Consiglio Nazionale delle Ricerche

Instituto de Astrofísica de Canarias

UNIVERSITÀ DEGLI STUDI DI MILANO

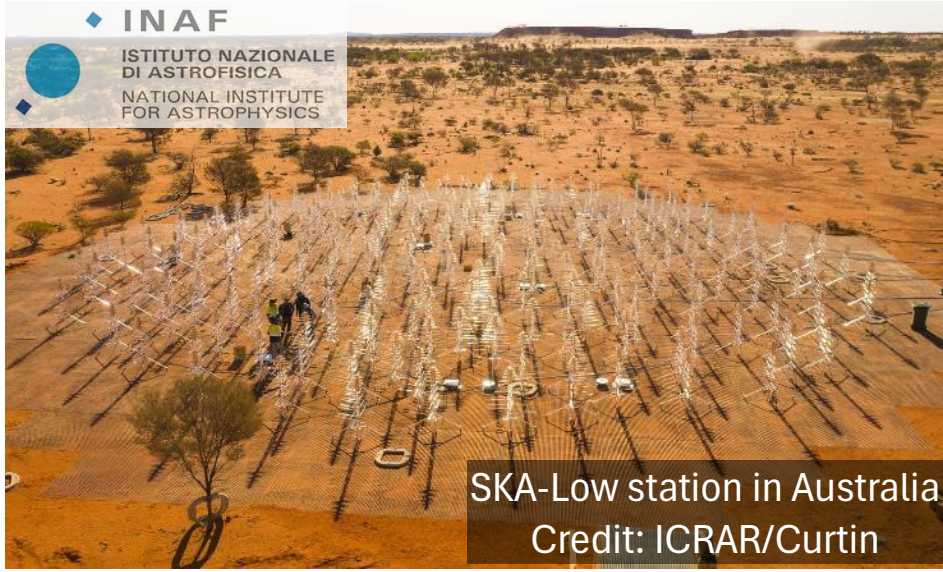
CMB-CAL 2024 @Bicocca

UAV-Based Artificial Source for LSPE-Strip and Overview of First Tests on QUIJOTE

F. Paonessa, G. Virone, G. Addamo, M. Bersanelli, C. Franceschet, R.T. Génova-Santos, R. Hoyland, C.H. López-Caraballo, J.A. Rubiño-Martín

UAV-Based Antenna Testing: CNR-IEIIT's Expertise and Role in LSPE-Strip

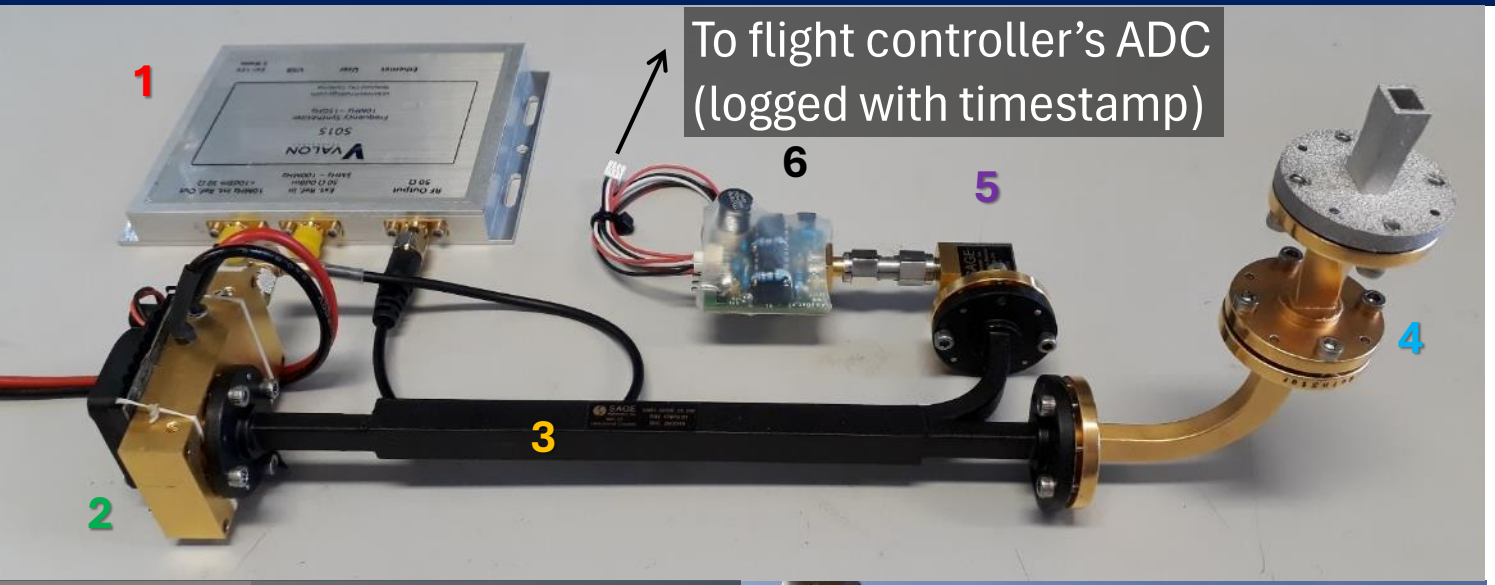
- CNR-IEIIT's expertise: since 2013 in **Low Frequency Aperture Array** characterization (SKA-Low @ 50–350 MHz)
- LSPE-Strip: ground-based cluster of 49 coherent Polarimeters @ Q-band (44 GHz) for CMB measurements on large angular scale
- In-situ beam verification and instrument characterization through CNR's UAV system



SKA-Low station in Australia
Credit: ICRAR/Curtin


The Strip focal plane

RF Payload Design Aspects



F. Paonessa et al., "Design and Verification of a Q-Band Test Source for UAV-Based Radiation Pattern Measurements," in IEEE Trans. Instrum. Meas., Dec. 2020.

Challenges of RF payload design @ Q-band: **motor vibration, temperature transients**

(1) tunable frequency synthesizer (CW @ X-band)

(2) active x4 multiplier full Q-band 33–50 GHz

(3) waveguide coupler

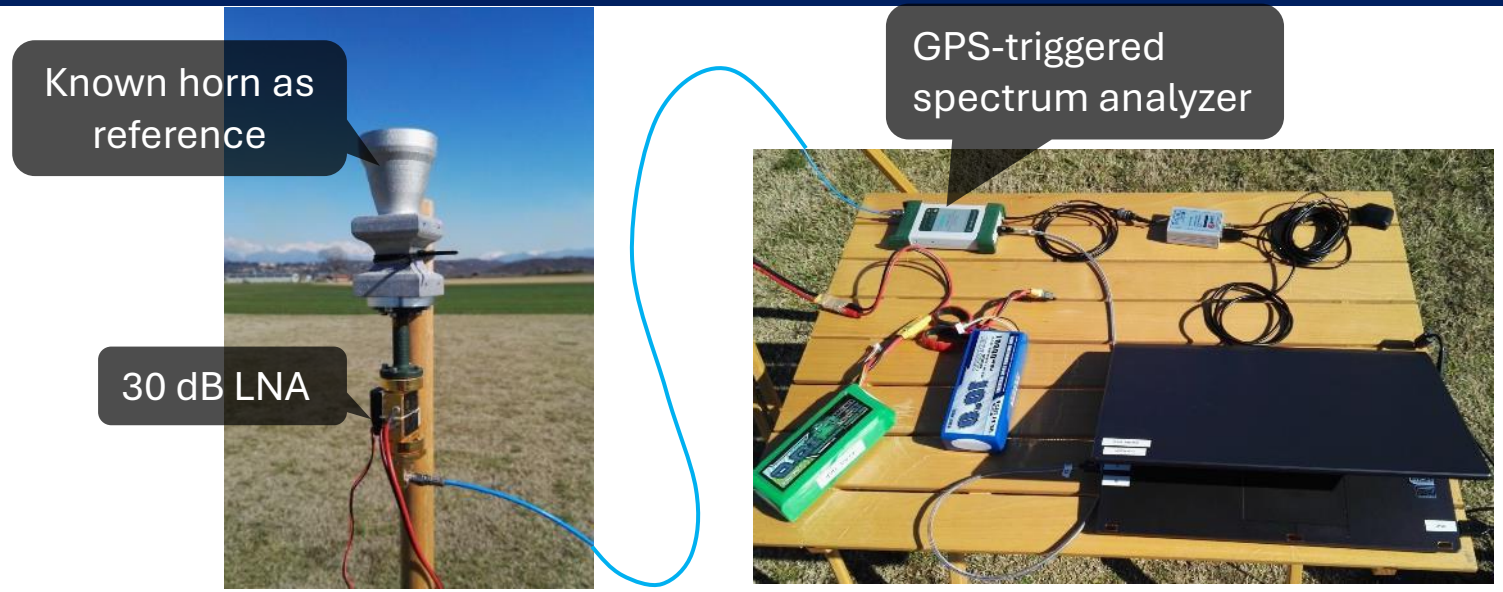
(4) bend, twist, attenuator, horn

(5) amplitude detector

(6) precision V amp→ output to autopilot's ADC

Payload Validation with Known Antenna @ 44 GHz

Validation w/ both indoor tests (power & frequency stability) and outdoor radiation pattern measurements



