Design of Narrow-Band Filters and Power Dividers for Sub-Millimeter Wave Direct Detection Atmospheric Sounding Radiometers

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The size distribution of ice particles in the upper troposphere needs to be accurately characterized, along with water vapor and temperature vapor profiles, to improve cloud characterization in climate change model predictions. Global observations of properties of ice clouds in the upper troposphere can substantially contribute to modeling the physical and microphysical properties of these clouds and their thermodynamic environment. To accurately characterize ice particles, humidity and temperature in the upper troposphere, temperature and humidity sounding measurements are needed at higher frequencies than are currently available from satellite measurements. These higher frequencies permit sensing at higher altitudes, in the regions where upper tropospheric ice clouds are formed.

This paper focuses on the development of sub-millimeter-wave components to enable the design and implementation of direct detection receivers rather than traditional heterodyne receivers. Measuring the atmosphere using direct detection rather than heterodyne receivers substantially decreases their power consumption and mass. These are both important design criteria for their ability to perform global observations from space on CubeSats and small satellites. Performing moisture profiling near 380 GHz and temperature profiling near 424 GHz will also improve their spatial resolution, as compared to lower frequency receivers. The realization of direct-detection receivers at these sub-millimeter-wave frequencies requires the design of both power splitters and narrow bandpass filters.

This paper addresses the design of sub-millimeter-wave bandpass filters and power dividers for operation near 380 GHz and 424 GHz. In this paper, waveguide filter and power divider topologies are discussed. Their performance is simulated using Ansys High Frequency Structure Simulator (HFSS) software. The design goal for these sub-millimeter-wave sounders is to measure three channels adjacent to each of the absorption lines at 380 GHz and 424 GHz. Therefore, three-way power division is required just after the low-noise amplifiers in the receiver chain. This is typically accomplished by designing a four-way power divider and terminating one output in a matched load. Model results show that at frequency bands of 380 GHz and 424 GHz, sufficiently narrow filter bandwidths can be achieved with waveguide filters. Reasonable machining tolerances have been taken into account. For the power dividers, model results indicate that nearly equal power division is possible in these sub-millimeter-wave frequency bands. Detailed simulation results will be presented for these component designs.