Ice-Cube: Spaceflight Validation of an 874 GHz Sub-millimeter Wave Radiometer for Ice Cloud Remote Sensing

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Importance of Ice Clouds and Their Processes

- Global climate modeling
  - Cloud as the leading source of uncertainties in predicting climate change.
  - Too many degrees of freedom
  - Tunable parameters: cloud cover, water content, microphysics
  - Differences by 2x - 10x
  - Accurate (25%) cloud ice needed
IceCube Measurement Objectives

• Raise the technology readiness of 874 GHz receiver technology for use in a future space flight mission.
  – The project will yield the first ever 874 GHz measurement of ice clouds from space.
  – The project outcome will directly benefit sub millimeter-wave imaging radiometer on future Earth Science missions.
Multi-channel CoSSIR measurements of ice clouds were used successfully to demonstrate retrieval of ice water path (IWP) and ice particle median mass-weighted ice particle size (Dme). Below is first ever 874 GHz cloud measurements acquired by CoSSIR in 2008.

The 874-GHz radiometer in the airborne Compact Scanning Sub millimeter wave Imaging Radiometer (CoSSIR) instrument, proved to have the greatest sensitivity to ice.
IceCube Radiometer

- The radiometer will have a noise figure of 15 dB with an NEDT of ~0.15 K for a 1-second dwell time. The instrument is both externally and internally calibrated using views of deep space and an internal IF noise source and reference state.

<table>
<thead>
<tr>
<th>Category</th>
<th>Functional Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Band</td>
<td>862-886 GHz with (f_c) at 874 GHz</td>
</tr>
<tr>
<td>Input RF Channel</td>
<td>V Polarization</td>
</tr>
<tr>
<td>NEDT</td>
<td>0.15 K</td>
</tr>
<tr>
<td>Calibration Sources</td>
<td>Noise Diode/Reference Load (internal)</td>
</tr>
<tr>
<td>IF Band</td>
<td>6-12 GHz</td>
</tr>
<tr>
<td>IF Gain</td>
<td>50-55 dB</td>
</tr>
<tr>
<td>A/D Sampling</td>
<td>10 KHz</td>
</tr>
<tr>
<td>Integration time</td>
<td>1s</td>
</tr>
<tr>
<td>Mass</td>
<td>(\leq 1) kg</td>
</tr>
<tr>
<td>Power</td>
<td>11.2 W including 30% contingency</td>
</tr>
</tbody>
</table>

*Key Performance Parameters*
The Radio Frequency (RF) receiver is comprised of an offset parabola reflector with feedhorn, mixer, stable oscillator, RF multiplier chain, Intermediate Frequency (IF) chain, detector and video amplifier. There are also supporting circuit boards including the instrument Power Distribution Unit (iPDU) and command and data handling (C&DH), which is shared with the spacecraft.
Instrument Operation and Calibration

- Calibration of the radiometer is achieved by both internal electronic (in the IF stage) and external natural target means (space). The noise source coupled into the IF path is used to estimate IF section gain.
- A calibration error of TB=2.0K or less as measured from deep-space observations.

Mission requirements:
- In-flight operation 28 days
- Periodical views of Earth (science) and space (calibration) within an orbit
- Science data 30+% (8+h /day)
- Pointing knowledge < 25 km
Spacecraft

- The 1.3U instrument is accommodated within a 3U Cubesat, with internal volume and mass margins adequate to fit within the required Cubesat specifications standards (CubeSat Design Specification Rev. 12, Cal Poly SLO).
Launch Opportunity and Orbit

- **NASA CubeSat Launch Initiative (CSLI)**
  - Coordination of upcoming launches
  - 1U, 2U, 3U, or 6U

- **International Space Station (ISS)**
  - Secondary cargo payload on ISS resupply missions
  - Mid 2016
  - 350-450 km, 51.6° inclination near-circular orbit
  - β angle variation: 0-75°

- **3U CubeSat Launchers**
  - NanoRacks CubeSat Deployer from ISS
  - Small-Sat Orbital Deployer (J-SSOD) from ISS/JEM
  - NASA NEXT
Conclusion

• IceCube is NASA’s Science Mission Directorate (SMD) first Earth science-related CubeSat mission. It will raise the technology readiness level of an 874 GHz Sub-millimeter Wave Radiometer for Ice Cloud Remote Sensing, and in doing so not only retire risks associated with development of larger, more expensive instruments, but also continue to demonstrate the utility of Cubesats as technology precursors.
Acknowledgments

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• IceCube Team

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- *IF subassembly*
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**874-GHz Receiver (Virginia Diode, Inc)**
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- *CAD and Mechanical*
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