Definition of the Calibration Terminology based upon the Tandem-L Mission

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Scope

DLR’s Tandem-L Mission

Constraints

• Verifiable

References

TerraSAR-X / TanDEM-X (TX-IOCS-TN-RB-4307)
Sentinel-1 SRD (S1-RS-ESA-SY-0001)
RadarSAT-2 (RN-SP-52-1238)
KompSAT (KARI-DLR-RP-2000)
CoReH2O (CRH.DLR.TN.00001)
BIOMASS SRD (BIO-RS-ESA-SY-0011)
Standard for Definitions of Terms for Antennas (IEEE 145-2013)
Recommended Terminology for Microwave Radiometry (NIST TN 1551)
Radiometric Accuracy

Are these numbers correct?

How correct are these numbers?

How are these numbers defined?
Naming Convention

Verification

Definition

Specification → Requirements
I. ABSOLUTE RADIOMETRIC ACCURACY
Currently used Definition

For a distributed target, the absolute radiometric accuracy is defined as the 1-sigma uncertainty resulting from measurement of $\sigma^0$ of an uniform invariant distributed target situated anywhere in the operating dynamic range of the system, anywhere in the swath and anywhere in the orbit assuming that the standard deviation of the estimate of $\sigma^0$ associated with each measurement is zero (ignoring speckle).

For a point target, the absolute radiometric accuracy is defined as the 1-sigma uncertainty resulting from measurement of the radar cross section. The point target may be located anywhere within the swath at any point within the orbit.
Concern: Two Definitions

For a distributed target, the absolute radiometric accuracy is defined as the 1-sigma uncertainty resulting from measurement of $\sigma^0$ of an uniform invariant distributed target situated anywhere in the operating dynamic range of the system, anywhere in the swath and anywhere in the orbit assuming that the uncertainty resulting from measurement of the radar cross section. The point target may be located anywhere within the swath at any point within the orbit.

Issue: two definitions for same matter

Solution: use a common definition
The absolute radiometric accuracy is defined as the 1-sigma uncertainty resulting from measurement of the radar cross section or backscattering coefficient of an target situated anywhere in the operating dynamic range of the system, anywhere in the swath and anywhere in the orbit assuming that the standard deviation of the estimate of $\sigma^0$ associated with each measurement is zero (ignoring speckle).
Concern: Condition not verifiable

The absolute radiometric accuracy is defined as the 1-sigma uncertainty resulting from measurement of the radar cross section or backscattering coefficient of an target situated anywhere in the operating dynamic range of the system, anywhere in the swath and anywhere in the orbit assuming that the standard deviation of the estimate of $\sigma^0$ associated with each measurement is zero (ignoring speckle).

**Issue:** speckle never zero

**Solution:** speckle out of definition -> calibration budget
Clarification: Remove speckle requirement

The absolute radiometric accuracy is defined as the 1-sigma uncertainty resulting from measurement of the radar cross section or backscattering coefficient of an target situated anywhere in the operating dynamic range of the system, anywhere in the swath and anywhere in the orbit.
Concern: Noise not considered

The absolute radiometric accuracy is defined as the 1-sigma uncertainty resulting from measurement of the radar cross section or backscattering coefficient of a target situated anywhere in the operating dynamic range of the system, anywhere in the swath and anywhere in the orbit.

**Issue:** noise is always present

**Solution:** noise needs to be negligible
Clarification: Add noise requirement

The absolute radiometric accuracy is defined as the 1-sigma uncertainty resulting from measurement of the radar cross section or backscattering coefficient of an target situated anywhere in the operating dynamic range of the system. The target may be located anywhere within the swath, at any point within the orbit and has to be of such magnitude that the receiver noise is insignificant.
Concern: Dynamic Range

The absolute radiometric accuracy is defined as the 1-sigma uncertainty resulting from measurement of the radar cross section or backscattering coefficient of an target situated anywhere in the operating dynamic range of the system. The target may be located anywhere within the swath, at any point.

