Radar Altimetry Calibration With Corner Reflectors: Current Status And Future Plans

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A trihedral corner reflector has been designed and tested to assess the capability of passive reflectors to calibrate radar altimeters such as the Poseidon-4 altimeter on board Sentinel-6A. The current facility, located within an astronomical observatory at the top of a mountain ridge, has shown to be idoneous for Sentinel-6, Sentinel-3B and CryoSat-2 monitoring. Results are comparable to what is currently achieved by means of active transponders and therefore it is demonstrated that passive reflectors may be of interest to support radar altimeter regular calibration. Furthermore, a portable corner reflector has been developed and validated to test new candidate sites.

PASSIVE REFLECTORS FOR RADAR ALTIMETER CALIBRATION

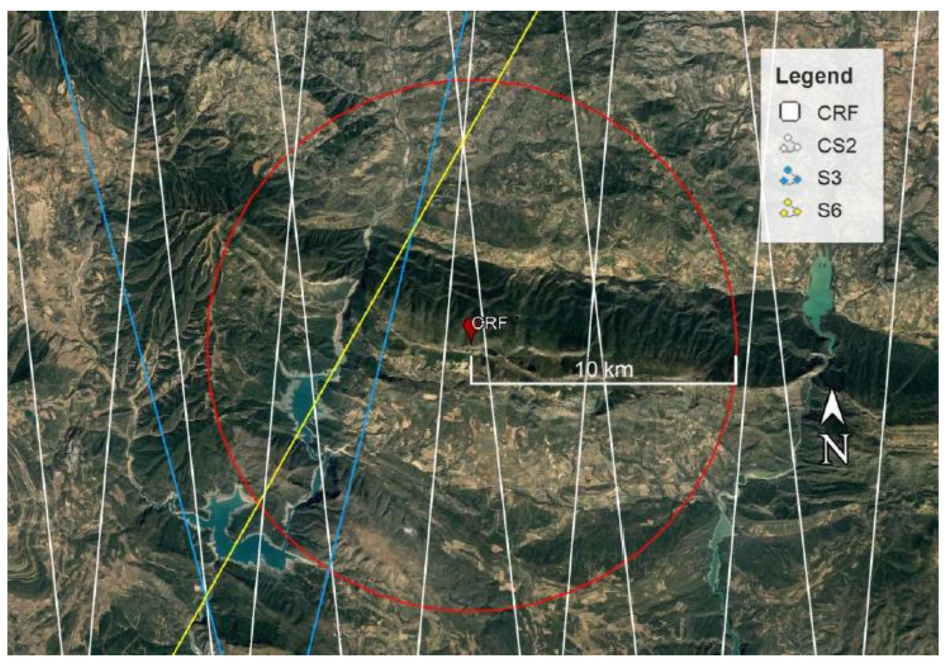
Spaceborne radar altimeters require periodic external calibration of their range measurements, which for pulse-width limited instruments has been conventionally carried out over natural targets such as the ocean surface.

With the advent of altimeters that can operate in SAR mode, active transponders have become far more useful for altimetry data calibration. Dedicated processing of the point target response, which is the transponder echo, provides essentially measurements of absolute range and associated time-stamping, and measurements of the instrument resolution in both range and azimuthal dimensions. There are transponders installed in Svalbard, Crete, and Corsica.

The use of passive reflectors instead of active transponders for radar altimeter range calibration was impractical for pulse-width limited altimeters due to the size required in order to achieve high enough Signal-to-Clutter Ratio (SCR).

However, recent developments in radar altimetry processing techniques such as Fully-Focussed SAR (FF-SAR) allow to strongly improve the along-track resolution down to the ~1m scale, thus significantly reducing the size of the area contributing to clutter. Such improvement is of key importance for passive reflectors since it notably reduces the requested reflector side length in order to get acceptable SCR, making them feasible in terms of practical application.

