Microwave Remote-Sensing Standards at NIST

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Outline

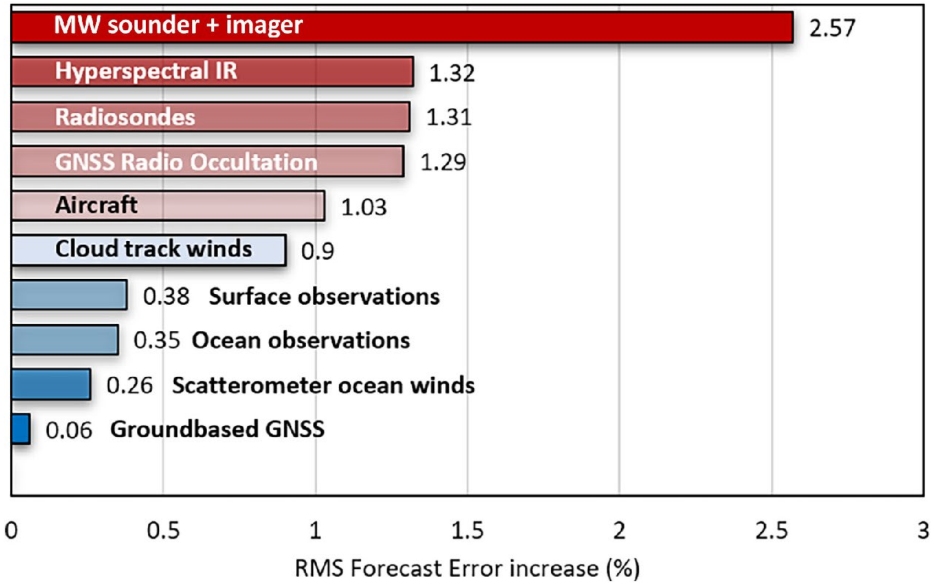
- What we do at NIST
- Remote-sensing standards motivation
- Approaches
- Past accomplishment
- Current development
- Future work

NIST

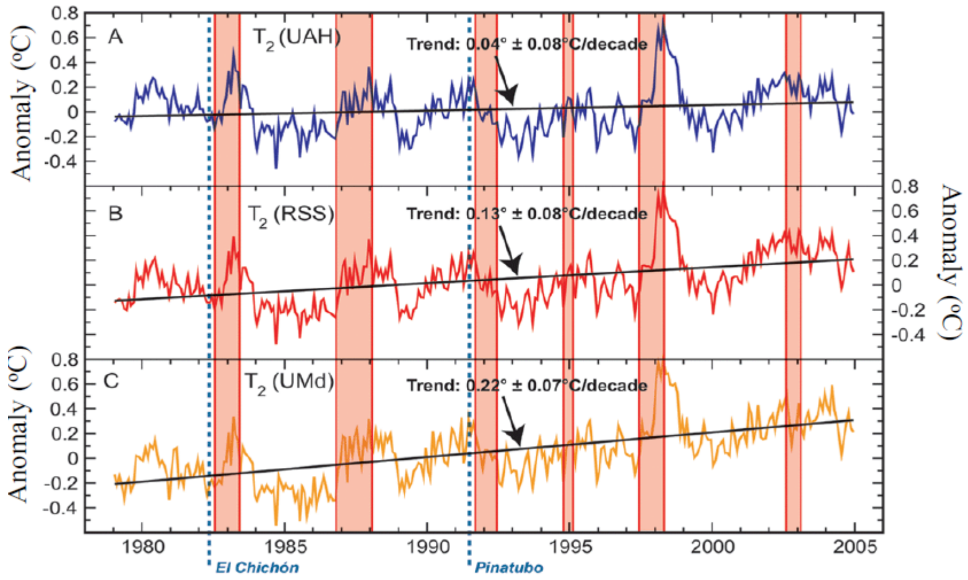
- National metrology institute (NMI) of the US
- Non-regulatory research agency under the Department of Commerce
- Perform research on the theory and practice of measurement science
- Develop standards and techniques enabling measurement traceability to fundamental units (constants)
- Neutral party in standards development and measurement assessment
- Provide calibration services to support US economy

Motivation

- NIST maintains UV/VIS/IR spectral radiance standards, no microwave free-space standards existed until 2011.
- Microwave data is one of the most critical parameters for weather and climate forecasting.
- All-weather capability due to its longer wavelength.
- Lack of traceability results in inter-satellite measurement differences.



