%
System Noise Figure	2.6dB
System losses	12.1dB
Instrument mass	101.5 kg
Power consumption (max)	800W
Tx Notching ability	Yes

Bright Sapphire II instrument key parameters

Aircraft integration

The sensor is current deployed on a B200 Super King Air (G-IMEA):

- The sinuous antenna is mounted within the radome.
- The instrument is installed into a compact E-rack that fits onto seat rails in the cabin.
- It is the largest pod installed on an aircraft of its category.

Trials aircraft showing large underbelly radome

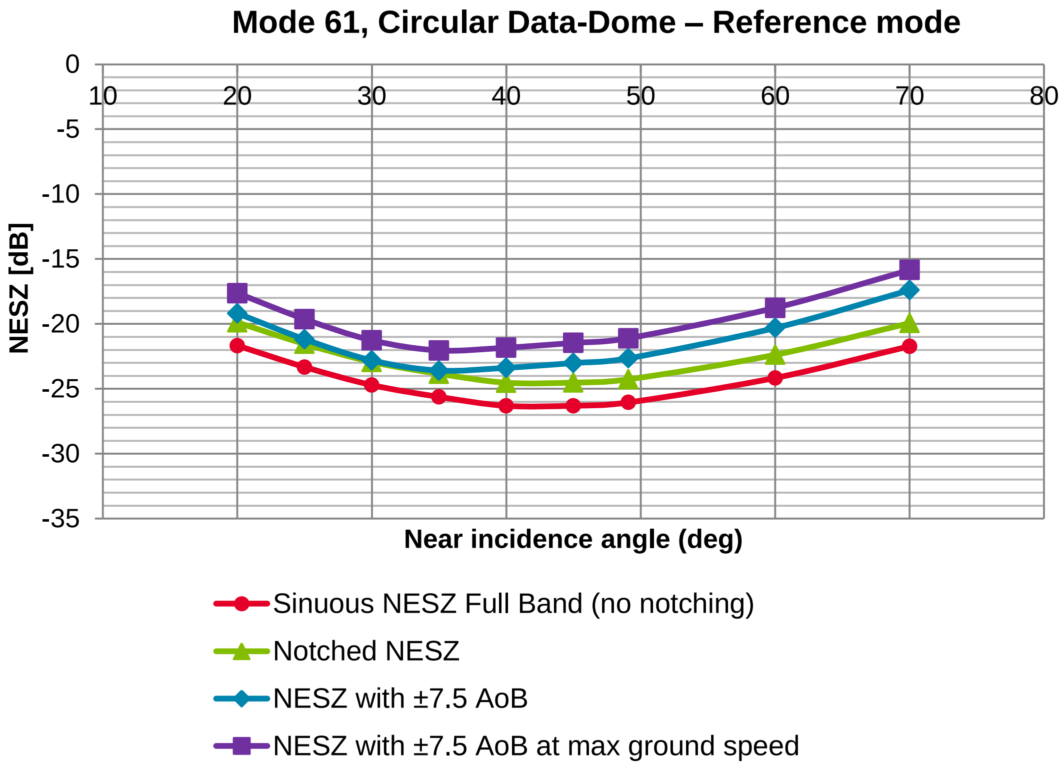
Instrument mounted in E-rack in aircraft cabin