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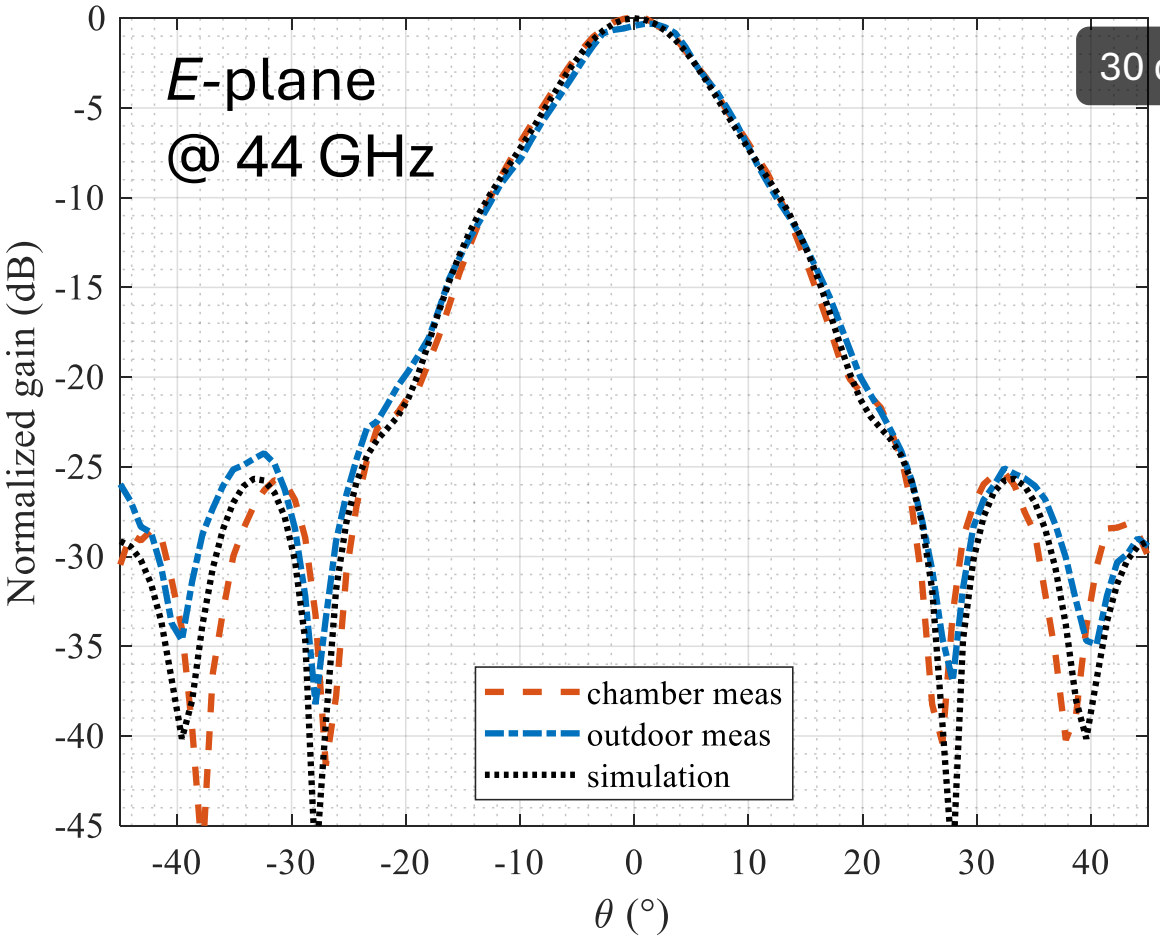

- Comparison both with anechoic chamber measurement and simulation
- Agreement
  - RMS = 0.15 dB (outdoor – simulation)
  - RMS = 0.11 dB (chamber – simulation)
  - RMS = 0.21 dB (outdoor – chamber)

  (weighted log-difference w/ simulation as weight func)

QUIJOTE Campaign: Objectives

- Characterization of the **QUIJOTE beam patterns** at both low frequency (TGI, 33 GHz) & high frequency (FGI, 40 GHz)

- Objectives

  - telescope's performance verification under actual operating conditions

  - insights into UAV system performance for further optimization (future Strip campaign)

QUIJOTE- Q-U-I JOint TEnerife CMB experiment
Credit: Instituto de Astrofísica de Canarias IAC

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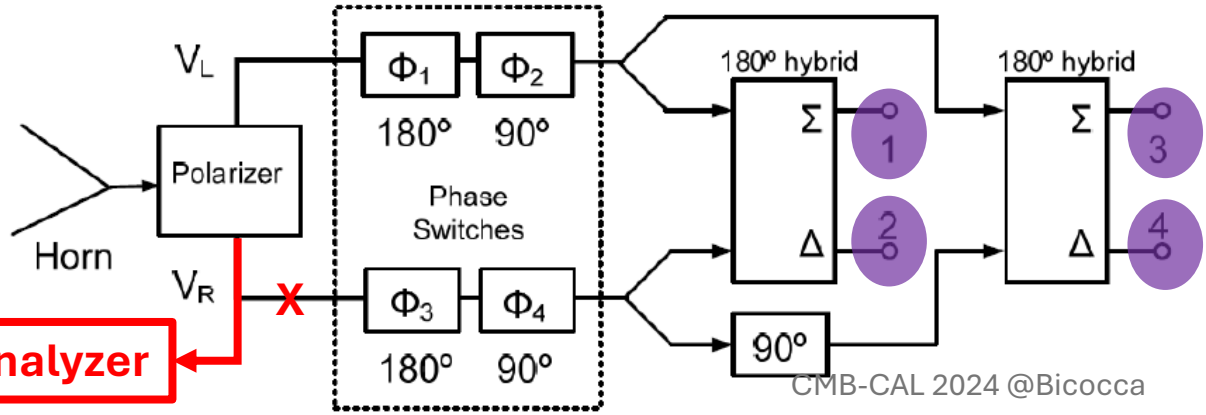
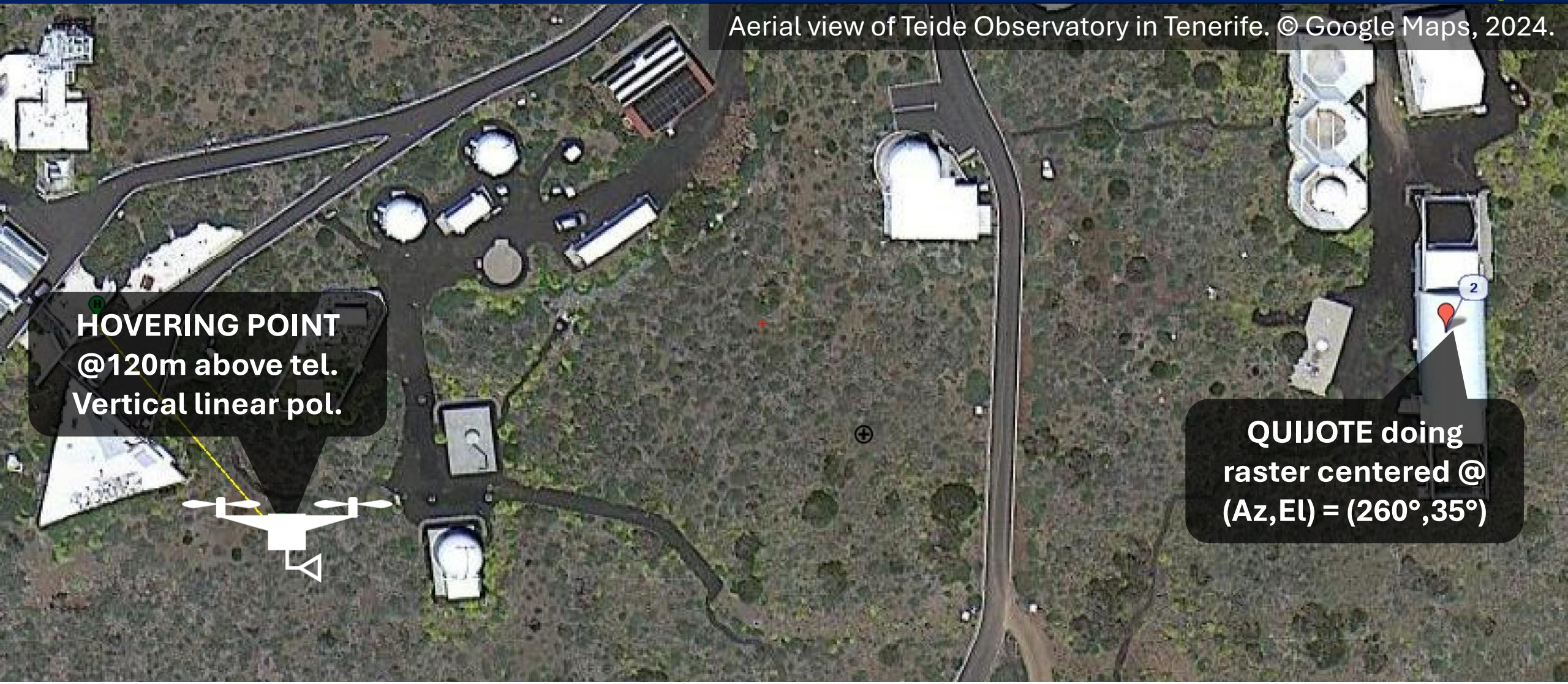
- Measurement types: **front-end output** & **polarimeter outputs (Stokes params)**

