From Ground to Space: Analyses and Demonstrations of Multistatic SAR

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German Aerospace Center (DLR), Microwaves and Radar Institute

Multistatic Radar Workshop 2025
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Funded by the European Union

ERC-Funded Project “Distributed Radar Interferometry and Tomography Using Clusters of Smallsats” (DRITUCS)

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clusters of smallsats

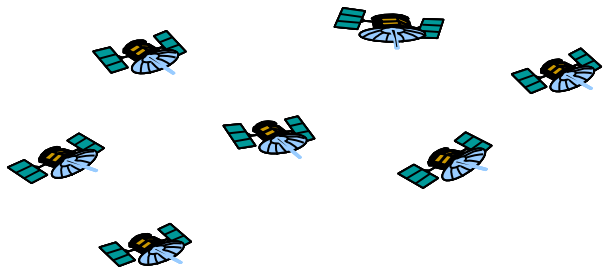
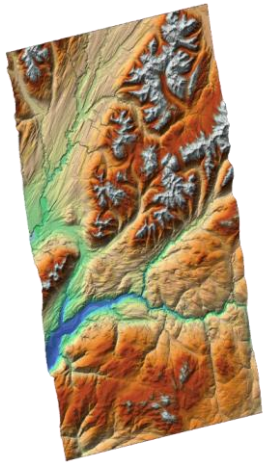


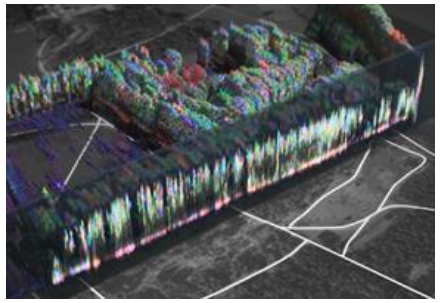
image 1 | image 2 | ... | image N

processing

digital elevation models



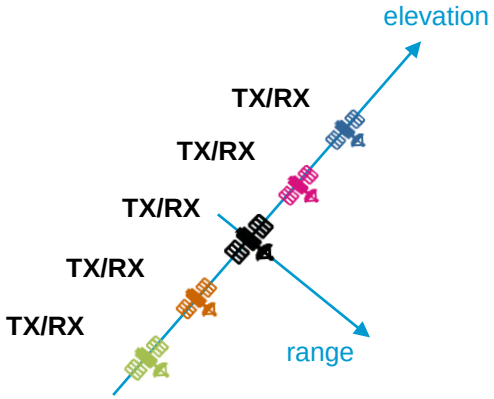
tomograms

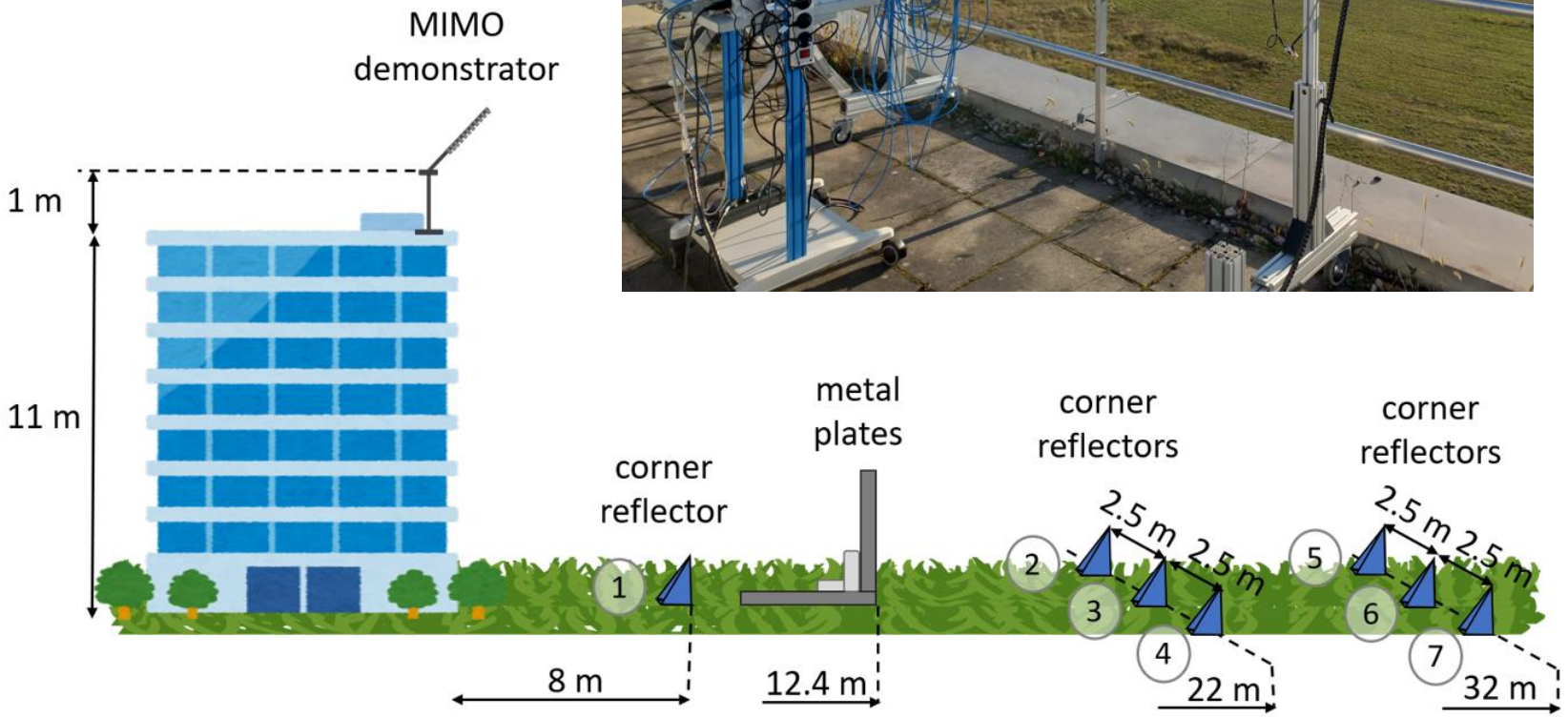


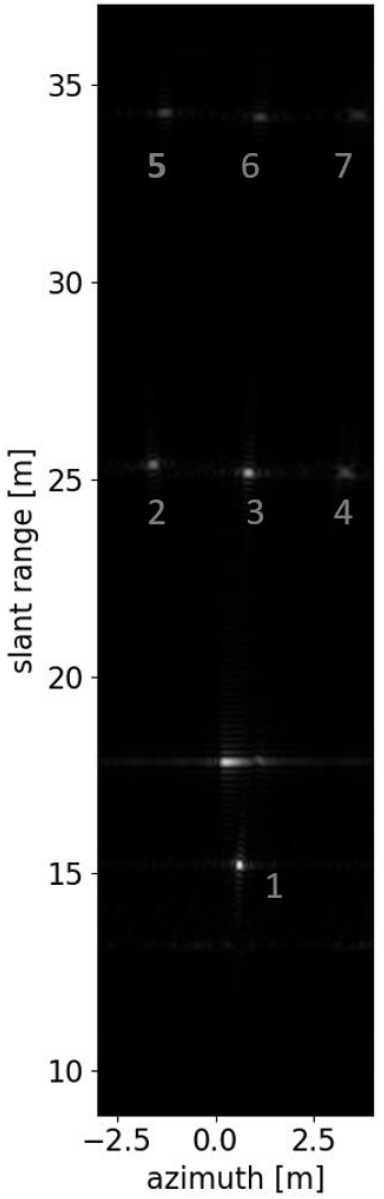
Talk on distributed INSAR by Maxwell Nogueira Peixoto today at 16:50

