SATELLITE RADIOMETER PRE-LAUNCH SENSITIVITY ESTIMATION USING ANECHOIC CHAMBER AND CHANNEL INTER-COMPARISON

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1. INTRODUCTION

The sensitivity of a radiometer to the brightness temperature variations of the target is one of the critical parameters of any radiometric measurement [1]. The goal of the European Space Agency's SMOS (Soil Moisture and Ocean Salinity) mission is to obtain global maps for soil moisture and sea surface salinity (SSS) using L-band radiometry. Especially SSS requires high sensitivity from the instrument [2],[3]. The synthetic aperture interferometric radiometer (called MIRAS) of SMOS uses three noise injection radiometers (NIR) to provide a precise measurement of the average brightness temperature of the observation scene [4]. SMOS uses a reference integration time of 1.2 seconds (one epoch), at which the radiometric resolution of the NIR units is less than 250 mK for vertical and horizontal polarization [5] (meeting the requirement set for the manufacturing). In theory, by increasing integration time, a better radiometric resolution can be achieved. However, this sensitivity may be limited by, for example, instrument behavior [1]. The purpose of this paper is to investigate the sensitivity limit of the brightness temperature measurement of the NIR units onboard SMOS.

The MIRAS instrument went through a series of tests at the test facilities of ESA's European Space Research and Technology Centre (ESTEC), Noordwijk, The Netherlands in spring 2007. A part of these tests was a so-called Image Validation Test (IVT) carried out in the Maxwell anechoic EMC (Electromagnetic Compatibility) chamber. The IVT was divided in two parts: IVT-1 and IVT-2. A part of the IVT-2 campaign was dedicated to determine the stability of the instrument in a relatively stable ambient environment and lasted several days. The data of this stability test is used in this paper.

2. METHODOLOGY

The brightness temperature of the chamber was measured with all NIR channels during the stability test. The so-called factory values of the calibration parameters, i.e. the values retrieved in the individual test campaign of the NIR units [5], were used to convert the raw output of the radiometers into brightness temperature. Note that the calibration was not done using the Cosmic Microwave Background (CMB) as the calibration target and therefore not entirely representative to the calibration in the orbit.

The physical temperature of the absorbers covering the walls and the ceiling of the Maxwell chamber was measured with three thermal sensors. The thermal sensors were attached to support bars at the level of the tips of the absorbers. Additionally, some absorbers were placed on the floor in order to attenuate all kind of possible interfering reflections. The height of the absorbers was at least 90 cm and specified to have reflectivity of less than -50 dB at L-band. The thermal sensor readings showed very similar values both in level and in profile shape and the fluctuations in the profile were only 0.25°C over a period of several days.

The measured brightness temperature was analyzed by 1) comparing its changes to the changes of sensor readings, i.e. relatively, 2) comparing the measured brightness temperature levels to the sensor reading levels, and 3) comparing the measured brightness temperature values of each channel of each NIR unit to each channel of other NIR units, which eliminates most importantly the effect of target fluctuations from the results. In each of these cases, the baseline was to use data averaged with a 10-minute sliding rectangular window, as the Allan variance analysis showed that this would yield optimum resolution in the test data. Note that in the Allan variance analysis the fluctuations in the chamber physical temperature were not compensated for, so the Allan time does not reflect the radiometer performance directly.

3. RESULTS

In order to do the relative comparison to the sensors, the average of the measured brightness temperature of each channel was adjusted to average of the sensor readings. The adjusted brightness temperature measured by each unit corresponds with remarkable accuracy to the mean of the three sensor readings without, for example, any kind of systematic drift. In many occasions, the match between the profile of the measured brightness temperature and the profile of the mean sensor reading includes shapes in order of 50 mK in magnitude. This result means that the NIR units have the potential to detect changes in sub 50 mK scale, which is in the right range in comparison to the requirement for the relative accuracy of SSS measurement [3].

The abovementioned adjusted bias of the brightness temperature measurements with respect to the sensor readings range from -0.86 K to 0.69 K. The accuracy requirement set for the manufacturing of the NIR units was 1.5 K [5], which is clearly met. However, the mean brightness temperature over all NIR channels is on average only 195 mK lower than the mean sensor value with standard deviation of 8 mK between different subsets of data (each several hours in duration). If it could be assumed that the sensors predict the true brightness temperature with precision, the accuracy requirement of 240 mK for the SSS measurement in the most demanding retrieval case [3] is met by the NIR units in these tests. Furthermore, as the small variation in the bias (8 mK) can be considered as error sources in the target, it can be concluded that the bias of the NIR measurement remains constant within the uncertainty of the test setup.

Finally, when each NIR channel is compared to each other the standard deviation is 17 mK on average for all pairs, ranging from 15 mK to 20 mK. The average is in fair agreement with the theoretical prediction of the sensitivity at 10 minute integration time (from 190-240 mK [5] sensitivity at 1.2 second integration time [1]) and shows the consistency among different NIR channels. Allan variance analysis was applied also to the differential data. The Allan time was not found and the deviation keeps decreasing with integration time. The data is limited to integration time of roughly 4 hours, with which the standard deviation falls under 5 mK. This further demonstrates the high consistency among channels and shows the potential for integrating NIR data over very long periods of time to increase the sensitivity to meet the requirements for SSS retrieval.

4. CONCLUSIONS

An anechoic chamber covered with absorbers was used to evaluate the sensitivity of an L-band satellite radiometer. The high stability of the physical temperature in the chamber made it possible to use this environment for the very demanding evaluation of the radiometer performance. With the measurements it was possible to demonstrate the sensitivity of the radiometer down to sub 50 mK scale, and by applying the analysis to differential data obtained through channel inter-comparisons, sensitivities and consistencies in order of 5 mK could be revealed. The radiometer under study is the noise injection radiometer of the ESA's SMOS mission, and this result contributes to the expected success of the mission.

5. REFERENCES

[1] F. T. Ulaby et al., "Microwave Remote Sensing: Active and Passive, Volume 1", Addison-Wesley Publishing Company, 1982.
[2] G.C. Thomann, "Experimental Results of the Remote Sensing of Sea-Surface Salinity at 21-cm Wavelength", IEEE Trans. Geosci. Electronics, vol. GE-14, no. 3, July 1976.
[3] S.H. Yueh, R. West, W.J. Wilson, F.K. Li, E.G. Njoku, Y. Rahmat-Samii, "Error Sources and Feasibility for Microwave Remote Sensing of Ocean Surface Salinity", IEEE Trans. Geosci. Remote Sensing, vol. 39, no. 5, May 2001.
[4] I. Corbella, F. Torres, A. Camps, A. Colliander, M. Martin-Neira, S. Ribo, K. Rautiainen, N. Duffo, M. Vall-llossera, "MIRAS End-to-End Calibration. Application to SMOS L1 Processor", IEEE Trans. Geosci. Remote Sensing, vol. 43, no. 5, pp. 1135-1143, May 2005.
[5] A. Colliander, L. Ruokokoski, J. Suomela, K. Veijola, J. Kettunen, V. Kangas, M. Levander, H. Greus, M.T. Hallikainen, J. Lahtinen, "Development and Calibration of SMOS Reference Radiometer", IEEE Trans. Geosci. Remote Sensing, vol. 45, no. 7, July 2007.