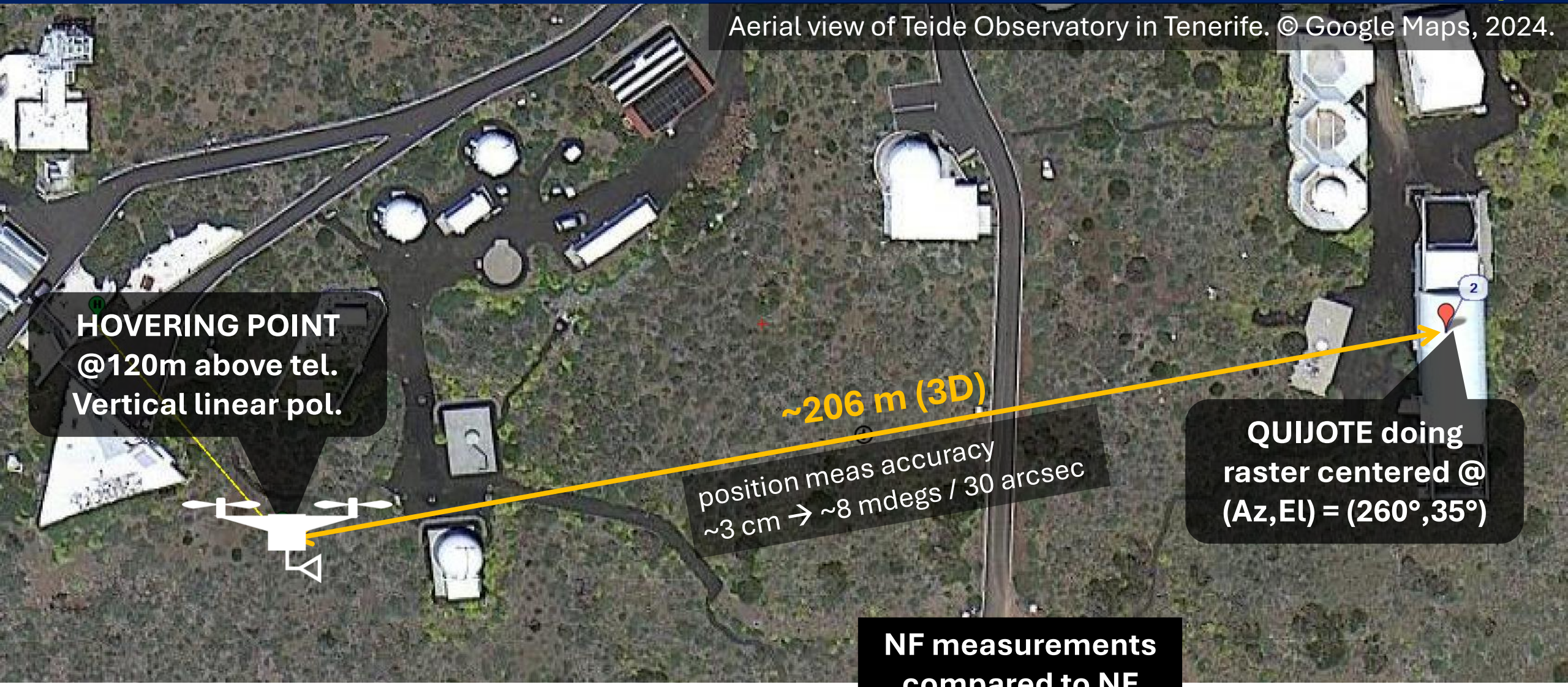
QUIJOTE- Q-U-I JOint TEnerife CMB experiment
Credit: Instituto de Astrofísica de Canarias IAC



QUIJOTE Campaign: Strategies

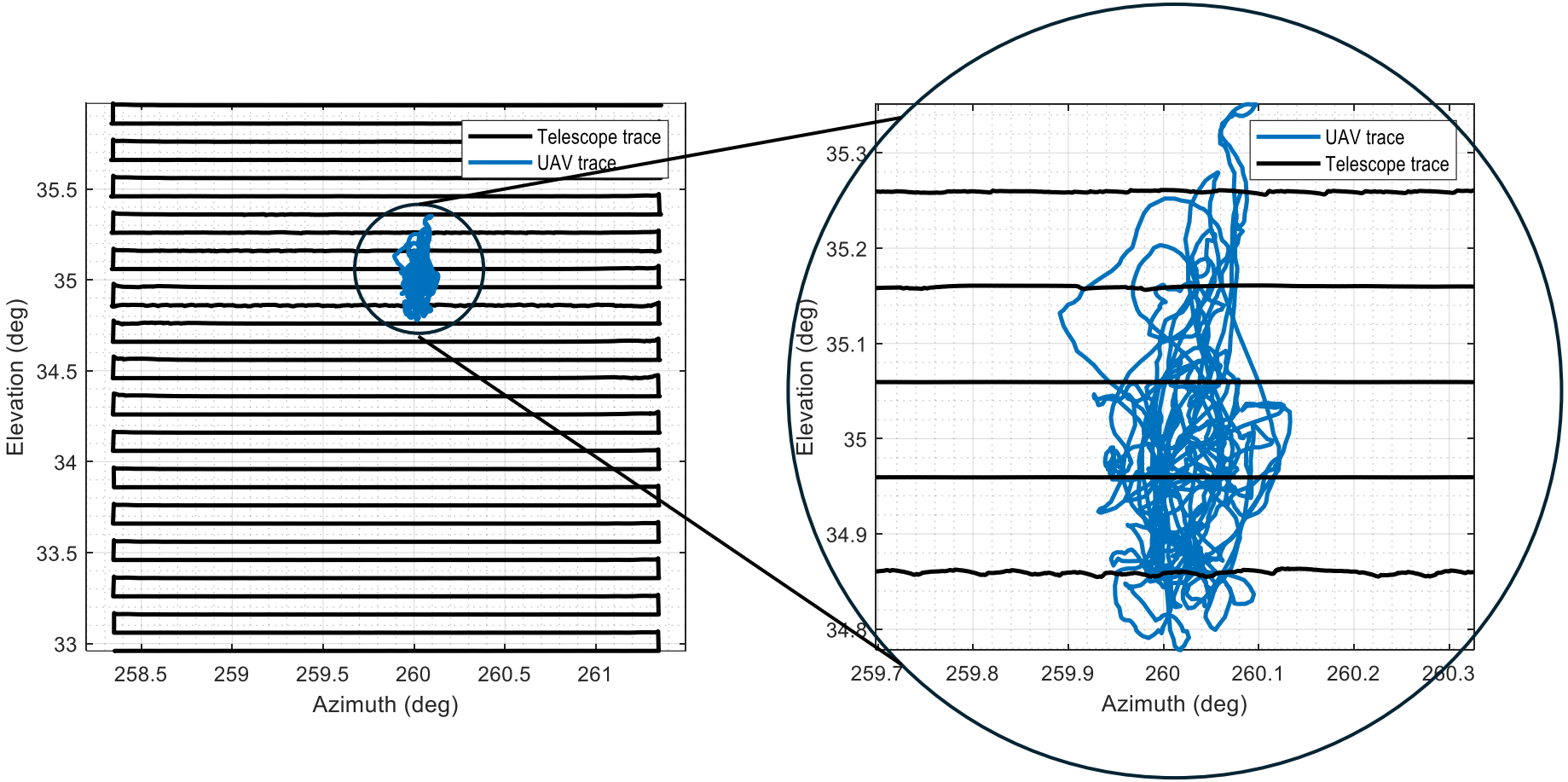


QUIJOTE Campaign: Strategies



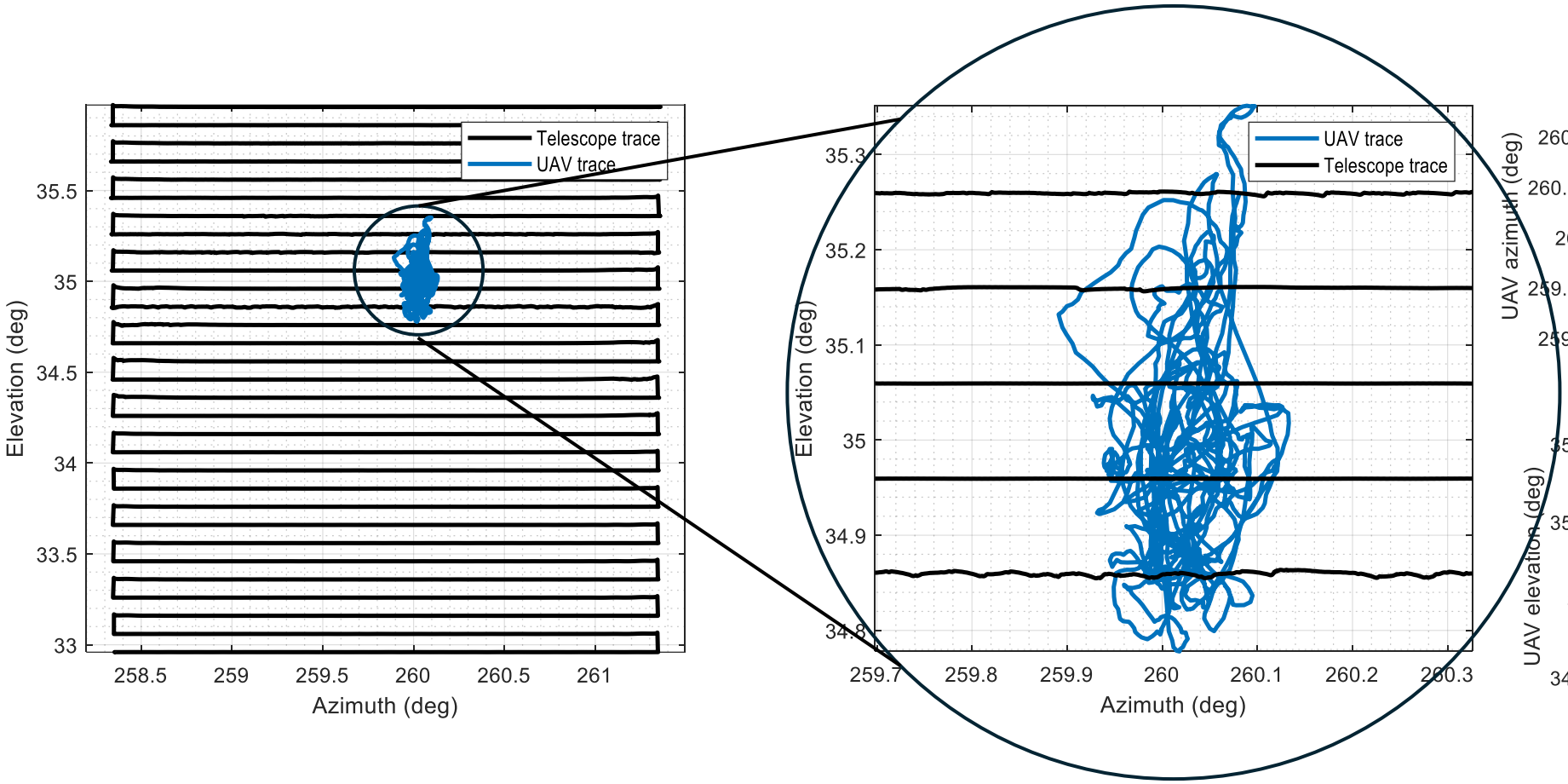
NF measurements compared to NF simulations