multiple-input multiple-output (MIMO) SAR tomography

Ground-based Demonstration of MIMO-SAR Tomography

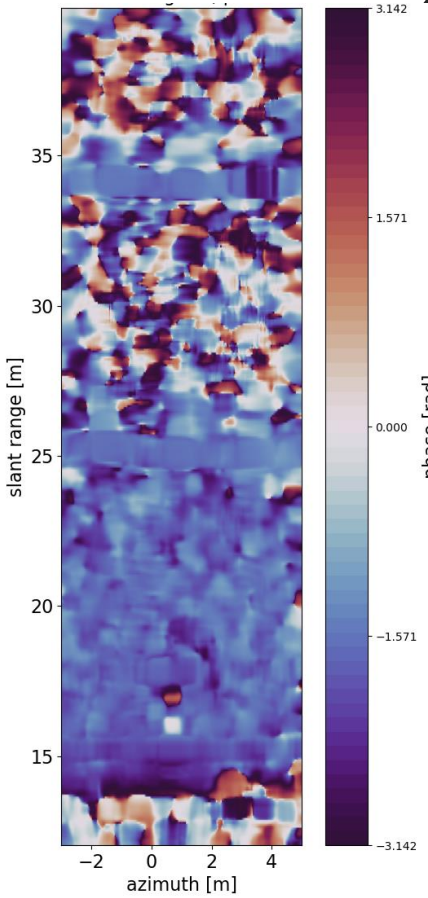


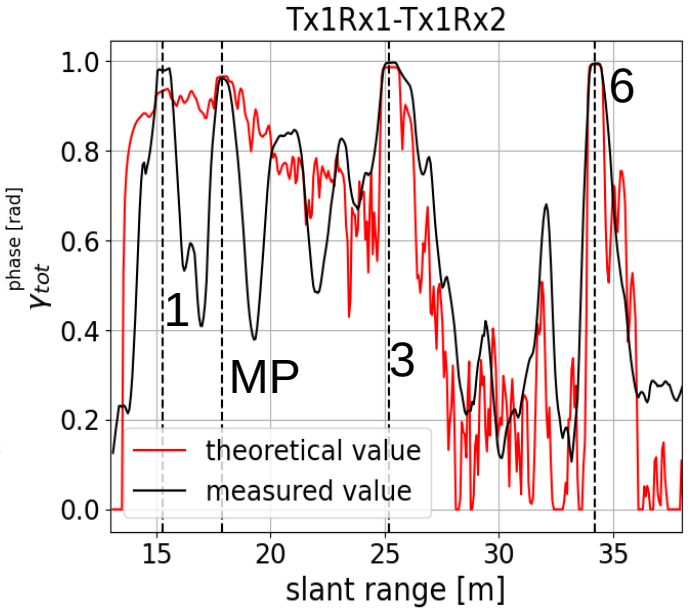




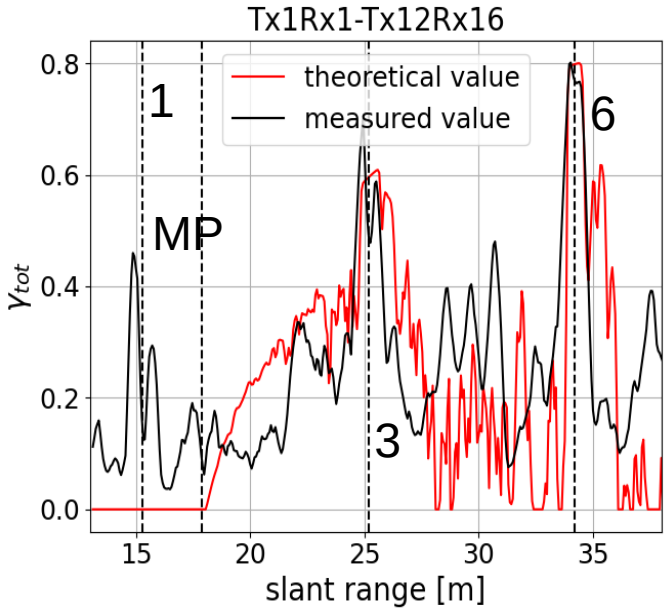
Interferometric Results

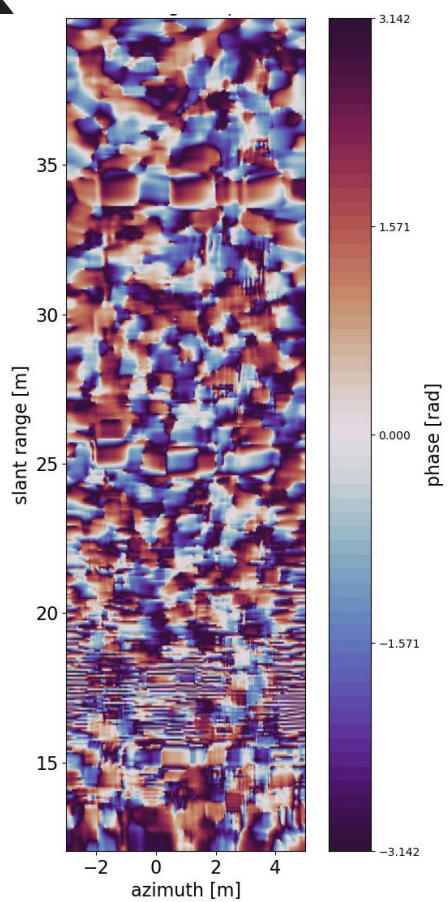
Tx1Rx1 – Tx1Rx2





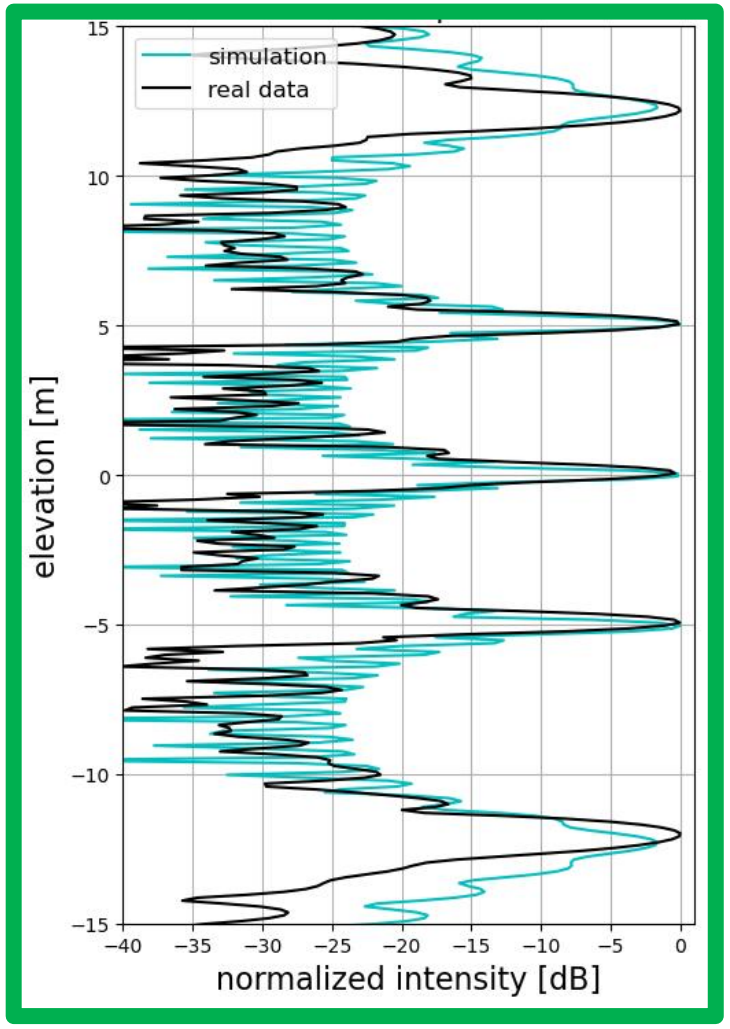
Tx1Rx1 – Tx12Rx16

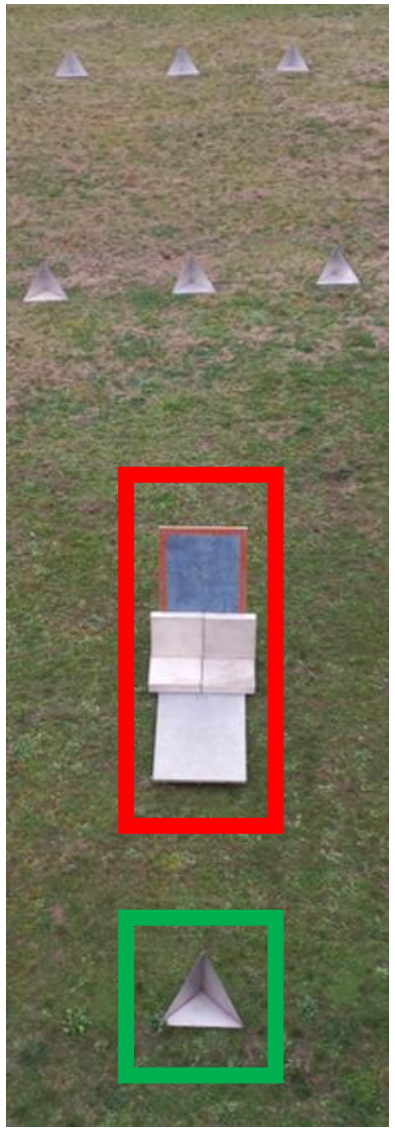




