Remote sensing of the Moon sub-surface from a spaceborne microwave radiometer aboard the European Student Moon Orbiter (ESMO)

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Abstract. As in 1969 when the Apollo astronauts walked on its surface, there is renewed and growing interest in returning to the Moon. This time the target is to establish a permanent presence there and then to start a new era of moon exploration and exploitation [1]. In this context in March 2006, the education department of the European Space Agency (ESA) approved the European Student Moon Orbiter (ESMO) mission, proposed by the Student Space Exploration & Technology Initiative (SSETI) association for a phase A feasibility study. If found to be feasible, ESMO will be the third mission to be designed, built and operated by European students through the SSETI association, and would join many other contemporary missions to the Moon such as ESA’s SMART-1, the Chinese Chang’e-1 [2], the Indian Chandrayaan, JAXA’s SELENE and Lunar-A, and NASA’s Lunar Reconnaissance.

For a long time, visible light and infrared have been the preferred wavelengths for lunar observations though microwave band was also used occasionally. Because of the synchronization of the Moon’s rotation and revolution, visible and near infrared light cannot ‘see’ the dark side of the Moon, but microwave can. Moreover, it can penetrate a certain depth under the surface of dielectric material. For these reasons and for its relatively low weight and simple design, among the proposed payloads for the ESMO mission, the microwave radiometetric sounder (MiWaRS) has been selected as a possible choice for flying on board of the ESMO satellite. The envisaged requirements of MiWaRS are: field-of-view in the order of one hundred kilometers, which leads to a very fine spatial resolution that cannot be easily obtained with Earth-based radiometers; limited power consumption, volume and weight; relatively low data rate; near-surface sounding capability.

The MiWARS payload is a low noise receiver and in order to be allocated into ESMO Micro-Satellite and to fulfill the prescribed requirements, it may exhibits the following features: i) use of the nadir-pointing face of the a three-axis-stabilized Micro-Satellite in order to observe at the Moon surface; ii) use of antennas (such as microstrip, backfire or horn antenna) with gain between 6 and 18 dBi in order to compact instrument volume, still obtaining enough spatial resolution; iii) use of multi-band antenna, tuned at different frequencies from C band up to K band to realize a sub-surface sounding capability; iv) use of a sufficiently long integration time in order to ensure a good radiometric accuracy of the order of few kelvins; v) use of on-board radiometer calibration device or, in alternative, known stable microwave targets such as cosmic noise or specific features on the Moon surface, in order to perform the on-board instrument calibration; vi) use of COTS (Components Off The Shelf) and low-power components, in order to reduce overall costs and power consumption; vii) use of an on-board data processing (filtering and compression) in order to adapt the data rate to downlink channel capacity. The MiWaRS configuration may exploit either a usual total-power topology (with the advantage of simple realization, but a poor calibration), pulsed-noise injection topology (with the advantage of good self-calibration, but a more complex technological design) or balanced Dicke architecture (with the advantage of high flexibility, but complex technological design).

This work summarizes the preliminary results obtained during the phase-A feasibility study for the MiWaRS with special attention on the description of the radiometric system design and its scientific objectives. The latter have been limited to the following: i) mapping of the surface microwave emissivity; ii) probing of sub-surface thermal
and conductivity properties; iii) sounding of the regolith layer and its possible anomalies. In order to quantitatively verify the fulfillment of these scientific requirements, the project has been subdivided into four main topic areas: model, retrieval, system and technology. We will present first results on the modeling efforts consisting on the development of a multi-layer inhomogeneous sub-surface model to simulate the microwave brightness temperature observed from the ESMO satellite. A sensitivity analysis of the simulated microwave response will be discussed together with the effects of antenna beam-width and related spatial resolution. This analysis shall lead to the optimal requirements in terms of radiometer frequencies, field-of-view and radiometric accuracy compatible with the technology and satellite mission constraints (still to be definitively assessed). Results on the system configuration analysis will be also presented discussing the advantages and disadvantages of each choice and aiming at defining a baseline and an advanced radiometer configuration. Antenna design and technological issues will be also dealt with to complete the whole feasibility study.

REFERENCES


PRINCIPAL AUTHOR’S BIO

Mario Montopoli received the Laurea degree in Electronic Engineering in 2004 from the University of L’Aquila, Italy. In 2005 he joined the Center of Excellence CETEMPS as a research scientist on ground-based radar meteorology, with a special focus on C-band applications and processing techniques. In 2005 he started a Ph.D. in radar meteorology in a joint program between the University of Basilicata and University “La Sapienza” of Rome. Since 2006 he is a research assistant at the Dept. of Electrical Engineering and Information of the University of L’Aquila.