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On the use of a UAV-mounted corner reflector as a calibration target for an X-band polarimetric weather radar

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CONTEXT

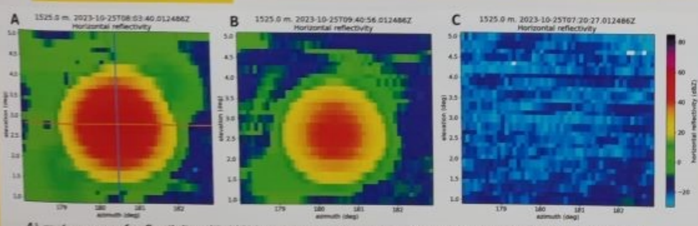
- Radar calibration with a reference target is typically performed using a **tethered balloon** or by mounting a **reflector** on a **tall building or pole**.
- Trade-off between **stability** in target position and **interference** from clutter.
- Commercial UAVs allow precise location thanks to accurate **IMU and GPS.**
- Unfortunately **European law** makes it very difficult to suspent target (sphere) from an UAV.
- As an alternative, mounting a corner reflector (CR) on an UAV **offers mobility and flexibility** and ensures a **consistent position** of the target with very **small interference** from the UAV.

FIELD EXPERIMENT

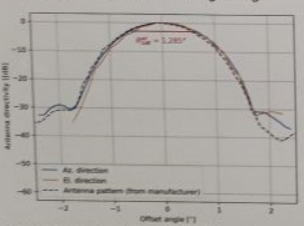
Swisstopo© map with topographical profile from radar to UAV

- Choice of location with very **weak background reflectivity**
- UAV flight height: 100 m and 115 m (two missions)
- Dist : 1523 m, elevation 1.5°/2.1°, azimuth 179.5°
- Dry weather, light wind 4-6 m/s
- Scan strategy:
  - raster scans with 0.1/0.2° resolution in azi/el
  - pointing scans at exact location of the UAV

RASTER SCANS



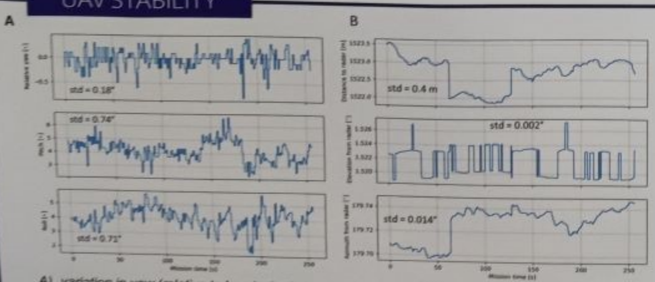
A) raster scan of reflectivity with UAV and CR, B) the same with UAV only (no CR), C) background reflectivity (no UAV), all at 115 m flight height



Antenna diagram retrieved from the refl. raster scans

- Well defined typical **Gaussian-like pattern** of the reflectivity signature
- Strong signal **enhancement** when using CR
- Retrieval of **antenna radiation pattern** was performed for az. and el. directions
- Results show **good agreement in both directions** with lab measured antenna pattern (from manufacturer).

UAV STABILITY



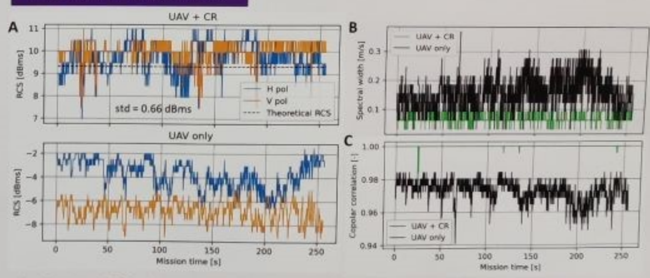
A) variation in yaw (relative to bearing), pitch and roll of UAV during mission (100 m height)
B) variation in angle and distance of UAV to radar during mission

UAV AND CR SETUP

- Custom made **aluminium** (8mm sheet) CR mounted on top of DJI Matrice 300 UAV.
- **Inclination** of the CR can be adjusted precisely with Thorlabs mounting plate.
- Theoretical RCS of CR is 9.32 dBms (**equivalent to 1.65 m ~~diam.~~ radius sphere**).
- **Counterweight** is needed to ensure stable flight behaviour of the UAV, weight is adjustable depending on corner reflector angle (total payload weight ~1.8 kg).
- UAV needs **calibration of the IMU** for every new corner reflector inclination.
- Tests were made with **Leonardo 50DX X-band polarimetric weather radar**. *frequency 9.45GHz, 1.27° 3dB beamwidth, 75 kW max power, 0.3/0.5/2 μs pulse width*

A) CR mounted on the UAV, B) UAV with CR in flight nearby the 50DX weather radar

POINTING SCANS



A) Measured RCS with and without CR at H/V polarizations, B) ρ_{hv} with and without CR, C) Spectral width with and without CR. All at 100 m flight height

- UAV with RC shows **small variability in RCS**, ρ_{hv} and spectrum width when compared with UAV only → good target consistency.
- With CR **diff. reflectivity is fluctuating around zero**, while the UAV has typically high values (around 4 dB due to assymetry in the drone shape).
- Copolar coefficient (ρ_{hv}) with CR is **almost always 1** indicating near perfect correlation between H and V returns.
- **Spectral width much smaller with CR** due to decrease in importance of HERM lines (propeller micro-Doppler signature) in Doppler spectrum.
- The average measured RCS is around **9.5 dBms** (slightly larger than theoretical RCS of CR: 9.3 dBms), this is likely due to contributions from UAV body.

CONCLUSIONS

- Due to the strict **European legislation**, suspending a calibration sphere from an UAV is extremely difficult: in this work we test whether attaching a corner reflector directly to an UAV could be a viable alternative.
- Results show that mounting a CR on an UAV allows to get a **quite stable radar signature** while ensuring a very **stable position** relative to the radar.
- A disadvantage of this method is that it requires **careful adjustment** of the elevation angle of the CR and azimuth angle of the UAV.
- Fluctuations in measured RCS are not well explained by UAV angles/position and are thus likely caused by the remaining contribution of the UAV → next experiment with **radiation absorbing foam**
- For calibration, the RCS of the UAV + CR system will need to be carefully measured for various incidence angles in an **anechoic chamber**.

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