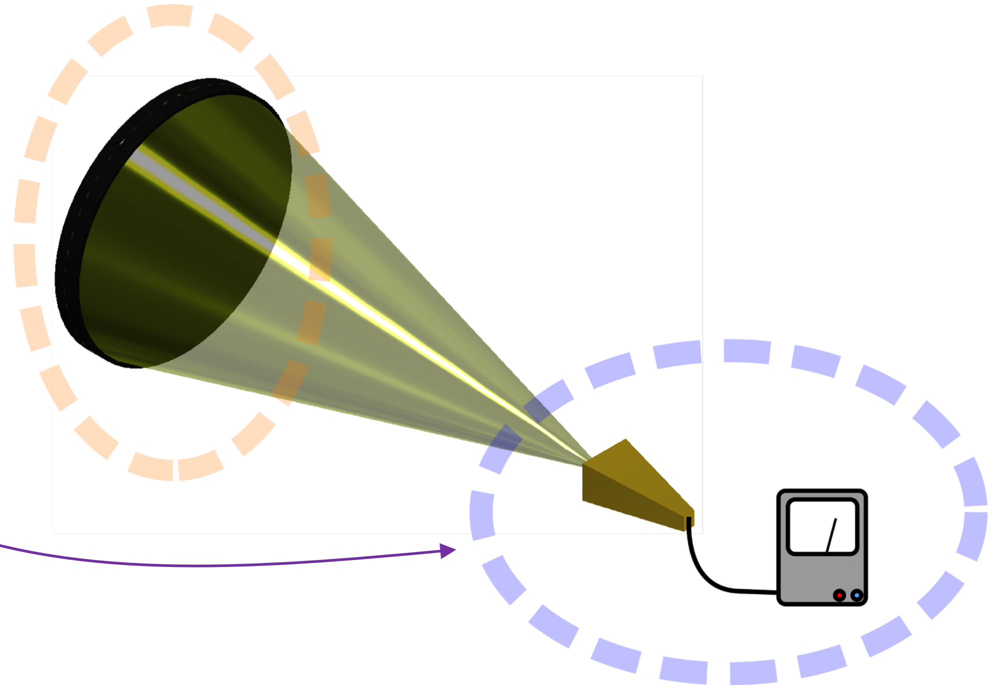
Saunders, Weather RMetS, vol. 76, no. 3, Mar. 2021