THE MONTSEC CORNER REFLECTOR FACILITY



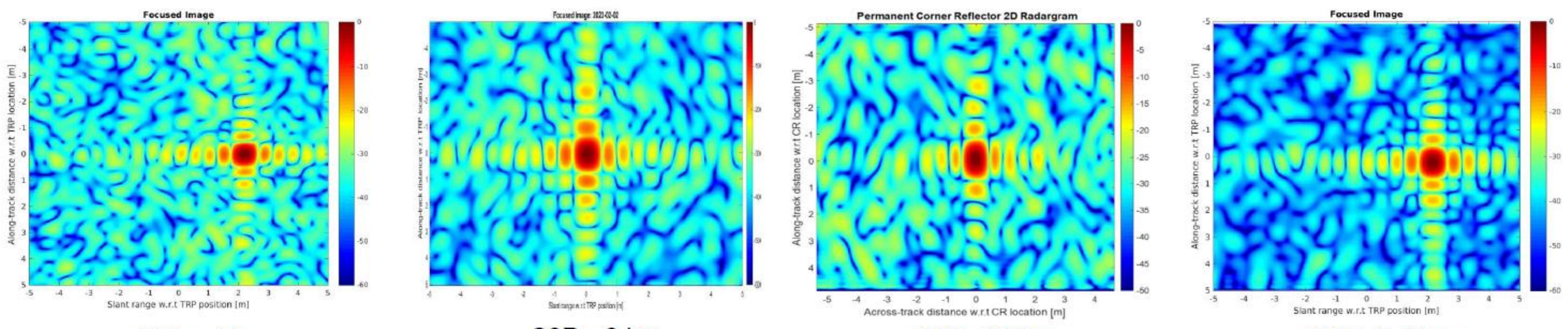
The chosen location was the Montsec Astronomical Observatory facility at 1,564 m, in the southern side of the Pyrenees. The corner reflector could be placed a few tens of meters from the observatory dome and other buildings in order to minimise clutter and across-track ambiguities, but still inside the facility area which ensures proper maintenance.

The corner reflector was installed the 16 April 2021 at final coordinates 42.0519ºN 0.7201ºE. [F. Gibert et al 2023] The corner vertex location was measured with a high precision GNSS device in a dedicated campaign on 31 January 2022.

The retroreflector built consists of a trihedral corner reflector made of three square plates. For typical Ku-Band radar altimeters this yields a maximum radar cross section (RCS) of 54.90 m², which allows to capture echoes with a Signal-to-Clutter Ratio of 40 dB.

The support structure consists of a triangular structure built with L-Shaped bars. The nominal orientation of the reflector is zenith pointing with a margin for eventual off-nadir pointing. The whole apparatus is fastened with iron nails directly to the ground, composed essentially by mountain rock.

- **L0 raw data are processed to L1A** by a L1 Ground Processor Prototype developed by isardSAT.
- **Calibrated echoes in L1A files are processed with a FF-SAR processor** based on Egido, 2016.
- Sentinel-6, Sentinel-3B (2 tracks) and CryoSat-2 (SAR/SARin) present good signal imprints.



S6A - 4 km | S3B - 3 km | S3B -12 km | CS2 -3.8 km

ANALYSIS OVER 2 YEARS

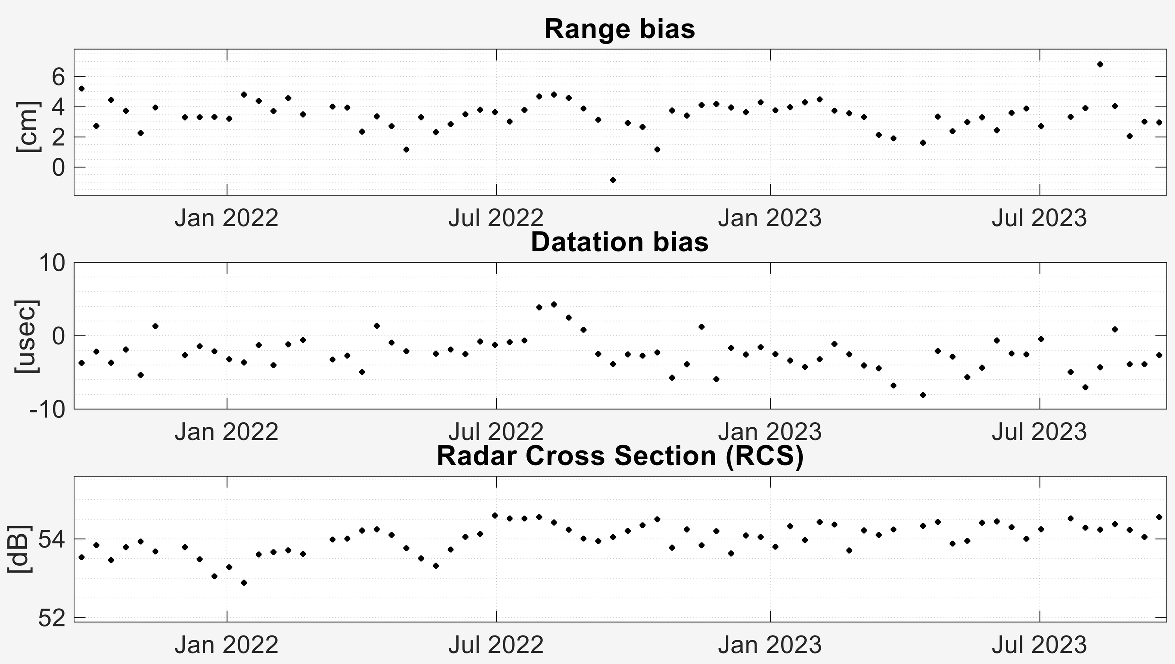
The Sentinel-6 timeseries comprises the period from September 2021 to October 2023. Range measurements are corrected for the following geophysical effects:

