Absolute Radiometric Calibration of C-Band Transponders with Proven Plausibility

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Abstract

The progressive development of upcoming satellite missions using synthetic aperture radar (SAR) lead to novel challenges also for the reference targets. In order to provide a reference target for an accurate absolute radiometric calibration the knowledge of the backscattering characteristics is essential. Whereas usually one single measurement is used for the estimation of the radar cross section (RCS), this paper presents two conducted, independent methods to derive the RCS of three C-band transponder leading to cross-validated results based on a compatibility analysis.

1 Introduction

The DLR recently finished the development of three C-band transponders [1] for the upcoming Sentinel-1 calibration campaign [2]. The satellite has been designed to contribute to the Global Monitoring for Environment and Security (GMES) programme by imaging of global landmasses, coastal zones, sea ice and further parameters with high geometric resolution and radiometric accuracy [3].

In order to meet the requirements for absolute radiometric calibration of a satellite, the knowledge about the backscattering characteristics of the reference target is essential. This is usually estimated with one single measurement method. After an uncertainty analysis the question remains, if hidden systematic errors are still undetected. Therefore it would be reasonable to use a second measurement method and its results to conduct a cross validation to achieve a plausible absolute radiometric calibration of the target as it is shown in Fig. 1.

Here, for the first time, two independent absolute transponder calibration campaigns are conducted leading to cross-validated results based on a compatibility analysis (detailed comparison of uncertainty intervals). The first measurement campaign was recently completed and first results are shown in the following section. The second method will be carried out on February 2014 and is described in Sec. 3 by referring to a former calibration campaign.

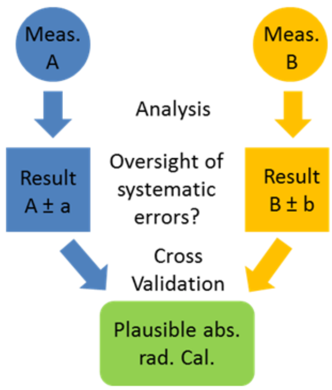

Figure 1: Schematic illustration of the need of two independent measurements to achieve plausible absolute radiometric calibration of the reference target.

2 Transponder Calibration with DLR's Compact Test Range

The DLR operates a compact antenna measurement range, which allows accurate antenna and RCS measurements of large structures [4]. This facility with a frequency range from less than 1 GHz up to 100 GHz was chosen for the first calibration campaign of the three C-band transponders.

2.1 The Measurement Setup

The measurement goal was to derive an accurate estimate of the RCS of the transponder with a corresponding uncertainty statement. For this purpose a measurement campaign was carried out in Oct. 2013. Besides the three C-band transponders, several passive reference targets (two circular plates and two trihedral corners) were measured. These targets were mounted on a 2.5 m arm on the positioner shown in Fig. 2. The RCS was measured over a limited observation angle and at frequencies between 4 and 8 GHz with an iteration step of 1 MHz, which allows filtering the disturbing response of the positioner in the time domain.

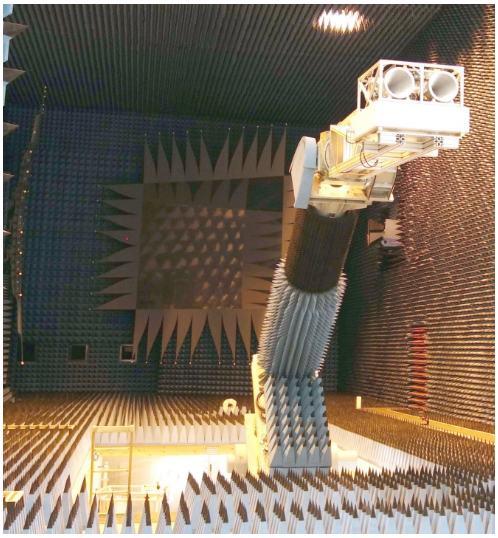

Figure 2: Photograph of the Compact Test Range with the transponder mounted on the 6-axis tower in the front and the two range reflectors in the background.

2.2 Reference Targets

Four different objects (two circular plates and corner reflectors) with an accurate manufacturing precision were used as reference targets. Table 1 shows the list of all objects with their geometric size and the calculated theoretical peak RCS. These values are estimated by the following two formulas [5].

$$\sigma_{CP} = 4\pi^3 \frac{r^4}{\lambda^2}$$
$$\sigma_{CR} = \frac{4}{3}\pi \frac{a^4}{\lambda^2} \tag{1}$$

Here, r is the radius of the circular plate, a the inner edge length of the corner and λ the wavelength.

Target	Theor. RCS
Circ. Plate, r = 0.6 m	37.1 dBm^2
Circ. Plate, r = 0.5 m	34.0 dBm^2
Corner refl., a = 0.71 m	25.3 dBm^2
Corner refl., a = 0.85 m	28.5 dBm^2

Table 1: Overview of all reference targets and their calculated theoretical peak RCS at 5.405 GHz. The transponders are designed to have a RCS in the order of 60 dBm^2.

