A Trihedral Corner Reflector to Support Radar Altimeter External Calibration Using FF-SAR Algorithms

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ABSTRACT

A trihedral corner reflector has been used to evaluate the capability of passive reflectors to calibrate radar altimeters such as the Poseidon-4 altimeter on board Sentinel-6A. 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.

Spaceborne radar altimeters have all required 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. Such transponders have been installed in Svalbard, Crete, and Corsica.

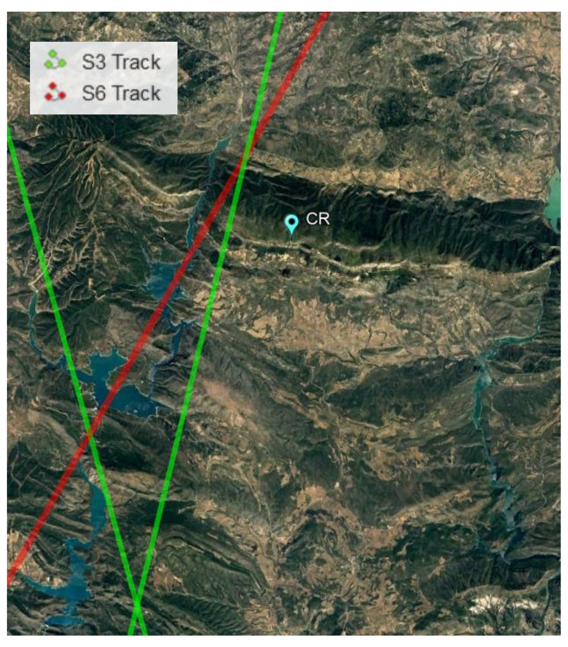
The use of passive reflectors instead of active transponders for radar altimeter range calibration was impractical for pulse width limited altimeters due to the size required in order to achieve high enough Signal-to-Clutter Ratio (SCR).

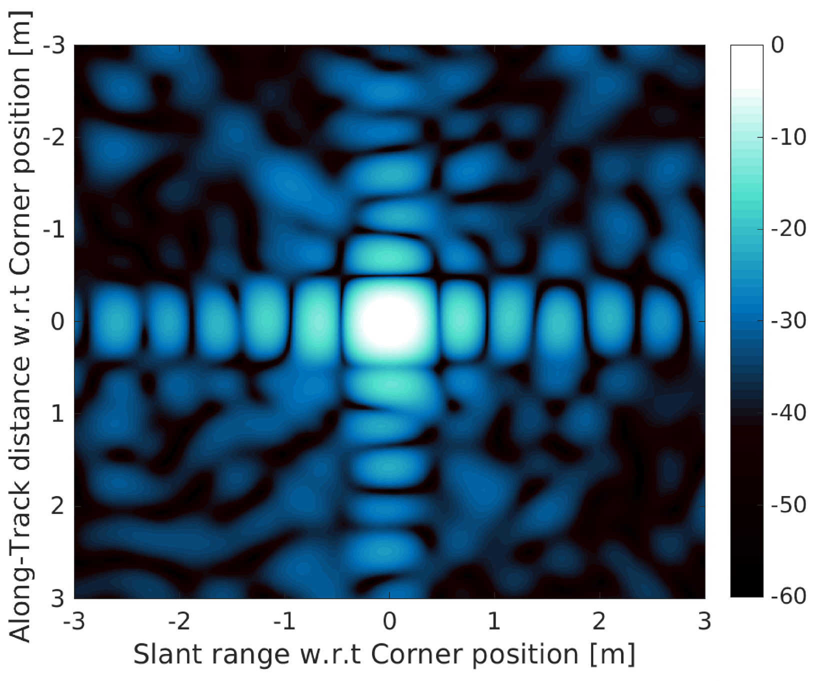
However, recent developments in radar altimetry processing techniques such as Fully-Focussed SAR (FF-SAR) allow to strongly improve the along-track resolution down to the ~1m scale, thus significantly reducing the size of the area contributing to clutter. Such improvement is of key importance for passive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

This poster presents the range, datation and σ0 bias results using a square-side trihedral corner reflector designed by isardSAT and deployed on the top of a mountain ridge and about 4-km off-nadir of the Sentinel-6A subsatellite track when processing the received data with a Fully-Focussed SAR algorithm, for a measurement campaign between September 2021 and September 2022.

