TWO Microwave Imaging radiometers for MetOp Second Generation

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Abstract— **Metop Second Generation (MetOp-SG) is a mission that will ensure the delivery of continuous, high-quality global meteorological data starting from 2020 onwards, providing weather data services for monitoring the climate and improving weather forecasts. The program is a continuation of current EUMETSAT Polar System (EPS), and is jointly funded by the EUMETSAT and ESA. MetOp-SG forms the space segment of EPS. In the framework of the Phase A study for MetOp Second Generation mission (MetOp-SG), CORISTA developed an instrument performance model for a Microwave Imaging Radiometer (MWI) and Ice Cloud Imaging radiometer (ICI)). The corresponding algorithms for the analysis of the performances of these two instruments have been implemented by means of dedicated software. Analysis tool was developed for instrument channels performances analysis as well as overall system performance parameters. The software tool was developed in MatLab language.**

Keywords: microwave, conical scanning radiometer, submillimeter radiometer, MetOp-SG

I. Introduction

The MetOp-Second Generation (MetOp-SG) encompass the objective of obtaining consistent, long-term collection of remotely sensed data of uniform quality for operational services for Meteorological and Climate monitoring state analysis, forecasting and operational service provision, in the context of the EUMETSAT's EPS-Second Generation (EPS-SG) system.

On MetOp-SG two conical scanning imaging radiometers will be dedicated to the weather forecast and climate monitoring: Microwave Imaging Radiometer (MWI) and Ice Cloud Imaging radiometer (ICI)) MWI is a multi-spectral microwave imager, working in a spectral bands ranging between 18 and 183 GHz, which observes precipitation content (liquid and frozen; total column and gross profile), total column water vapor and atmospheric water vapor ICI is a submillimeter microwave imager, working in a spectral bands ranging between 183 and 664 GHz, which gives water vapor profile, cloud ice water path retrieval, ice and cirrus clouds.

The radiometer measurement data are also useful for the determination of surface emissivity and soil moisture over land, for surface energy budget investigations to support atmospheric and hydrologic studies and for ice surfaces.

During the Phase 0 the instruments concept of these instruments has been developed. In these framework, Corista developed an instrument performance model in matlab language in the frame of MetOp-SG.

II. MWI/ICI Instrument

MWI is a conical scan passive radiometric imager. The MWI instrument will rotates continuously about an axis parallel to the local spacecraft vertical with an active portion of the scan of ~±65 deg centred on the fore (or afterward) direction of the spacecraft and the antenna system will view the Earth scene with a nearly constant incidence angle of about 53 deg. A mechanical layout of the MWI instrument is presented in Figure 1.

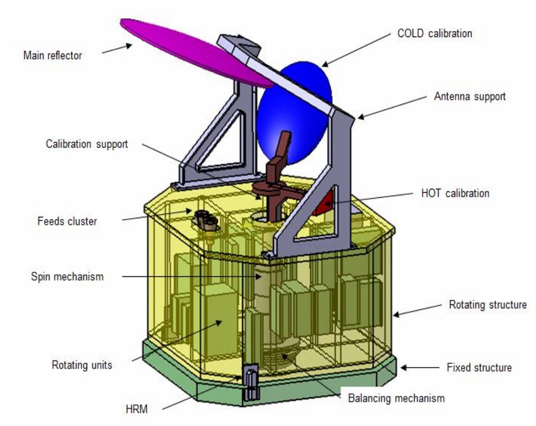

Figure 1. Mechanical layout of MWI radiometer

A fixed rod through the scan assembly emerges above the rotating drum upper plane providing off axis mechanical support in a fixed position for the two calibration targets that consist in a small reflector and a hot blackbody load, which once per rotation illuminates the feed horns obscuring them from the view of main reflector. The calibration targets, Cold Calibration Reflector (CCR) and Hot Load (HL), are accommodated in such a way that the CCR is constantly pointing to the deep space in the opposite side of Sun direction. The structural design and the adopted materials of the rotating assembly shall be such to optimize the stiffness to mass ratio and minimize the in orbit mechanical and thermal distortions MWI includes 28 channels as summarized in the TABLE I.

TABLE I. MWI CHANNELS

Channel	*Centre Frequency [GHz]*
MWI-5	18.7
MWI-6	23.8
MWI-7	31.4
MWI-8	50.3
MWI-9	52.6
MWI-10	53.2
MWI-11	53.8
MWI-12	89
MWI-13	100.49
MWI-14	118.7503±4.0
MWI-15	118.7503±2.1
MWI-16	118.7503±1.4
MWI-17	118.7503±1.2
MWI-18	166.9
MWI-19	183.31±8.4
MWI-20	183.31±6.1
MWI-21	183.31±4.9
MWI-22	183.31±3.4
MWI-23	183.31±2.0

ICI will fly on a spacecraft in a near circular sun-synchronous, near polar orbit. In order to acquire measurements on a wide swath the instrument will rotates continuously about an axis parallel to the local spacecraft vertical with an active portion of the scan of ~±65 deg centred on the foreword direction of the spacecraft and the antenna system will view the Earth scene with a nearly constant incidence angle of about 53 deg.