Zou and Chen, Suomi NPP SDR Science and Products Review, Dec. 2013

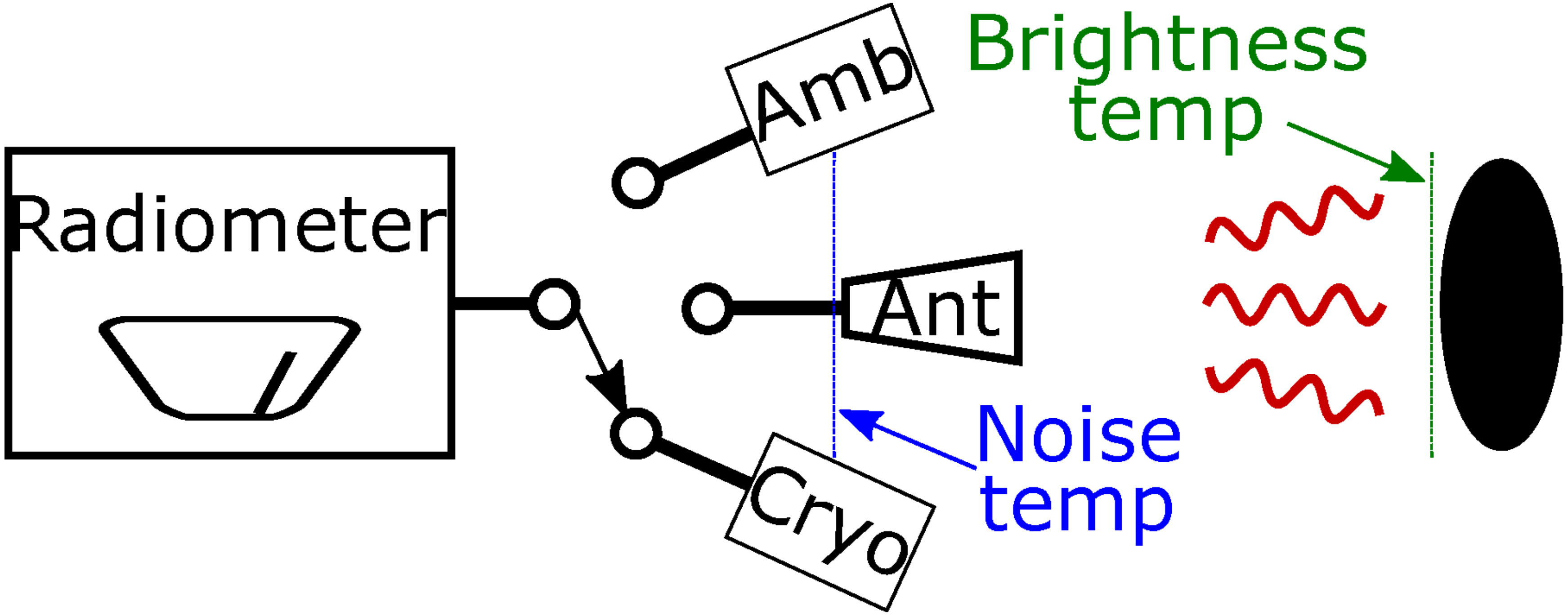
Approaches

- Remote-sensing brightness temperature traces to physical temperature through Planck radiation law.
- Develop capabilities at microwave & mm-wave frequencies, providing a link between microwave remote-sensing measurements and NIST measurements & standards.
- Two general approaches
  - Standard radiometer
  - Standard blackbody



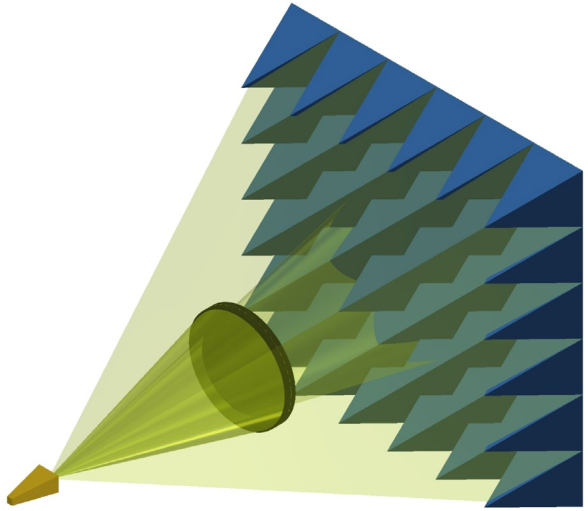
Approaches – Standard Radiometer

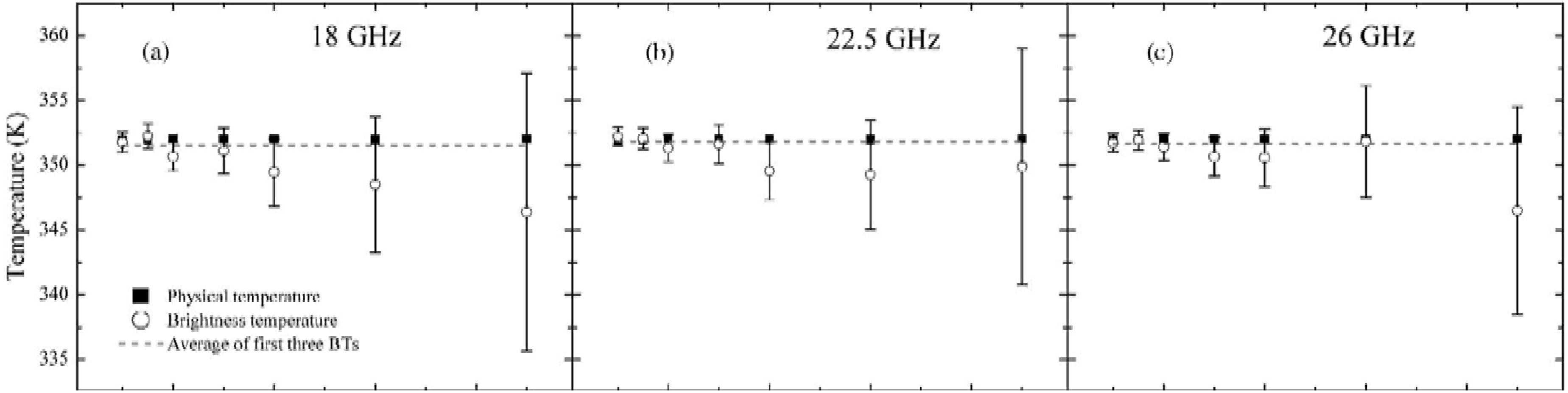
- Long established traceable thermal noise radiometry in conductive media (coaxial lines and waveguides).
- Need to extend to free-space (over-the-air OTA) noise measurements.