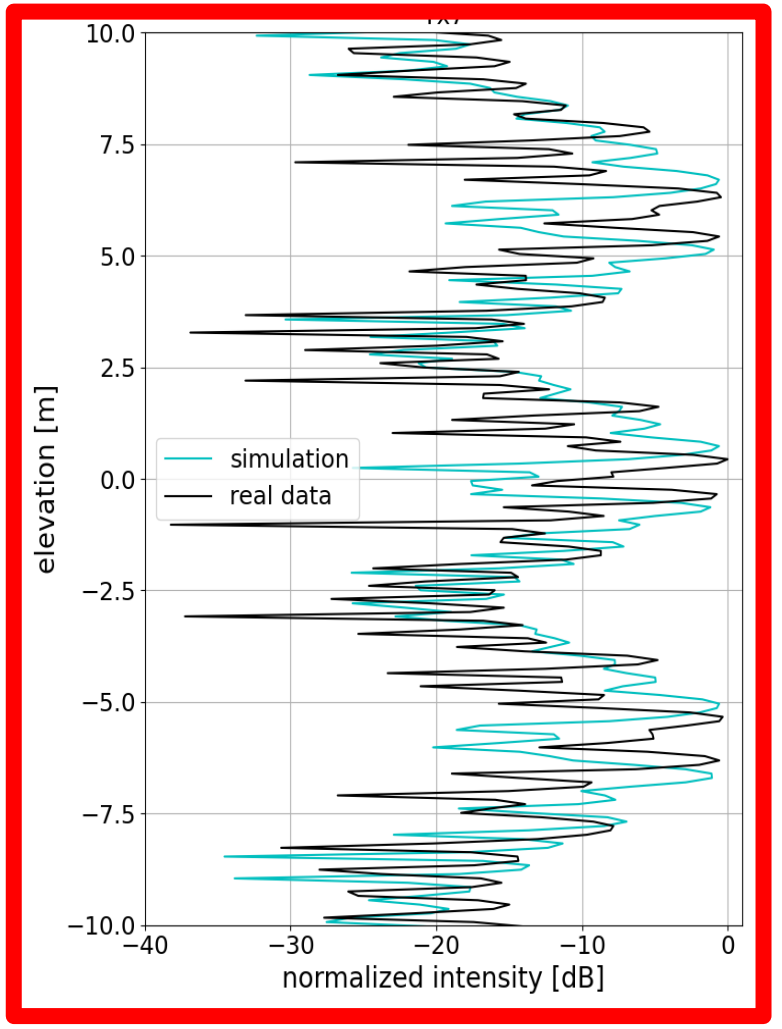
Multistatic Tomography

corner reflector

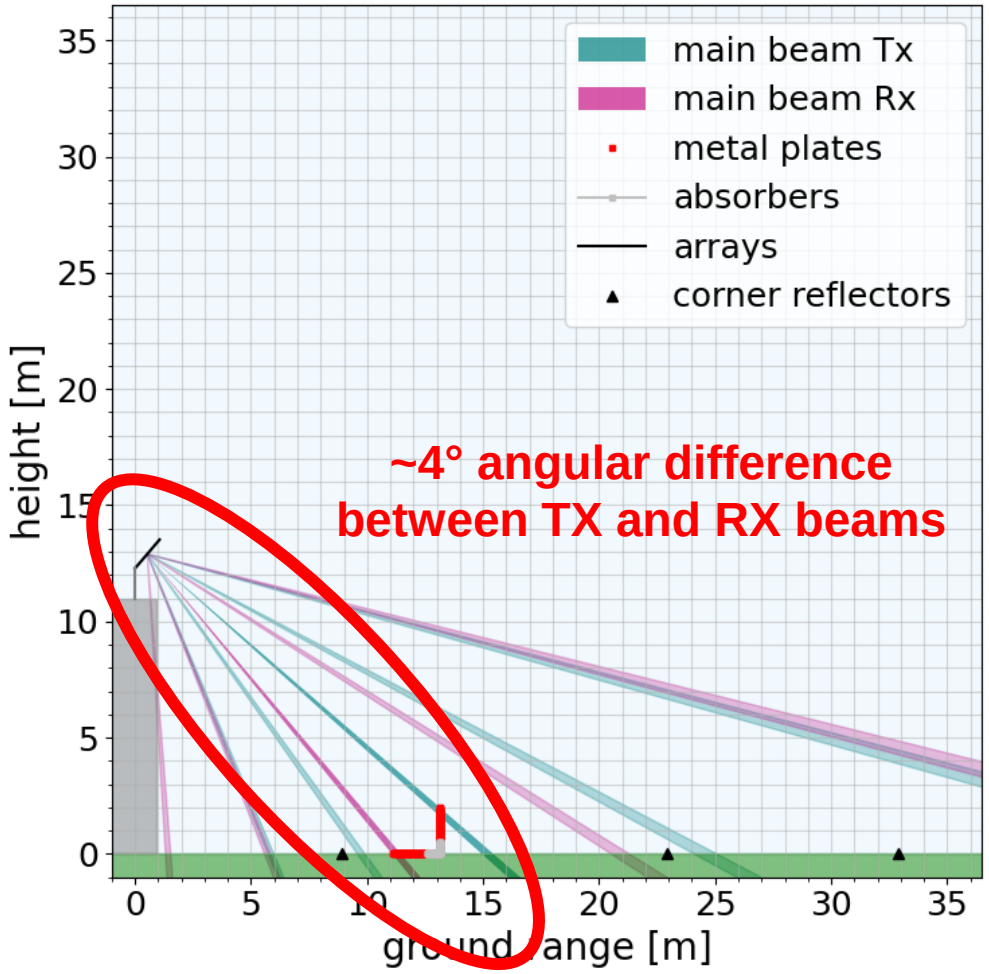


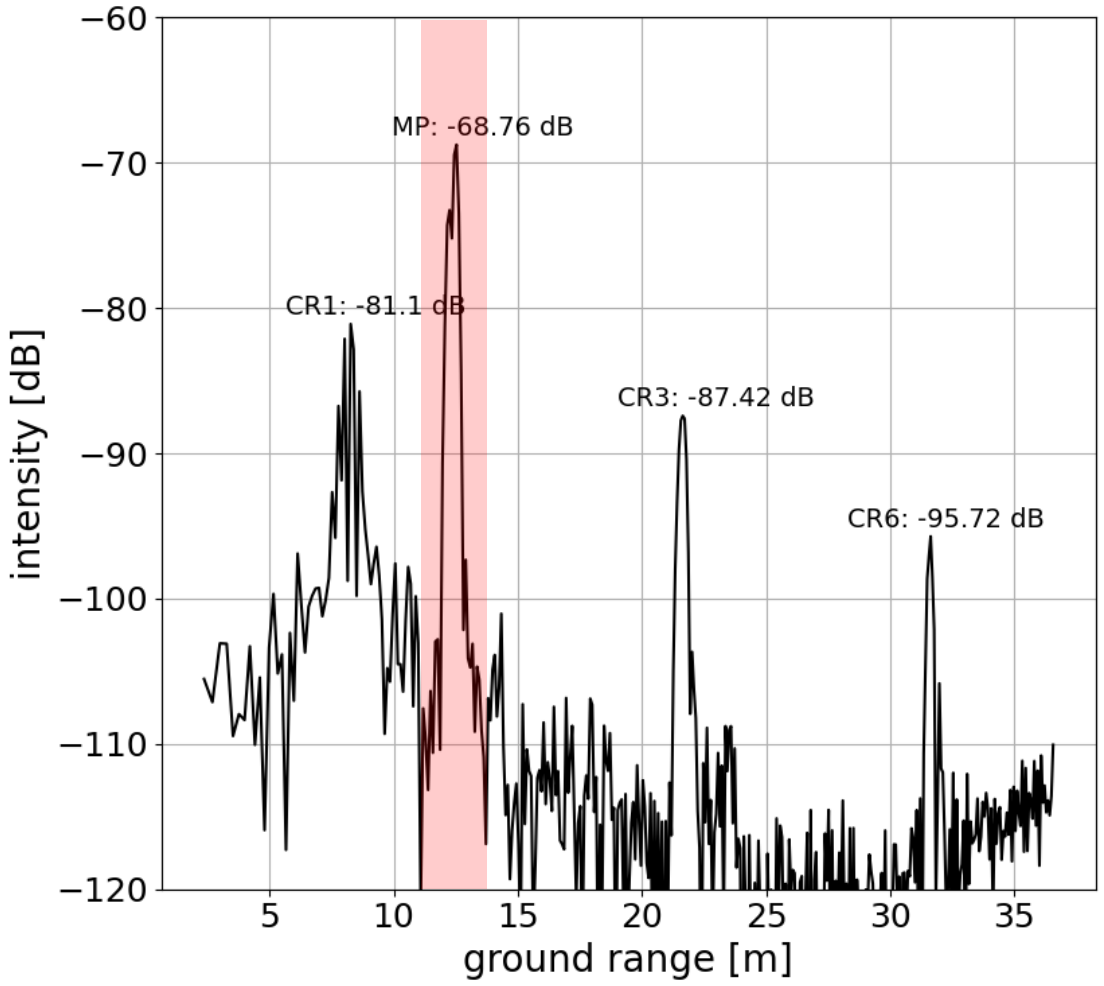


metal plates



"*A Posteriori*" Beamforming in Both TX and RX





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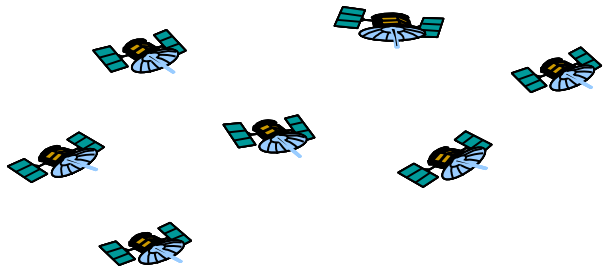
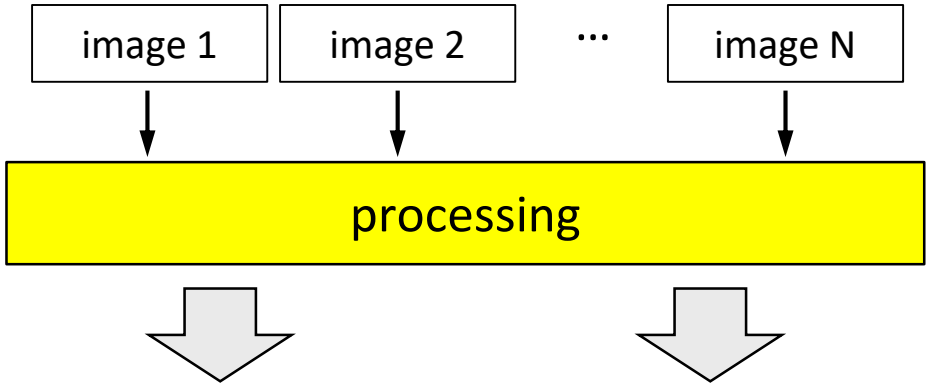
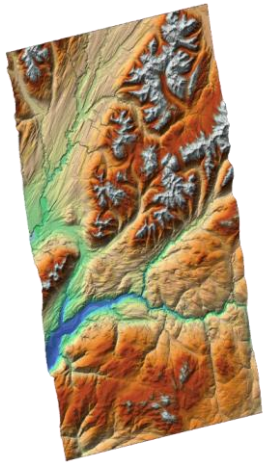


