MICROWAVE REMOTE-SENSING PROJECT UPDATE

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- Prof. Bill Emery, CU Aerospace Engineering Dept.
- Prof. Al Gasiewski, CU-CET Director
- Ed Kim, NASA GSFC
- Paul Racette, GSFC
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OUTLINE

- Current research topics:
  - Brightness-temperature (Tb) standards
    - Standard radiometer
    - Standard target
  - Ocean salinity standards
  - Robotic antenna range (CROMMA facility)
  - Advanced radiometer calibration methods
- Summary & plans
  - NB: Tb and GPS-RO traceability

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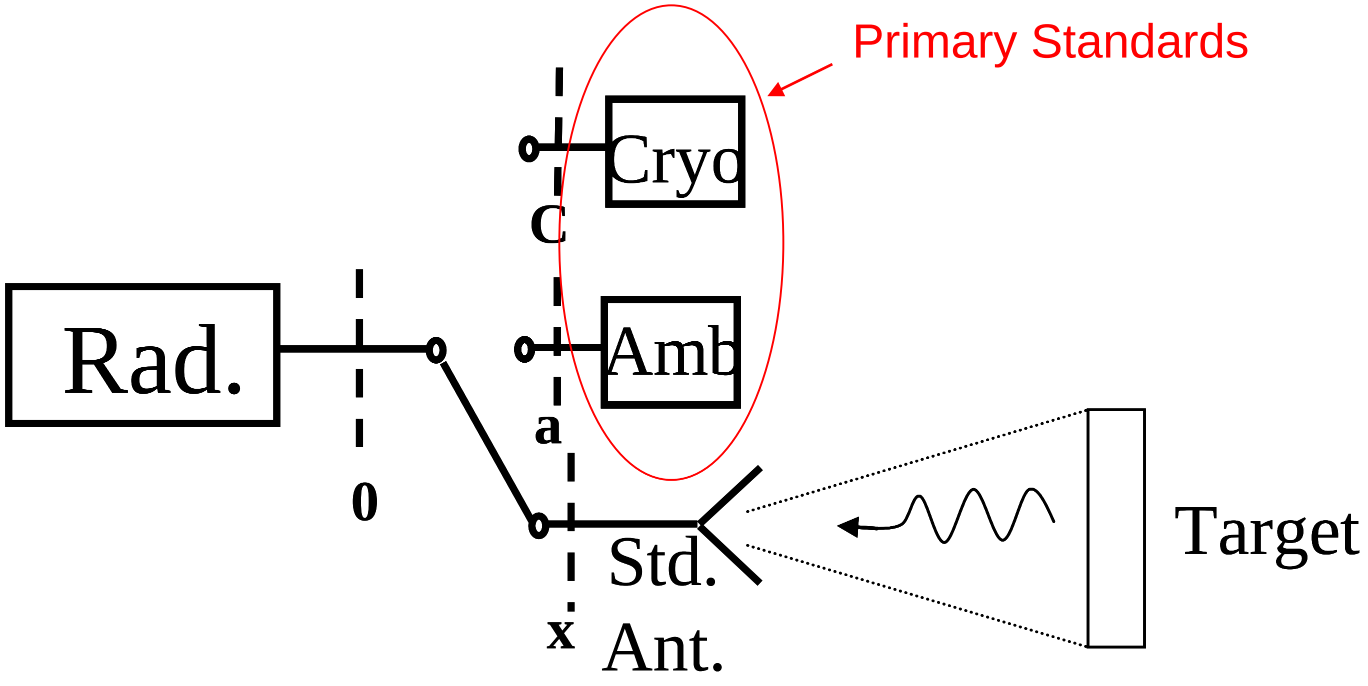
Radiometric Target Measurement

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



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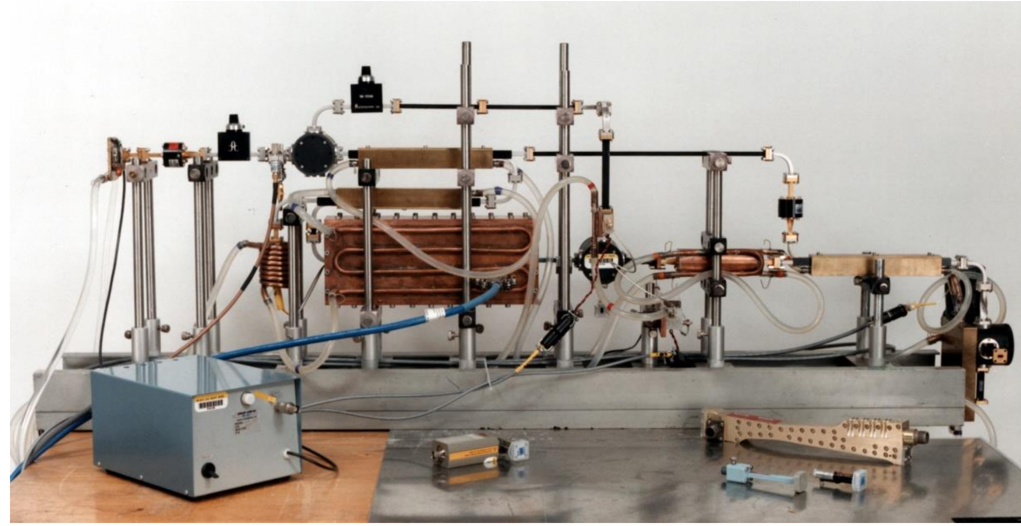
Waveguide 6-port reflectometer
with heterodyne receiver



Waveguide banded radiometers

Primary Noise Standards

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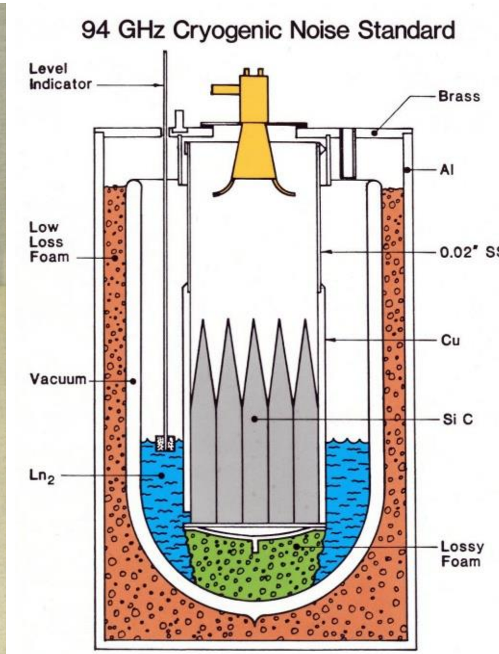
Thermal Noise Primary Standards

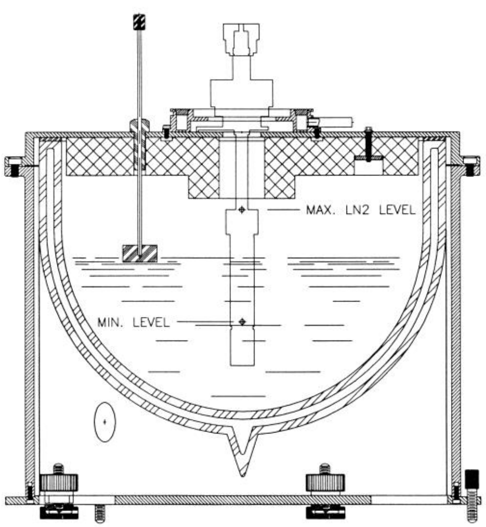
- Ambient & cryogenic (liquid nitrogen) standards.