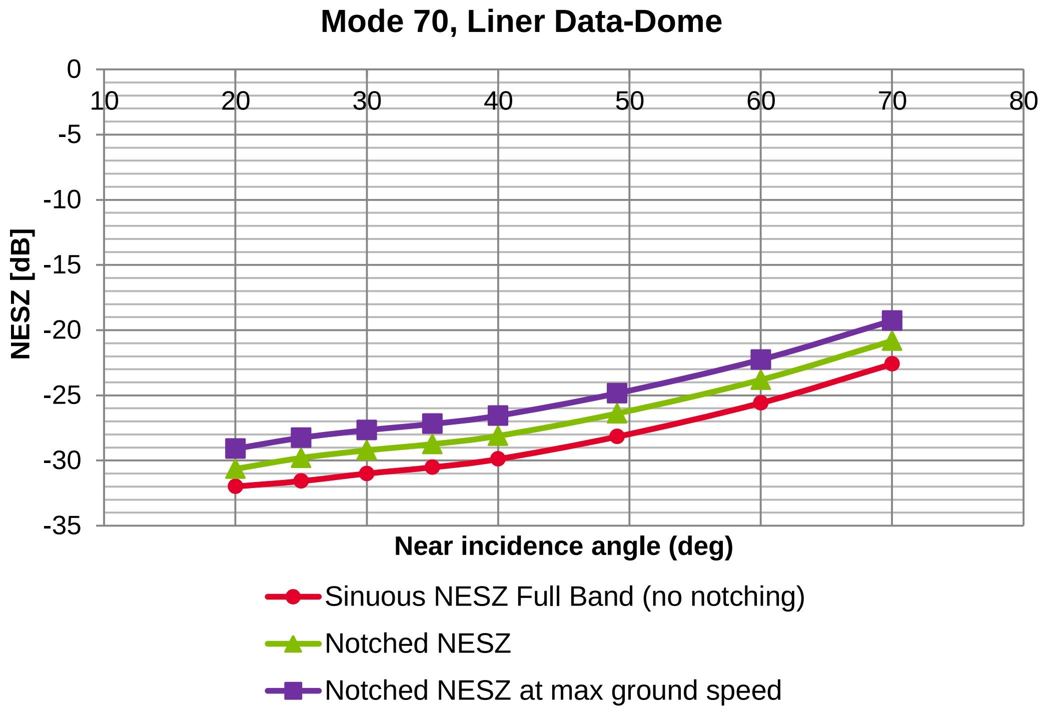
Predicted performance

The main limitations to NESZ performance are:

- Maximum antenna size that can be fitted in the aircraft, and therefore, limited gain.
- Need to notch part of the Tx spectrum due to OfCom regulations in the UK.
- Flight accuracy and weather conditions that will cause variations in the pointing angle and ground speed (circular runs).
- In circular runs, minimum distance to the target is limited by the aircraft turning rate and angle of bank.

Linear acquisitions have been used for some collections to have enhanced NESZ performance (and hence, SNR)