Past Accomplishment – Standard Radiometer

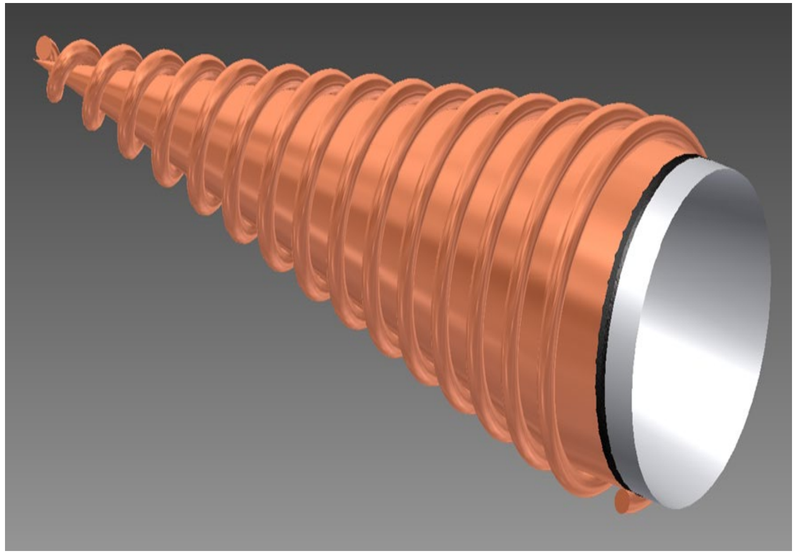
- Developed temperature-variation method.
- Linearized radiometer measurements with physical temperature of calibration target.
- Demonstrated remote-sensing traceability with precision as good as 0.7 K (IEEE TGRS vol. 50 no. 11, 2012).