$u_{TCry} \approx 0.65$ K

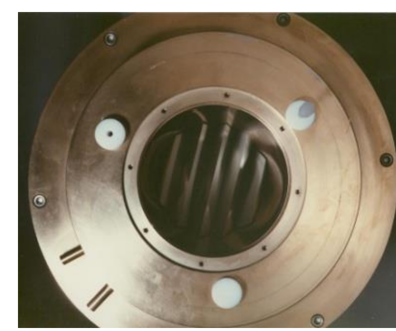
◄Coaxial

Waveguide►





$u_{TAmb} \approx 0.1$ K



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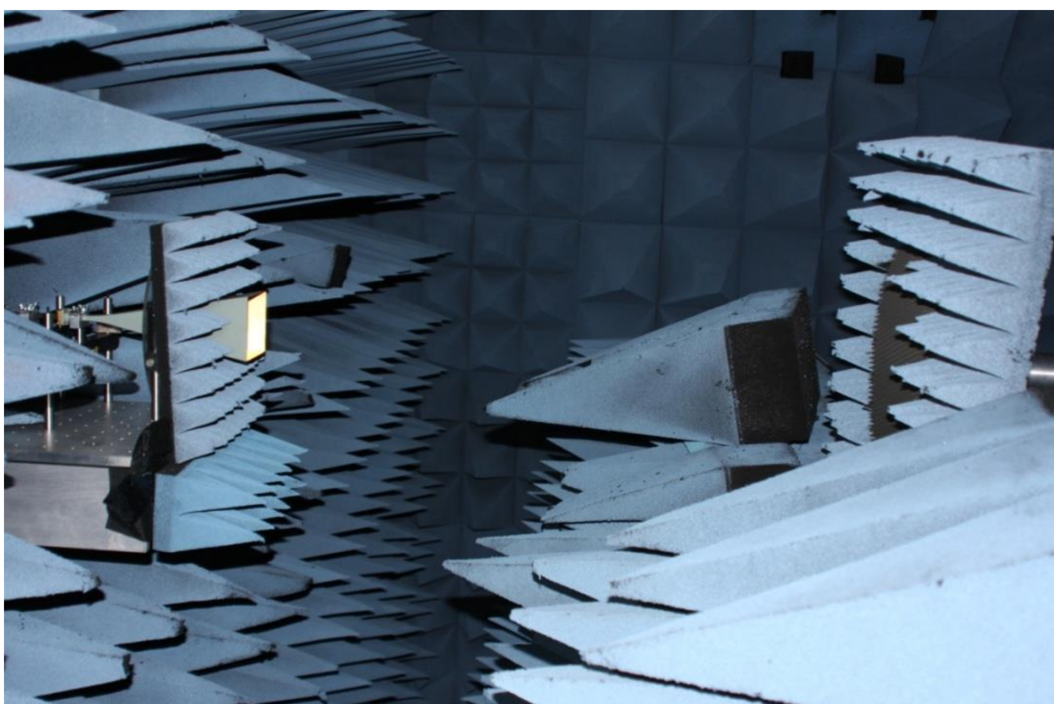
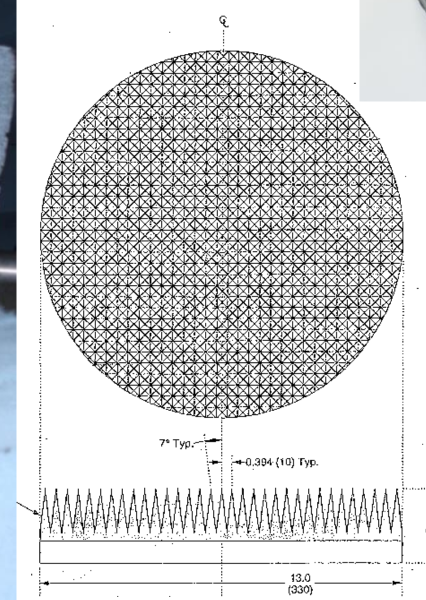
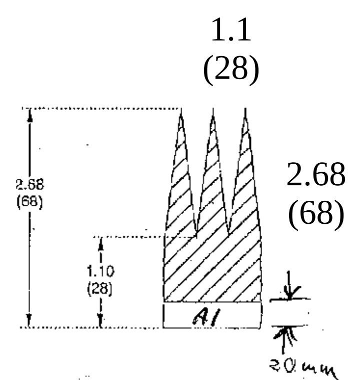
Setup for Target Reflectivity Characterization and Brightness Temperature Calibration

- NIST anechoic chamber
- *K*-band pyramidal horn attached to NIST radiometer
- 13-inch target from NASA







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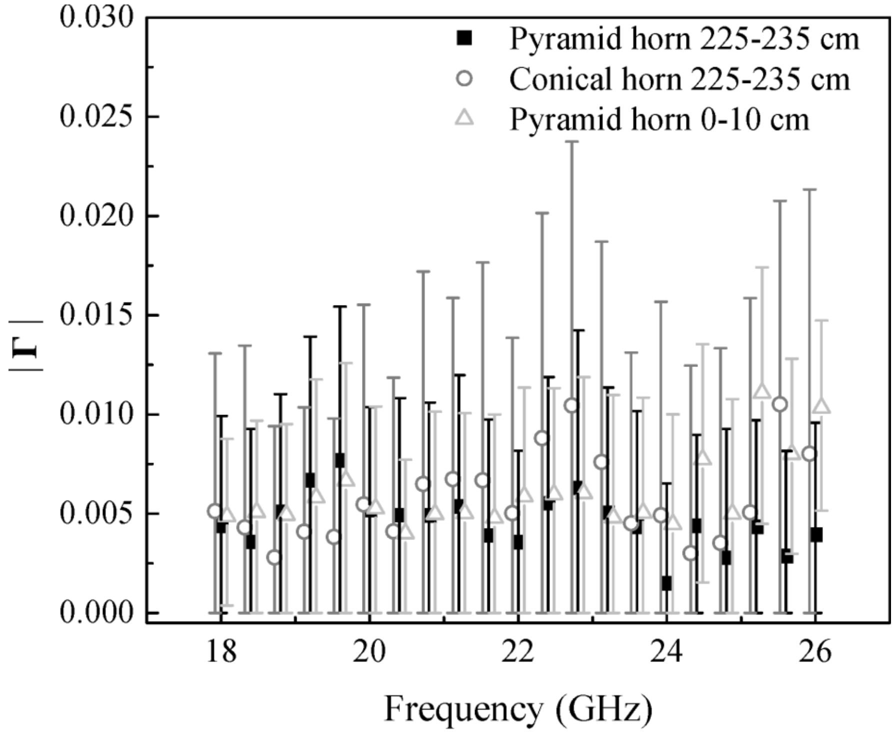
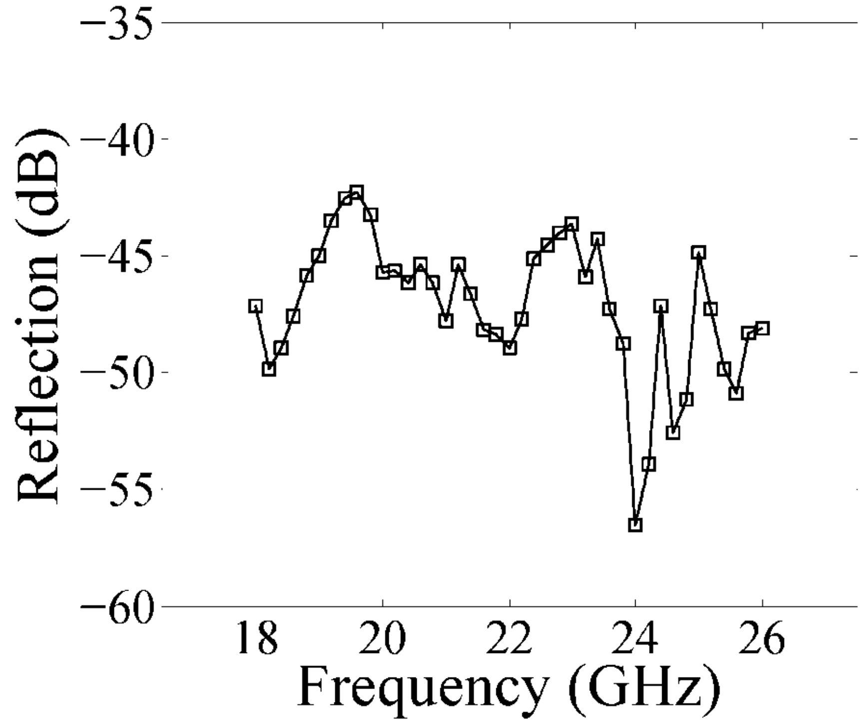
Target Reflectivity

