SMOS Mission & MIRAS Instrument. Synthetic Apperture Radiometer in Space

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Abstract — **SMOS is the second mission in the Earth Observation Opportunity Programme of ESA. The main objective of the mission is to measure the ocean salinity and soil moisture of the whole Earth with a revisit time of three years and a pixel resolution of 50 x 50 Km. The heart of the satellite is a Microwave Radiometer with Apperture Synthesis that constitutes an innovative way to observe the Earth with greater possibilities for the future.**

I. INTRODUCTION

SMOS (Soil Moisture and Ocean Salinity) is the second Earth Explorer Mission of Opportunity within the European Space Agency (ESA) Living Planet Program. The missions of opportunity were conceived for advancement in the knowledge of the Earth's behaviour and in the development of new technologies that permit the elaboration of new observation techniques from space.

The purpose of the SMOS mission is to launch a satellite to provide soil moisture and ocean salinity maps, as well as data to assist in an in-depth study of the structure of the cryosphere. To date it has not been possible to obtain moisture and salinity maps from space, whereby the measurement of these geophysical parameters is localized and not continuous. This is why it is important to have a satellite that provides the measurement of the planet's two geophysical parameters over the entire surface and with a high rate of repetition (between three and five days).

II. DATA TO BETTER UNDERSTAND THE WATTER CYCLE

Oceanographers, geologists and biologists give a great deal of importance to obtaining and quantifying salinity and moisture maps for improving climatologic forecasts, increasing the understanding of the connection between the water cycle and meteorology and providing new approaches to knowledge on the phenomenon of climatic change. Salinity influences the circulation of water masses in oceans that lead to the formation of climatologic phenomena such as El Niño or La Niña, which cause flooding or droughts. The evaporation or filtration of water depend upon the degree of moisture in the soil and the vegetation water content, key aspects to understanding the water cycle and monitoring the planet's fresh water reserves.

III. INSTRUMENT ARCHITECTURE

The mission is comprised of a satellite in a low sun synchronous orbit, with an altitude of 755 Km and a revisit time of 3 days, that passively measures the electromagnetic noise generated by Earth at L-band (1.4 GHz) with a spatial resolution of 50-100 Km and radiometric sensitivity of 5K, in addition to a ground operations segment for the control and processing of data. The launch of the satellite is targeted for March of 2007.

SMOS is the result of cooperation among three European institutions dedicated to the promotion of the space industry and science, which are the ESA (European Space Agency), the French CNES (National Centre for Space Studies) and the Spanish CDTI (Centre for Industrial Technological Development).

The SMOS satellite under development for the ESA is comprised of a generic platform, in this case the Proteus, and the payload based on the MIRAS (Microwave Imaging Radiometer with Aperture Synthesis) radiometer, for which EADS CASA Espacio is the prime contractor.

A radiometer is an instrument that detects the electromagnetic radiation emitted by a body at a certain temperature within a given frequency band. Since microwaves are sensitive to changes in the dielectric constant of the medium, any change in the water content leads to changes in dielectric properties and affects the emissivity and therefore the radiant temperature detected by the radiometer. Microwave theorists have encountered a direct relationship between soil moisture and ocean salinity with Earth emissivity at 1.4 GHz. Furthermore, the chosen work frequency is a band protected for radio astronomy and therefore free from interference.

The MIRAS instrument is a 2D synthetic aperture interferometric radiometer. Synthetic aperture interferometry is an alternative to real aperture instruments, since this permits the synthesis of a theoretical antenna of very large aperture, starting from a diverse collection of small antennas, which achieves an instrument weight / geometric resolution ratio that is very suitable to space missions.

MIRAS has three arms in "Y" form and a central structure that supports them. Analyses undertaken prove that this configuration, with antennas distributed along the arms, optimizes space resolution and Instrument sensitivity. Each arm is comprised of three segments that are connected by a hinge. The arms are folded to the sides of the central structure during launch. The payload mechanism consists of a spring-operated motors, a speed regulator and a collection of belts and pulleys that convey engine torque to all arm segments so that the extending is simultaneous and does not cause kinetic moment disturbance to the satellite.

