SMAP Instrument Antenna,
On Orbit Performance Validation & Verification

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***Abstract*—NASA's Soil Moisture Active Passive (SMAP) Mission is currently flying in a 685 km orbit. Featuring a Synthetic Aperture Radar (SAR) and a radiometer sharing the same antenna, SMAP was developed in collaboration between Jet Propulsion Laboratory (JPL) and Goddard Space Flight Center (GSFC). While the radar requirements on the instrument antenna were more benign from an RF point of view, the radiometer requirement were more difficult to meet because of the stability required by the radiometer to operate to its full potential. The instrument antenna performance was predicted by a very detailed RF model and verified by measuring a 1/10th scale model with great accuracy before launch. Once in orbit, we had the opportunity to measure the antenna performance for both the radiometer and the radar and compare it with the predicted performance given by our RF model. This paper discusses the work done both at JPL and GSFC in order to verify and validate the on orbit performance of the SMAP instrument antenna.**

Keywords*—*on orbit performance; on orbit validation and verification; reflector antenna; offset reflector; SAR; radiometer.

I. INTRODUCTION

SMAP was launched in January 2015 and started operations after a very successful and smooth commissioning phase in April 2015. Launched into a 685 km near sun-synchronous 6AM/PM orbit, SMAP measures soil moisture on a 1000 km swath with a spatial resolution of about 40 km for the radiometer and 3 km for the radar. It measures the same area on the ground every 3 days. Early in the mission, by combining radar and radiometer data, SMAP provided 10-km resolution soil moisture data globally. Unfortunately, in July 2015 the SAR ceased its operation due to an apparent power supply failure. The radiometer, on the other hand, continues to operate smoothly and still provides high quality brightness temperature data but with a spatial resolution limited to 40 km.

Once both instruments were operational and calibrated, we were able to compare the measurements that were being made from space with predictions made using our RF model. In the next paragraph we will first describe the basic architecture of the SMAP instrument antenna and its RF model. Then we will present some of the work done at JPL to validate the performance of the radar instrument. The following paragraph will discuss the work done at GSFC on the radiometer front. In both cases the RF model was able to predict with high fidelity the performance of the antenna. Both instruments performed beautifully and produced incredibly detailed maps of soil moisture from space.

II. THE SMAP INSTRUMENT ANTENNA

SMAP features a 6m deployable mesh reflector, in an off-set configuration, with a 4.2m focal length and boresight pointed 35.5° off from Nadir. The reflector was provided by Northrop Grumman, Astro Aerospace Division, while the feed-horn is a JPL in-house design. The dual band, dual polarization circularly-corrugated feed-horn is attached to the Spin Mechanism Assembly (SMA) along with the radiometer electronics. The feed, the boom and the reflector spin together at 14.7 rpm to cover a 1000 km swath on the ground. The radar electronics is instead inside the rectangular bus which supports the solar panels, the telecom antennas, the star tracker and all other systems. The radar is connected to the feed-horn through a rotary joint. A diplexer right behind the OrthoMode Transducer (OMT) is used to separate radar and radiometer signals into their respective bands.

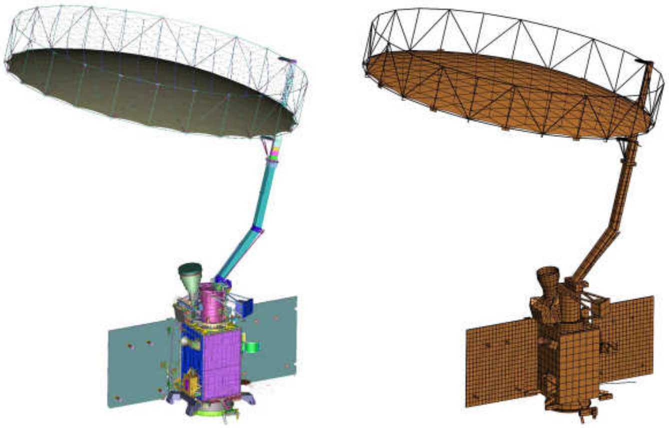

Fig. 1, Comparison between SMAP CAD (left) and RF (right) models.

Fig. 1 shows a comparison between the CAD model and the RF model. All meaningful details from an RF point of view were accounted for in the RF model. Radiation patterns were calculated every 22.5° of azimuthal rotation of the top deck.

III. The SAR Instrument

After the successful deployment of the reflector, the radar performance was assessed by examining the echoes received from Earth's surface. Fig. 2 shows an example of a comparison between the expected echo from the radar based on our RF model and the echo actually observed from the ground. The vertical axis is the received power level, scaled in amplitude and adjusted for a small pointing shift.

