

NISAR: A Test case for ESA's ROSE-L System Calibration

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Abstract

NASA/JPL just launched its latest SAR sensor, NISAR. It is a joint development between the American space agency NASA and the Indian Space Research Organization (ISRO). ISRO is responsible for the S-band SAR instrument, and NASA operates the L-band sensor. The sensor is designed to monitor the Earth globally, detect deformation on land and ice and changes in land cover, with application to sea-level rise, climate modeling, natural hazards, water resources, and food security, among others. Meanwhile, the European Space Agency (ESA) is developing ROSE-L, its first L-band sensor, which is designed to expand its Copernicus program. The first ROSE-L satellite is scheduled to launch in 2028, with a second to follow in 2031. Since NISAR is already launched, there is a unique opportunity to test calibration procedures for the ROSE-L commissioning well before its launch.

1 Introduction

The European Space Agency (ESA) is currently developing an L-band Synthetic Aperture Radar (SAR) sensor called ROSE-L [1] as part of its expansion of the Copernicus program. The first unit (see Figure 1) is expected to launch in 2028, followed by a second unit in 2031. Recently, the National Aeronautics and Space Administration (NASA) and the Indian Space Research Organisation (ISRO) launched their NISAR satellite [2], [3], [4] which also carries an L-band SAR sensor. Both the NISAR and ROSE-L systems face similar challenges, such as digital beamforming and propagation effects in the ionosphere. Therefore, having NISAR as a similar SAR sensor in space provides a unique opportunity to test ROSE-L's calibration procedures, algorithms, and tools well before the launch of ROSE-L.

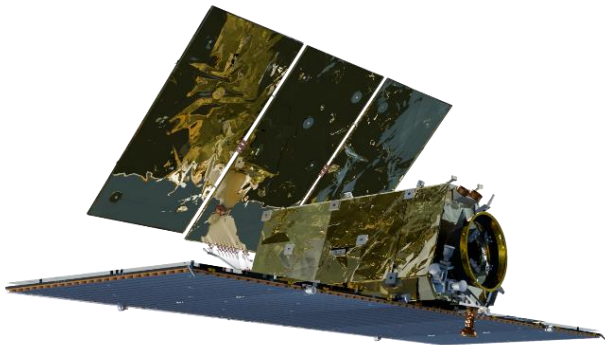


Figure 1: Rendering of the ROSE-L satellite.

2 DLR's role in ROSE-L

The DLR SAR Calibration Center [5] is responsible for the end-to-end SAR system calibration of ROSE-L. This includes developing the overall system calibration concept, defining the calibration tasks and procedures, and developing suitable calibration algorithms and tools.

The DLR uses currently available L-band sensors, such as SAOCOM-1 and ALOS-2, to verify these calibration procedures and algorithms as well as a novel L-/X- dual-band transponder prototype that has been developed and tested for more than two years [5], [6].

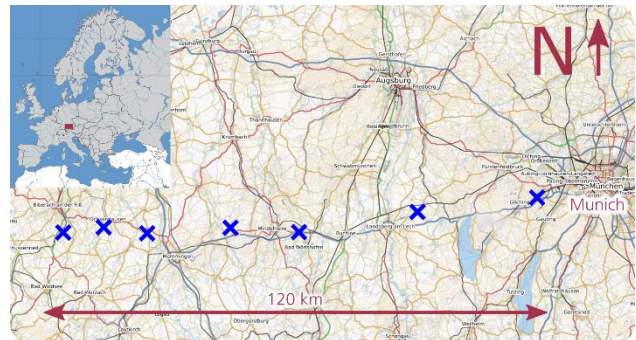


Figure 2: Map of the calibration field used for the ESA's Sentinel-1 missions, which will be extended for ROSE-L.

Like ROSE-L, the newly available NISAR system uses a scanning beam on receive (SCORE or SweepSAR). This allows for realistic testing of ROSE-L calibration algorithms, including the compensation of ionospheric effects present at L-band. As the sun is currently in the maximum phase of its 11-year cycle it causes high perturbations in the ionosphere of the Earth. Solar activity will decrease in the coming years until the launch of ROSE-L. Therefore, current measurements present the worst-case scenario to be expected for the commissioning of ROSE-L.

Furthermore, innovative techniques such as using active transponders to geometrically calibrate a SAR system, can already be tested using NISAR.

