High-Resolution Earth Atmospheric Sensing Using Combined Microwave Radiometry and GNSS Radio Occultation[1]

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We introduce a new technique for absolute "through-the-antenna" calibration of cross-track-scanning passive microwave radiometers viewing earth from a low-earth orbit. This method offers significant advantages, in that neither internal calibration targets nor noise diodes are needed to calibrate the radiometer. The algorithm does require periodic updates of the atmospheric state, which can be readily provided by GNSS radio occultation observations, for example. An iterative algorithm retrieves the radiometer gain given a sequence of observations of the earth's limb. The algorithm uses a parameterized radiative transfer model of a spherically-stratified atmosphere.

We will present results showing that this method yield calibration accuracies similar to those that could be obtained with ideal internal calibration targets. This analysis is based on global Monte Carlo simulations using the NOAA88b profile set. An analysis will also be presented showing how calibration performance degrades as the radiometer characteristics deviate from the ideal case. Among the factors considered are: 1) antenna pattern, 2) spectral passband, 3) pointing errors, 4) atmospheric state variability, 5) the number of limb observations required, and 6) sensitivity to sensor noise.

There are several key benefits to the use of the earth's limb for calibration: 1) nearly the entire dynamic range of the radiometer is covered with each scan of the limb; 2) the largest sources of validation error in the non-opaque radiometer channels are surface emissivity and boundary layer temperature variability, and these are minimized to negligible levels because of increased absorption due to the longer line-of-sight associated with the limb viewing geometry; 3) the shape of the limb brightness temperature distribution with angle can be used to estimate radiometer boresight direction with very high accuracy.

To demonstrate the concept described above, the Microwave Radiometer Technology Acceleration (MiRaTA) CubeSat mission will launch in 2015 into an orbit with ~400-km initial altitude and 52-degree inclination. The MiRaTA CubeSat will carry out mission objectives over a 90-day mission, including the on-orbit checkout and validation period. MiRaTA is a 3U CubeSat comprising V- and G- band radiometers (52-58 GHz, 175-191 GHz, and 206.4-208.4 GHz), the Compact TEC/Atmosphere GPS Sensor (CTAGS) with five-element patch antenna array to permit radio occultation atmospheric profiles, and relatively standard CubeSat spacecraft subsystems for attitude determination and control, communications, power, and thermal control. The spacecraft dimensions are 10 × 10 × 34 cm, total mass is 4.0 kg, and total average power consumption is 6W. The cross-track scanning capabilities to be demonstrated by the MicroMAS cubesat mission (Dec 2013 launch) together with the multi-band radiometer and GPS radio occultation capabilities of MiRaTA could be combined into a 6U CubeSat to offer unprecedented performance at very low cost.

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