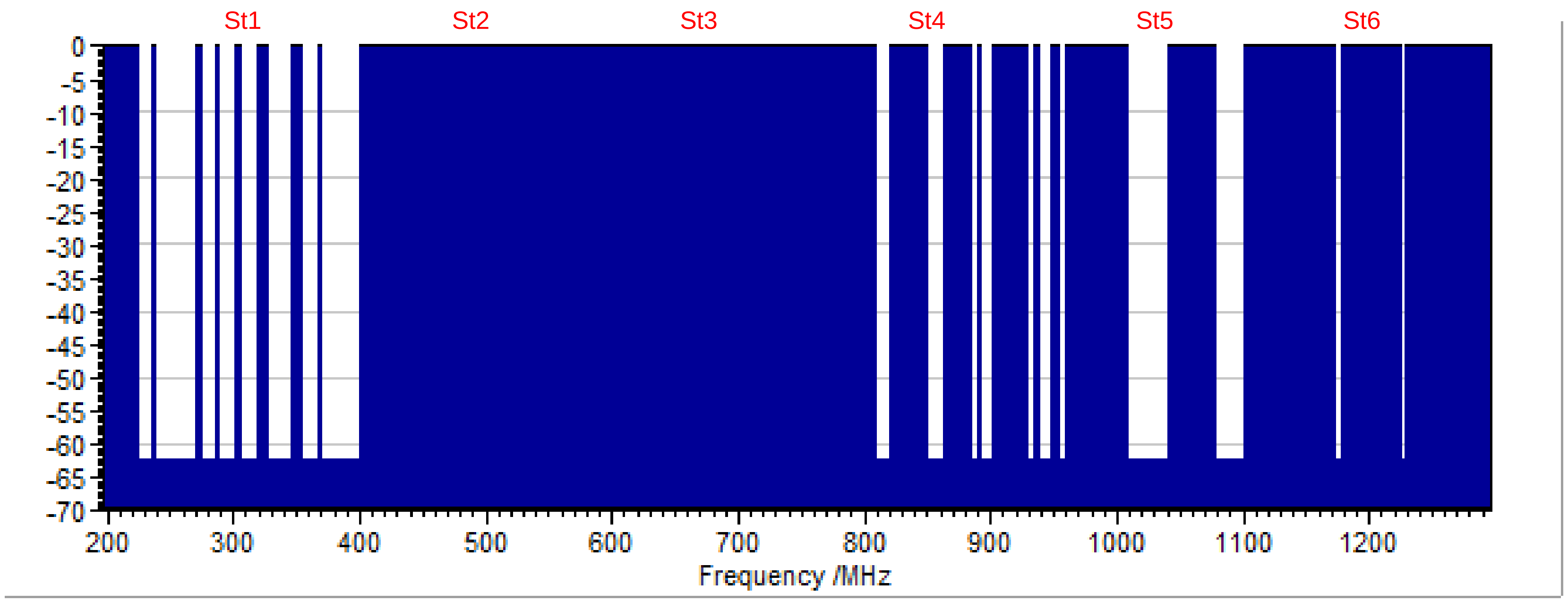




Key challenges

The key challenges encountered with the development and operation of such a sensor are:

- *Antenna performance and accommodation*
  - The sinuous antenna used has a low gain and a very wide beamwidth illuminating reverse ambiguous regions
  - Higher gain antennas, such as the log periodic, could not be accommodated on a small aircraft.
- *Ofcom Licence*
  - Required for radio transmission in the UK, requiring notches in the transmit signal.



Key challenges

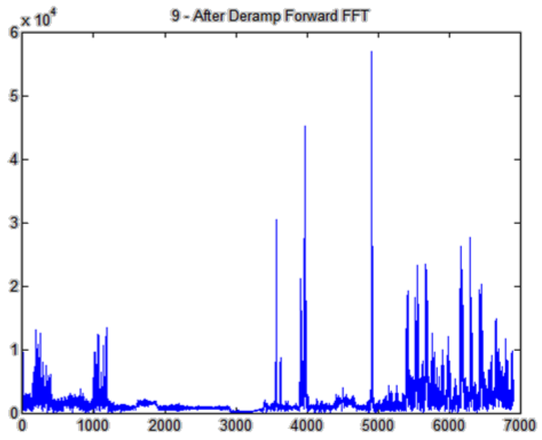
The key challenges encountered with the development and operation of such a sensor are:

- *Interferers*

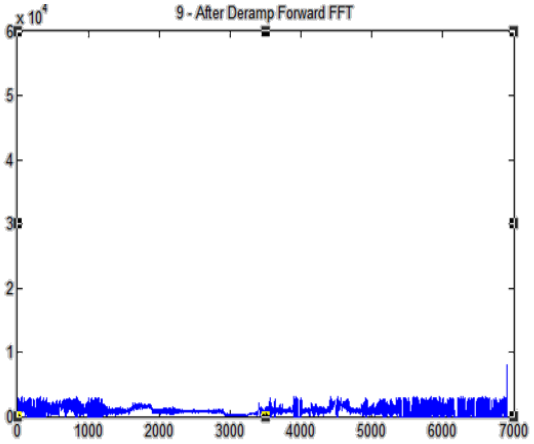
  The frequency band of operation contains a lot of strong in-band interferers.

  A simple method of nulling bins in the data containing interferers has been used for the preliminary results presented.

