A Compact Terahertz Instrument for Continuity Microwave Limb Sounding of Atmosphere

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***Abstract*— Spaceborne observations have been pivotal in enhancing our understanding of Earth's atmosphere. Atmospheric limb sounding provides excellent vertical resolution and a robust signal-to-noise ratio for measuring trace gases. Here, we provide a brief overview of the Aura MLS instrument currently in space and then introduce the next generation "Continuity-MLS" in development now. This new instrument achieves nearly all Aura MLS measurements but with a significantly smaller form factor and better sensitivity, leveraging on the recent advances in CMOS, microwave and terahertz technologies.**

***Keywords*—Microwave limb sounding, Terahertz, Schottky, CMOS.**

I. Introduction

SINCE its launch in 2004, the AURA Microwave Limb Sounder (MLS) has provided a wealth of highly reliable and stable atmospheric observations with excellent vertical resolution [1]. Even after almost two decades of being in space, the measurement data from MLS instruments remain crucial for understanding the composition of the stratosphere and upper troposphere and their impacts on Earth's surface climate. Acknowledging the importance of this data, NASA's Earth Science Technology Office (ESTO) is actively supporting technology development initiatives for the next generation of MLS-like instruments. These efforts are directed towards crafting CubeSat/SmallSat-class instruments with the capability to investigate issues associated with the stability of the stratospheric ozone layer, climate change, and the impact of stratospheric ozone on air quality.

The Continuity-MLS (C-MLS) initiative seeks to uphold the MLS instrument's legacy while achieving better sensitivity and significant reductions in mass, power, volume, and cost. This is reflected in its name, Continuity-MLS, which achieves almost all the measurements performed by Aura MLS but with a much more compact form factor, weighing about 60kg and requiring around 80W of power. In contrast, the larger and more power-intensive Aura MLS weighs 500kg and demands 500W. These significant improvements have been possible due to the advancements and utilization of recent innovations in the areas of CMOS, microwave, and terahertz technology, including CMOS System on Chip (SoC) digital spectrometers, and CMOS W-band synthesizers, compact intermediate-frequency (IF) processors, state-of-the-art Schottky diode mixers and multipliers, as well as low-loss waveguide-based diplexers.

Aura MLS covered measurements in seven spectral regions from 118 GHz to 2.5 THz. The Continuity-MLS instrument focuses specifically on the 340 GHz and 640 GHz spectral regions due to its relevance for key molecules like H_2O, CO and HCl. This region allows measurements down to ~10 km altitude with low atmospheric absorption.

The C-MLS instrument comprises an antenna conducting limb scans over a tangent altitude range of 0 to 100 km approximately every 26 seconds. Calibration is performed through a switching mirror that provides perspectives of a spectrally flat calibration target and space. These views are spectrally divided by a polarizing beam-splitter into two receiver subsystems operating at 340 GHz and 640 GHz. The 340 GHz subsystem employs a sideband-separating architecture, utilizing a low-loss waveguide-based diplexer as a passive high/low pass filter for the incoming RF signal. The filtered RF bands undergo mixing with the LO signal through sub-harmonically pumped Schottky diode mixers, enabling down-conversion of observations to an IF of 0–18 GHz. A compact and low-power IF processor refines the IF signal and directs it to dedicated digital spectrometers. The spectral refinement is significantly improved through the use of spectrometers employing all-digital signal processing. Each digital spectrometer has a bandwidth of 3 GHz, comprising 4096 channels, and consumes 1.5 W. The 340 GHz receiver channel lacks spectral lines for hydrogen chloride (HCl), an essential molecule for understanding ozone destruction in the stratosphere and as a marker for stratospheric air transport. To address this, a second Schottky-based heterodyne receiver operating at 640 GHz is incorporated into C-MLS.

This presentation will provide an overview of the Continuity-MLS (C-MLS) instrument architecture, emphasizing key enabling technologies as these technologies are instrumental in maintaining the continuity of AURA MLS observations while significantly reducing the form factor and overall cost of the instrument.

References

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