Development of Internally-Calibrated, Direct-Detection Millimeter-Wave Radiometers for High-Resolution Remote Sensing of Wet-Tropospheric Path Delay

Victoria D. Hadel[(1)]*, Steven C. Reising[(1)], Xavier Bosch-Lluis[(1)], Pekka Kangaslahti[(2)], Sharmila Padmanabhan[(2)], Chaitali Parashare[(2)] , Shannon T. Brown[(2)], Alan B. Tanner[(2)] and Oliver Montes[(2)]

(1) Microwave Systems Laboratory, Colorado State University, Fort Collins, CO 80523
(2) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91125

Current satellite ocean altimeters include nadir-viewing, co-located 18-34 GHz microwave radiometers to measure wet-tropospheric path delay. Due to the large antenna footprint sizes at these frequencies, the accuracy of wet path retrievals is substantially degraded within 40 km of coastlines, and retrievals are not provided over land. A viable approach to improve their capability is to add wide-band millimeter-wave window channels in the 90-180 GHz band, thereby achieving finer spatial resolution for a fixed antenna size. In this context, the upcoming Surface Water and Ocean Topography (SWOT) mission is in formulation and planned for launch in late 2020 to improve satellite altimetry to meet the science needs of both oceanography and hydrology and to transition satellite altimetry from the open ocean into the coastal zone and over inland water. To address wet-path delay in these regions, the addition of 90-180 GHz millimeter-wave window-channel radiometers to current Jason-class 18-34 GHz radiometers is expected to improve retrievals of wet-tropospheric delay in coastal areas and to enhance the potential for over-land retrievals.

To this end, an internally-calibrated, wide-band, cross-track scanning airborne microwave and millimeter-wave radiometer is being developed in collaboration between Colorado State University (CSU) and Caltech/NASA's Jet Propulsion Laboratory (JPL). This airborne radiometer includes microwave channels at 18.7, 23.8, and 34.0 GHz at both H and V polarizations; millimeter-wave window channels at 90, 130, 168 GHz; and temperature and water vapor sounding channels adjacent to the 118 and 183 GHz absorption lines, respectively. Since this instrument is a space flight prototype, substantial effort has been devoted to minimizing the mass, size and power consumption of the radiometer's front end.

One of the most noteworthy design features of these millimeter-wave window channel radiometers is the inclusion of integrated internal couplers in the multi-chip modules (MCM) housing each RF front end. These couplers not only provide improved performance compared to commercially-available waveguide couplers but also significantly reduce the size and mass of the radiometers and increase their modularity. Additionally, a second waveguide port and integrated coupler were added to provide the capability to quantitatively measure the balance of the input impedance presented by the Dicke switch to the first low-noise amplifiers. Along with the design of these new couplers, internal matched loads were designed, fabricated, and placed at the isolated port of the couplers inside of the MCMs. Another improvement was the design of waveguide-based band definition filters to replace the previously used microstrip filters. These filters showed a significant performance improvement and increased tolerance to manufacturing variations. The millimeter-wave window channels at 90, 130 and 168 GHz have been fabricated and are currently being tested for integration into the overall airborne instrument for initial flights on Twin Otter aircraft in early 2014.