- Reflectivity lower than 40 dB in K-band (18-26 GHz), inline with the specification of the target.
- Negligible difference between hot and ambient conditions.
- Validated by different hardware and measurement conditions
- Developing full emissivity char. with robotic range





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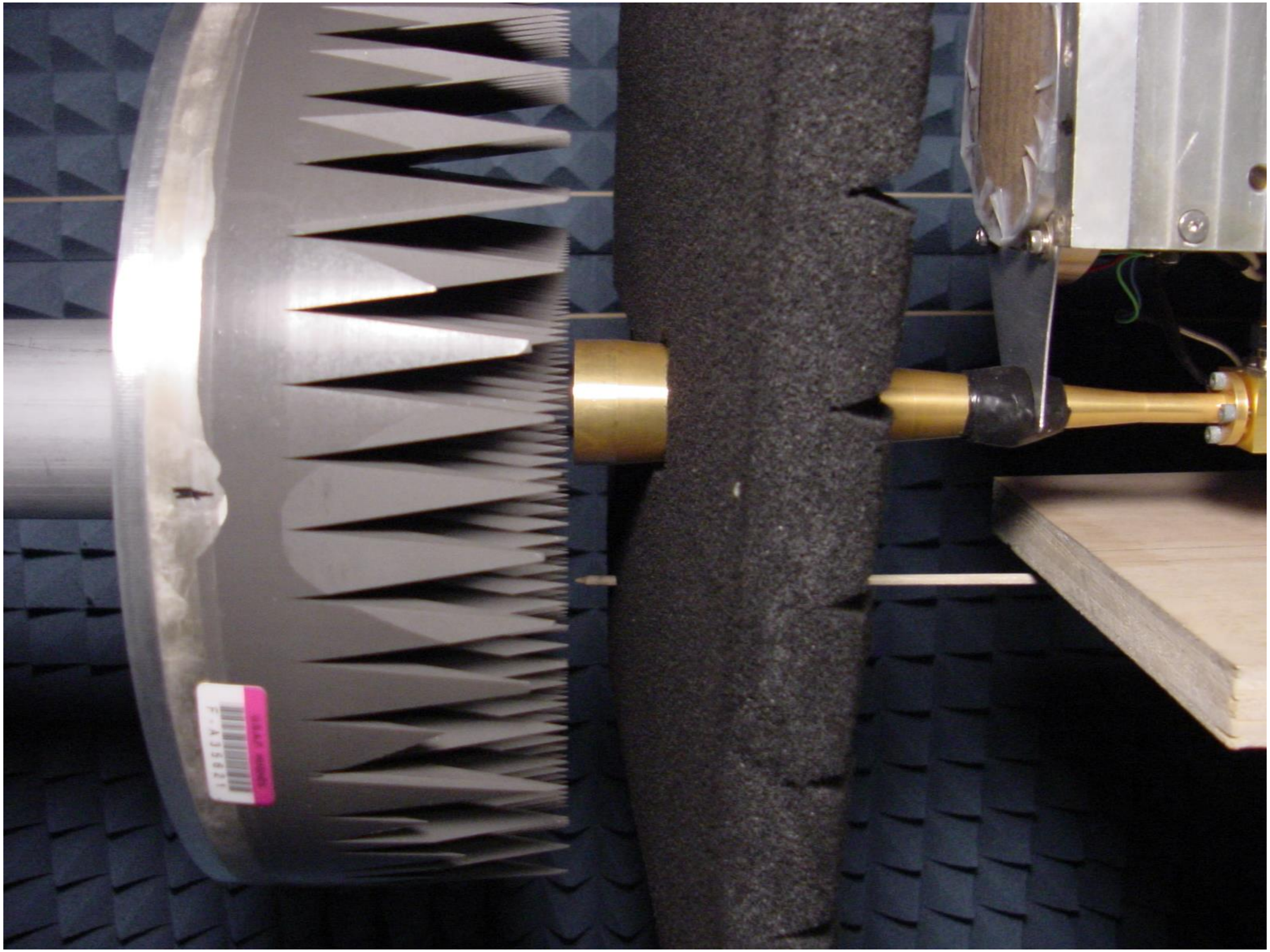
Target reflection characterization at 183 GHz, performed at CU-CET



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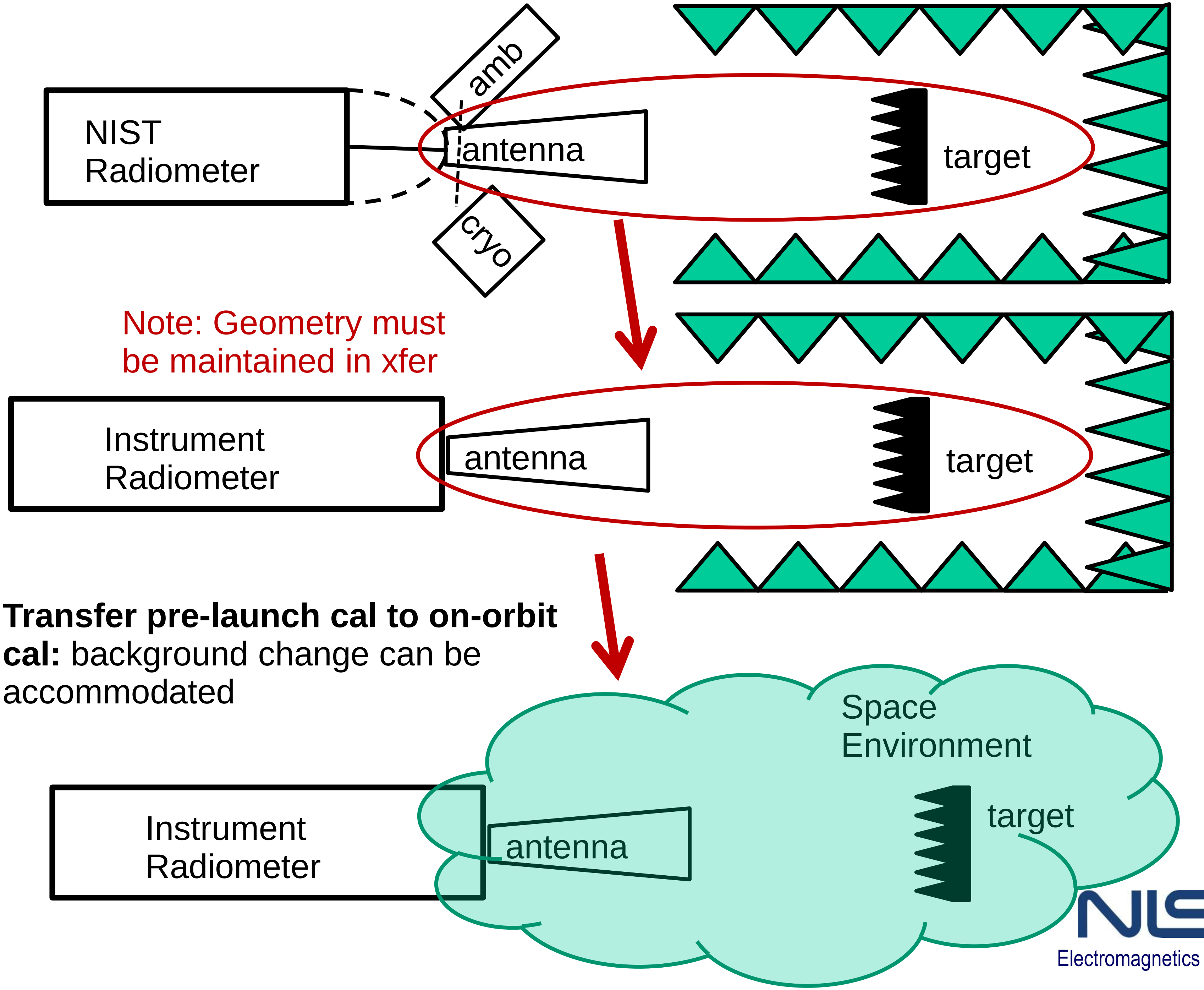
Achievable Uncertainty with Standard Radiometer (only)