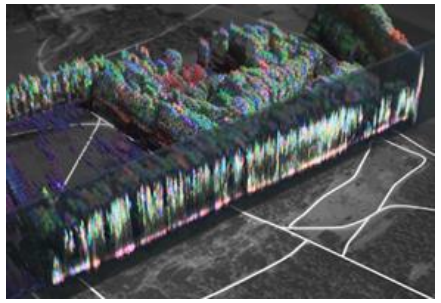
drones



digital elevation models



tomograms

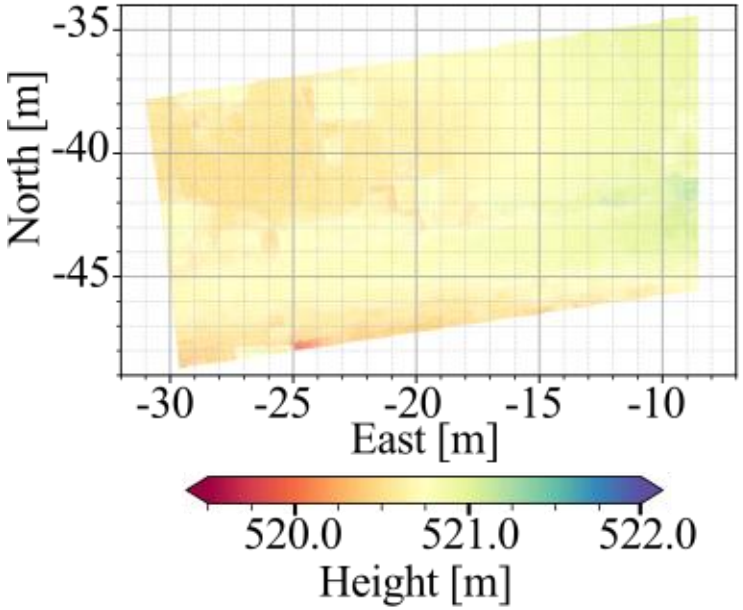


multiple-input multiple-output (MIMO) SAR tomography

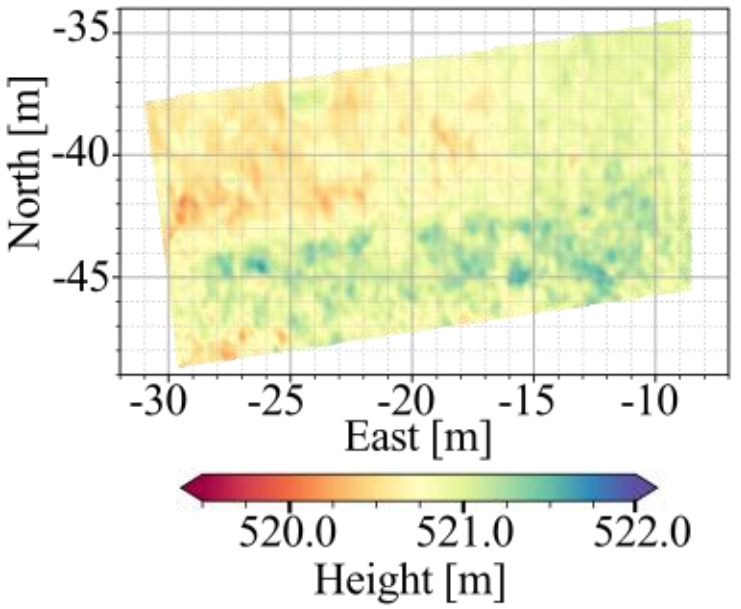
Wideband Drone-Based InSAR for DEM Generation

- Multi-baseline, repeat-pass acquisitions
  - 1-4 GHz and 6-9 GHz bands
  - Height of ambiguity ~ 50 – 100 cm
- Phase unwrapping using radargrammetry