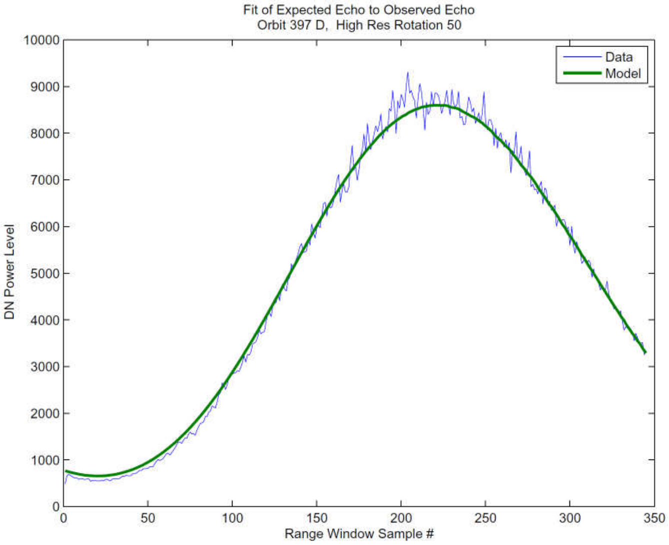

Fig. 2, Expected radar echo (green) versus measured echo (blue).

The data in Fig. 2 demonstrates that the calculated pattern does an excellent job of predicting the on-orbit performance of the antenna. In terms of pointing, the radar was expected to have a Nadir bias of 0.270° out of an allocation of 0.500°. It was actually measured to be 0.291°. A difference of just 21 milli-degrees demonstrates that all mechanical and RF systems worked well together to achieve the predicted pattern performance. Fig. 3 shows a global map of radar backscatter cross section from the SAR data.

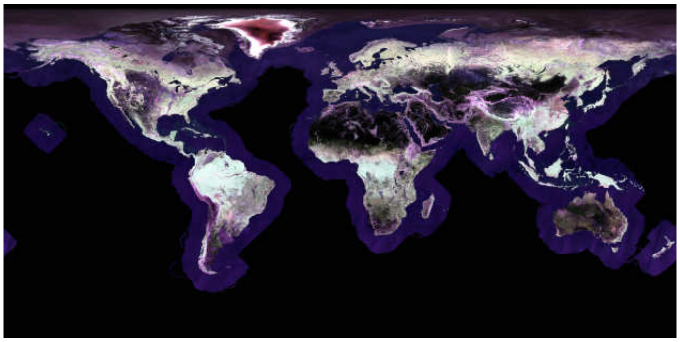

Fig. 3, Global map of radar back-scatter cross section.

IV. The Radiometer Instrument

The first check of radiometer performance was done even before the reflector was deployed. With the reflector still stowed, the feed-horn had a clean view of cold space. Fig. 4 shows a comparison between the calculated and measured antenna temperature with the feed horn pointed at cold space.

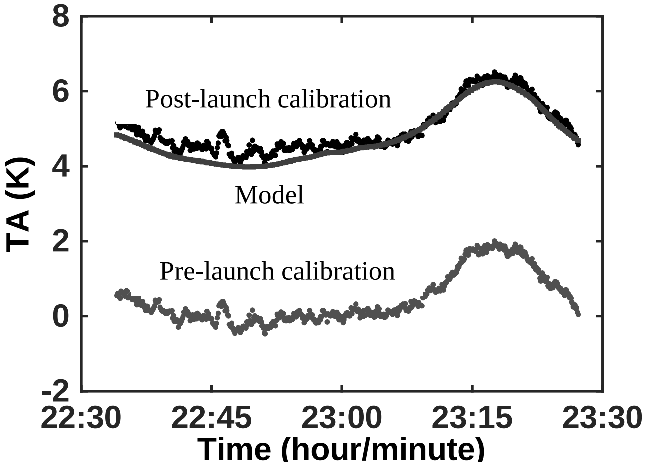

Fig. 4, Antenna temperature (V-Pol) measured in stowed configuration showing pre- (gray dots) and post-launch (black dots) calibration results compared to modeled cold-space antenna temperature (solid curve). The initial result is biased 5° K low consistent with pre-launch calibration uncertainty. H-Pol measurements showed a smaller 1° K difference.

The agreement shown in Fig. 4 is remarkable. After the deployment of the reflector the antenna pattern correction error was calculated to be of the order of 0.1%, which is about 10 times smaller than what was calculated for AQUARIUS, which measured ocean surface salinity from space.

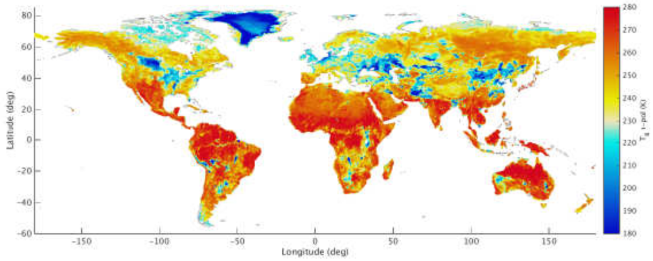

Fig. 5, SMAP brightness temperatures (H-Pol) over land from the first four days of radiometer operation (Antarctica is excluded for clarity).

The SMAP RF model predicted with great accuracy the performance of a complex instrument antenna taking into account the effect of the entire spacecraft. The increase in size and complexity of science missions combined with having reliable tools that predict antenna performance with great accuracy is enabling the design of instruments with unprecedented accuracy and resolution.

Acknowledgment

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