Goal is to reach the accuracy requirements for climate change study:

	NIST radiometer	Troposphere	Stratosphere	Precipitation	Water vapor	Sea surface temp
u	~ 0.7-1.0 K	0.5 K	1 K	1 K	1.25 K	0.03 K

Ref: "Stability and accuracy requirements for satellite remote sensing instrumentation for global climate monitoring," ISPRS 2004.

Transfer NIST T_b cal to instrument radiometer



Transfer pre-launch cal to on-orbit cal: background change can be accommodated

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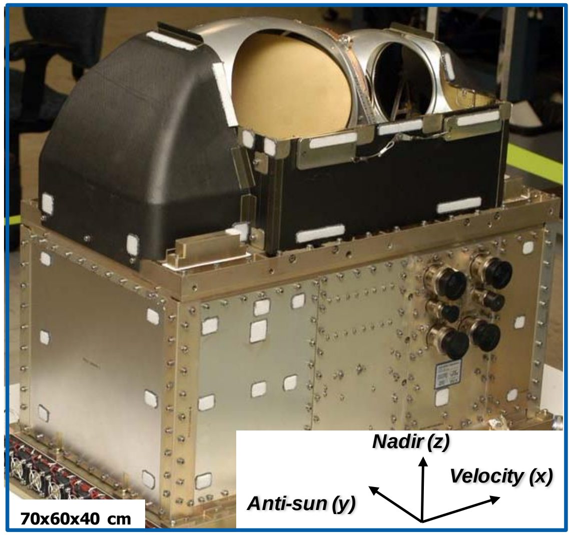
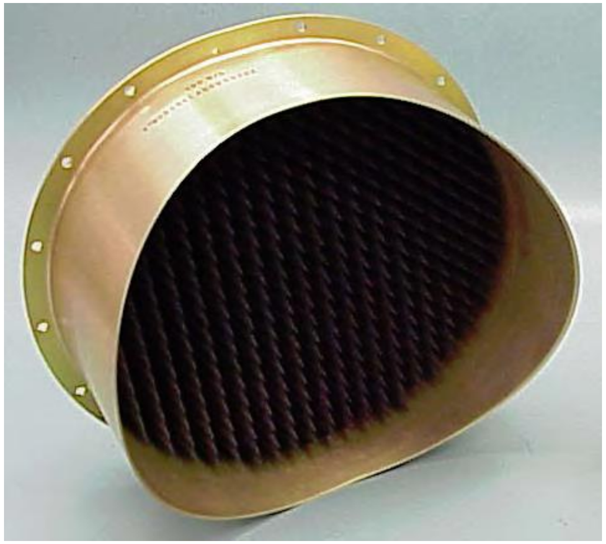
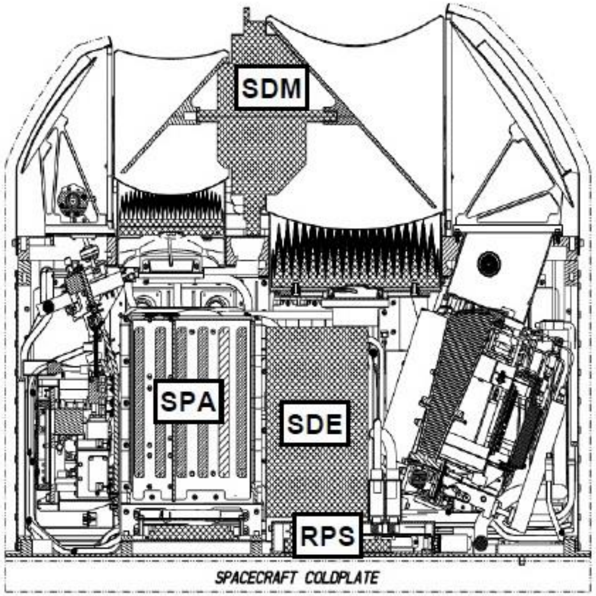
End Point: SI-Traceable calibration of ATMS pre-launch and on-orbit







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Standard Radiometer vs. **Standard Target**

- Independent realizations of T_B
- Independent, full uncertainty analyses
- Combined (full) standard would be a weighted average of the two
  - Possible √2 uncertainty improvement vs. single std.
- Transferring the T_B standard would involve either:
  - A second (portable) target calibrated with the full standard
  - Measuring a customer's target or radiometer at NIST with the full standard

