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Space systems — Calibration requirements for satellite-based passive microwave sensors

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Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

Water is one of the key elements for survival of all creatures on earth. Water brings us the blessings of food thanks to agriculture, but water is also responsible for providing forest products and fish, which are essential for our lives. However, too much or too little water can lead to environmental disasters such as hurricanes, heavy rains, floods, droughts and wild fires.

Many satellite sensors are launched through international cooperation ventures with the aim of monitoring the behaviour of the water cycle and estimating some of the parameters related to it, e.g. soil moisture, vegetation biomass, snow cover, sea ice, and so on. A systematic and timely monitoring of land surface parameters that affect the hydrological cycle at local and global scales are of primary importance in obtaining a better understanding of geophysical processes and in order to manage environmental resources and mitigate for natural disasters.

At present, some applications to assist our human activities are provided, such as weather forecasts and predictions of climate change. Nowadays, the observation data acquired by passive microwave sensors are used for weather forecasts, fishery services, drought monitoring on a daily basis, and for predicting climate change in the future. However, errors due to bias, gain, and sensitivity among passive microwave sensors can degrade accuracy of applications and users could waste effort and time for compensation by on-orbit operation.

This document standardizes calibration methods (requirements and verification methods) to minimize errors of observation data among passive microwave sensors. It is expected that this document can improve the accuracy of weather forecasts, sea surface temperatures for fishery services, soil moisture monitoring to decrease water waste for farmers, snow cover and depth for water storage. Moreover, these observations can provide useful information for climate change prediction that is relevant to our daily lives.

Space systems — Calibration requirements for satellite-based passive microwave sensors

1 Scope

This document defines the requirements and verification methods from design to on-orbit operation for Satellite Based Passive Microwave Sensors.

This document covers the requirements for, design, analysis, manufacturing, ground tests and on-orbit self-sensor calibration and validation. In addition, this document includes the conditions considered for on-orbit inter-comparison among sensors as preparation for cross-calibration. This document includes some examples on how to apply the development of passive microwave sensors as shown in Annex A through D.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10795:2011, *Space systems — Programme management and quality — Vocabulary*

ISO 14302, *Space systems — Electromagnetic compatibility requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10795:2011 and the following apply. ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
calibration
set of operations that establish, under specified conditions, the relationship between sets of values of quantities indicated by a measuring instrument or measuring system and the corresponding values realized by standards

3.2
validation
process of assessing by independent means the quality of the data products derived from the system outputs

3.3
level one processing
type of processing where the antenna brightness temperature of the sensor instrument is calculated and compensated radiometrically and geometrically based on evaluation results of ground test and on-orbit calibration

4 Abbreviated terms

ANT	Antenna sub-system
BTE	Bench Test Equipment
CCT	Cold Calibration Target
DT	Data Processor
EIA	Earth Incident Angle
FOV	Field Of View
GCP	Ground Control Point
GPS	Global Positioning System
ICS	Interface Control Specification
IF	Intermediate Frequency
LO	Local Oscillator
LCT	Low Calibration Target
MR	Main Reflector
NCS	Noise Calibration Source
RE	Radiated Emission
RF	Radio Frequency
RS	Radiated Susceptibility
RTT	Radiative Transfer Theory
Rx	Receiver
SRT	Standard Reference Target
VTS	Variable Temperature Source
WCT	Warm Calibration Target

5 Space based passive microwave sensor calibration overview

5.1 Mission and system overview

Satellite based passive microwave sensors observe weak microwave energy emitted from various components of the Earth's surface (rain, water vapour, clouds, snow, sea ice, soil, vegetation, etc.) using a variety of frequency bands from about 1 GHz to 200 GHz.

Each space-based passive microwave sensor design is tailored to meet its specific observation purpose. Observation data are collected at defined intervals and over defined integration periods. These data are downlinked through the spacecraft. Following Level One processing to perform radiometric and geometric compensation, the data are delivered to information providers.