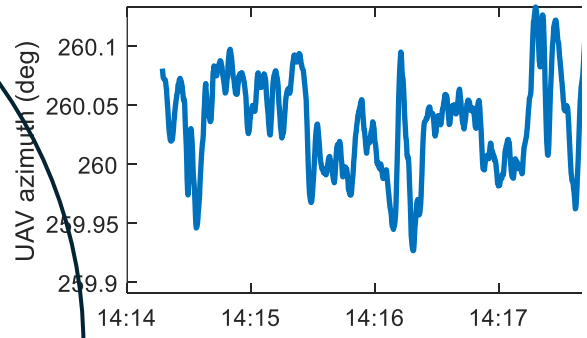
QUIJOTE Campaign: Results



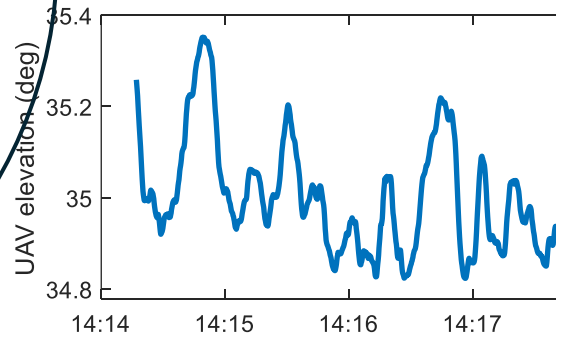
Telescope raster and UAV position overlaid

QUIJOTE Campaign: Results





~1m Variation (horiz.)



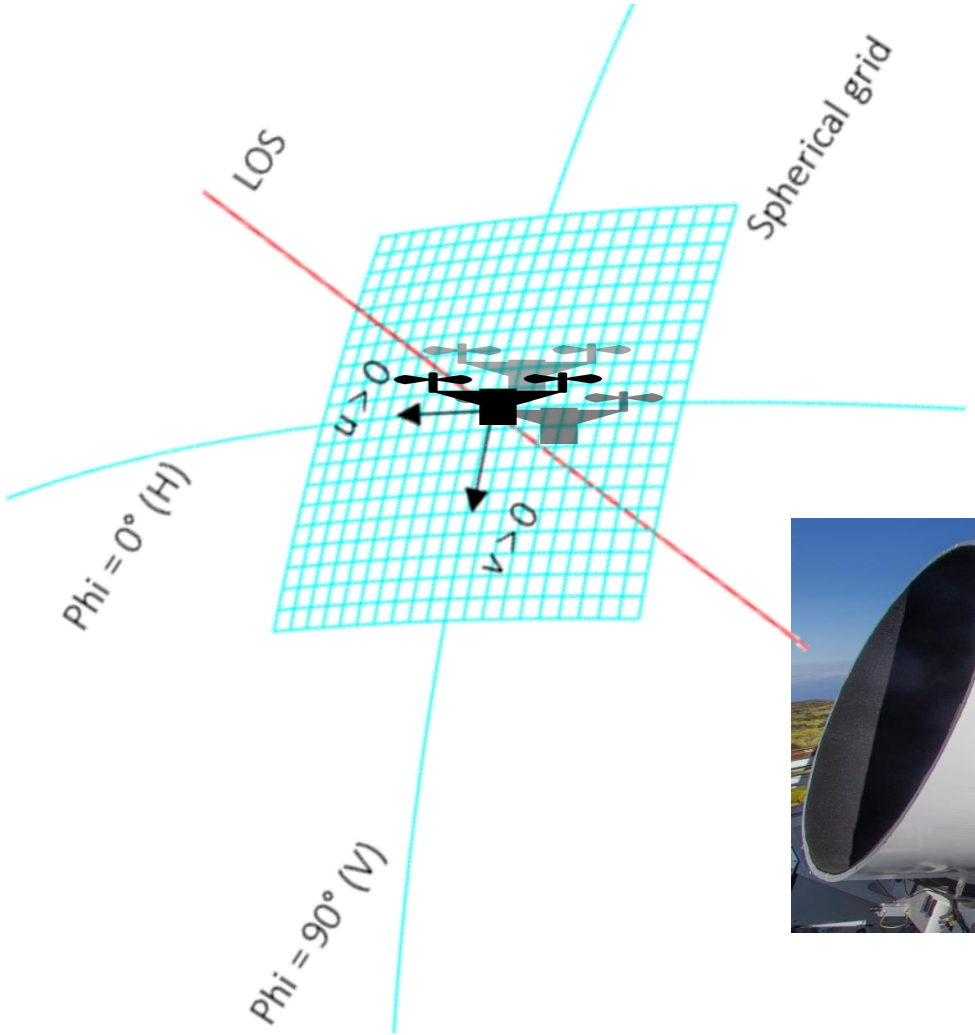
~2m Variation (height)

Telescope raster and UAV position overlaid

QUIJOTE Campaign: Aspects of Data Processing

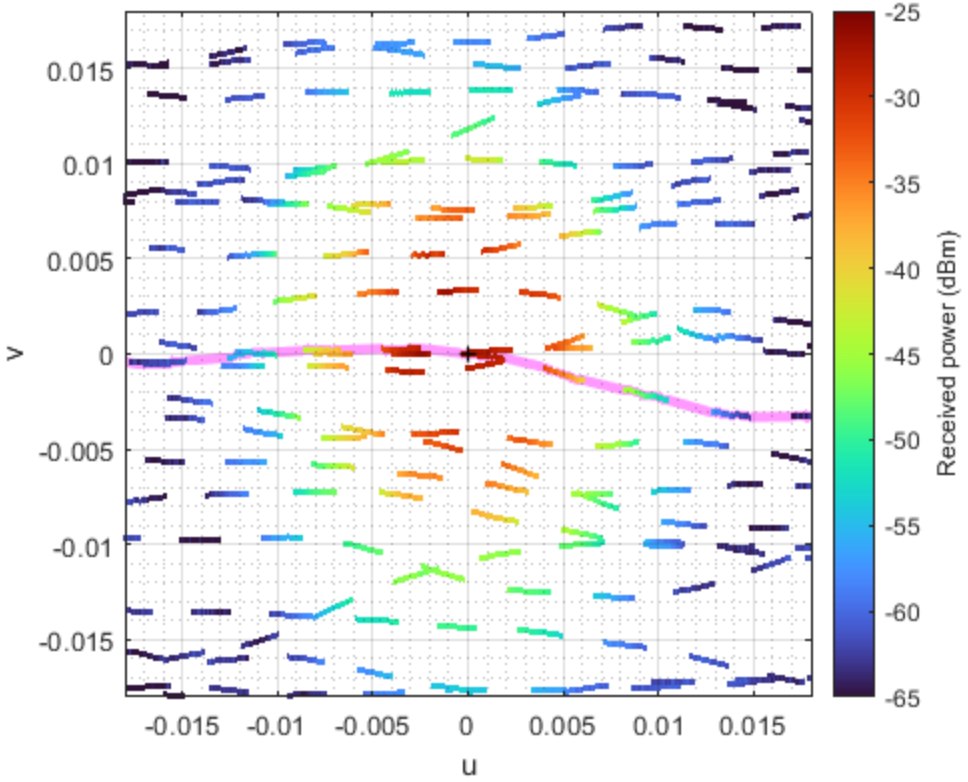
Two objects in continuous relative motion (UAV & telescope)

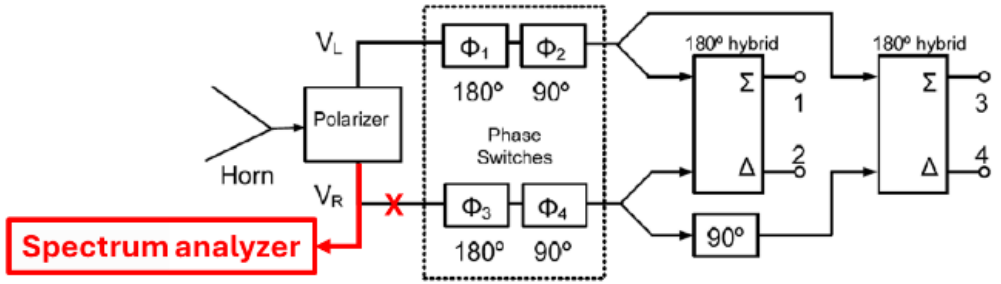
Sample-wise reference frame transformation (rotation matrices)
→ **UV grid (also for simulations)**



