MICROWAVE REMOTE-SENSING PROJECT UPDATE

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OUTLINE

• Current research topics:
  • Brightness-temperature (Tb) standards
    • Standard radiometer
    • Standard target
  • Robotic antenna range (CROMMA facility)
  • Advanced radiometer calibration methods
  • WR-10 (75 to 110 GHz) radiometer
  • Ocean salinity standards
• Summary & plans
Radiometric Target Measurement

--Use existing NIST radiometer linked to primary noise standards (SI Traceable):

![Diagram of radiometric target measurement setup]

Primary Standards

- Radiometer (Rad.)
- Standard (Std.)
- Ambient (Amb.)
- Cryogenic (Cryo)
- Antenna (Ant.)
- Target

Electromagnetics Division
Waveguide 6-port reflectometer with heterodyne receiver

Waveguide banded radiometers

Primary Noise Standards
Achievable Uncertainty with Standard Radiometer (only)

Goal is to reach the accuracy requirements for climate change study—data for 18 to 26.5 GHz

<table>
<thead>
<tr>
<th></th>
<th>NIST radiometer</th>
<th>Troposphere</th>
<th>Stratosphere</th>
<th>Precipitation</th>
<th>Water vapor</th>
<th>Sea surface temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>$u$</td>
<td>~ 0.7-1.0 K</td>
<td>0.5 K</td>
<td>1 K</td>
<td>1 K</td>
<td>1.25 K</td>
<td>0.03 K</td>
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Current coverage: 12 to 65 GHz; soon to include 75 to 110 GHz band (WR-10)
Transfer NIST $T_b$ cal to instrument radiometer

Note: Geometry must be maintained in xfer

Transfer pre-launch cal to on-orbit cal: background change can be accommodated
Black Body Targets--Current Design

Constrained volume and mass for space and aircraft calibration

large temperature gradients

Up to 0.6 K mean offset from recorded temp

Narrow optimal operating frequency range due to periodic pyramid structure


NIST BB Standard Target Design

Single open conical structure

Uniform emissivity $\approx 1$ over broad microwave frequency spectrum (10-200 GHz)

Minimal temperature gradients

Operating temperature range: 80 K to 350 K
Std Target--Thermal Modeling

- Physical T of BB design simulated with CFD software
- TVAC as well as ambient environment
  - Thin polyethylene foam insulating layer necessary even in vacuum

Simulated streamlines in anechoic chamber (left) and resulting temperature contour with 3 mm insulation layer (right)
Electromagnetic Modeling

• Optimized absorber layer solution input to full wave finite element electromagnetic solver (HFSS*)

• Emissivity derived from reflectance distribution
  • ~1 hour/frequency point running on 16-processor 130 GB RAM HPC
$T_B$ and Uncertainty Calculation

- Calculate effective brightness temperature from physical temperature, electromagnetic blackbody reflectivity, and antenna pattern simulations
- 350 K set temperature
- U calculation by Monte Carlo simulation including:
  - Mat'l parameter U
  - EM simulation convergence error
  - CFD simulation error
- Total $u = \sim 0.05$ K
- $U (k=2) = \sim 0.1$ K
**BB Standard Target—Status**

- Design finalized FY15 with $\varepsilon$ and $u(T)$ goals met
- Contract let to Thomas Keating, Ltd.
  - 2 targets: 23 cm and 13 cm apertures, to match ATMS requirements
  - Absorber test samples being measured to confirm model-fabrication compatibility
  - Target fabrication will include absorber “witness samples” to verify EM performance
  - Estimated completion: September 2016
Transfer NIST BB $T_b$ std to instrument radiometer

**Compare/Calibrate** instrument cal target(s) with NIST BB std

**Transfer pre-launch cal to on-orbit**

*cal:* background change can be accommodated
WR-10 Radiometer

- WR-10 cryogenic noise standard:
- Similar architecture to other NIST noise radiometers, with 2 separate IF chains
- Component evaluation and subassemblies under construction

WR-10 Radiometer Circuit schematic

![WR-10 Cryogenic Standard |S11|](image1.png)

![Balanced Mixer Conversion Loss](image2.png)
Summary & Plans

- $T_B$ standard radiometer
- Initial development 18-26.5 GHz band; 12 to 65 GHz now, with 75-110 GHz radiometer in 2017
  - Demonstrate practical cal. transfer to flight instrument
- Primary standard target
  - Significant reduction in uncertainty—U $\sim$ 0.1 K
  - Provides a means for $T_b$ transfer & verification
  - Modeling & design completed
  - Fabricate & test target FY16-17
- Ocean salinity
  - Resonant cavity for L-band under construction
  - Sea water traceable measurements in FY17
- Robotic antenna range (CROMMA) operational