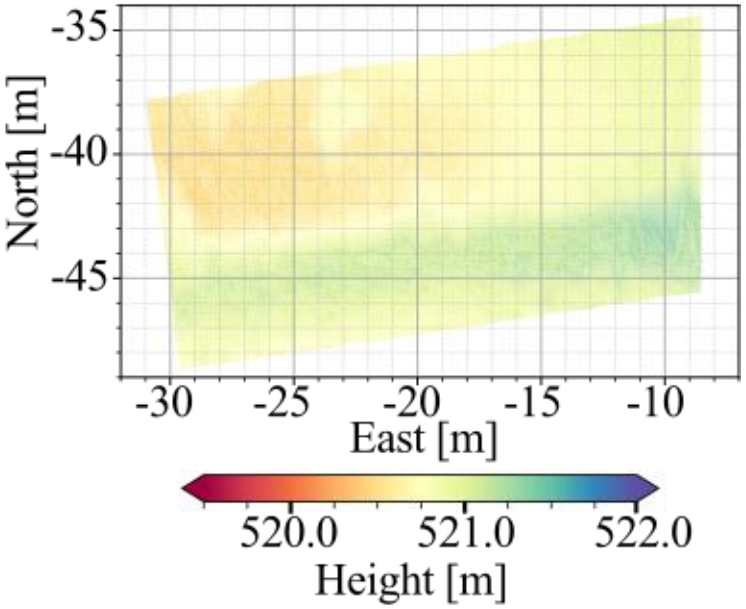
InSAR DEM (with unwrapping errors)



DEM from radargrammetry

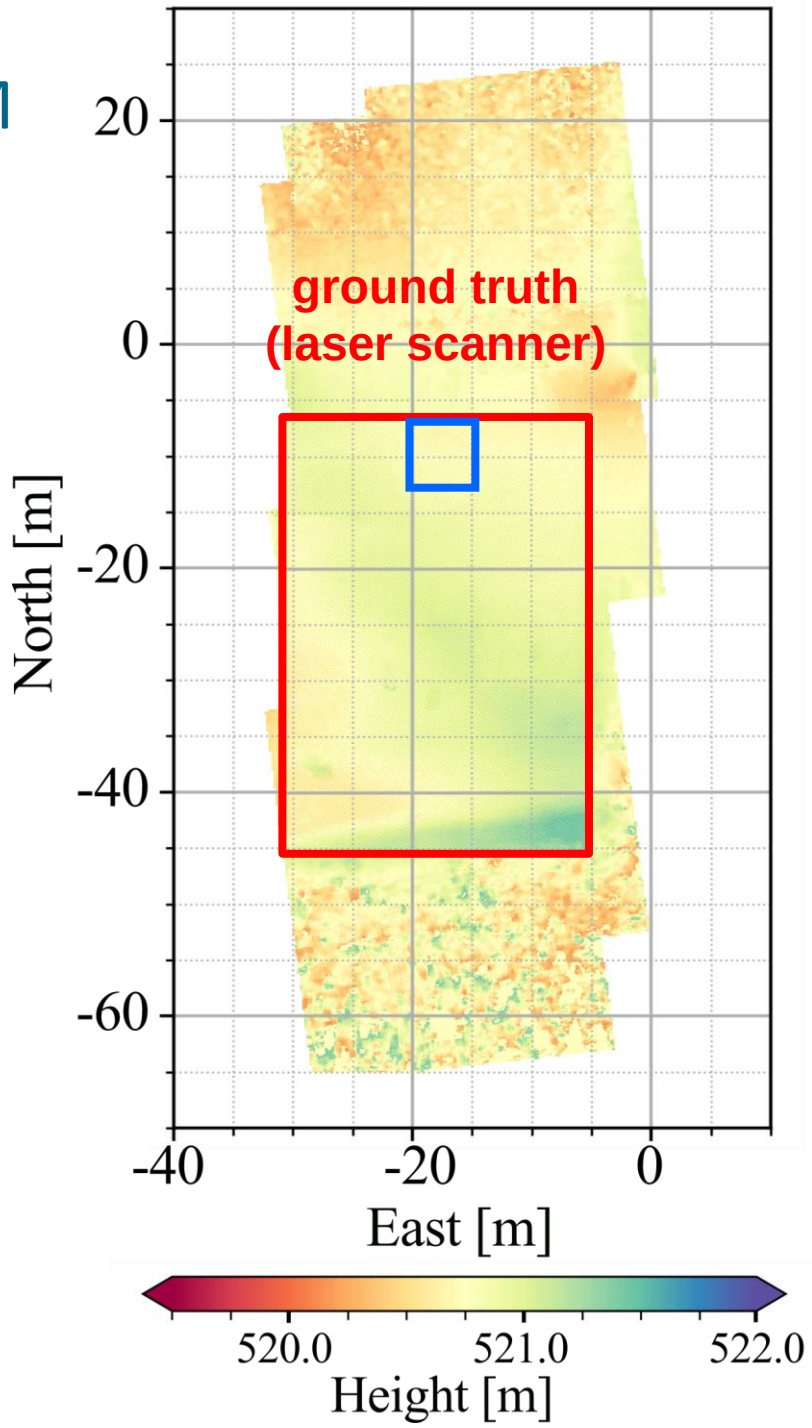


Corrected InSAR DEM

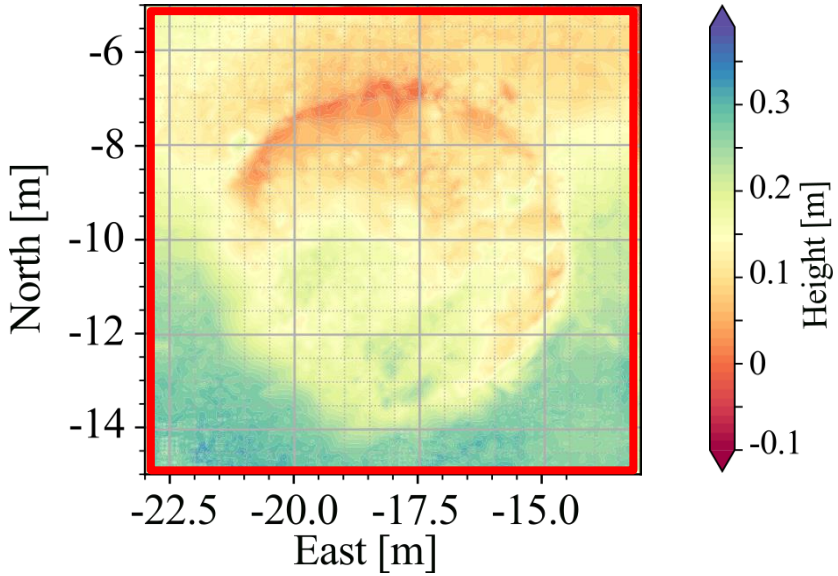


Mosaicked InSAR DEM

- Very high quality
  - Accuracy: 13 cm
  - Posting: 25 cm
- Further experiments planned in the coming months

