Optimal Antenna Coatings for High Frequency Microwave Radiometers: DMSP SSMIS Case Study

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1. INTRODUCTION

The Defense Meteorological Satellite Program (DMSP) has flown three Special Sensor Microwave Imager/Sounders (SSMIS), first conceived in early 1989, and first flown in October of 2003. Many technical challenges have been overcome during the design, build, and test phases of the program, and many challenges have presented themselves during the calibration and validation phases of the program for the first instrument launched in 2003, the second in 2006, and the third in 2009. All of the identified performance issues have been solved including the subject of this paper, namely, the design of optimal antenna coatings for microwave radiometers up to 190 GHz. The purpose of this paper is to share our research on the design, build, and test of the new high performance antenna.

2. BACKGROUND

The SSMIS is a 24 channel radiometer operating in frequency from 19 to 190 GHz (figure 1). The primary users of this combined Air Force and Navy developed radiometer are the DoD and DoC as well as International partners at the European Centre for Medium-range Weather Forecasting (ECMWF). The primary products produced by the SSMIS are well known: atmospheric vertical temperature profiles, atmospheric vertical moisture profiles, surface characterizations (e.g. ocean surface wind speed, soil moisture), and integrated atmosphere quantities (e.g. total water content in a column).

Accurate measurement of radiances by SSMIS depends on having reflectors with extremely low microwave emissivity. The reflectors can contribute radiances outside the calibration loop if they are emissive. The original coating formula for all of the flight reflectors is given in table 1. All were coated at approximately the same time with the notable exception of the antenna flying on the latest SSMIS on Flight 18, more discussion on this is to follow. During the first launch and calibration of the SSMIS in October of 2003, uncharacterized biases were observed in brightness temperatures and retrieved data (most pronounced at frequencies above 150 GHz). The biases depended on latitude, and season [1]. This launched an intensive investigation process that was concluded when the second SSMIS achieved orbit in November of 2006. With two SSMIS's on orbit, it was possible to cross-calibrate when the instruments viewed the same area at the same time, a condition which occurs frequently at higher latitudes. The team discovered (after eliminating many possibilities) that the most likely rationale for the biases was that the antenna coating was emissive. This conclusion was supported by the cross-calibrations which indicated differing responses of the instruments when they went in and out of the sun illumination. This led to laboratory measurements of the conductivity of coatings of the remaining flight reflectors. The 32 GHz conductivity measurements implied that the antennas were anomalously emissive. Remaining antennas that were maintained in storage for future flights were examined and it was determined that a spare, which had an out of family coating, exhibited excellent conductivity. This antenna was installed on the Flight 18 SSMIS. The consequences of the emissivity contamination on F16 and F17 have led to water vapor retrievals that fall outside our specified RMS performance. The scene dependent biases are most pronounced at the highest frequencies thus contaminating the 183 Ghz radiances limiting the skill of the water vapor retrievals. On F18, with the higher performance antenna, preliminary results indicate that the water vapor retrieval skill has been fully recovered.

3. ANTENNA COATING ANALYSIS AND RESULTS

After several years of experimentation, an optimal coating was designed and tested. DMSP is now in the process of stripping and re-coating the remaining main and cold sky antennas that will fly on the last two DMSP flights, 19 and 20. The key to the process was recognizing that Si0x did not age well with respect to the ambient moisture environment as the first two flight reflectors were built many years ago, and stored in a lab environment. The silica fill (Cabosil) used to roughen the surface coating (in order to reduce solar reflection onto the SSMIS instrument) was also a possible contributor to increased emissivity. Finally, it was recognized that the aluminum coating must be highly conductive on a macroscopic scale, thus cracking must be avoided. The new coating (table 2) is Si02-based, and all of the reflectors will be purged up until vehicle encapsulation on the launch pad. Surface roughening was introduced by a sand blast process applied to the supporting substrate surface. This reduced surface discontinuity relative to the original particle under-layer and lessened the opportunity for undesired chemical and physical aging processes to occur at the particle-metal interface. In summary, the conductivity results from the heritage flight coatings formula, and the newly designed formula that will fly on all remaining SSMIS instruments are presented.

4. FIGURES AND TABLES

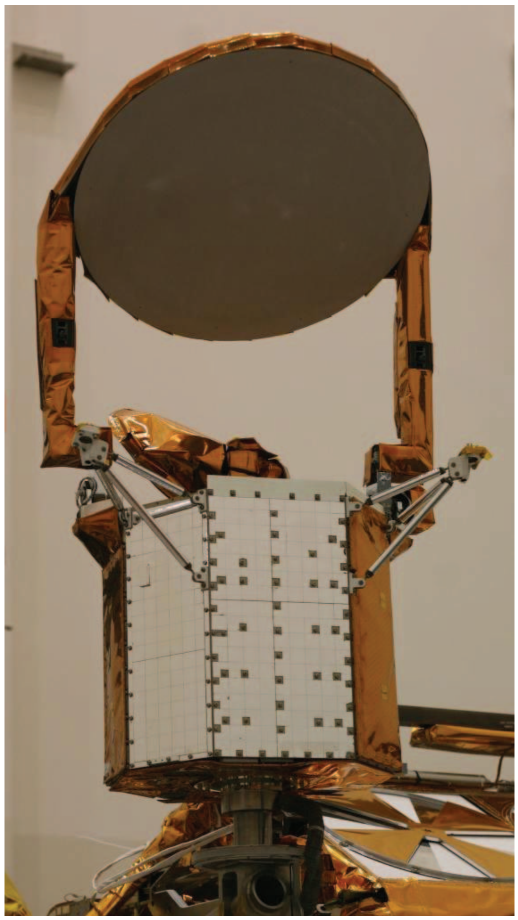

Figure 1. SSMIS Mounted On Spacecraft for Testing

	Coating Material	Thickness
Layer 1	Chromium	600 ± 100 Å
Layer 2	VDA	6,000 ± 500 Å
Layer 3	SiOx	5,000 ± 500 Å
Layer 4	VDA	6,000 ± 500 Å
Layer 5	SiOx	22,000 ± 1,000 Å

Table 1. Original Coating Formula

	Coating Material	Thickness
Layer 1	Chromium	600 ± 100 Å
Layer 2	VDA	12,000 +1,200 / -0 Å
Layer 3	SiO2	10,000 ± 500 Å

Table 2. New High Performance Coating Formula

4. REFERENCES/BIBLIOGRAPHY

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