Figure 1. SMOS satellite with MIRAS Instrument in deployed configuration

The central payload and the arms are made of carbon fiber, which provides a high degree of rigidity to withstand the loads sustained by the Instrument during launch, with a minimum of weight. With its arms extended the Instrument has a wingspan of 8 meters and a weight of 360 Kg.

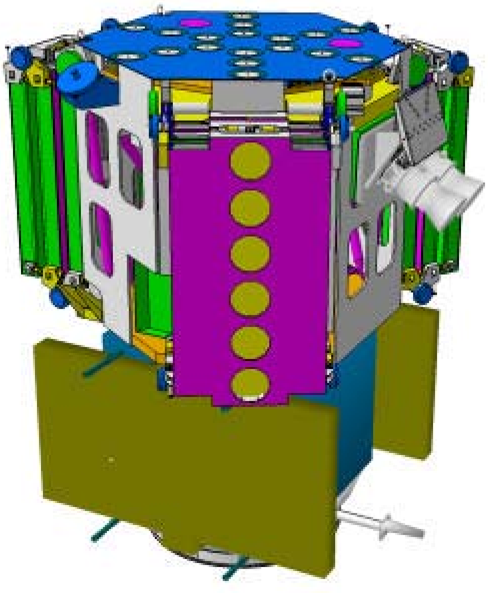

Figure 2. SMOS satellite with MIRAS Instrument in stowed configuration

There are 66 LICEF (Light Cost Effective Front-end) all along the three arms and the central structure. Each LICEF is comprised of an L-band receiver (1404 – 1423 MHz) and a four-probe patch antenna with a combination/polarization circuit that makes it possible to place one sole receiver design on in any position being the Instrument the antenna one to polarize the LICEF to the global electric axis. The LICEF are the eyes of the Instrument. Each LICEF measures the noise emitted by Earth in L-band by means of a complex amplification chain and filtered in RF and IF, comprised of MMIC (Miniaturized Monolithic Integrated Circuit) for reducing consumption and weight. The result is a 1 or a 0 in phase and quadrature of the received signal, depending upon the noise uptake level. LICEF is a highly frequency-selective receiver that avoids capturing disturbing signals from adjacent bands that would disguise the noise sought from Earth for measurement..

The digital signal produced by each LICEF is transmitted to the DICOS (Digital Correlator) whose function is to correlate the signals produced by all the LICEF to create the synthetic antenna. The transmission of these signals is done by fiber optics because they are immune to interference and allow high transmission speeds. The project is conducting the qualification of the necessary electro-optic components for space, increasing the technological challenge posed by the launch of SMOS.

Temperature variations affect the performance of MIRAS, since the LICEF are distributed along the entire structure and the environmental conditions in space vary from one to another along the orbit and the stations. A very precise thermal control system has been designed to ensure that the temperature between any two LICEF is less than 6ºC. Nevertheless, the LICEF are calibrated every so often to unify their performance. The calibration takes place by injecting all the LICEF with the same noise and correlating the signals from each LICEF as if the Instrument were in the Observation mode.

The data generated by DICOS during observation and calibration are sent to Earth by an X-band antenna for post processing. The radiant temperature maps are obtained on the basis of the instrument's visibility function. The Polytechnic University of Catalonia has developed a method known as "Extended CLEAN" which is a modification of the inverse Fourier transform of correlations generated on the basis of the LICEF ones and zeros. The radiant temperature maps are transformed into moisture and salinity maps following the application of scientific algorithms.