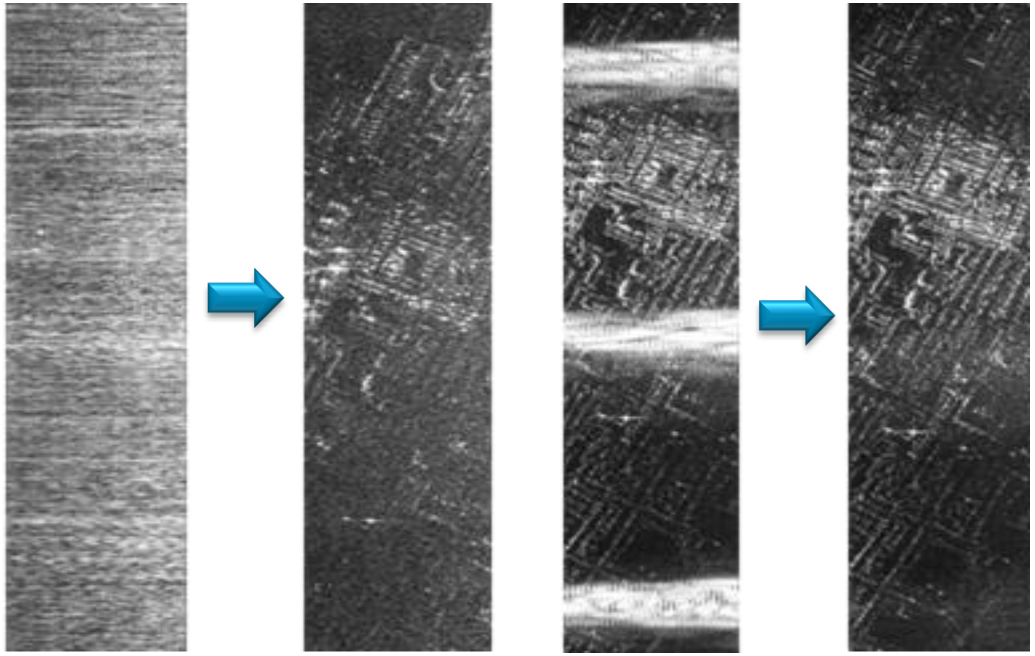
  However, due to the number and range of strengths of interferer, a robust method is required.



Interferer spectrum



Spectrum after simple interferer removal



Interferer removal example for stitches 5 (left) and 6 (right)