- Dry tropospheric delay is provided at sea level altitude and adjusted to the actual CRF altitude using local pressure and temperature.
- Wet tropospheric delay, ionospheric delay, solid Earth tide, ocean loading tide and pole tide correction values are obtained from L2 products.

Datation measurements are corrected by the horizontal component of solid Earth tide, and RCS measurements are corrected for atmosphere attenuation and antenna pattern. Since February 2023, a GNSS station is providing independent tropospheric corrections.

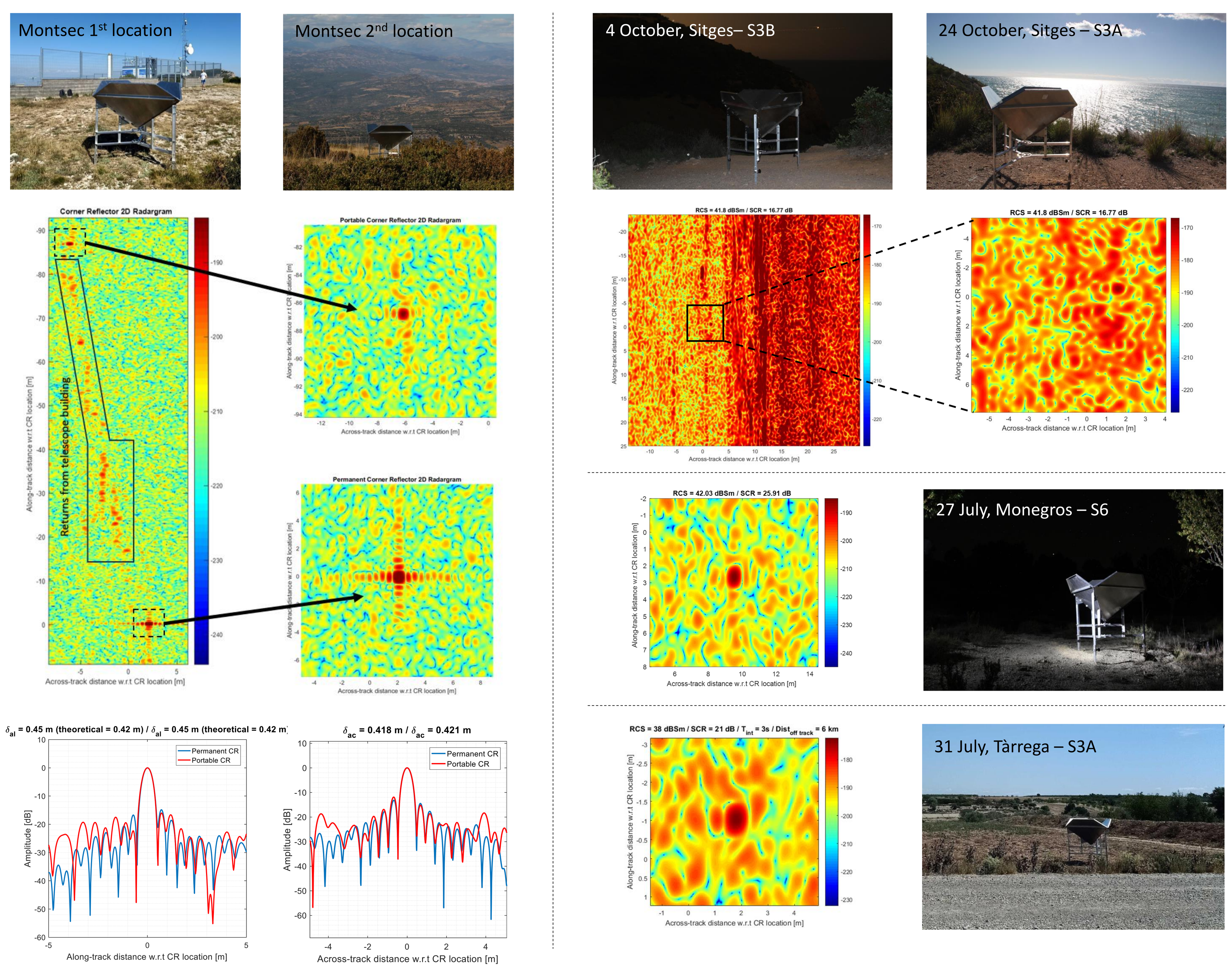
		TRP	CRF
Range bias [cm]	Mean	-0.17	3.29
	Std	1.05	1.07
Datation bias [µs]	Mean	1.1	-2.44
	Std	5.6	2.31
Radar Cross Section [dB]	Mean	--	54.01
	Std	--	0.37