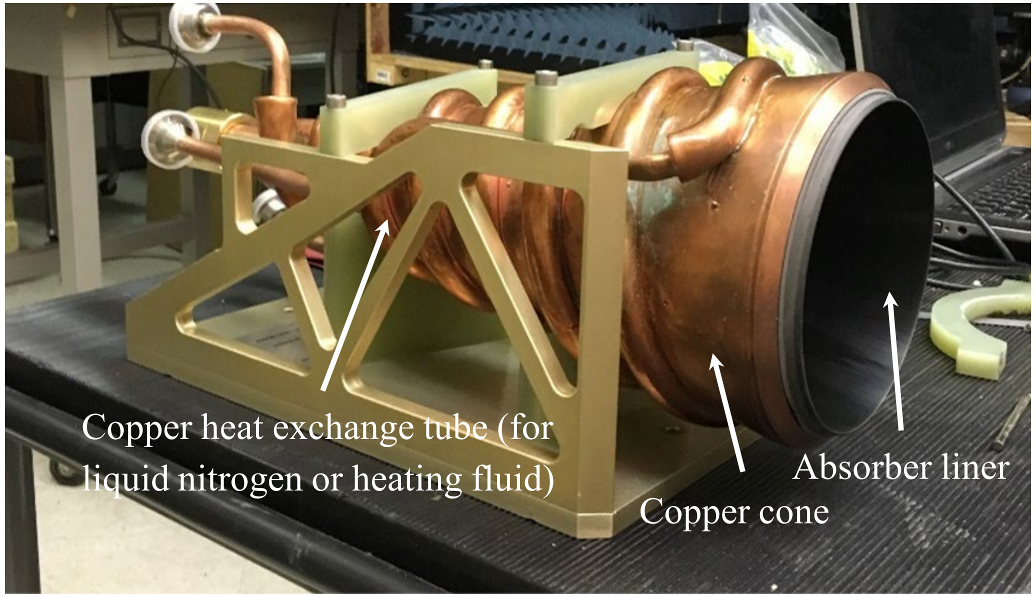
Approaches – Standard Blackbody

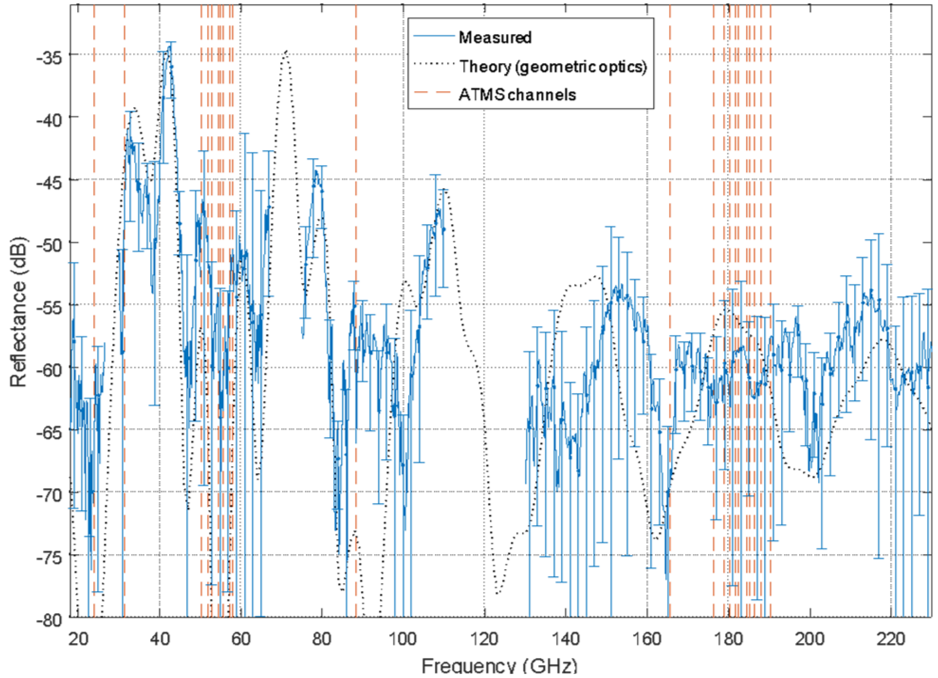
- Standard radiometer brings challenges in dissemination of traceability.
- Conventional blackbody target made of array of pyramids (or wedges, cones), polarization dependent, temperature nonuniformity, limited bandwidth.
- NIST prototype standard blackbody made of copper hollow cone with absorptive layers, heat exchange tubing for temperature regulation.



Past Accomplishment – Standard Blackbody

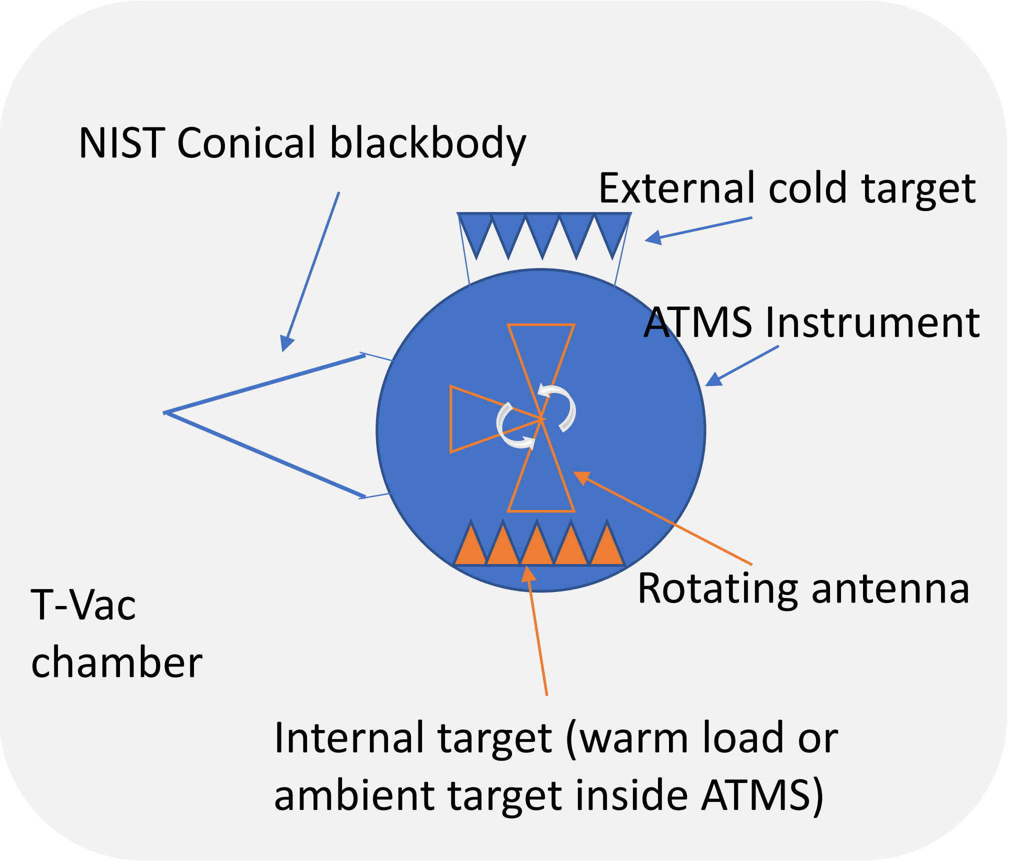
- Designed to maximize performance at frequencies aligned with ATMS channels.
- Stand-alone unit for convenient pre-launch calibration and traceability transfer.
- Reflectance mostly below -40 dB (close to ideal emissivity) up to 220 GHz.
- Objective is to achieve brightness temperature precision as low as 0.1 K.