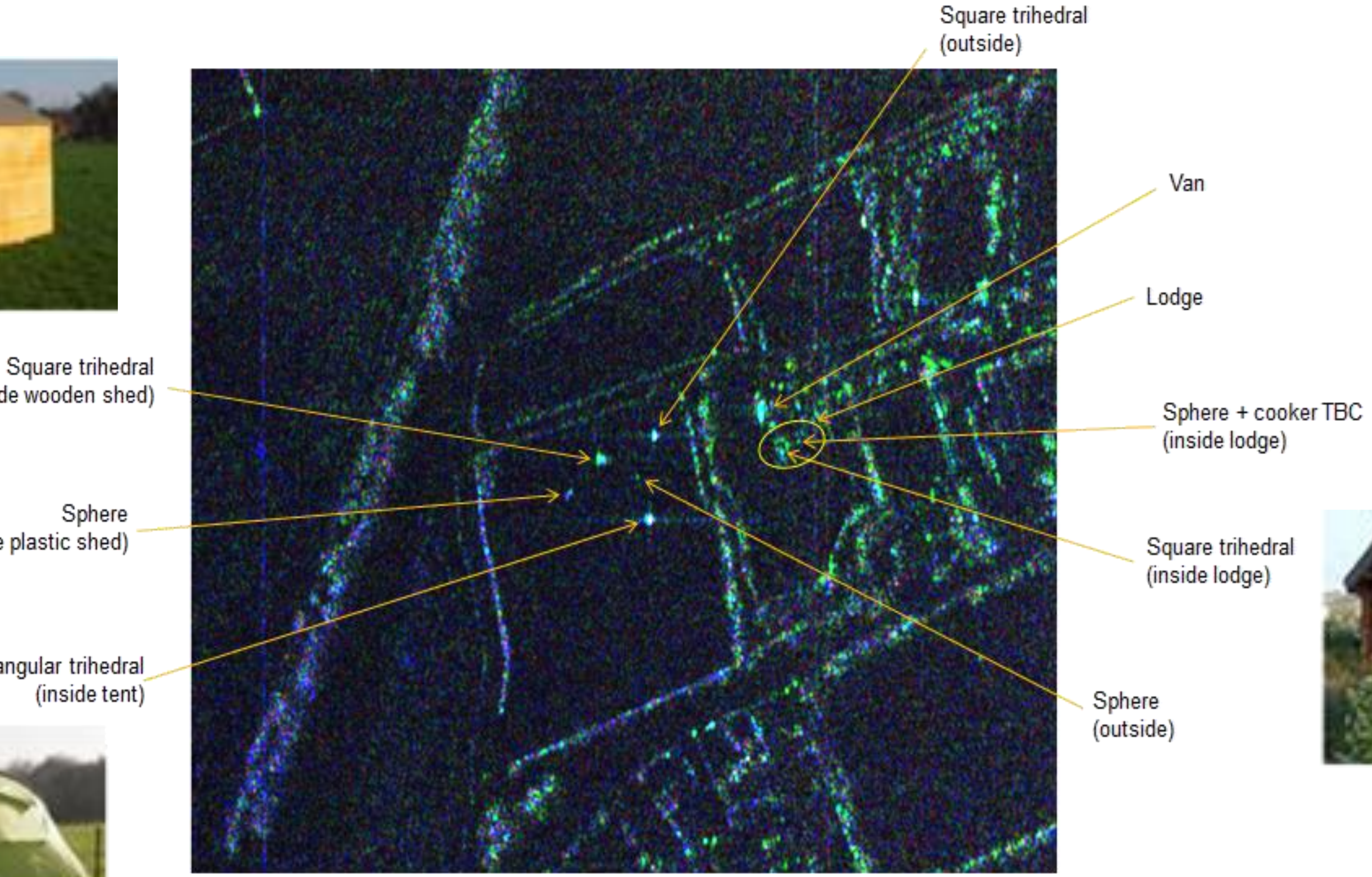
LFSAR Data Dome Results

Capability of remote sensing building interiors

1m resolution – not finest possible!

Preliminary results: Potential for building penetration

An initial assessment of the data after the first week on collection DD1/DD2/DD7 shows the potential for building penetration. The corner reflectors inside the tent, wooden shed, plastic shed and wooden lodge are all detected with the instrument.



Quad pol image: Red = cross-pol, green = VV, blue = HH
(even weighting)

DD1_b quad polar image, showing the building structures inside which each calibration target was placed

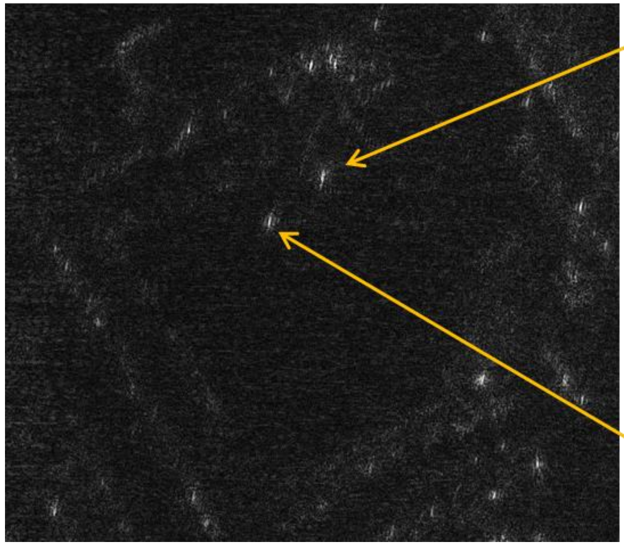
AIRBUS

1m resolution – not finest possible!