DATA

Sentinel-6 uses Poseidon-4 Ku/C Radar Altimeter, which is capable of both LRM (Low Resolution Mode) and SAR (Synthetic Aperture Radar) modes of operation.





- **L0 raw echoes are processed up to L1A calibrated echoes** by a L1 Ground Processor Prototype developed by isardSAT [1].
- **Calibrated echoes in L1A files are processed with a FF-SAR processor** in time-domain based on the back-projection algorithm [2].
- **Range measurements are corrected** for the following geophysical effects:
  - Dry Tropospheric delay correction is provided at sea level altitude and adjusted to the actual CR altitude using local pressure and temperature measurements.
  - Wet tropospheric delay, ionospheric delay, solid Earth tide, ocean loading tide and pole tide correction values are provided in L2 products for each pass.

THE CORNER REFLECTOR SITE

Corner Reflector spot inside Montsec Astronomical Observatory facility area.

Corner Reflector developed by isardSAT in 2021.

LOCATION

The chosen location was the Montsec Astronomical Observatory facility at 1564 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 16th of April 2021 at final coordinates 42.0519ºN 0.7201ºE. The corner vertex location was measured with a high precision GNSS device in a dedicated campaign on 31 January 2022.

CHARACTERISTICS

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 m^2, 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.

RESULTS

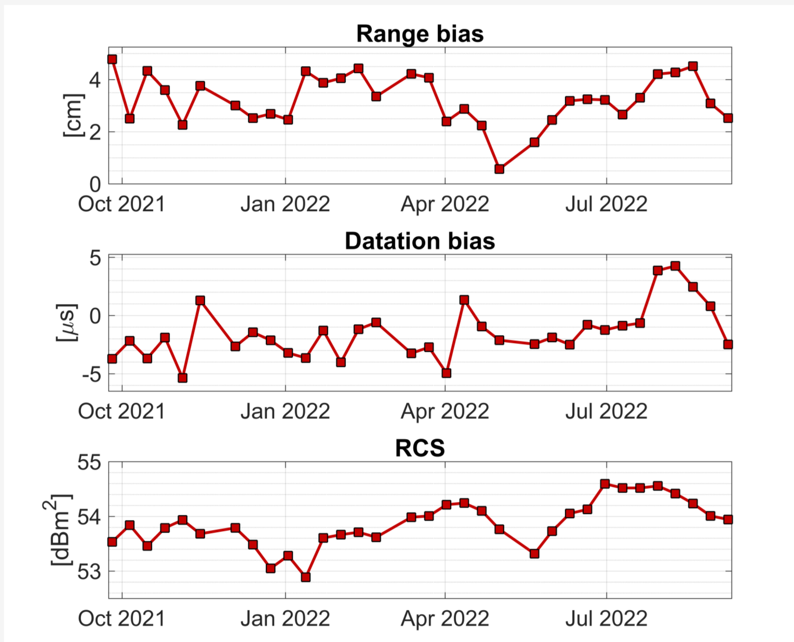
The system stability is addressed by comparing a series of consecutive passes processed with ~4.70 s integration time.

Range bias (*top*) for the full period after correcting for geophysical contributions and geometry presents an average bias of **3.23** cm and a standard deviation of **9.5** mm.

The **datation bias** (*centre*) measurements present a standard deviation of **2.25** μs (**12.9** mm). The mean datation is **-1.51** μs (**-0.8** cm).