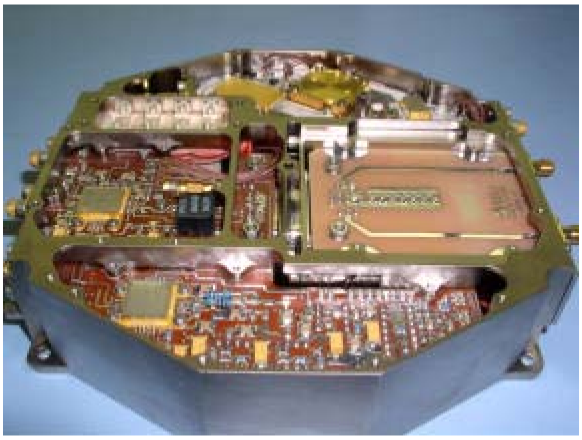

Figure 3. LICEF unit

IV. GROUND SEGMENT

The ground segment of the SMOS mission will be comprised of two subsegments: the control and data exploitation segments.

The control segment is responsible for planning, controlling and verifying satellite operations. It will verify the proper operation of space and ground segments and will ensure compliance with mission objectives. To do so it will be equipped with a link between satellite and Ground Segment in S-band. The current base scenario for the SMOS mission contemplates the use of Kiruna (Sweden).

The data exploitation ground segment will be comprised of the following elements a X-band station to receive the telemetry data and the Payload Data Processing Center (PDPC), responsible for the processing, archiving and distribution to users of the SMOS products. The calibration and quality control of the products generated is likewise the responsibility of the this center.

The Instrument's X-band data reception station and the PDPC data processing center will both be located at the ESA satellite tracking station in Villafranca (Madrid).

V. PROJECT STATUS

The origins of the instrument date back to 1998 when EADS--CASA Espacio was chosen by ESA to develop the prototype of a fully equipped arm of the Instrument (MIRAS Demonstrator Pilot Project I/II). The objective of the prototype was to develop all the space technologies necessary for the construction of the Instrument and the undertaking of various tests to demonstrate the viability of the concept. Project accomplishments materialized in the payment tests of one complete arm and the validation of images.

The initial MIRAS demonstration project was followed by contracts for phase A (mission analysis, mission viability and initial conception of the Instrument architecture) and phase B (detail design of the Instrument).

During phases A and B the SEPS (SMOS Performance Simulator) has also been developed. SEPS is an Instrument and mission simulator that faithfully reproduces the performance of the MIRAS and permits the validation of the architecture, performance and data processing algorithms by means of simulation, utilizing commercial radiant temperature maps of the Earth as stimulus.

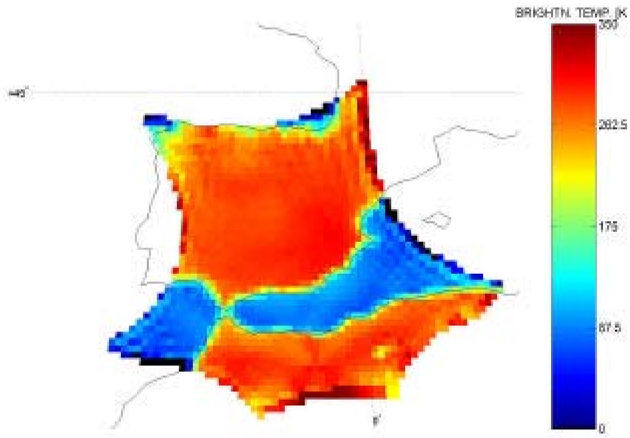

Figure 4. Brightness Temperature Map made with SEPS of North-East of Spain

The instrument's construction phase (phase C/D) started in December 2003 and the delivery of the PLM to be integrated into the satellite is foreseen for June 2006. Three models are envisaged: Engineering model, Structural and Thermal model and Flight model.

VI. CONCLUSION

SMOS and MIRAS are a real challenge to the European Space Industry and Institutions to launch a new way to make Earth Observation. The Instrument concept and technology developed in the mission are a step forward for future Earth Observation Missions, in which the use of Microwave Radiometers will be considered essential. The SMOS objective are indeed a major qualitative leap to scientific community to provide radical new means to observe to paramount geophysical parameters to understand the water cycle and to improve the weather forecasts.

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