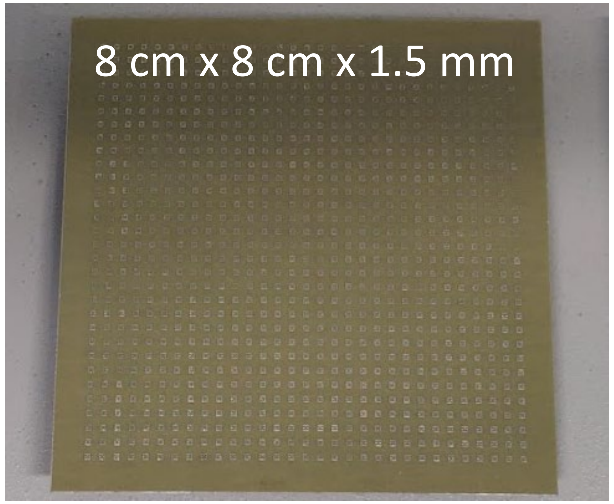
Current Developments – Traceability

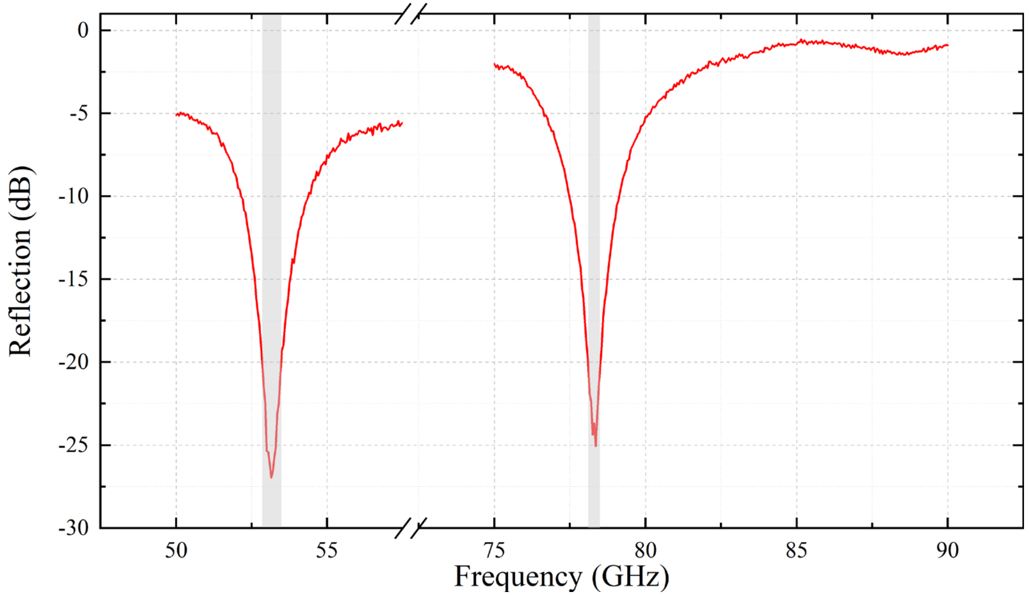
- Validating NIST prototype blackbody target in a thermal-vacuum chamber.
- Extending SI traceability to space radiometer by integrating calibration procedures in pre-launch validation.
- Improving satellite intercalibration, temporal calibration, and historical data record.