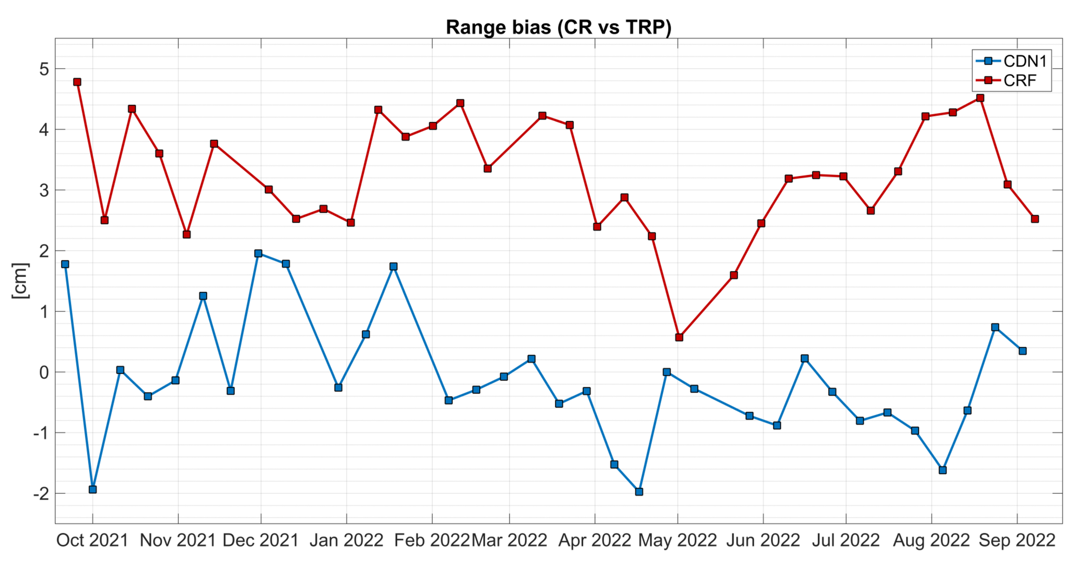
Regarding the **RCS** (*bottom*), an average value of **53.87** dBm^2 with standard deviation of **0.42** dBm^2 is found after compensating for the antenna pattern. The averaged difference with respect to the theoretical is consistent with the bias of 1.2-1.3 dB observed when comparing LR Ku σ0 retrievals from Sentinel-6 with respect to Jason-3.

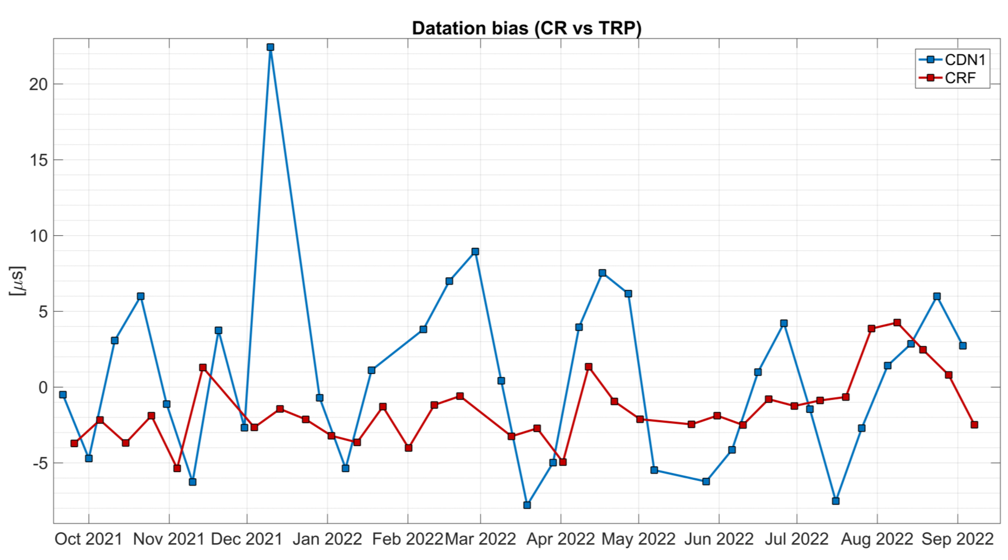
Amongst the full time span only three cases are removed from the time series: a pass lost because of snow storm on 23 November 2021, a pass which coincided with a satellite maneuver on 2 March 2022, and a pass discarded due to inaccurate orbital data on 5 May 2022.