From a mechanical point of view the instrument configuration is given by a fixed part and a rotating part.

While the rotating part has to be external to the platform the fixed one could be accommodated either internally or externally to the platform.

The advantage of having the fixed part placed inside the P/F is the reduction of instrument envelope that makes easier to manage the ICI payload accommodation.

The moving part is rotated about the axis of the instrument by a coaxially mounted motor and it includes the reflector and feed horns that are mounted on a "drum" which contains the receivers, a digital processing unit and a power supply unit.

The analyses performed indicated that there is no need for an antenna deployment mechanism because of small size of the instrument. A mechanical layout of the MWI instrument is presented in A mechanical layout of the MWI instrument is presented in Figure 2.

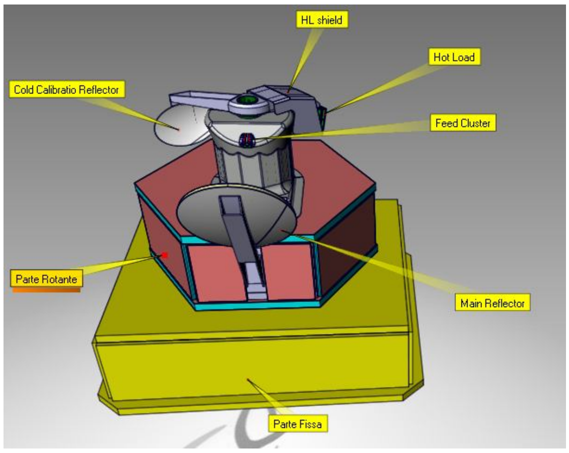

Figure 2. Mechanical layout of ICI radiometer

ICI includes 28 channels as summarized in TABLE II.

TABLE II. ICI CHANNELS

Channels	*Centre Frequency [GHz]*
ICI-19	183.31±8.4
ICI-21	183.31±4.9
ICI-23	183.31±2.0
ICI-24 a	243.2±2.5
ICI-24 b	243.2±2.5
ICI-25	325.15±9.5
ICI-26	325.15±3.5
ICI-27	325.15±1.5
ICI-29	448±7.2
ICI-30	448±3.0
ICI-31	448±1.4
ICI-32 a	664±4.2
ICI-32 b	664±4.2

III. PERFORMANCE MODEL

The parameters which characterize the performances of a conical scan imaging radiometer are geometrical and radiometric parameters.

Starting from input parameters which identify the radiometer configuration, the software calculates the MWI main performance parameters. These include total instrument sensitivity (NEDT), accuracy and geometric figures.

The software can evaluate the performance of an instrument having up to 45 channels. It is possible to distinguish between imaging and sounding channels. Both the two points and the four points calibration of the instrument can be deeply investigated. Also the mismatch and the nonlinear behavior of the receiver have been taken into account.

Some parameters can be changed in real time allowing an on line trade off analysis. A schematic block of the performance model is shown in Figure 1

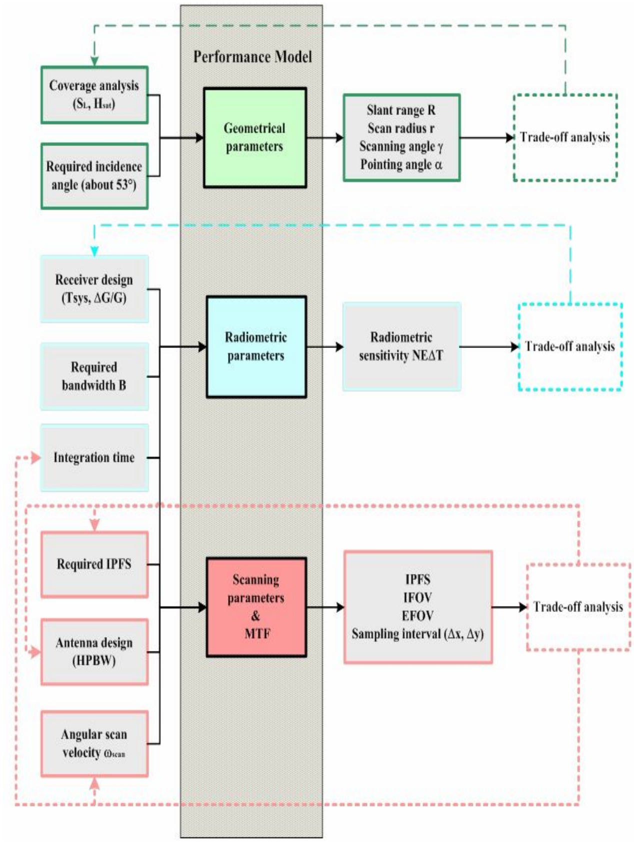

Figure 1 Schematic block of performance model

A. Radiometric sensitivity evaluation

The radiometric sensitivity is evaluated by distinguishing two different contributions:

