Microwave and Millimeter-Wave Radiometers for CubeSat Deployment for Remote Sensing of the Earth’s Atmosphere

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Abstract—Recent developments in millimeter-wave technology from 90 to 183 GHz are now being leveraged to enable CubeSat deployment of passive microwave remote sensors of atmospheric variables, including temperature, humidity, clouds and precipitation. These radiometers have the potential to revolutionize remote sensing observations by enabling revisit times of less than 30 minutes from low Earth orbit from constellations of such CubeSats when deployed as secondary payloads on frequently available launches of opportunity.

I. INTRODUCTION

Accurate monitoring of severe weather to improve its prediction and monitor the role of climate provides tremendous societal and economic benefits. High temporal-resolution measurements available from visible and infrared sensors on geostationary satellites have greatly improved weather prediction, including nearly continuous monitoring of hurricanes and tropical cyclones. However, these sensors are unable to penetrate into nearly all clouds and precipitation, arguably where the most important information is. Nevertheless, constellations of passive microwave and millimeter-wave sensors in low-Earth orbit (LEO) can provide day/night, nearly all-weather observations of the atmosphere on a global basis. However, measurements of atmospheric quantities including temperature, humidity and precipitation, with a revisit time of 30 minutes or less are needed to monitor the global hydrological cycle and provide the necessary data to improve forecasting of severe weather. However, the combination of all currently available microwave radiometers in LEO orbit provides a revisit time of only 3-6 hours.

To address this need, recent technology developments in microwave and millimeter-wave and CubeSat components and standards are currently converging to enable deployment of LEO constellations for atmospheric remote sensing. They have the potential to provide observations of the Earth’s atmosphere with revisit times of tens of minutes in the tropics and midlatitudes for weather and climate applications.

II. RESULTS

A number of research groups are now developing passive microwave instruments for launch on CubeSats. The CubeSat standard is based on units (U) of 10 cm cubes, each with a mass of up to 1.3 kg. For instance, common standards are 3U (30 cm x 10 cm x 10 cm, up to 4 kg mass) and 6U (30 cm x 20 cm x 10 cm, up to 8 kg mass), which needs to accommodate the entire satellite, including all components. Two launches of microwave radiometers aboard CubeSats are expected during the third quarter of 2014. First, JPL’s Radiometer Atmospheric CubeSat Experiment (RACE) will demonstrate atmospheric water vapor measurement in two frequency channels near 183 GHz with a 15-km footprint from an initial orbit altitude of 400 km [1]. Second, MIT-LL’s Micro-sized Microwave Atmospheric Satellite (MicroMAS) is a cross-track scanning microwave spectrometer with nine channels near the 118.75-GHz oxygen absorption line for sensing temperature and precipitation at approximately 20-km spatial resolution from an initial altitude of 400-km orbit [2]. Both of these missions are in 3U CubeSats with several months of planned science operations, but future CubeSats for atmospheric remote sensing can be deployed in a low-drag configuration to achieve more than one year of science operations from 400-km orbit. Constellation simulations show that approximately 20 CubeSats in three orbital planes could provide revisit times of 30 minutes in the tropics and midlatitudes, with the potential for revolutionizing observation of hydrological variables for atmospheric sounding and precipitation science [2].

JPL is leading a related effort to develop millimeter-wave radiometers near 118 and 183 GHz for remote sensing of atmospheric temperature and humidity, respectively. The CubeSat Microwave Scanning Radiometer (CMSR) instrument fits within 1.5 U of 6U CubeSat, including a rotating reflector to accomplish both cross-track scanning and two-point calibration using ambient and heated microwave blackbody targets. The receivers are based on extremely-low-noise 35 nm InP HEMT broad-band low-noise amplifiers with low power consumption as well as a multi-frequency integrated horn and multiplexer, both developed under NASA’s Earth Science Technology Office ACT and IIP programs, e.g. [4].

REFERENCES