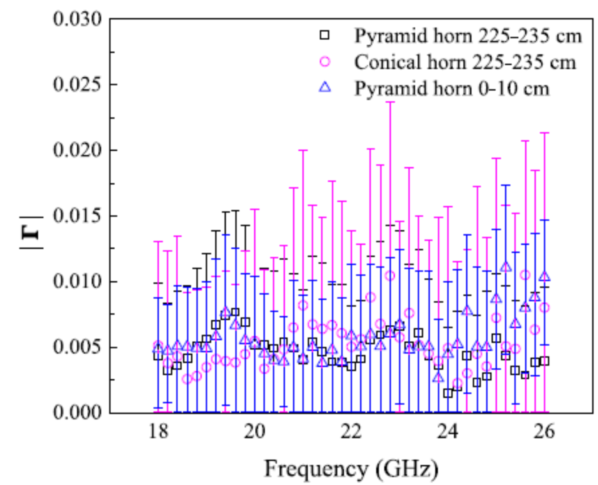
Black Body Targets--Current Design

Constrained volume and mass for space and aircraft calibration

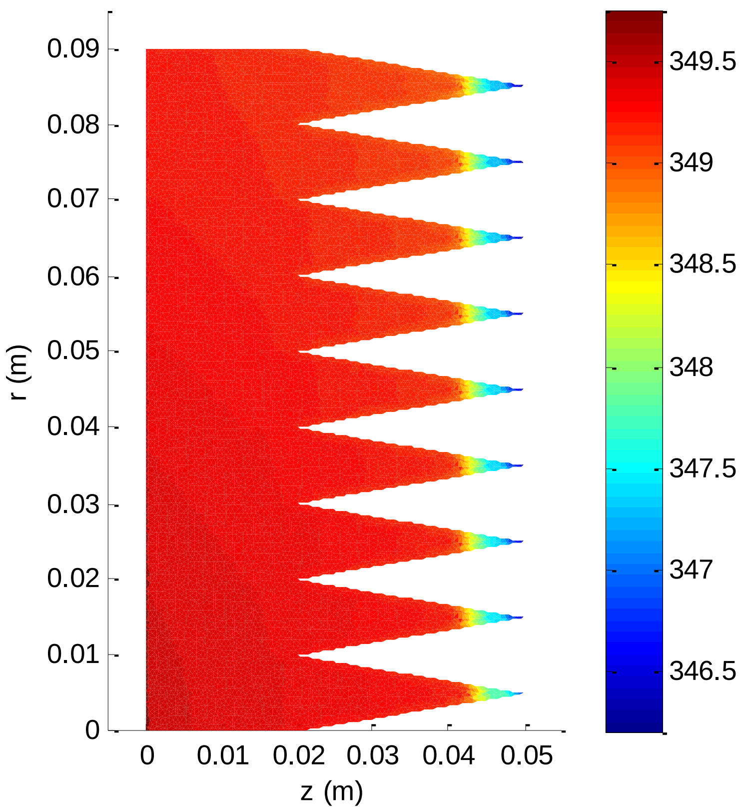
large temperature gradients

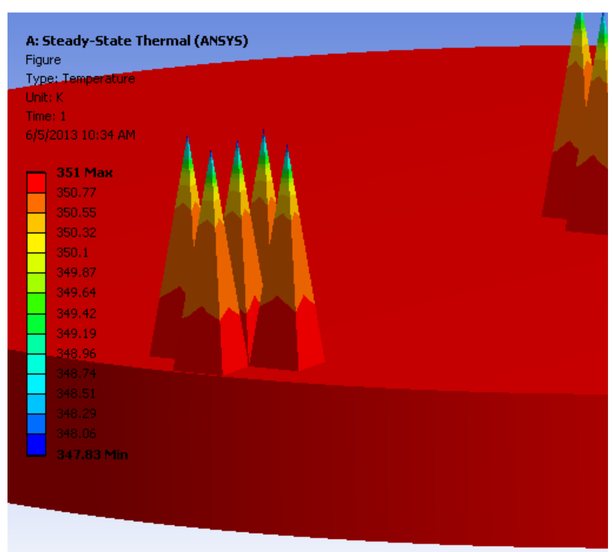
Up to 0.6 K mean offset from recorded temp

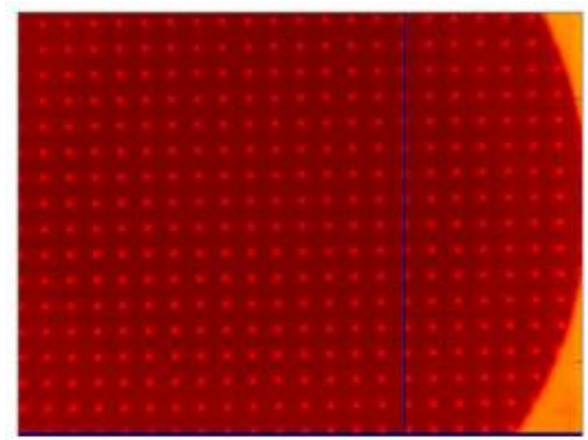
Narrow optimal operating frequency range due to periodic pyramid structure



Gu, Dazhen. “Reflectivity Study of Microwave Blackbody Targets” Trans. on Geoscience and Remote Sensing, vol. 49, No. 9, Sept. 2011.







Cox, A.E. et al. “Initial Results from the Infrared Calibration and Infrared Imaging of a Microwave Calibration Target” Int. Geoscience and Remote Sensing Symposium, Denver 2006.

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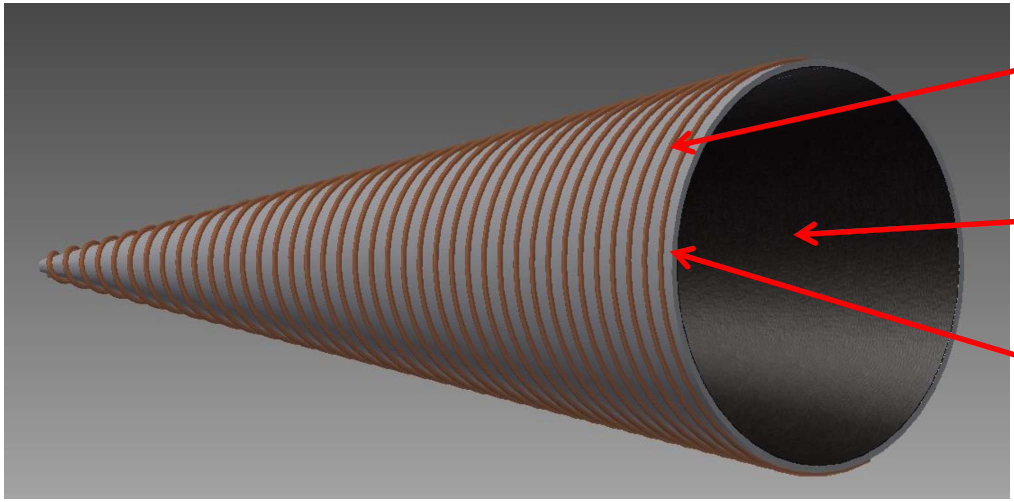
Proposed Design

single open conical or folded cone structure

- Uniform emissivity ≈ 1 over broad microwave frequency spectrum (10-200 GHz)
- Reduction in temperature gradients
- Hot and cold source with water or LN2 circulation



Copper fluid circulation tubing

absorber (Eccosorb or thin layer of microwave similar)

Aluminum substrate

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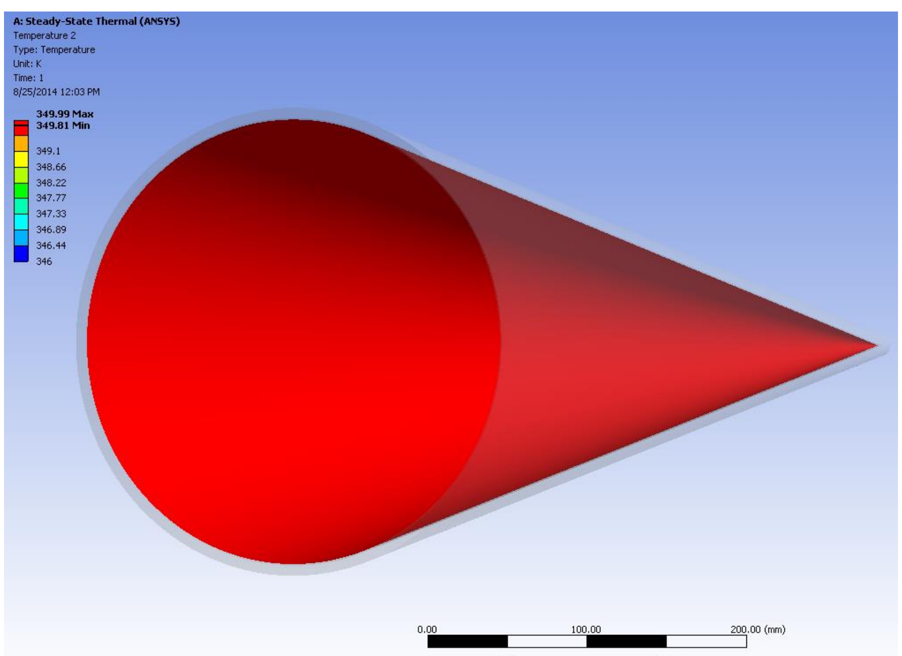
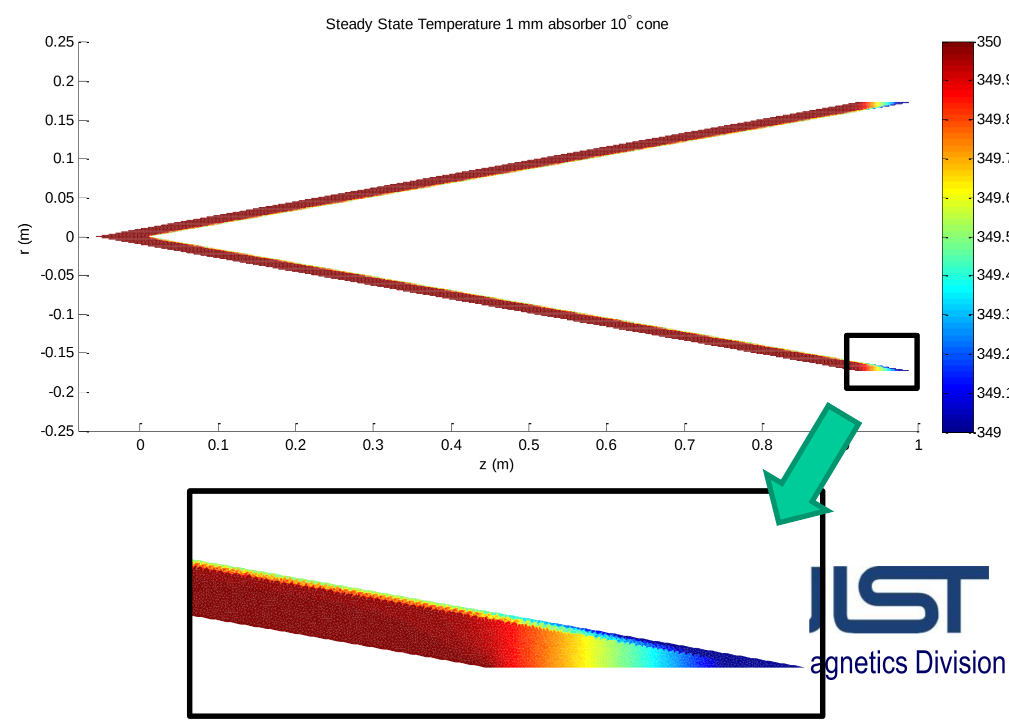
Std Target--Thermal Modeling