3 Calibration of NISAR

The NISAR project has developed its own calibration concept for the commissioning of the system. This includes the deployment of reference corner reflectors near Fairbanks,

Alaska and near Tulsa, Oklahoma, as well as using the existing corner reflectors in the Rosamond dry lake bed in California. This is complemented by the InSAR Scientific Computing Environment 3 (ISCE3), which is responsible for processing the SAR data. ISCE3 contains the necessary algorithms and tools for conducting the calibration of NISAR, including the ability to extract the impulse response function (IRF) of point-like targets, such as corner reflectors. The analysis of NISAR reference targets for the calibration of L1 data is conducted by the NISAR team.



Figure 3: Image of the DLR's novel /L-/X- dual-band transponder prototype.

4 Usage of DLR's reference targets for NISAR

In preparation for the commissioning of ROSE-L, DLR developed a polarimetric active radar calibrator (PARC) to complement the existing 2.8-meter remote-controlled corner reflectors (Figure 2) that had already been used for the calibration of Sentinel-1 [8], [9]. The calibration transponder (Figure 3) has a fully polarimetric design based on individual receive and transmit channels for horizontal and vertical polarization and allowing for the generation of multiple polarimetric signatures during a single satellite overpass [10]. A prototype of this device was deployed at DLR's premises in Oberpfaffenhofen, Germany, in 2023, and has been operational ever since.

The PARC can generate point-like targets with a high radar cross sections (RCS) of 57 or 67 dBm² (Figure 4), which would otherwise require impractically large trihedral corner reflectors. Beyond that, during an overpass, polarimetric antenna pattern measurements can be captured by the transponder's detection unit and recorded on the ground (Figure 6).

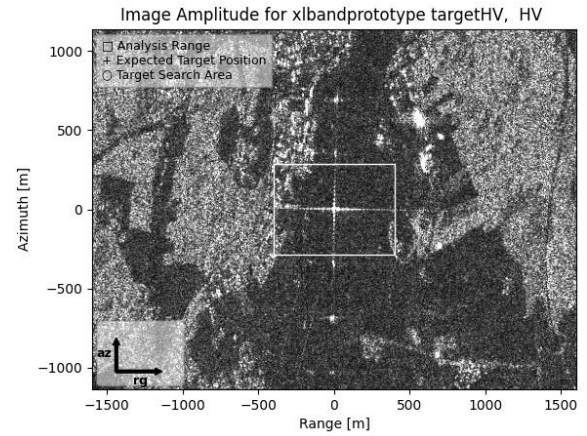


Figure 4: Response of the PARC in a NISAR L-band image showing its bright signature.

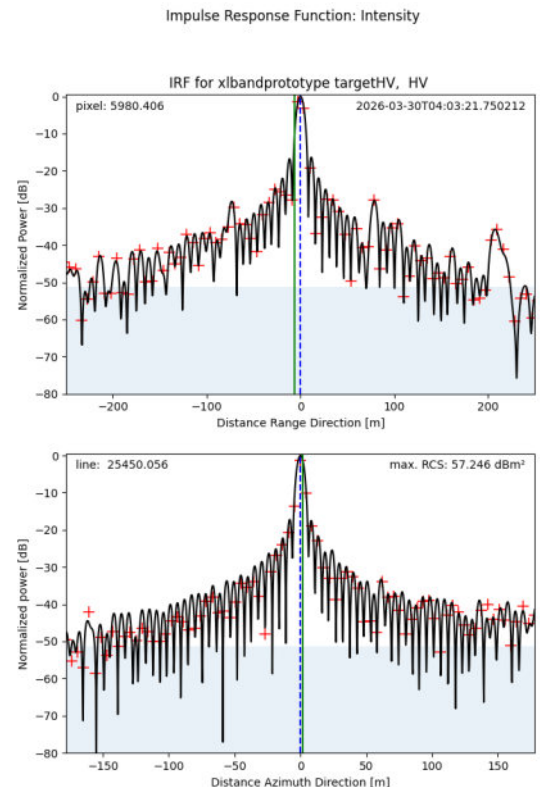


Figure 5: Cut through the impulse response function of the PARC in range (top panel) and azimuth (bottom panel) direction. The red crosses indicate the pixel values of the SAR image, and the black line shows the oversampled signal. The blue area at the bottom indicates the estimated background clutter level. Note that the peaks at ± 70 m in the range direction are caused by the other polarimetric signatures generated by the PARC.