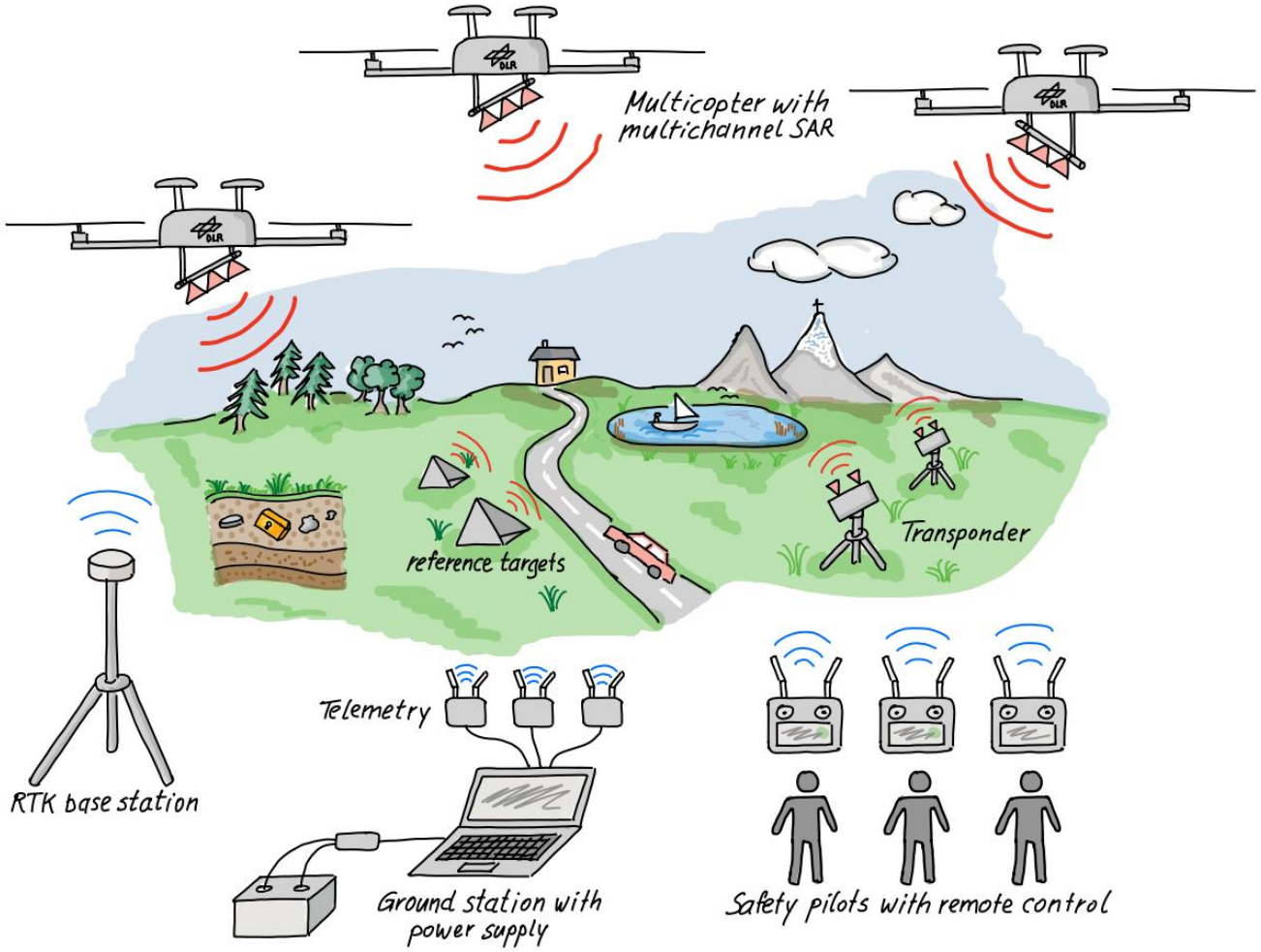


ground truth
(laser scanner)

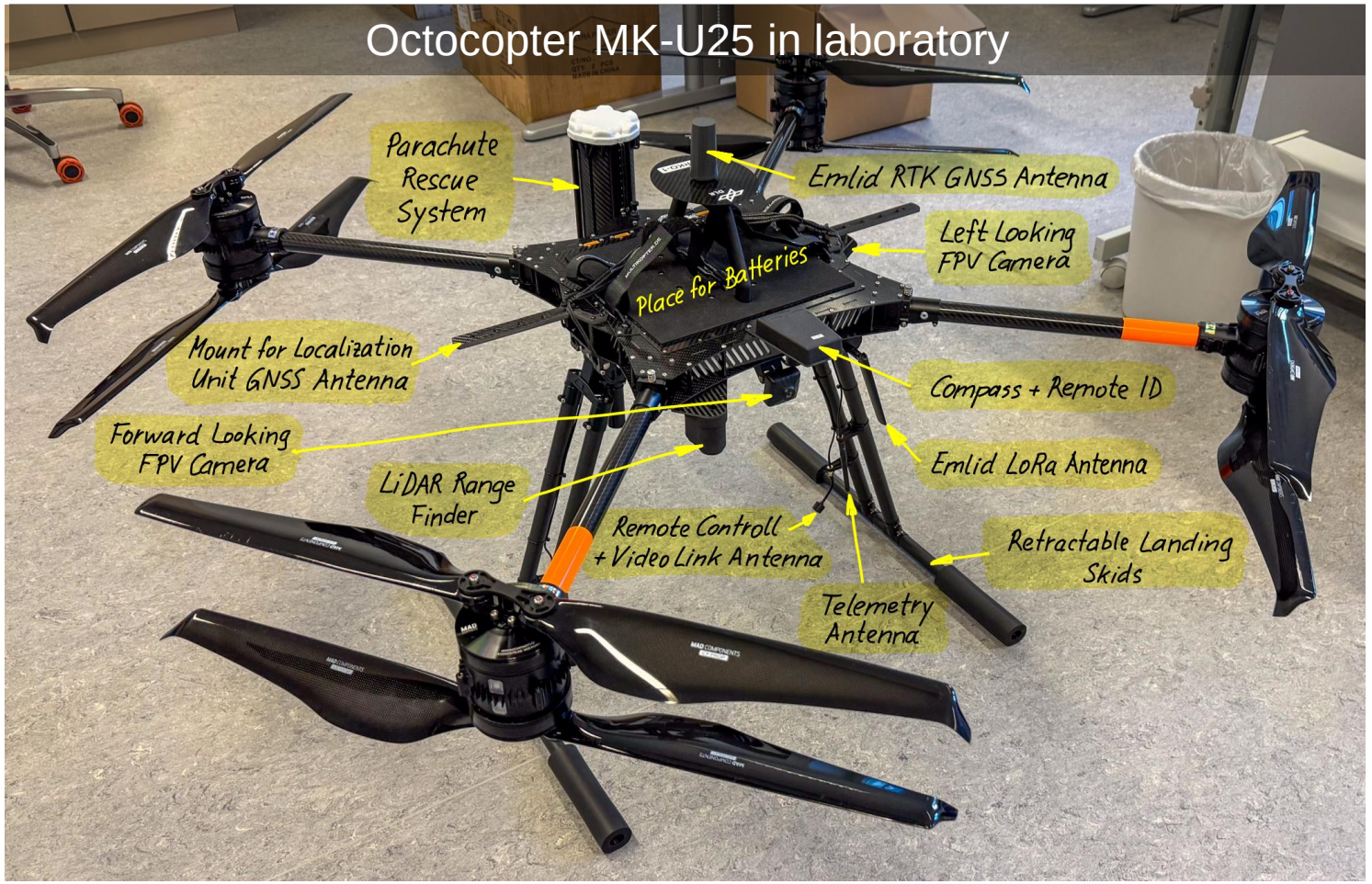


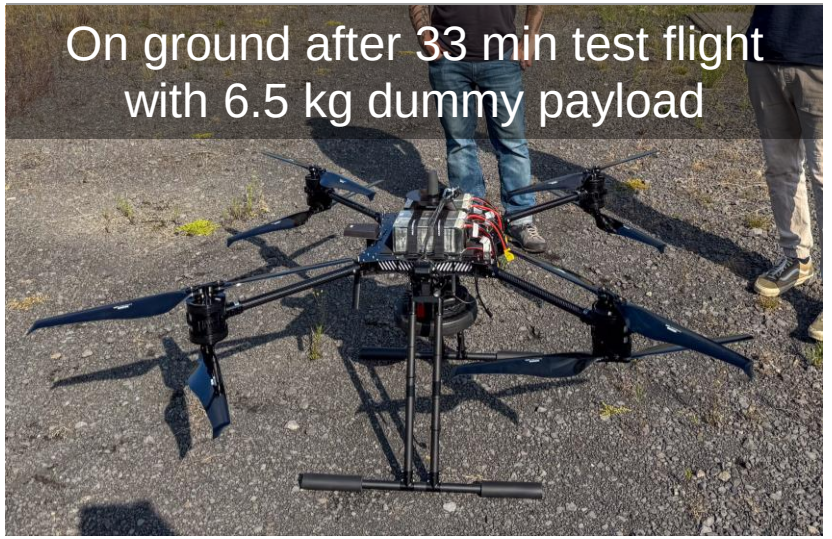
Distributed Drone-Based SAR Infrastructure at DLR

- Main components of system
  - multicopters
  - multichannel radars
  - onboard localization units with radar synchronization capability
  - ground station with telemetry
- This concept will also be exploited for the development of a distributed drone-based demonstrator within the ESA-funded project DEDALO (DLR, UniNa, UPB, UUlm)



