Quad-band Total Power Radiometer Payload for the Micro-sized Microwave Atmospheric Satellite II

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***Abstract*— A 1U microwave radiometer is successfully designed, fabricated, and tested for temperature and humidity sounding, with sensitivity <1.1 K on all sounding channels.**

***Keywords*— Reflector antenna; radiometry; atmospheric sensing; CubeSat;**

I. Introduction

The Micro-sized Microwave Atmospheric Satellite II (MicroMAS-2) is a dual-spinning 3U CubeSat equipped with a 12-channel passive microwave spectrometer providing imagery near 90 GHz (W-band), temperature sounding near the oxygen absorption line at 118.75 GHz (F-band), moisture sounding near the water vapor absorption line at 183.31 GHz (G1-band), and cloud ice measurements at 206 GHz (G2-band). The satellite consists of a 2U bus and a 1U radiometer payload. The 2U bus includes avionics, attitude determination and control system, communication radio and antenna, solar panels, battery, and an electrical power system for power generation and storage. The radiometer payload is highly integrated and compact, consisting of an antenna, a super-heterodyne microwave receiver system, electronic calibration system, voltage conditioning and distribution system, and a control and data handling system, as shown in Fig. 1. The MicroMAS-2A satellite has been designed, fabricated, and tested at MIT Lincoln Laboratory. MicroMAS-2A launched as a secondary payload on January 12, 2018 aboard the PSLV-C40 mission. The MicroMAS-2 CubeSat was built and tested as a risk-reduction effort for the Time-Resolved Observations of Precipitation Structure and Storm Intensity with a Constellation of Smallsats (TROPICS) mission, which intends to fly several MicroMAS-2 satellites in a constellation to provide unprecedented science returns from CubeSat platforms (see Fig. 2). We present here the design and environmental test results of the MicroMAS-2 radiometer payload.

II. Radiometer Payload Design

The aim of the MicroMAS-2 mission is to observe convective thunderstorms, tropical cyclones, and hurricanes from low-earth orbit [1]. The MicroMAS-2 radiometer is a 12-channel total power radiometer, employing electronic calibration via weakly coupled noise diodes. The nominal field of views are 3.0°, 2.4°, 1.5°, and 1.35° at W-, F-, G1-, and G2-band, respectively. The radiometer's input is an offset-fed quad-band reflector antenna [2], utilizing dual feedhorns, laterally shifted from the reflectors focal point. One feedhorn provides W- and F-band coverage, and the other provides both G-band coverage. A picture of the reflector antenna is shown in Fig. 3. Each antenna outputs into a super-heterodyne receiver, as shown in the payload block diagram in Fig. 4. The receiver's frontend circuitry provides input frequency band selection and amplification of the incoming signal.

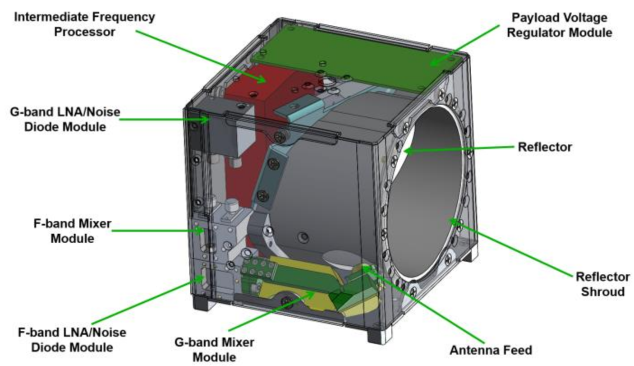

Fig. 1. CAD Rendition of MicroMAS-2 payload components

Calibration of the radiometer is implemented in the frontend circuitry via weakly coupled noise diodes [3]. The diodes inject known noise temperature into the signal path with which calibration is implemented.

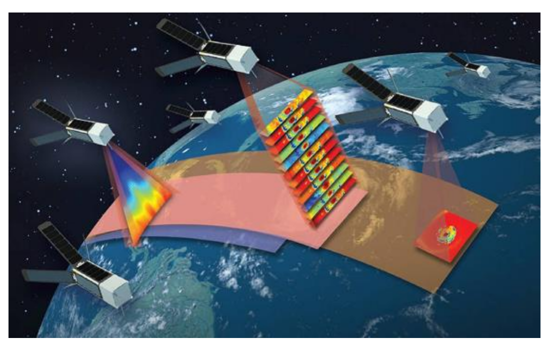

Fig. 2. TROPICS Mission will employ MicroMAS-2 satellites in CubeSat constellation

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A local oscillator (LO) provides the LO frequency to mix down the incoming RF frequency. Finally, the intermediate frequency processor (IFP) amplifies, channelizes, detects, and digitizes the IF spectrum produced by the receiver frontends. Integration time is 8 ms and digitization is to 16-bit resolution. The control and data-handling module timestamps and packages the radiometer data, and sends it to the CubeSat bus for storage. The radiometer is a cross-track scanning radiometer, with the radiometer being scanned about the satellites velocity vector at 30 RPM. The radiometer will sample 80 earth views and 20 cold space views. Noise temperature is injected on ten of the cold space views for calibration. The radiometer is designed for two-point calibration on each scan line.