2.3 Evaluation of the RCS

Due to the recent completion of the campaign, only preliminary results are available for this abstract. A more detailed analysis will be given in the final paper. For a first estimation the 1.2 m circular plate was chosen as reference target. The derivation of the transponder RCS σ_{TR} after the subtraction of the background is done according to the proportionality (2).

$$\sigma_{TR} = \frac{P_{TR}}{P_{Ref}} \sigma_{Ref} \tag{2}$$

The factors, P_{CR} and P_{Ref}, are the respective maximum power and the value of σ_{Ref} relating to Tab. 1 is 37.1 dBm^2. First estimations of the measured transponder RCS lead to values about 61.5 dBm^2 at 5.405 GHz (goal: more than 60 dBm^2). Furthermore from the measurements of the second circular plate (1 m diameter) a RCS of about 33.9 dBm^2 could be derived. Compared to the theoretical RCS according to Tab. 1 the difference is merely in the range of 0.1 dB, which could be seen as a first indication for a precise measurement execution.

The next step will be a full analysis of all measurements and the complete bandwidth to derive one accurate RCS estimate for each transponder. In addition the evaluation of the other reference targets shall proof the plausibility of these results. Finally an uncertainty statement shall be derived for each measured RCS. These results will be presented in the final paper.

3 Transponder Calibration with RADARSAT-2 Acquisitions

As a second, independent RCS measurement approach, the transponders shall be measured by RADARSAT-2, a SAR system in orbit with similar system parameters in comparison to Sentinel-1. The radiometric reference is provided by several corner reflectors, which are also placed within the imaged scene. This approach was already successfully demonstrated in April 2013, although with a transponder prototype [6]. Based on the experience, the following setup is foreseen for the calibration of the three manufactured transponders in February 2014.

3.1 The Planned Measurement Setup

In the last campaign an amount of 8 overpasses was used to derive the RCS of the prototype. As reference targets two different sized corner reflectors were aligned together with the transponder for each upcoming overpass. The alignment of the reflectors in elevation and azimuth was carried out manually with an inclinometer and a compass. The results of this campaign figured out that a wisely chosen number of reference targets and overpasses was necessary to reduce the uncertainty by averaging. Therefore it is planned to perform the upcoming campaign under similar conditions.

3.2 Evaluation of the RCS

For the analysis and estimation of the RCS of the prototype the corner reflector with an inner edge length of 1.5 m was chosen as reference target. All in all an amount of nine targets was used for this purpose. Figure 3 illustrates one single look image product of RADARSAT-2, kindly provided by MDA Systems Ltd., containing all ten impulse responses of the different targets.

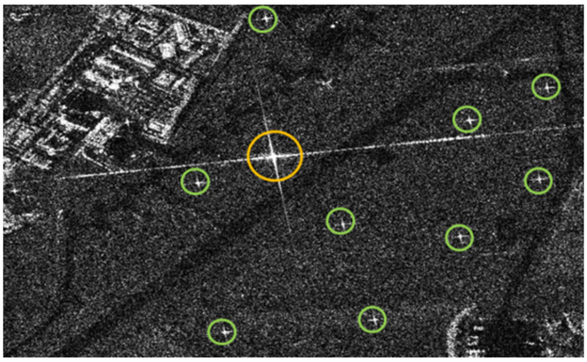

Figure 3: Demo campaign example of a single look image with the relevant targets situated around the DLR site at Oberpfaffenhofen. The transponder impulse response is marked with an orange and the responses of the corner reflectors with green circles. Further six CRs are placed outside the visible area.

The derivation of the transponder RCS will be in this case also achieved through comparison, see equation (2). Analogue to the method described before the values P_{TR} and P_{Ref} are the intensities of the respective point targets exploited from the processed SAR image with an integral method. Due to the sufficient number of overpasses and reference targets it will be possible to compensate and reduce almost all drifts and variations. The remaining dominating uncertainty of the RCS will be caused by the knowledge of the RCS of the reference targets. Nevertheless, hand in hand with the evaluation of the transponder RCS an analysis of the uncertainty statement will be performed.

4 Cross-Validation

The results of the cross-validation of both independent measurement campaigns will also be shown in the final paper.

5 Conclusions

In this paper two different methods of estimating the accurate value of the RCS of three C-band transponders are presented. The first results of the measurements in the compact test range are shown and further analysis of the complete data will lead to an accurate RCS value with an associated uncertainty statement. Furthermore the second method, here explained on the basis of a former calibration campaign, and the corresponding evaluation will be presented in the final paper. Finally an analysis will be carried out for a cross-validation of both results by a detailed comparison of the estimated uncertainty intervals with the goal to derive a plausible absolute radiometric calibration for the transponder.

References

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