QUIJOTE Campaign: Results @ Front-end Output

Feed 1 @ 33 GHz





Combination of
Telescope + UAV + Spectrum analyzer

Spectrum analyzer acquires 50% of the time

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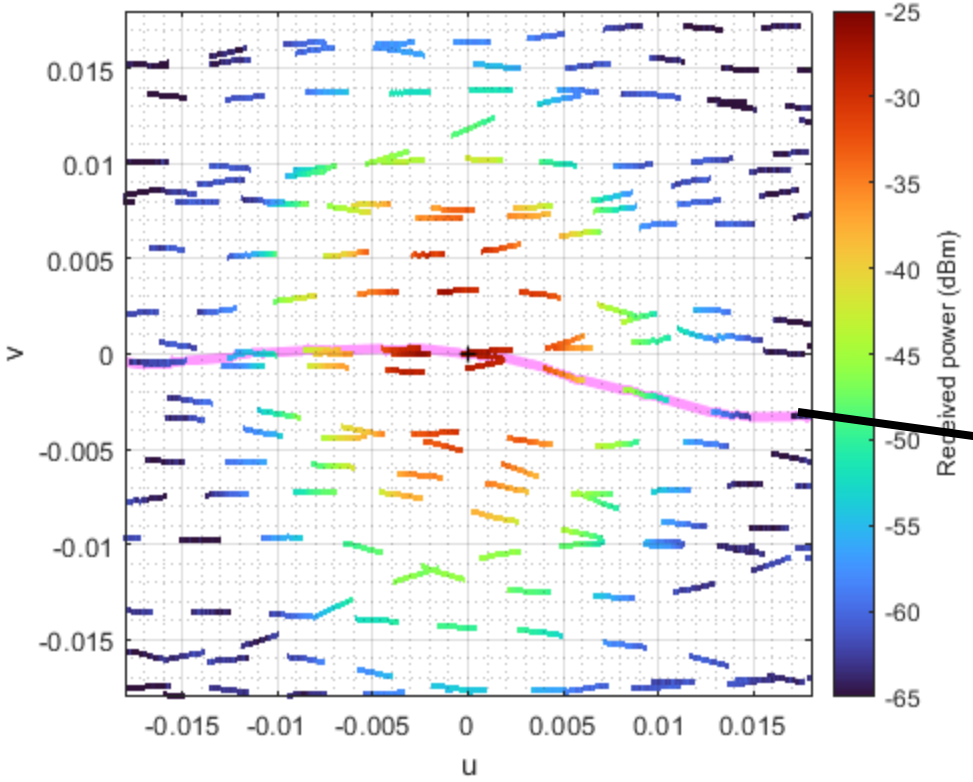
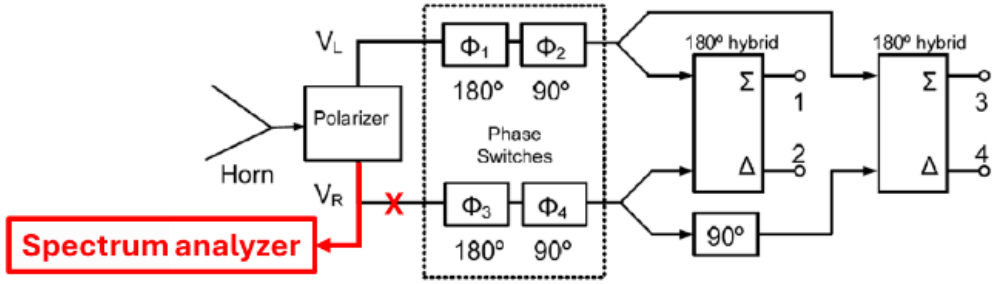
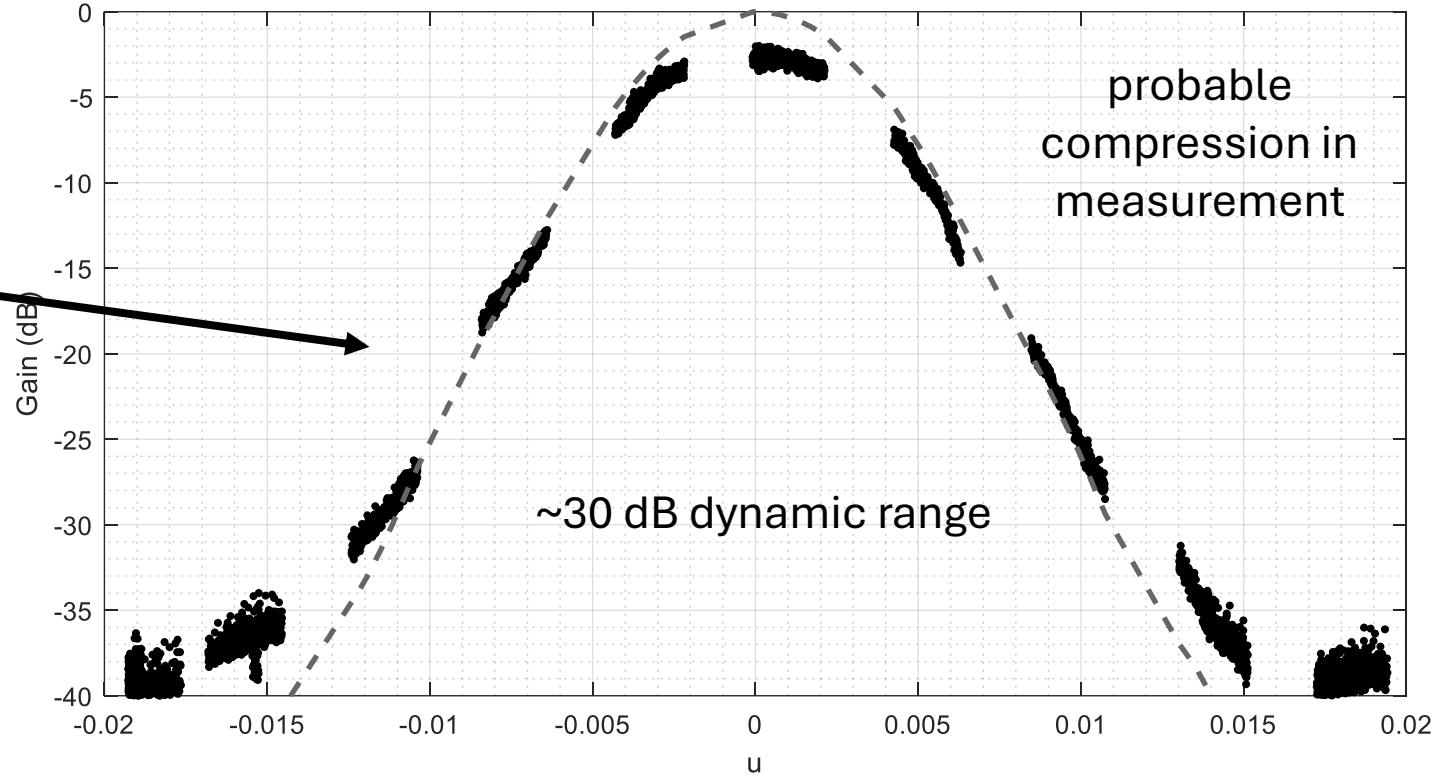






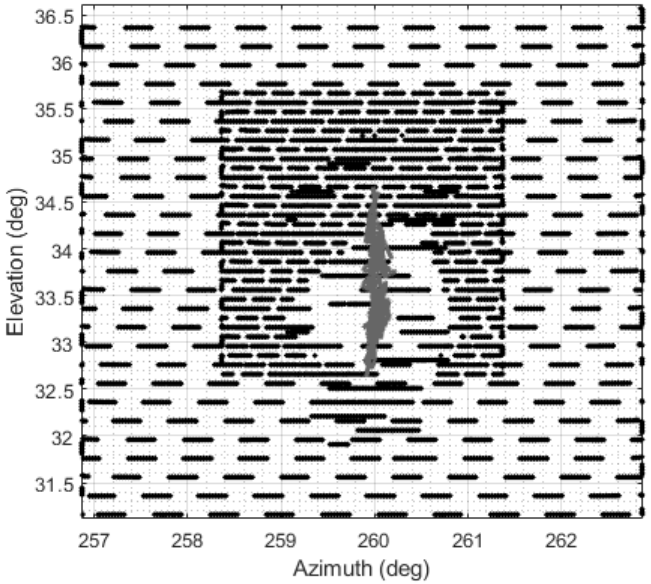
~0.03° full –3dB beamwidth

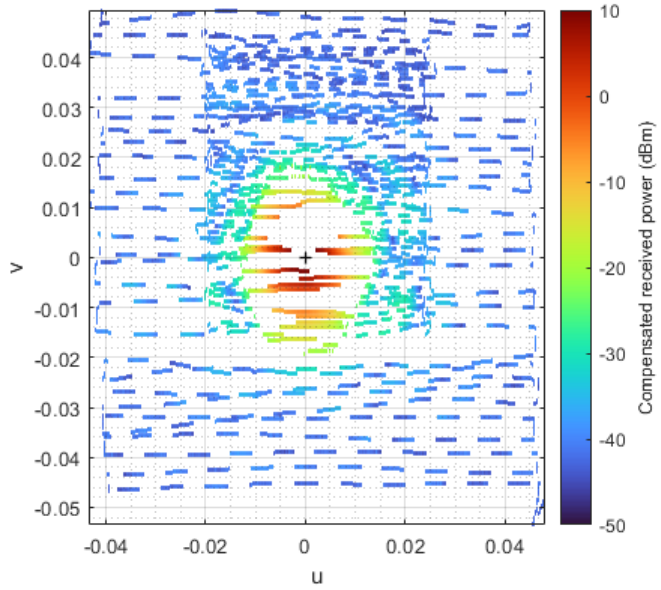
Combination of
Telescope + UAV + Spectrum analyzer

Spectrum analyzer acquires 50% of the time

QUIJOTE Campaign: Results @ Front-end Output

improving dynamic range & covered area through several measurements (flights) w/ different power