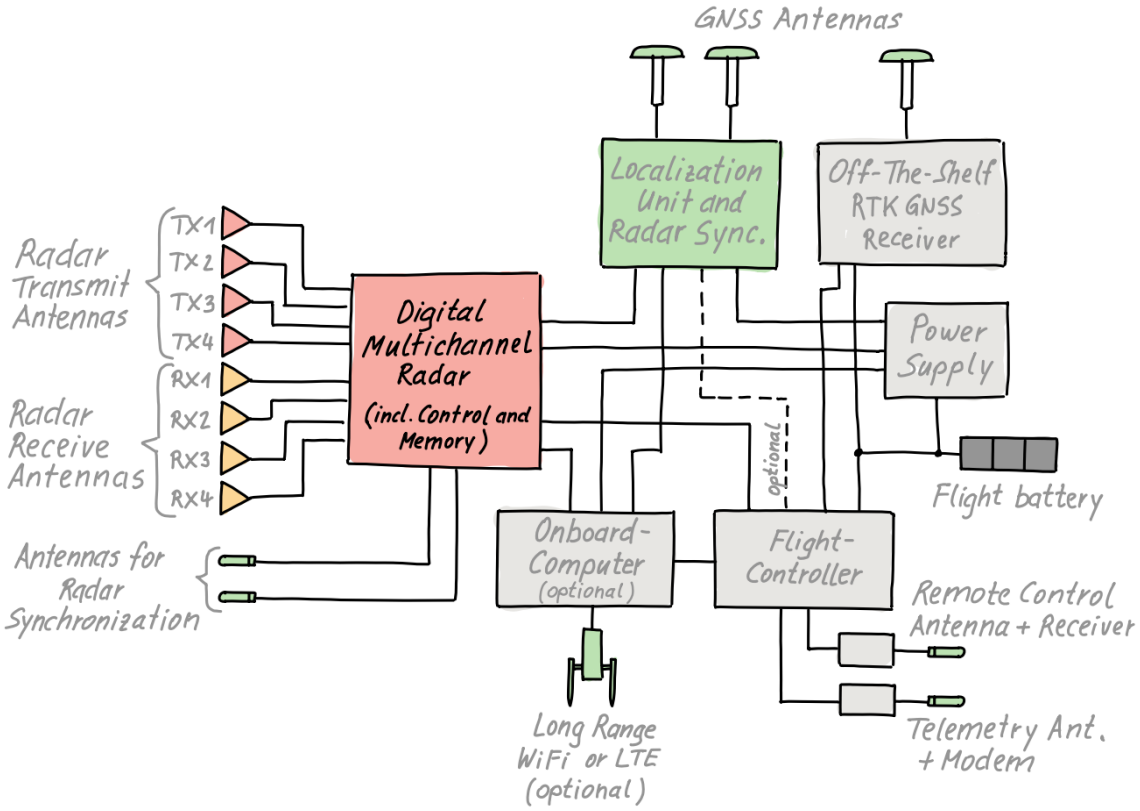
Multicopters MK-U25





Radar Sensor Specifications

- Fully digital and coherent radar
- Requirements
  - Frequency range 500 MHz – 3,5 GHz
  - Instant. bandwidth ≤ 2.5 GHz
  - FMCW and SFCW operation
  - TX power ≥ 30 dBm, weight ≤ 6 kg
  - Swath width ≥ 120 m @ 120 m height
  - Scene size per flight ≥ 1 km²
  - 4 independent TX and RX channels
  - Controllable via mission planning software
  - Synchronization capability



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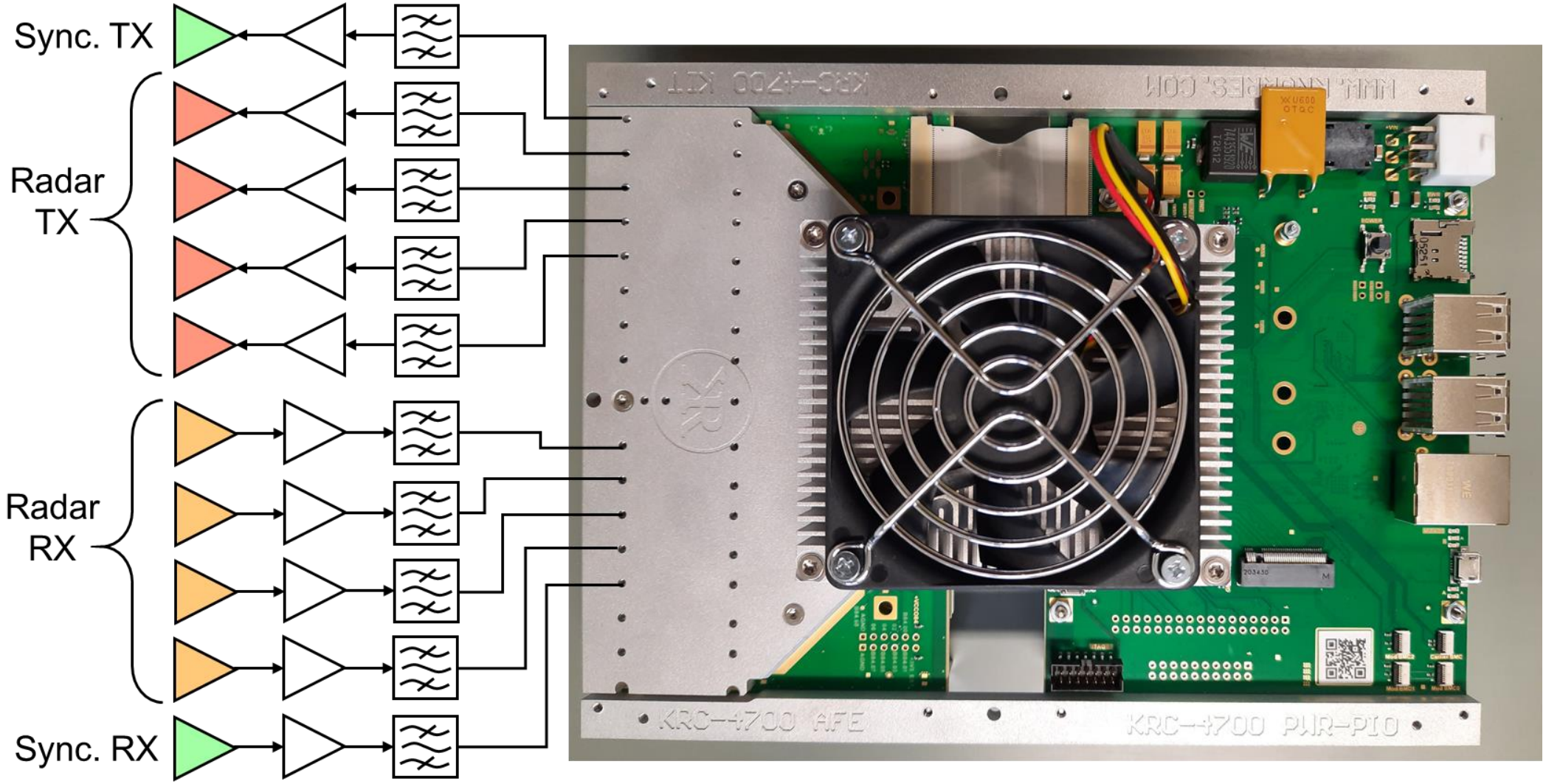
(Xilinx Zynq Ultrascale+) RFSoC FPGA



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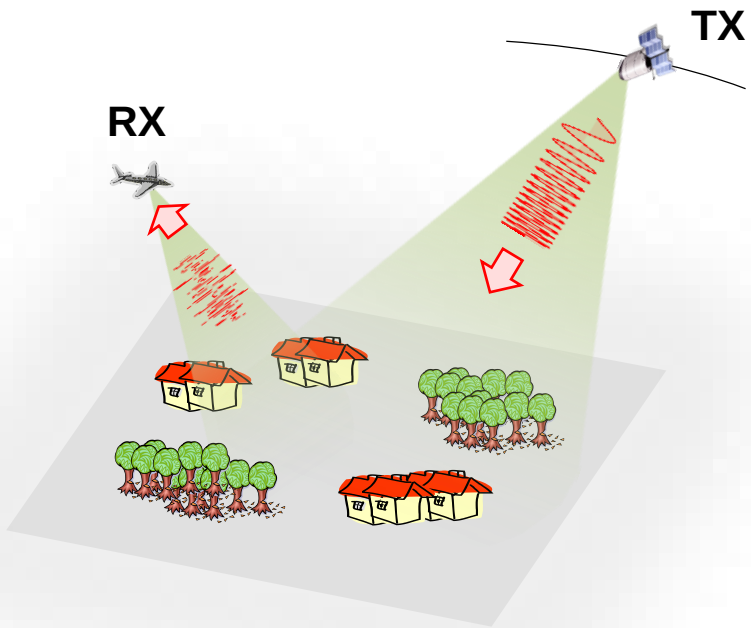
Multistatic Spaceborne-Airborne SAR