Current Developments – Miniaturization

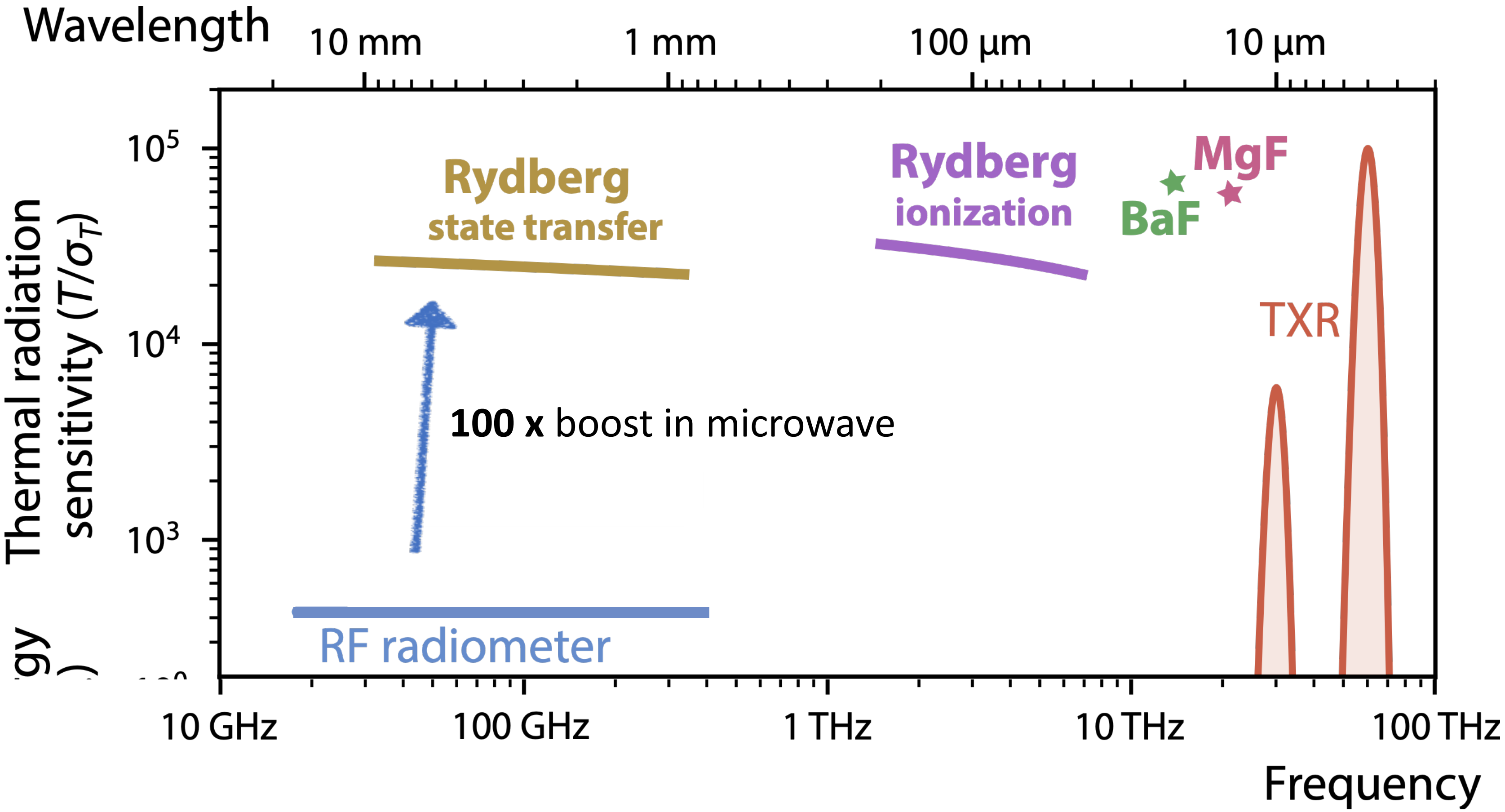
- New calibration targets made of meta-material PCB boards.
- Reduced size, weight and power consumption.
- Absorption frequencies aligned with sounding and imaging channels.
- Designed for deployment on small satellite (CubeSats and NanoSats) platforms.





Future Work

- Quantum-based radiometer: atomic, direct-to-the-SI, and calibration-free thermal radiation sensors.



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