- Steady state temperature field using uniform empirical heat transfer coefficients
  - 0.06 K offset between aluminum substrate and mean radiating surface





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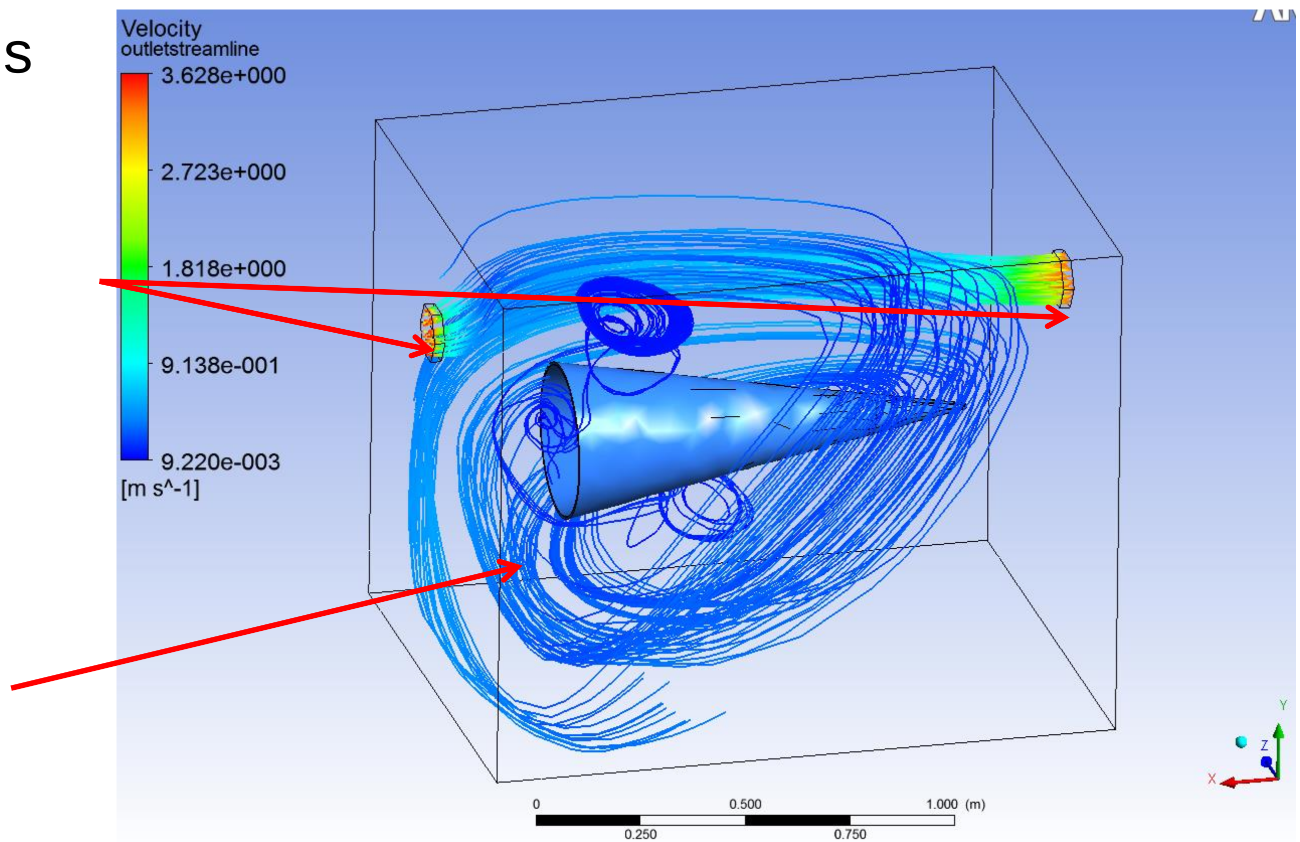
CFD – Conjugate Heat Transfer Analysis

- Full computational fluid dynamics simulation of blackbody in anechoic chamber
  - Determine heat transfer coefficients on specific geometries
  - Forced convection on blackbody from cooling fans in chamber
  - Investigate insulations



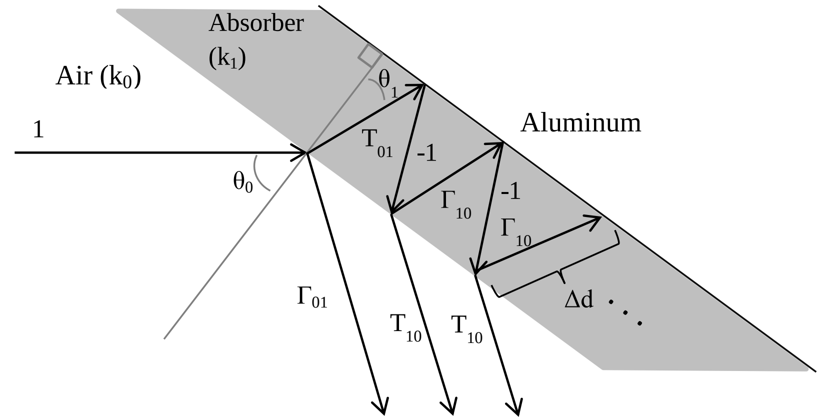
Electromagnetic Modeling

First order physical/geometric optics (PO) calculation

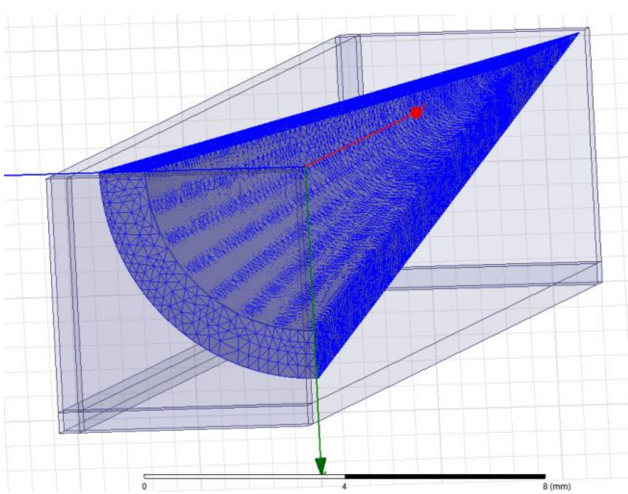
- Calculate reflectivity (infer emissivity) from multiple bounces inside structure
- Runs quickly to compare absorber types