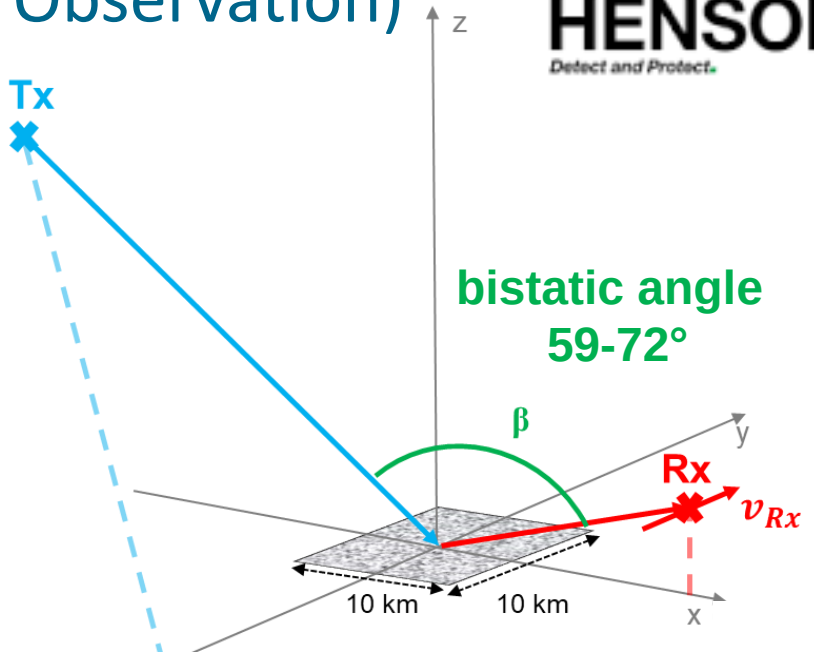
- Dedicated spaceborne trasmitter
  - GEO
  - LEO (constellation)
  - Molniya (highly elliptical)
- Airborne receiver(s)
  - ~10 km altitude
  - Side-looking or forward-looking
  - Digital beamforming

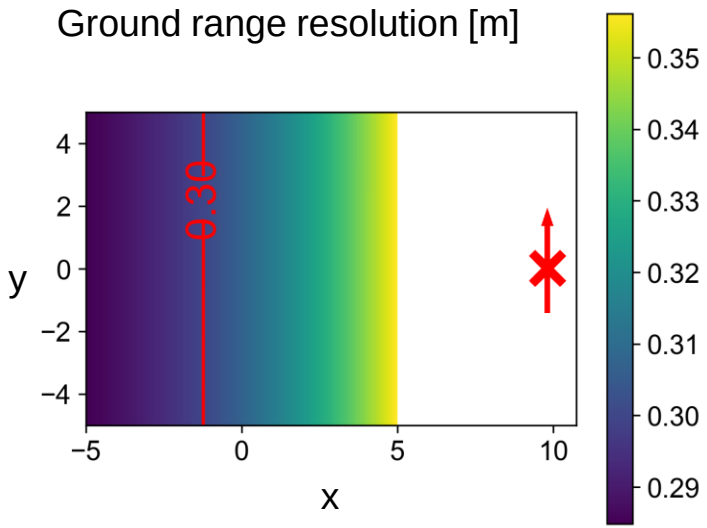


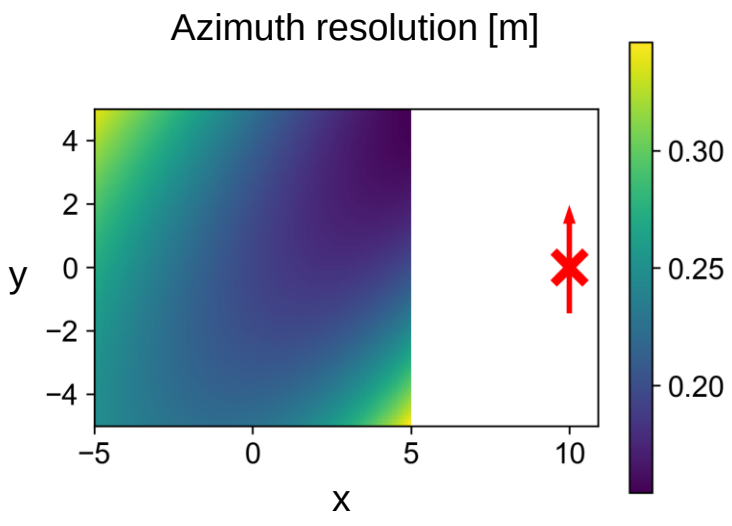
Example with TX in GEO (Continuous Observation)

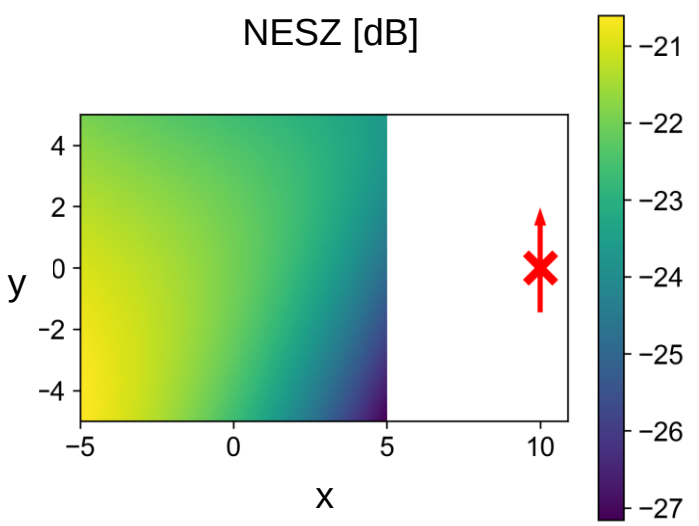
- Scene size: 10 km × 10 km
- Bistatic angle: 59°-72°
- Average TX power: 600 W
- Bandwidth: 700 MHz at X-band
- Antenna size TX/RX: 81 m^2/0.36 m^2

- Ground range/az. resolution below 0.4 m
- NESZ better than -20 dB



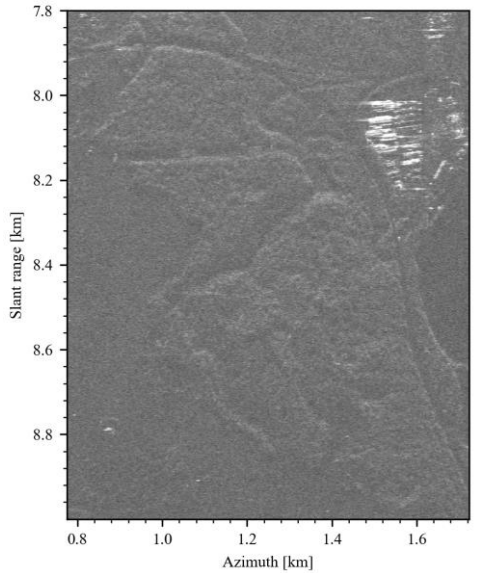




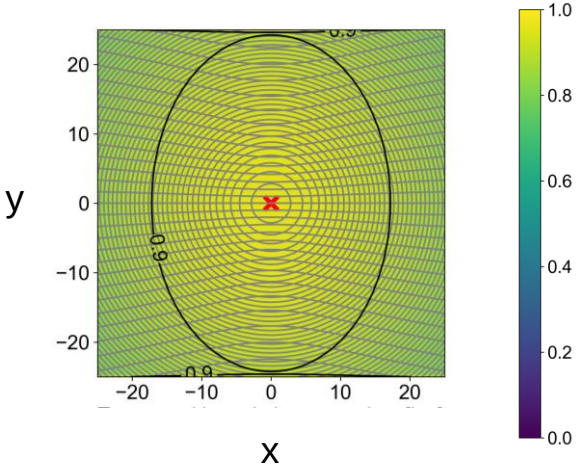


Use of Transmitters of Opportunities

- Broadband LEO megaconstellations
  - E.g., Starlink and OneWeb
  - Power density at the Earth's surface: -68 dBm/m^2
- Performance
  - Very high azimuth resolution (up to 20 cm)
  - NESZ: -5 dB – 0 dB (for a RX range of 20 km)
  - Incoherent integration of multiple images
    - Increased detection probability



Detection probability
(Swerling I, RCS = 10 m^2, Pfa = 10^{-6})



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Thank you for your attention!