5 Intercomparison

Ideally, all SAR sensors within the same frequency band would be perfectly calibrated with respect to each other, enabling comparable measurements between sensors. This would allow users to benefit from more SAR data, which could be used for scientific analysis. However, achieving this compatibility requires calibrating the SAR sensors using the same standards, such as reference targets, algorithms, and tools. Unfortunately, this is not yet the case. Organizations like the CEOS-WGCV working group for

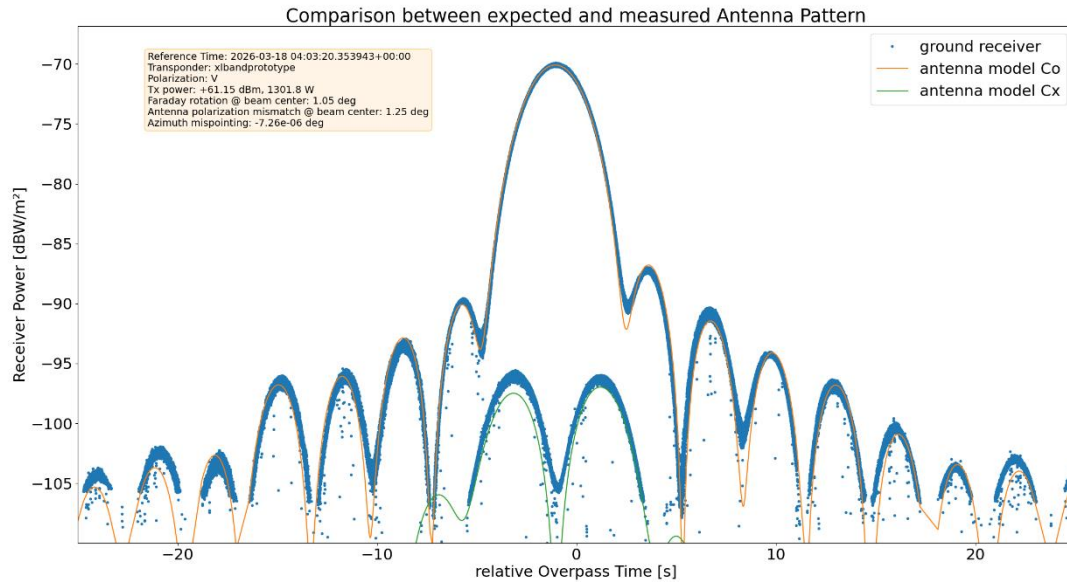


Figure 6: Exemplary NISAR azimuth antenna patterns measured during an overpass by the detection unit of DLR's novel L-/X- dual band transponder and comparison to those derived by the NISAR antenna model.

the “Calibration and Validation of SAR Systems” [11] are working towards achieving intercomparison.

Apart from these efforts, DLR and NASA/JPL took the opportunity to work on NISAR and ROSE-L compatibility. First, the calibration software used by NISAR (ISCE3) and DLR was compared. Several NISAR acquisitions over the Oklahoma and Alaska calibration fields were analyzed using both tools, and the results were compared. While image quality parameters, such as resolution, integrated sidelobe, and peak sidelobe ratio, as well as geolocations, showed nearly identical results, radiometric offsets between the software tools were identified. These corrections, which have either already been applied or are under review, ensure the proper handling of NISAR's squinted acquisition geometry and the accurate derivation of the RCS from image products.

After ensuring that both calibration softwares produced the same results, one-way data, specifically the transmitted pulses from the SAR sensor were analyzed using DLR's PARC ground receiver feature. Both individual, full-resolution sampled pulses (not shown) and the overall azimuth antenna gain pattern (see Figure 6) were verified. The antenna pattern could be compared over a timespan of more than 50 seconds and a dynamic range of >35 dB from the boresight gain. This allows even for the verification of the

cross-polar antenna pattern, as shown in , which considers effects such as Faraday rotation and polarization alignment between the antenna coordinate system and the ground.

Finally, the impulse response functions of the DLR reference targets (PARC and 2.8 m remote-controlled corner reflectors) were analyzed in the NISAR L1b products (Figure 5).

6 Summary

DLR's analyses of the NISAR system shows its excellent performance. Cross-validation of the results between the teams identified a few issues related to radiometric offsets that have been or will be resolved.

ROSE-L will benefit tremendously from this, as potential issues that could affect the upcoming mission have already been identified and resolved. Cross-comparison of the calibration software tools and reference target is a major step toward cross-calibration between the already-launched NISAR and the upcoming ROSE-L system.

This cross-comparison could serve as a blueprint for comparing other similar SAR missions and significantly advance the development of compatible SAR products across different SAR missions.

7 Literature

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