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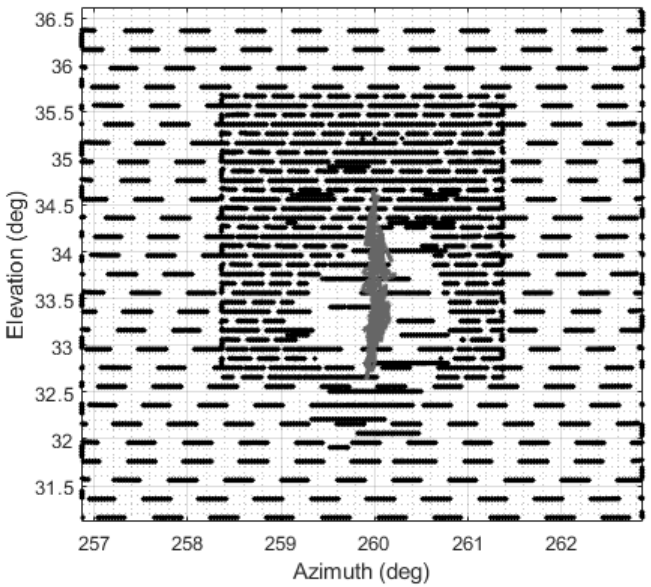
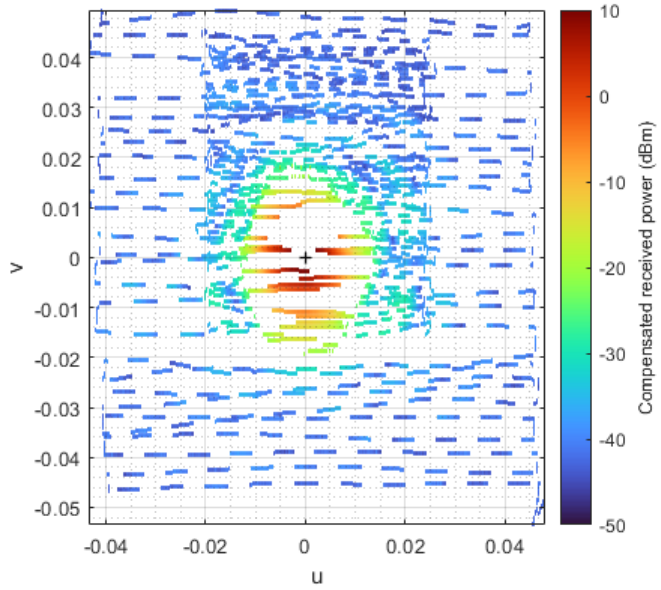
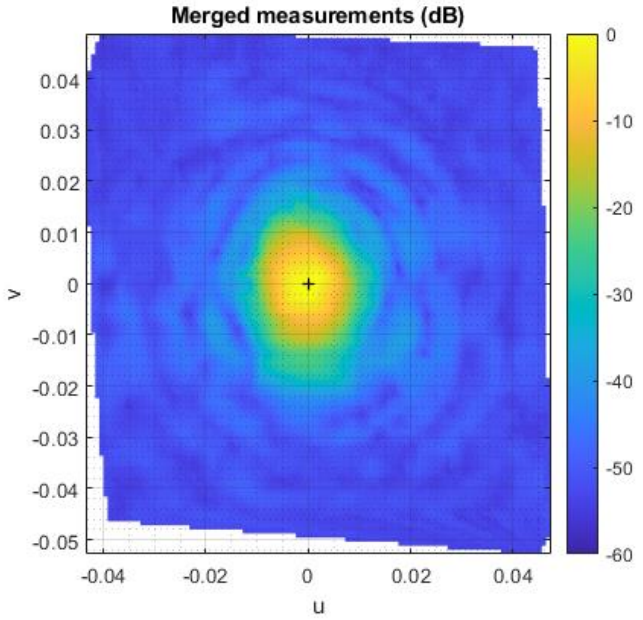
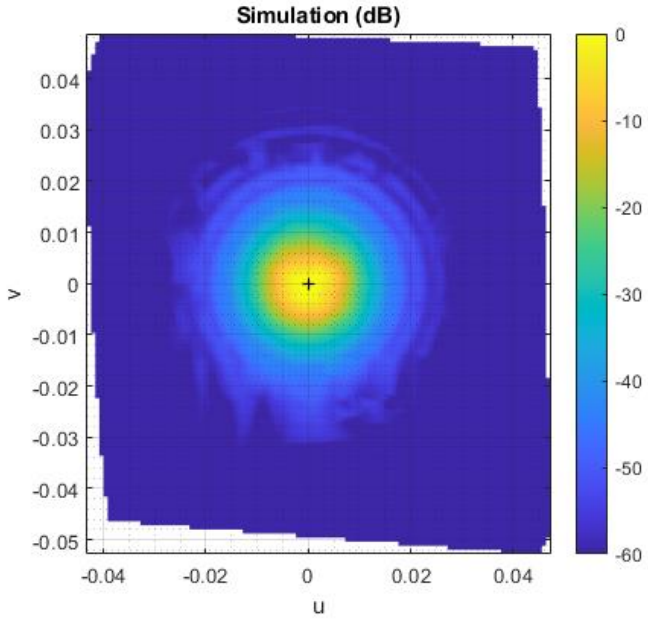




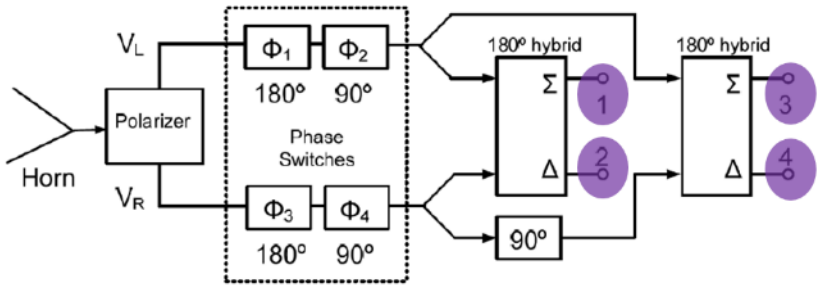
Linear interpolation

50 dB DR





QUIJOTE Campaign: Results @ Polarimeter Outputs



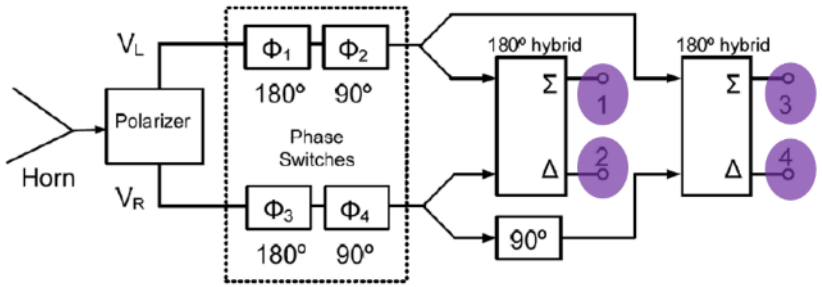
$$Vd1 \propto I + Q$$
$$Vd2 \propto I - Q$$
$$Vd3 \propto I + U$$
$$Vd4 \propto I - U$$

Linearity hypothesis & equalization @ sky level (no source)