Comparison between Crete transponder (TRP) and Montsec corner reflector (CRF)



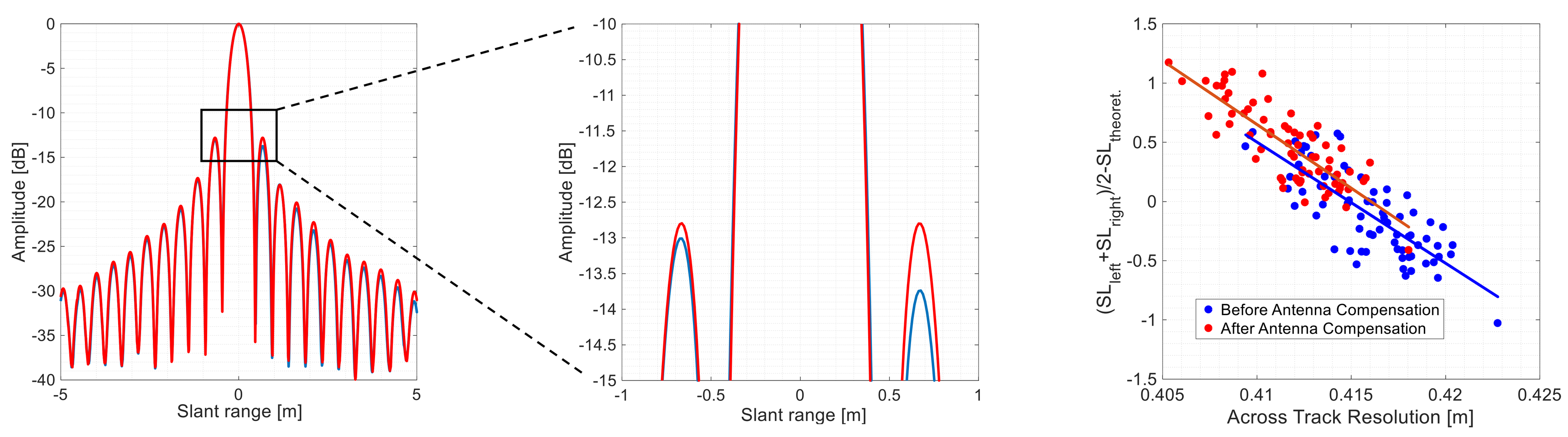
PORTABLE CORNER REFLECTOR

isardSAT has developed a portable corner reflector to assess suitability of calibration site candidates. The portable CRF is a 1-m trihedral diamond-shape reflector, with a RCS of 45 dB, and an overall weight of 35 kg. The measured resolutions are comparable to the ones from the permanent reflector. 5 Sentinel-6, 5 Sentinel-3A, 7 Sentinel-3B, and 3 CryoSat-2 passes in different areas (flat, prominent, near the sea...) have been analysed during the first 3 months.



ANTENNA PATTERN MONITORING

The S6 P4 antenna does not transmit uniformly through the whole band. A fast-time correction proposed by S. Dinardo onto the received echoes allows to compensate for this effect, reducing the side lobe left-to-right difference to <0.01 dB when averaging multiple PTRs (before: 0.73 dB):



CONCLUSIONS

- Trihedral corner reflectors can provide key external calibration measurements for periodic radar altimeter performance monitoring.
- The **performance** achieved is **comparable to conventional active transponders** in terms of range bias, datation bias, stability, and signal impulse response.
- As purely passive devices, corner reflectors are also attractive from the point of view of low cost, on-site operation, and easy maintenance.
- Due to its broad beamwidth (opposite to transponders), the Montsec corner reflector has been used to **analyse the range PTR stability** that will help to **monitor the antenna pattern** aging.
- Results from the 2-year calibration results at the Montsec facility may have an impact on future strategies, encouraging the use of corner reflectors for radar altimeters external calibration. The Montsec facility as already been added as a calibration site within the Sentinel-3 Mission Performance Cluster.
- The different measurements using the 1-meter portable corner reflector have provided a preliminary assessment of the corner sensitivity at different clutter levels. It has provided key information to be used in the feasibility studies for future corner sites.