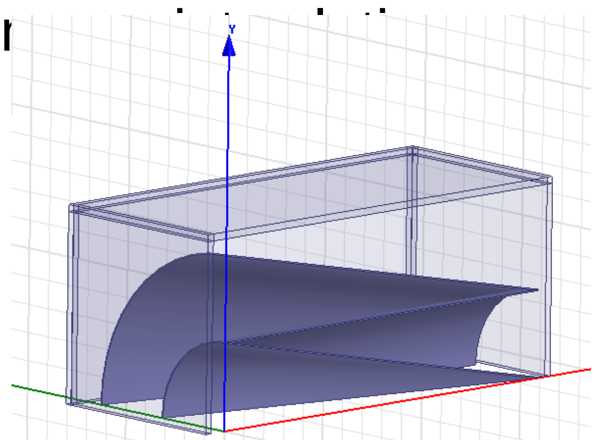
High Frequency Structural Simulator

- Commercial full wave EM solver)
- Finite element method, high accuracy
- Runs on 16 processor 130 GB RAM HPC



Considerations for single bounce on absorber material inside cone





HFSS models, ¼ cropped at symmetry axes, (left) mesh example, (right) folded cone example

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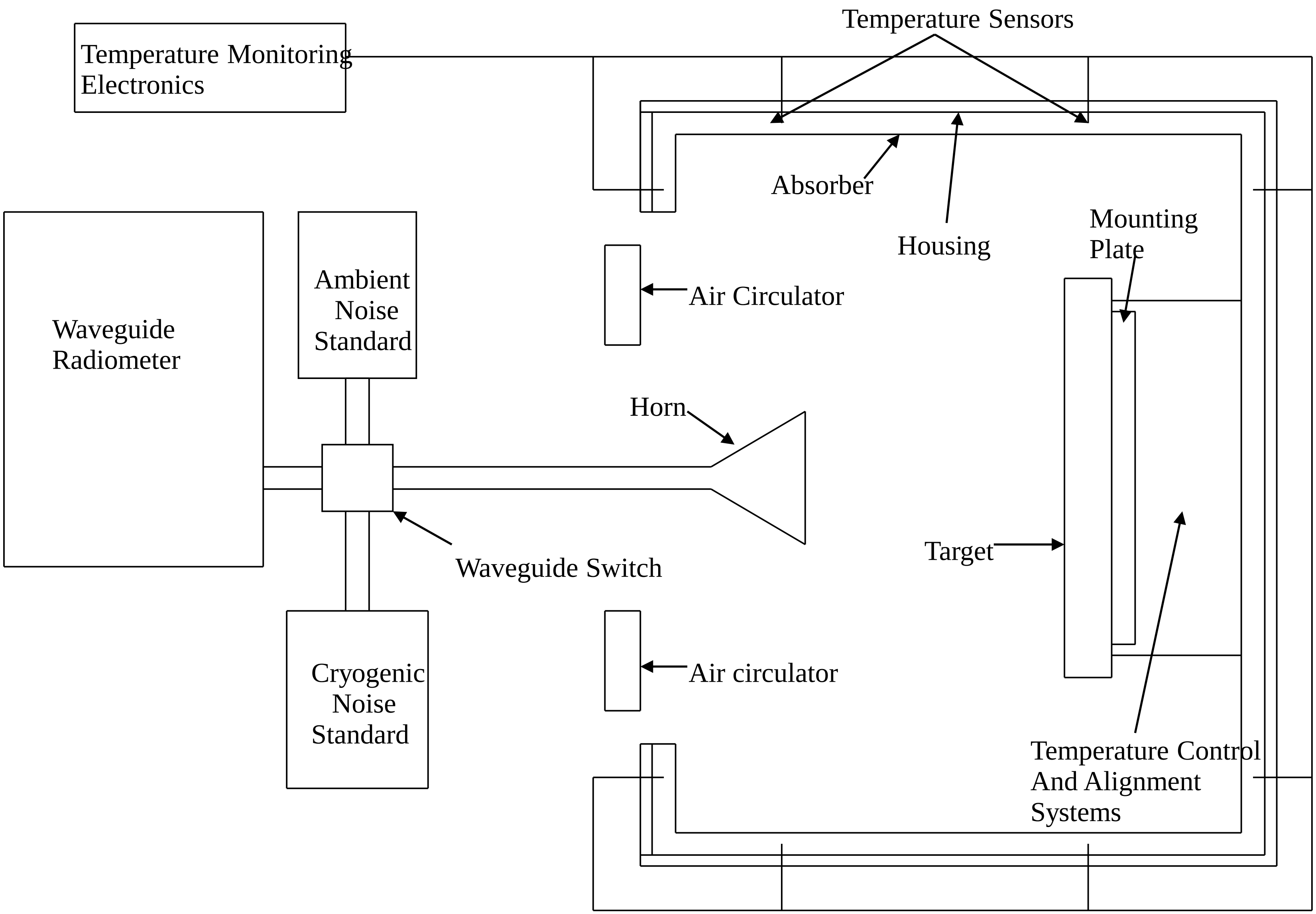
Target calibration/test chamber



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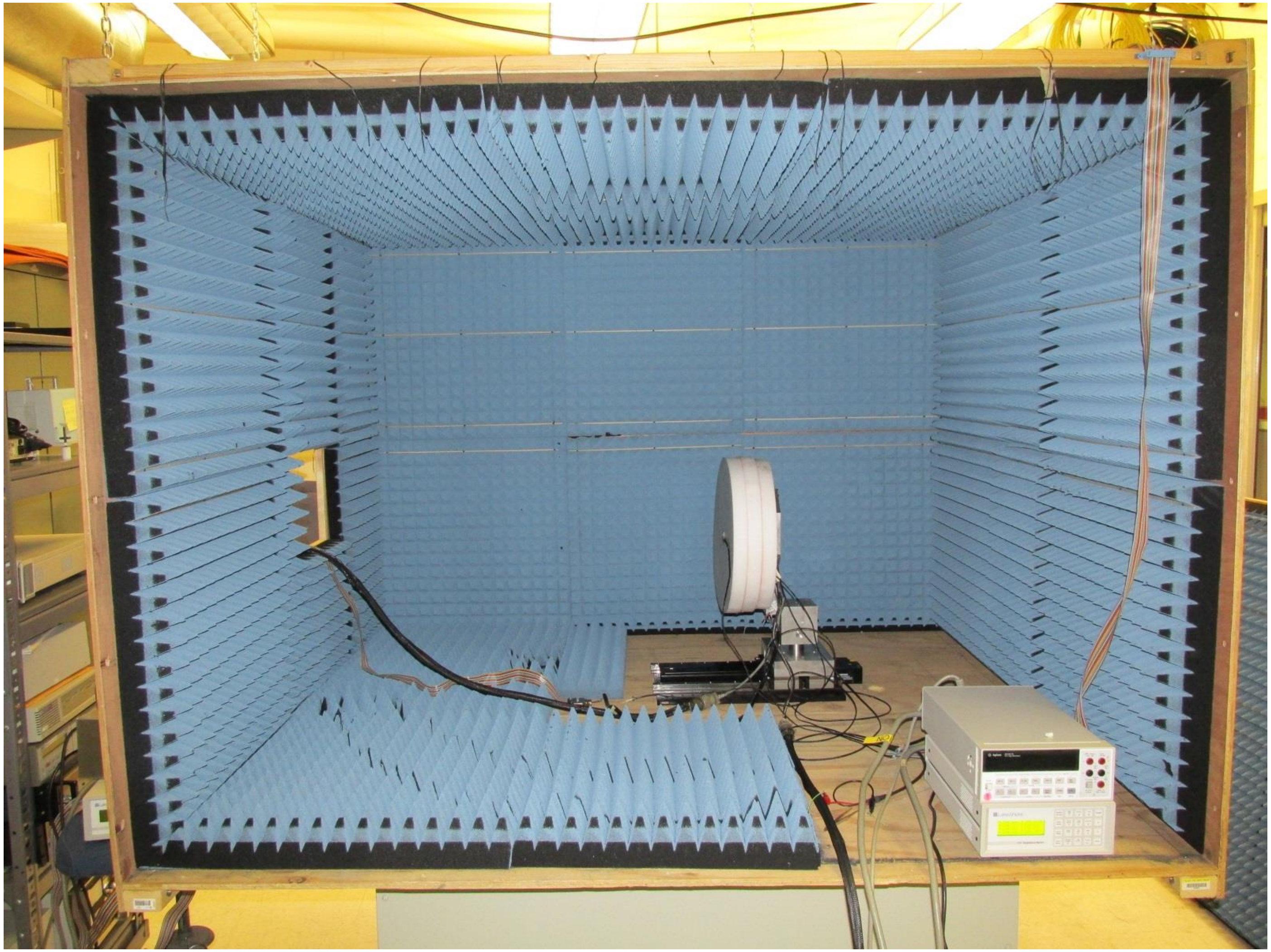
Bench-Top Anechoic Chamber