$$Vdx = (I \pm Q)Kx + Cx$$

requires diodes calibration

QUIJOTE Campaign: Results @ Polarimeter Outputs



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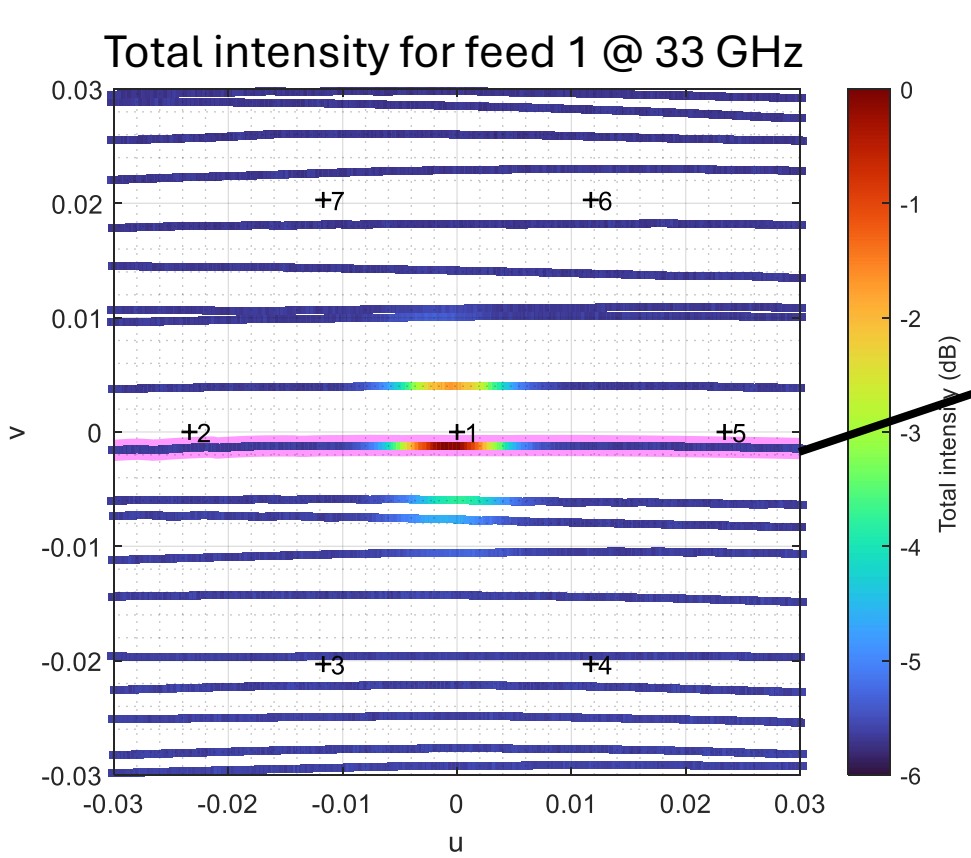
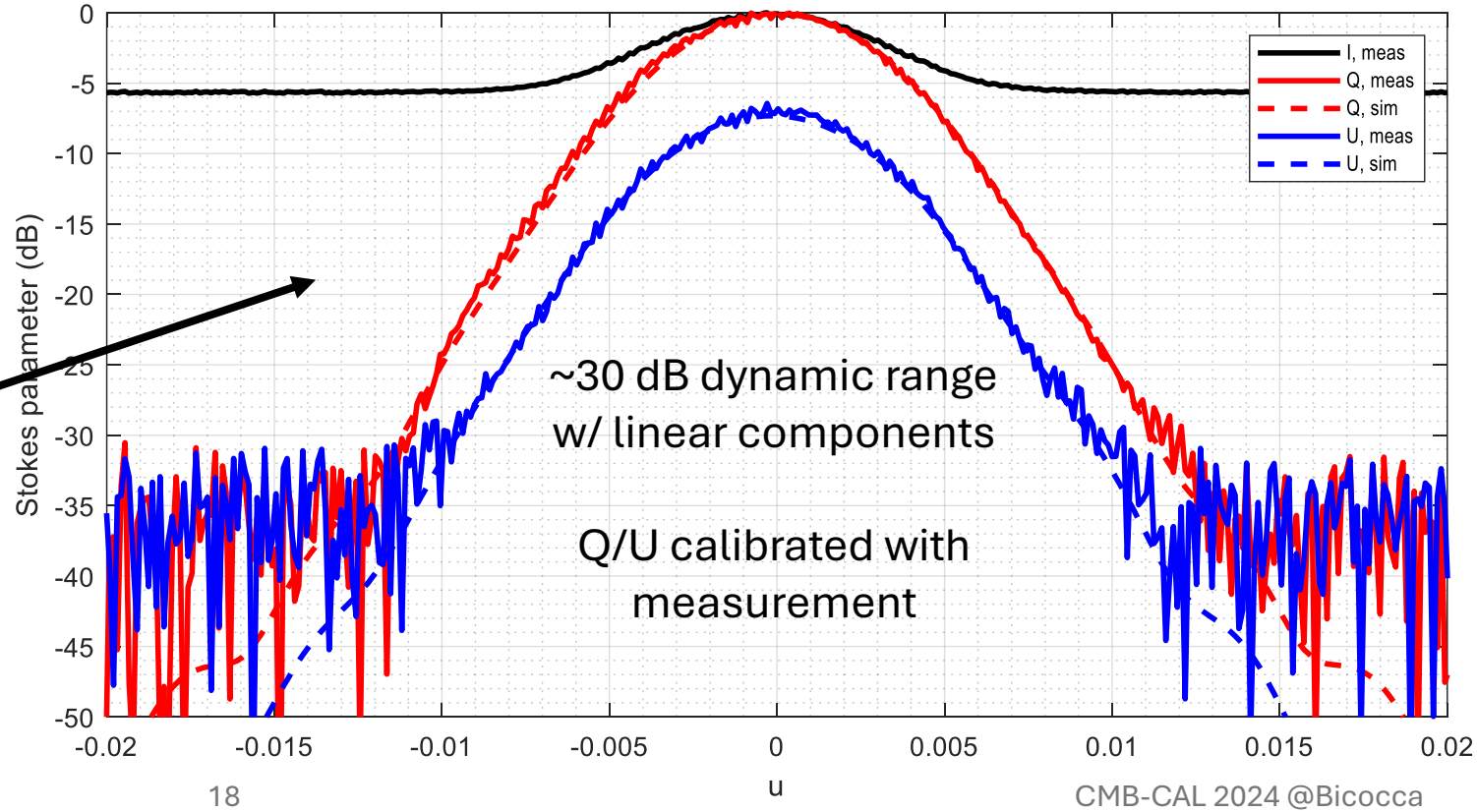
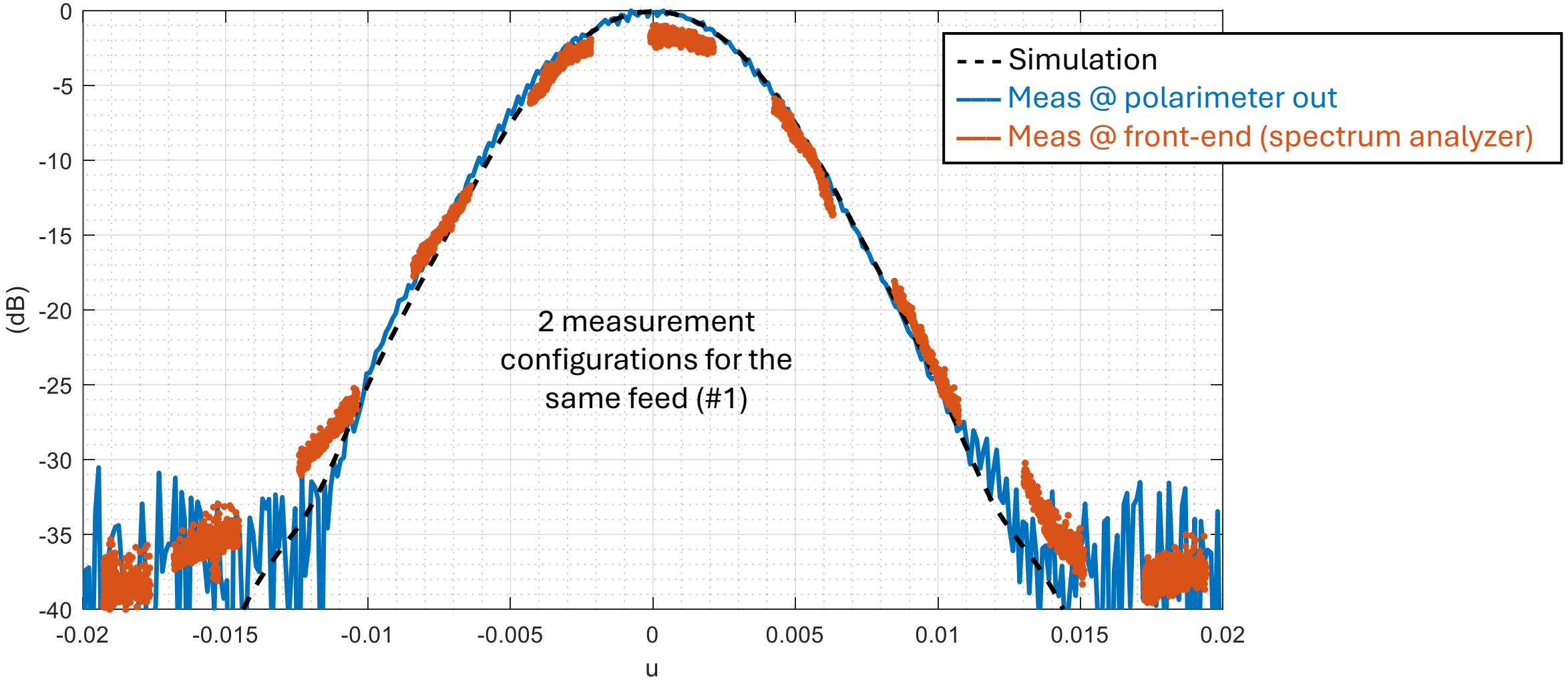
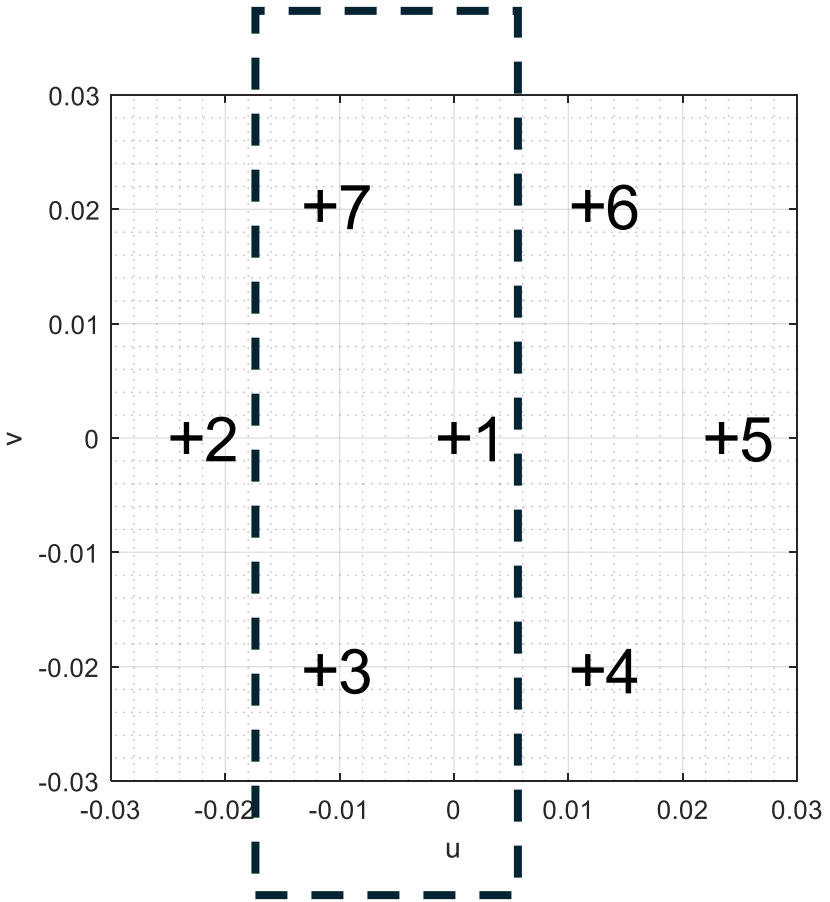


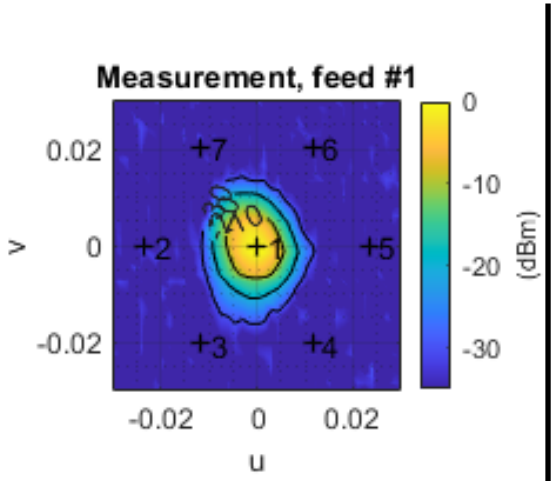


QUIJOTE Campaign: Results Comparison

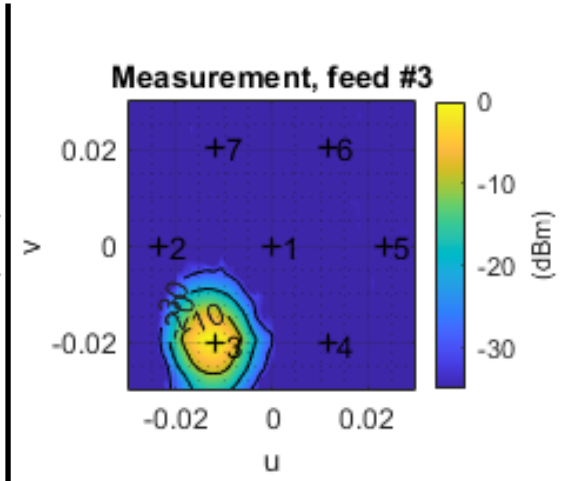


QUIJOTE Campaign: Results Overview @ 33 GHz (TGI)