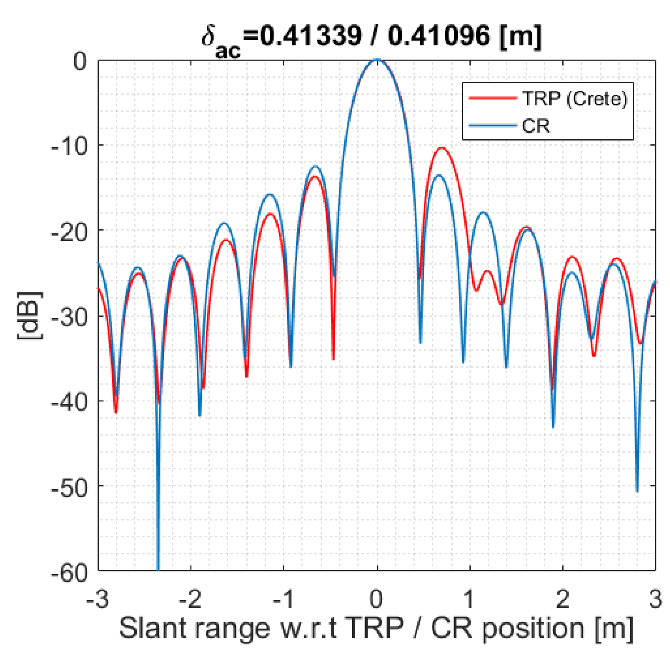
CR vs TRP ANALYSIS

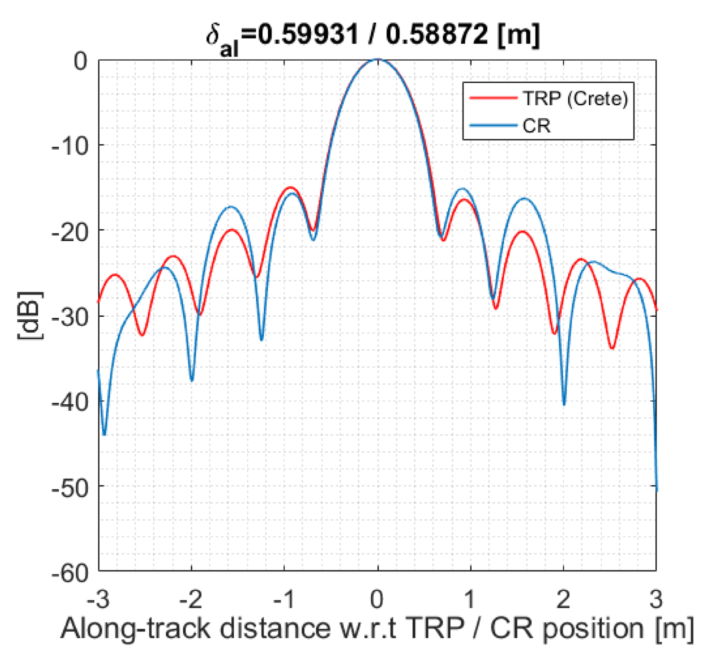
		TRP	CR
Range [cm]	Mean	-0.13	3.23
	Std	1.01	0.95
Datation [μs]	Mean	0.92	-1.51
	Std	6.12	2.25





The **performance achieved is comparable to conventional active transponders** in terms of **range bias, datation bias, stability and signal impulse response**. Regarding along-track resolution, similar values are obtained when processing the CR passes with the maximum integration time available during the TRP passes, 3.4 s.





CONCLUSIONS

- Trihedral corner reflectors can provide key external calibration measurements for periodic radar altimeter performance monitoring.
- Calibration with corner reflector reports comparable performances of the same order of magnitude than Transponder calibration.
- As purely passive devices, corner reflectors are also attractive from the point of view of low cost, on-site operation, and easy maintenance.
- Results from this campaign may have an impact on future strategies, encouraging the use of corner reflectors for radar altimeters external calibration.

References

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