- σ^{sens}: calculation with the assumptions that calibration measurements are ideal and that calibration path parameters are known without any random errors (infinite precision). This corresponds to consider antenna temperature depending only on antenna measurement

$$T_A = f(C_A) \tag{1}$$

where C_A is the antenna count.

- σ_{cal}: calculation with the assumptions that antenna measurement is ideal and that calibration path parameters are known without any random errors (infinite precision). This corresponds to consider antenna temperature depending only on calibration measurements:

$$T_A = f(C_h, C_c, C_{hn}, C_{cn}) \tag{2}$$

where C_h is the hot load count and C_c is the cold reflector count (C_{hn} and C_{cn} are respectively the hot load and cold reflector counts with contribution of noise diode used for the four points calibration).

Therefore the total sensitivity can be written as

$$\sigma = \sqrt{\left(\sigma^{sens}\right)^2 + \left(\sigma^{cal}\right)^2} \qquad (3)$$

using RSS for the evaluation of total sensitivity.

B. Radiometric accuracy evaluation

Instrument radiometric accuracy can be evaluated mainly by considering contributions corresponding to antenna temperature and brightness temperatures.

If we indicate with Δ_{T_h} and Δ_{T_c} the hot and cold temperature accuracies, antenna temperature accuracy $\left(\Delta_{T_A}\right)$ can be written as:

$$\Delta_{T_A} = \sqrt{\left|\frac{\partial T_A}{\partial T_h}\right|^2 \Delta_{T_h}^2 + \left|\frac{\partial T_A}{\partial T_c}\right|^2 \Delta_{T_c}^2} \qquad (4)$$

In case of nonlinear gain, the terms due to the non-linear temperature (T_{nl}) accuracy should be added:

$$\Delta_{T_A} = \sqrt{\Delta_{T_A}^{Linear^2} + \left(\frac{\partial T_A}{\partial T_{nl}}\right)\Delta_{T_{nl}}^2} \qquad (5)$$

The brightness temperature accuracy can be expressed as:

$$\Delta_{T_{ML}^A} = \sqrt{\left|\frac{\partial T_{ML}^A}{\partial \eta_{oh}^A}\right|^2 \Delta_{\eta_{oh}^A}^2 + \left|\frac{\partial T_{ML}^A}{\partial \eta_{ML}^A}\right|^2 \Delta_{\eta_{ML}^A}^2 + \left|\frac{\partial T_{ML}^A}{\partial T_{Ph}^A}\right|^2 \Delta_{T_{Ph}^A}^2 + \left|\frac{\partial T_{ML}^A}{\partial T_E}\right|^2 \Delta_{T_E}^2 + \left|\frac{\partial T_{ML}^A}{\partial T_A^e}\right|^2 \Delta_{T_A^e}^2} \qquad (6)$$

IV. RESULTS

After the implementation of the algorithm into the software and the realization of a graphical user interface, a test has been carried on in order to evaluate the performance of the instrument at a given frequency. The analyzed frequency is of 36.5 GHz and the chosen input values are reported in TABLE III.

TABLE III. INPUT VALUES

Input	***Value***
Centre frequency [GHz]	36.5
Number of polarisation	2
Pre-detection bandwidth [MHz]	1000
Noise figure	3
Gain fluctuation	0.0001
Front-end losses [dB]	0.46
Integration time	5
IFOV requirement [Km]	20
Sensitivity requirement [K]	0.6
Accuracy requirement [K]	0.5

With the previous values, the results showed TABLE IV. are obtained.

TABLE IV. OUTPUT VALUES

Output	***Value***
Receiver Temperature [K]	353
Sensitivity (linear part) [K]	0.3218
Sensitivity requirement [K]	0.6
Measurement sensitivity contribution [K]	0.2902
Hot calibration sensitivity contribution [K]	0.1383
Cold calibration sensitivity contribution [K]	0.0136
Hot temperature accuracy contribution [K]	0.1738
Cold temperature accuracy contribution [K]	0.2999
Brightness temperature accuracy contribution [K]	0.3991
Accuracy requirement [K]	0.5
IFOV [Km]	20
IFOV requirement [Km]	20

As it is possible to see from TABLE IV. the performances of the instrument respect the requirements imposed for the chosen frequency.

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