Preliminary results: Potential for building penetration

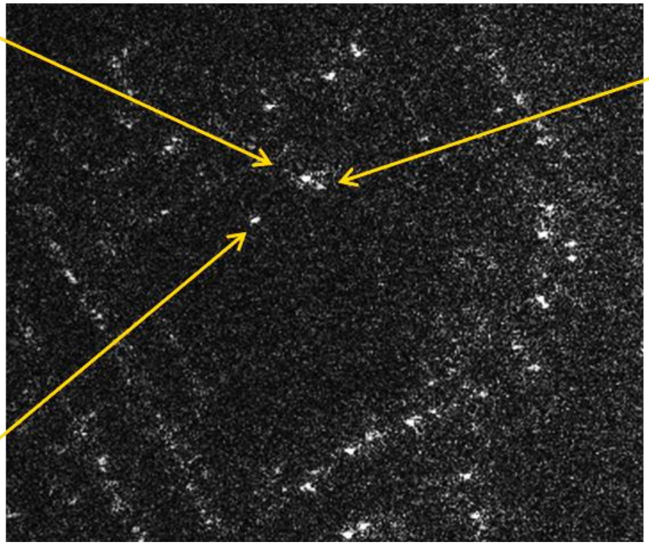
An initial assessment of DD6 (brick Mablethorpe Athletics Club), comparing the upper half of the spectrum and the lower half, appears to show the internal trihedral when using the lower frequencies.

Stitch 4,5,6 imagery



Corner of building (acts like trihedral) TBC

Trihedral (outside)



Trihedral (inside) TBC

Stitch 1,2,3 imagery

Optical image of building

Trihedral inside building

AIRBUS

Conclusions

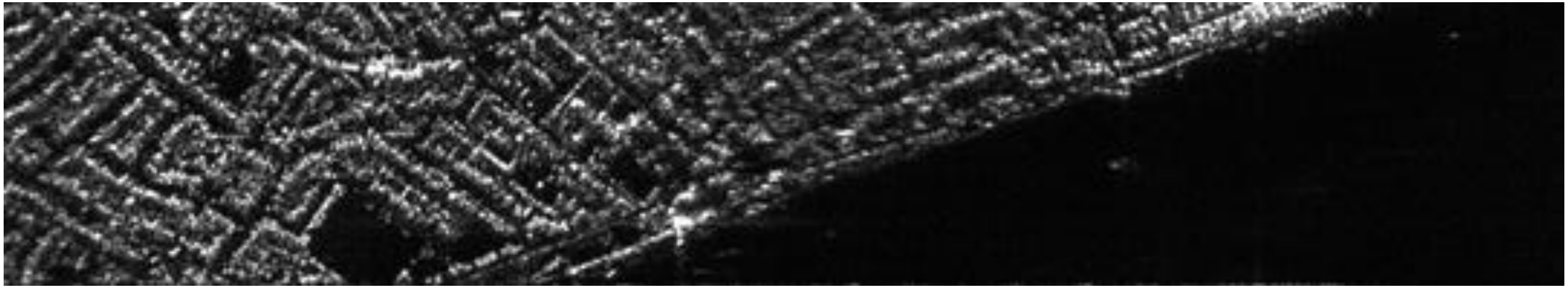
The airborne trials undertaken with the Bright Sapphire II sensor have proven the **instrument capability to see through optically opaque objects and detect targets inside buildings of different construction types.**

Further enhanced processing including a robust method for interferer removal will allow full exploitation of the data:

- Better resolution: 12-17 cm slant range resolution (after notching).
- 3D tomographic and volumetric exploitation of the building.

To observe ‘weaker’ objects within buildings then a larger instrument development would be required to improve SNR and reduce the impact of interferers on the data.

Data can be made available to those that would like to process and analyse it.



Imagery from DD17 processing only stitch 1 VV (200-383 MHz) at 2m resolution.


Thank you