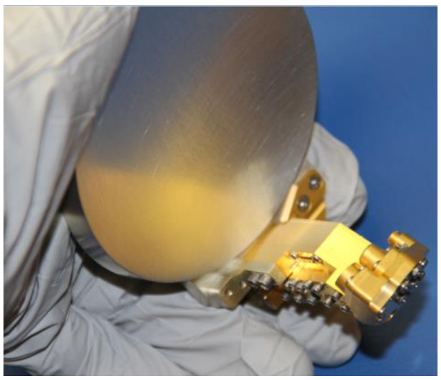

Fig. 3. Quad-band antenna subsystem for the MicroMAS-2 radiometer

III. Test Results and Analysis

The radiometer was designed with one 90 GHz channel, five channels near 118 GHz, three channels near 183 GHz, and one channel at 206 GHz. The channels were characterized using Y-factor measurements, and receiver temperatures of approximately 2500 K at F-band and noise diode temperatures of approximately 290 K obtained. Thermal vacuum calibration, with thermally controlled blackbody targets simulating cold space and varying earth scenes, was conducted.

A key metric tested for is the temperature sensitivity or noise equivalent delta-temperature (NEΔT), which is a measure of the minimum change in antenna temperature that is detectable by the radiometer. Results show a radiometer temperature sensitivity less than 1.1 K on both temperature and humidity sounding channels. Temperature sensitivity on the imaging channels had a maximum value of 2.1 K at W-band.

An important portion of the integration and test process was the stability testing of the noise diode. The noise diodes are operated over a period to ensure proper burn-in and stable noise temperature output. For accurate on-orbit calibration, the output of the noise diode must be stable and well characterized over temperature. The temperature of the instrument was controlled through the full range of expected orbital temperatures (with margin) for several days during environmental testing.

The radiometer payload is fitted with voltage and temperature monitors, which report constantly to the control and data-handling module. The temperature data is used in calibration as radiometer characteristics, such as gain, vary with temperature. The payload is also equipped with a survival heater.

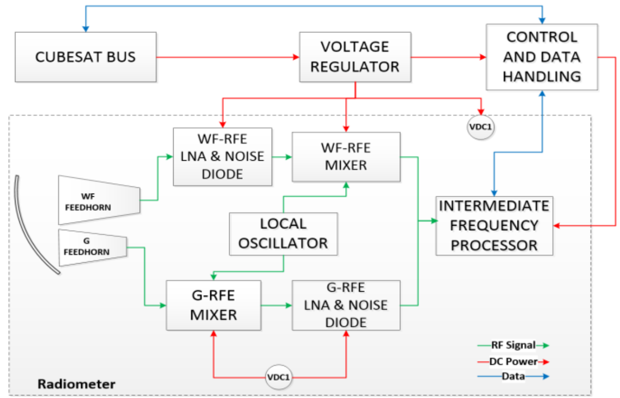

Fig. 4. MicroMAS-2 radiometer payload block diagram

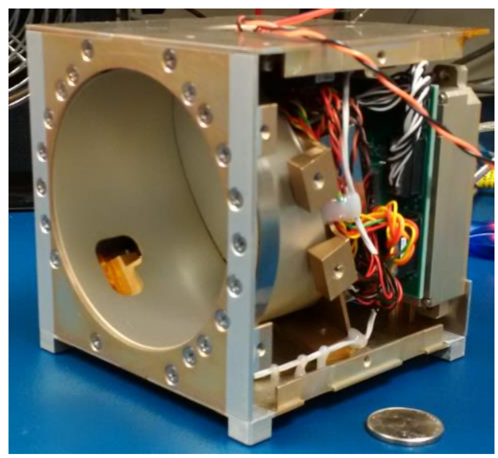

Fig. 5. Assembled MicroMAS-2 radiometer payload

IV. Summary

A compact microwave radiometer has been successfully designed, fabricated, and tested for applications on CubeSat platforms. On-orbit characterization and performance will highlight a new environmental monitoring tool to help improve global forecasts.

References

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