Figure 1 shows the general operational concept view of space-based passive microwave sensor system integration. Space-based passive microwave sensors, to which this document applies, include the following components:

a) Cold Calibration Target (CCT) to determine deep-space limit or equivalent;

b) Warm Calibration Target (WCT) to monitor ambient temperature;

c) Main Reflector (MR) to capture the power of microwave emission from the earth; and

d) Receiver (Rx) sub-system to amplify the tiny power of the microwave emission.

Self-calibration is performed at specific time intervals using the WCT and the CCT.

Information providers process antenna brightness temperature to derive physical information and deliver that information to end users.

5.2 Types of passive microwave sensors

Satellite based passive microwave sensors are generally categorized as follows. This document covers the requirements for the following two types.

a) Microwave radiometer (or Microwave Imager)

   To mainly measure energy emitted from water related substances at sub-millimetre-to-centimetre wavelengths.

b) Microwave sounder

   To mainly measure the vertical profile of atmospheric temperature and moisture for operational weather and climate applications at sub-millimetre-to-centimetre wavelengths.

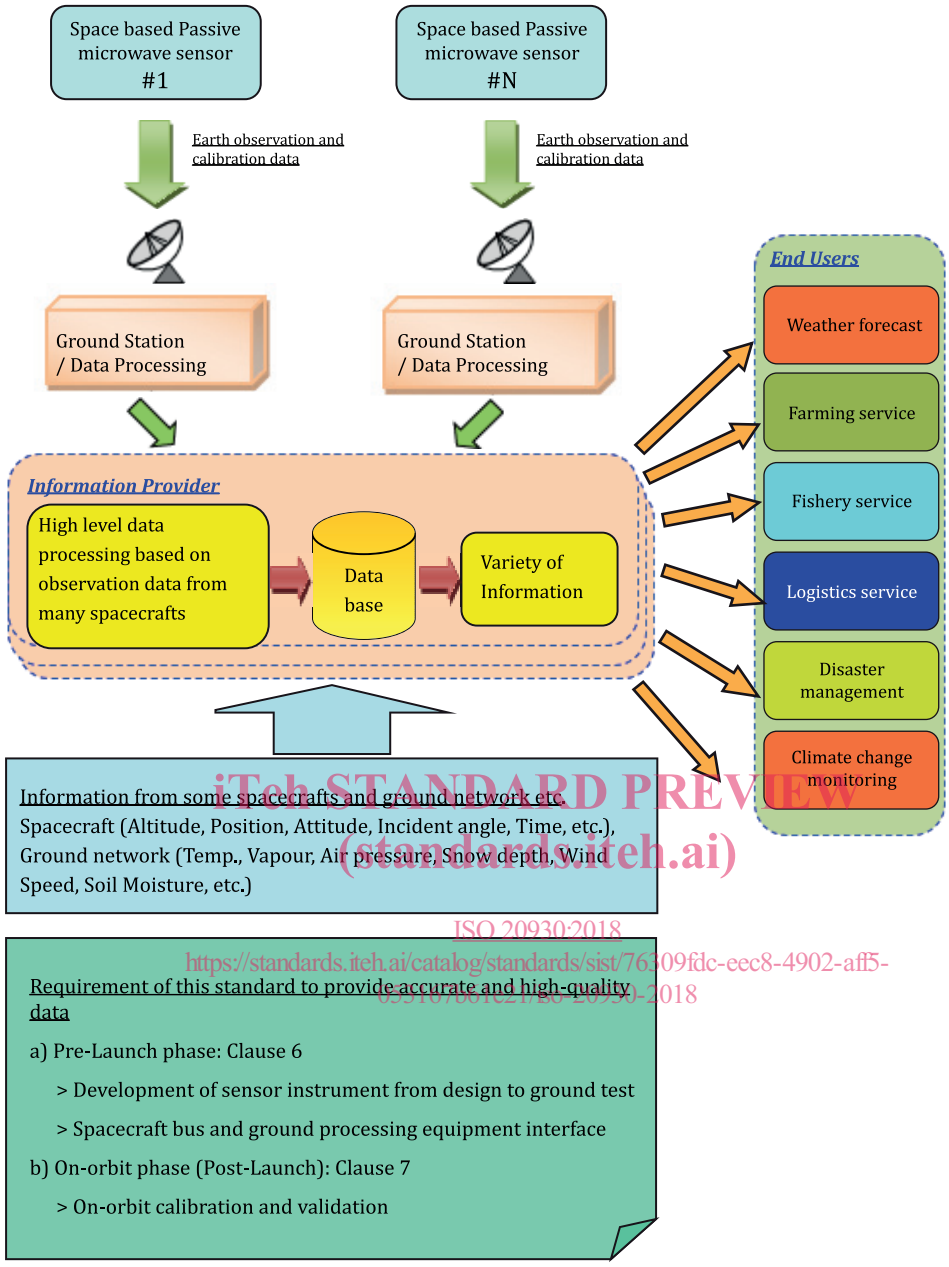

Figure 1 — Concept diagram of space based passive microwave sensor system

5.3 Concept of calibration and scope

Satellite based passive microwave sensors receive weak microwave emission from the earth. Errors among the sensors would cause or degradation of observation data quality (e.g. 0,1 K or around for sea surface temperature of climate change monitoring).

Therefore, it is necessary to understand the sensor characteristics in both pre-launch phase (design, manufacturing and ground test before launch campaign) and on-orbit phase (On-orbit activity for calibration).

This document covers not only requirements for the sensor itself but also those for the spacecraft bus and ground system because interfaces between the spacecraft bus and the ground system affect sensor performance.

Figure 2 shows the concept of calibration process and scope of this document.