Issue: requirement cannot be verify near the noise floor

Solution: two sections: 1. definition, 2. verification consider more than just dynamic range
Clarification: Separate definition and verification section

Definition
The absolute radiometric accuracy is defined as the 1-sigma uncertainty resulting from measurement of targets with known radar cross section or backscattering coefficient with the instrument working in its specified operational conditions. The target may be located anywhere within the swath, at any point within the orbit and has to be of such magnitude that the receiver noise is insignificant.

Verification
The absolute radiometric accuracy is to be verified using one or a series of calibration targets with known absolute RCS. The absolute radiometric accuracy shall be verified at least at one point within the dynamic range of the SAR instrument. Point targets must provide a signal to clutter ratio sufficient to allow the verification of the absolute radiometric accuracy requirement.
II. RADIOMETRIC STABILITY
Relative Radiometric Accuracy

Defined to prevent visible artefacts

-> Antenna pattern knowledge

Problem

Within which image size is the requirement applicable?

Scene lengths > half an orbit in modern SAR systems like Sentinel-1

-> requirement needs re-design

Image: Larson-C, Antarctica
Relative radiometric accuracy can be translated into a stability requirement.

<table>
<thead>
<tr>
<th>Stability</th>
<th>Relative Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>fast time</td>
<td>across range lines</td>
</tr>
<tr>
<td>slow time</td>
<td>across a synthetic aperture</td>
</tr>
<tr>
<td>short time</td>
<td>within a scene</td>
</tr>
<tr>
<td>intra orbit</td>
<td>within one orbit</td>
</tr>
<tr>
<td>intra repeat cycle</td>
<td>within on repeat cycle</td>
</tr>
<tr>
<td>seasonal</td>
<td>sun dependent changes</td>
</tr>
<tr>
<td>long term</td>
<td>between calibration campaigns (e.g. aging)</td>
</tr>
</tbody>
</table>

Definition is more flexible!
Radiometric Stability

**Definition**

The **standard deviation of repeated** radar cross section or backscatter coefficient measurements of one or a series of **targets** located on the Earth’s surface and acquired within the specified operational conditions, **sufficiently sampled** over a given **time span T** is called **Radiometric Stability** over T. The time span T is sufficiently sampled if all **characteristic variations over T** are **captured**.

**Verification**

The **Radiometric Stability** is to be verified using **one or a series of calibration targets** considering their **variability and stability**. The radiometric stability shall only be verified at **one point** within the **dynamic range** of the SAR instrument which is of such magnitude that the **receiver noise** is insignificant. The **variability** is defined for **point targets** as the difference of RCS between several targets and for **isotropic distributed targets** as the **spatial homogeneity** of backscatter.
Conclusions

In the Scope of Tandem-L

- examined currently used definitions
- *absolute radiometric accuracy* was revised and consolidated
- *relative radiometric accuracy* discarded in favor of *radiometric stability*

Consolidated definitions are freely available at

Absolute Radiometric Accuracy

**Definition**
The absolute radiometric accuracy is defined as the 1-sigma deviation resulting from measurements of targets with known radar cross section or backscattering coefficient with the instrument working in its specified operational conditions. The target may be located anywhere within the swath, at any point within the orbit and has to be of such magnitude that the receiver noise is insignificant.

**Verification**
The absolute radiometric accuracy is to be verified using one or a series of calibration targets with known absolute RCS. The absolute radiometric accuracy shall be verified at least at one point within the dynamic range of the SAR instrument. Point targets must provide a signal to clutter ratio sufficient to allow the verification of the absolute radiometric accuracy requirement.
Radiometric Stability

Definition
The standard deviation of repeated radar cross section or backscatter coefficient measurements of one or a series of targets located on the Earth’s surface and acquired within the specified operational conditions, sufficiently sampled over a given time span T is called Radiometric Stability over T. The time span T is sufficiently sampled if all characteristic variations over T are captured.

Verification
The Radiometric Stability is to be verified using one or a series of calibration targets considering their variability and stability. The radiometric stability shall only be verified at one point within the dynamic range of the SAR instrument which is of such magnitude that the receiver noise is insignificant. The variability is defined for point targets as the difference of RCS between several targets and for isotropic distributed targets as the spatial homogeneity of backscatter.