#1



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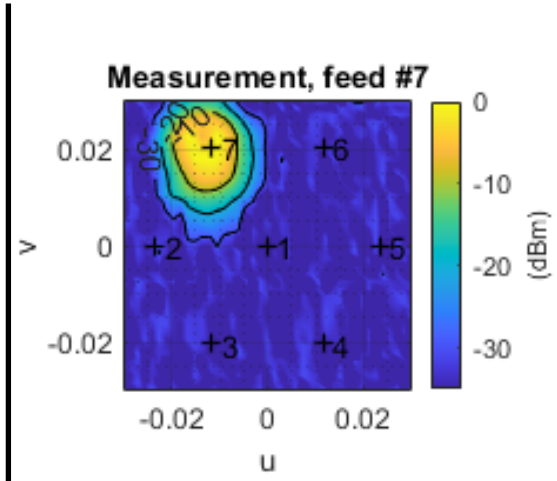
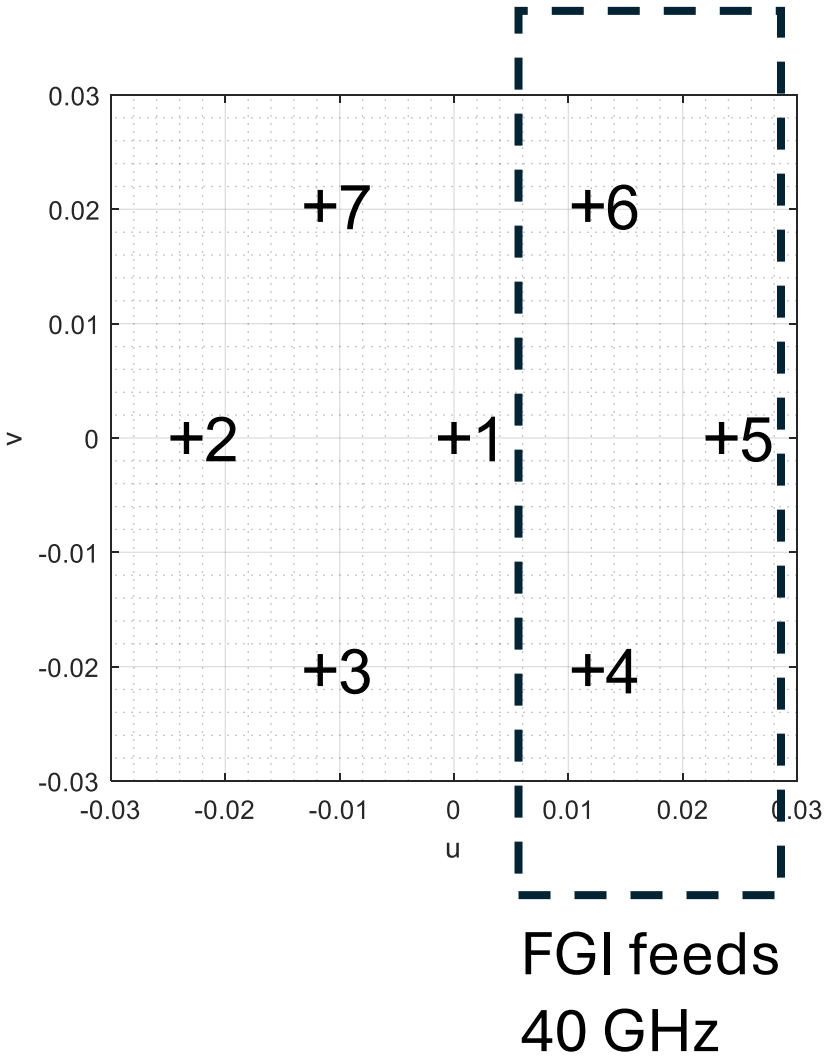
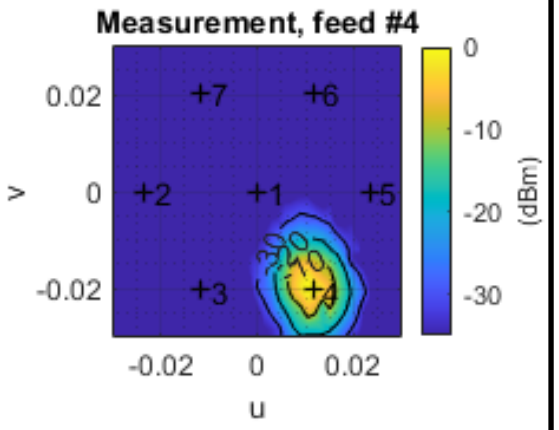


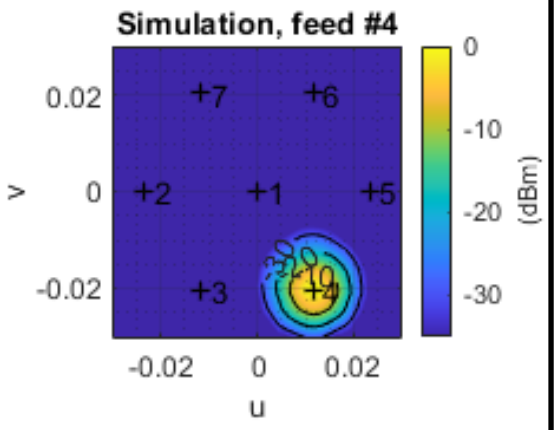
#7

QUIJOTE Campaign: Results Overview @ 40 GHz (FGI)



FGI feeds
40 GHz





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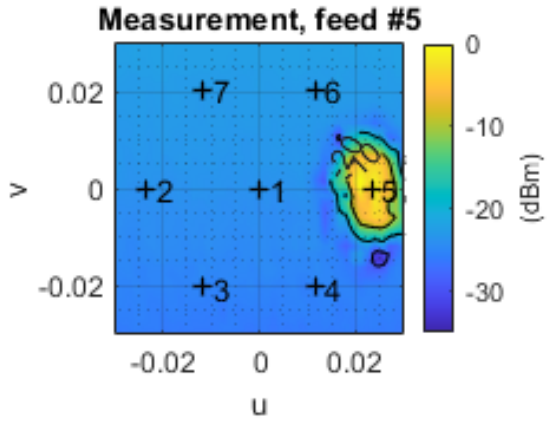

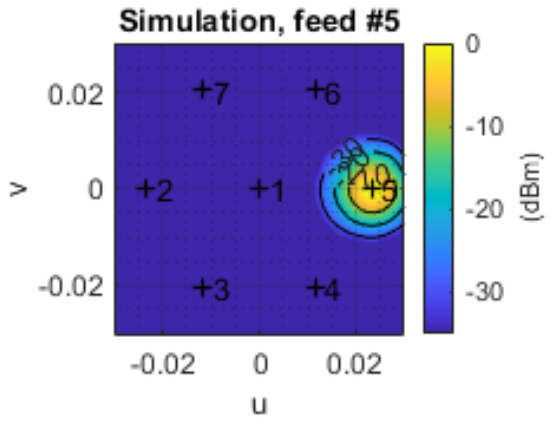

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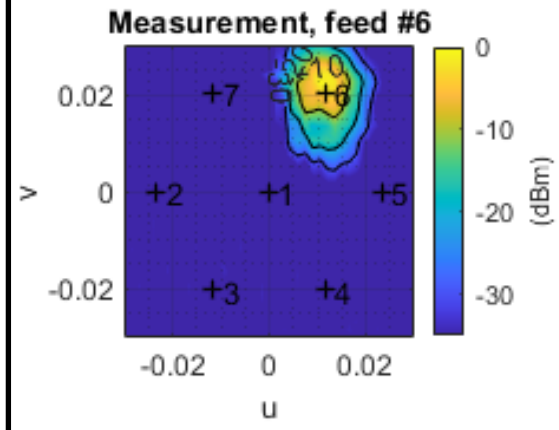

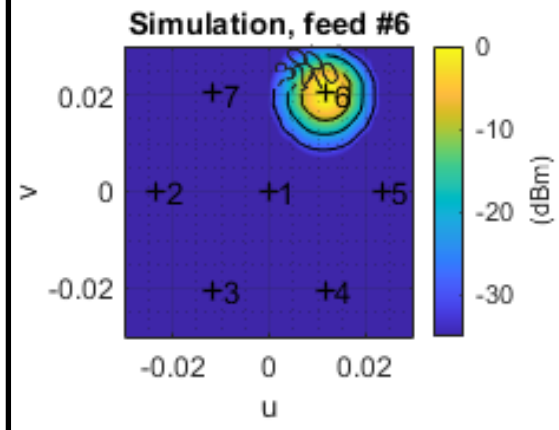

#6

Conclusion

- **Modeling & testing approaches validated**
  - double-checked w/ two receivers on same feed
- **Preliminary data highlight high accuracy depending on scan strategy**
  - High accuracy on horizontal cut
  - Additional experimental activity needed for further considerations on vertical cut & complete 2D maps
- **Expected updates in view of Strip campaign**
  - More strategies (vertical rasters w/ telescope, different elevations, rasters with UAV)
  - Sensor improvements of UAV system (e.g., attitude)