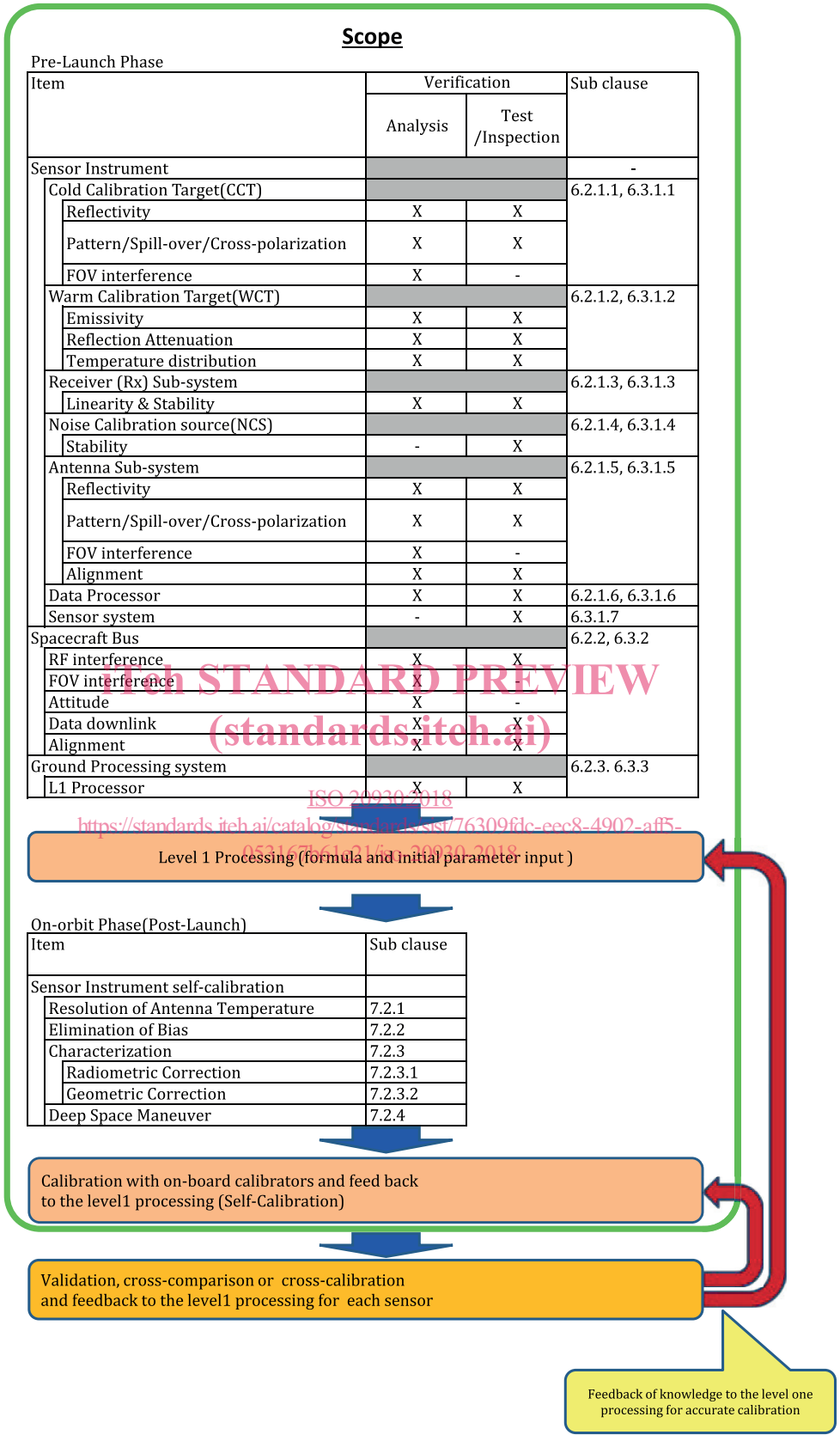

Figure 2 — Concept of calibration process

6 Requirements for pre-launch phase

6.1 General

Before the launch campaign, the characteristics of sensor instruments shall be precisely specified and verified, and those characteristics should be registered in the ground processing system. This sub clause explains the requirements for designing, manufacturing and ground testing. The formula and their parameters prepared through the ground test and/or analysis shall be submitted to the ground processing system for accurate calibration and observation of data processing.

6.2 Requirements for design and manufacturing

This sub clause defines the requirements for the sensor instrument, the spacecraft bus and the ground systems.

To satisfy the on-orbit performance, the following requirements shall be considered through design, manufacturing and ground test phase.

6.2.1 Requirements for sensor instrument

The requirements for the sensor instrument, especially for the following equipment, are described in this sub clause:

a) Cold Calibration Target (CCT);

b) Warm Calibration Target (WCT);

c) Receiver (Rx) sub-system;

d) Noise Calibration Source (NCS);

e) Antenna sub-system (ANT); and

f) Data Processor (DP).

Engineering formulas and parameters obtained during the development stage shall be submitted to the ground processing system.

6.2.1.1 Cold Calibration Target (CCT)

The design of the Cold Calibration Target (CCT) shall meet the following requirements.

a) The CCT shall be designed (modelled or measured, or both) to meet the following:

   i) reflectivity of the CCT shall be specified; and

   ii) normal-incidence power reflection coefficient (Γ) shall be specified and included in the uncertainty calculation for the antenna brightness temperature (Tb).

b) At the position of beam centre of the Rx front-end antenna corresponding to that of the CCT, an analysis or measurement (or both) shall be conducted to obtain the distribution pattern of antenna spill-over and its weighting parameters in order to accurately calculate the antenna brightness temperature for CCT.

c) The specification of the CCT shall include either measuring or modelling the entire antenna power pattern to tune the instrument performance precisely on-orbit.

d) For precise calibration, analysis, or measurement, or both shall be made to obtain data of emissivity and antenna temperature of the interfered structure (or obstruction) out of –3 dB bore sight of the CCT, and engineering formula and parameters based on the above data shall be prepared.