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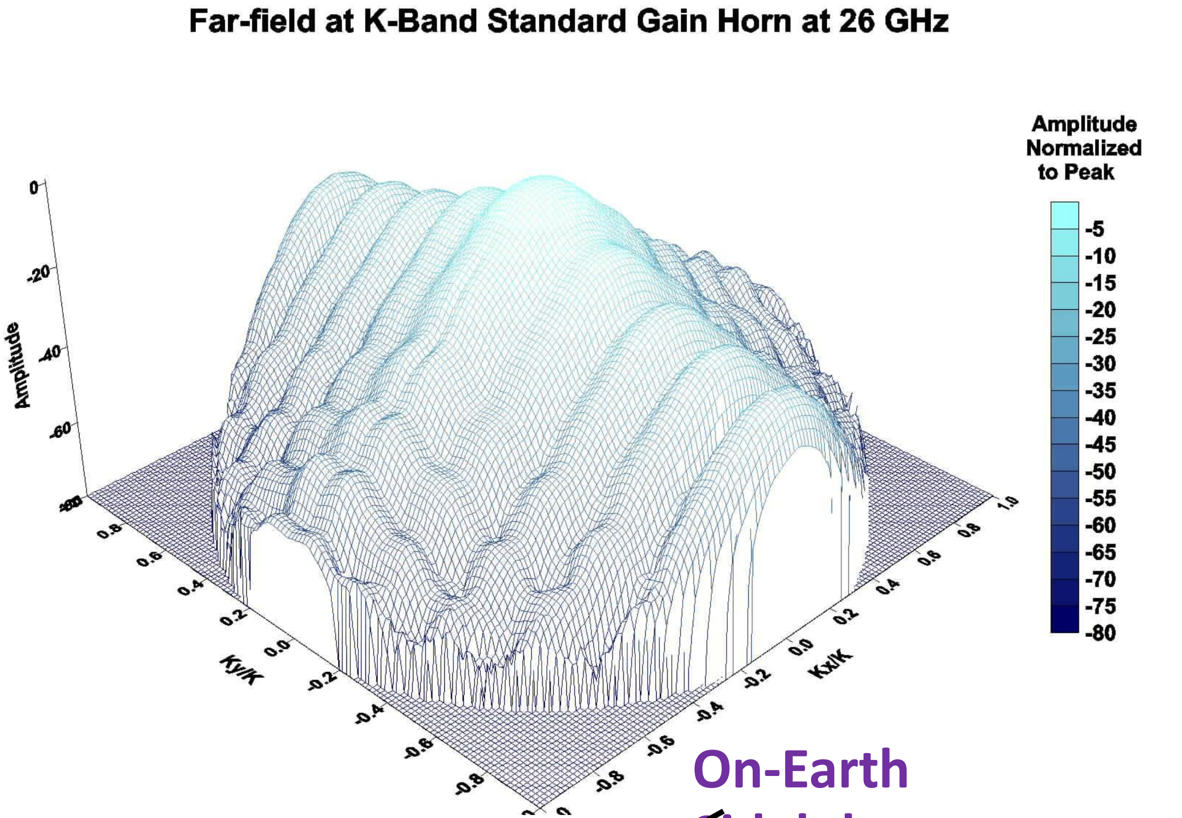
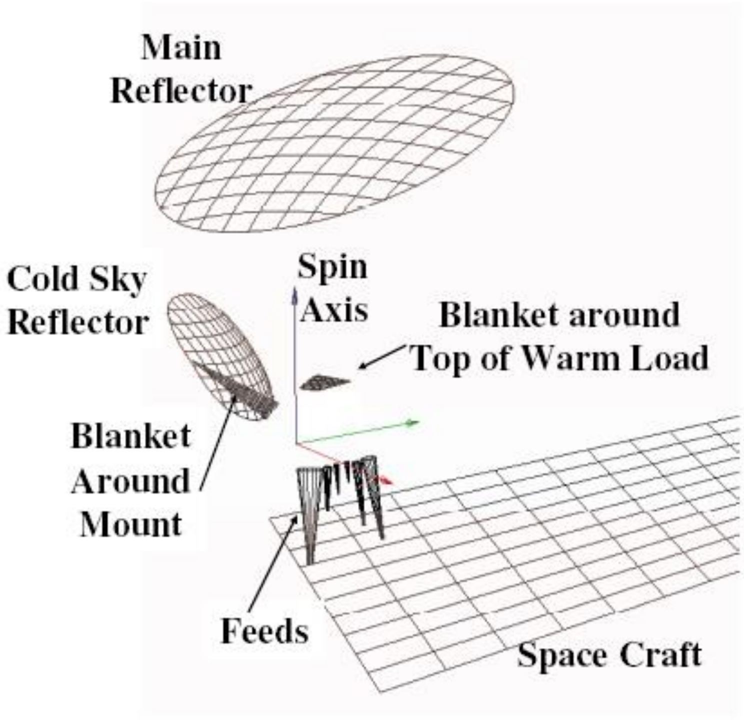
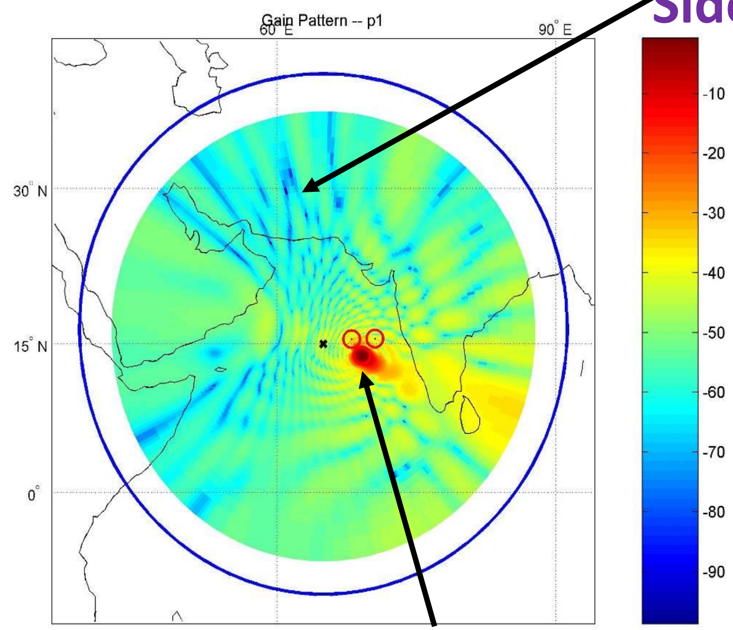
Accurate antenna pattern measurements and pattern correction algorithms are essential to environmental data record (EDR) retrievals.







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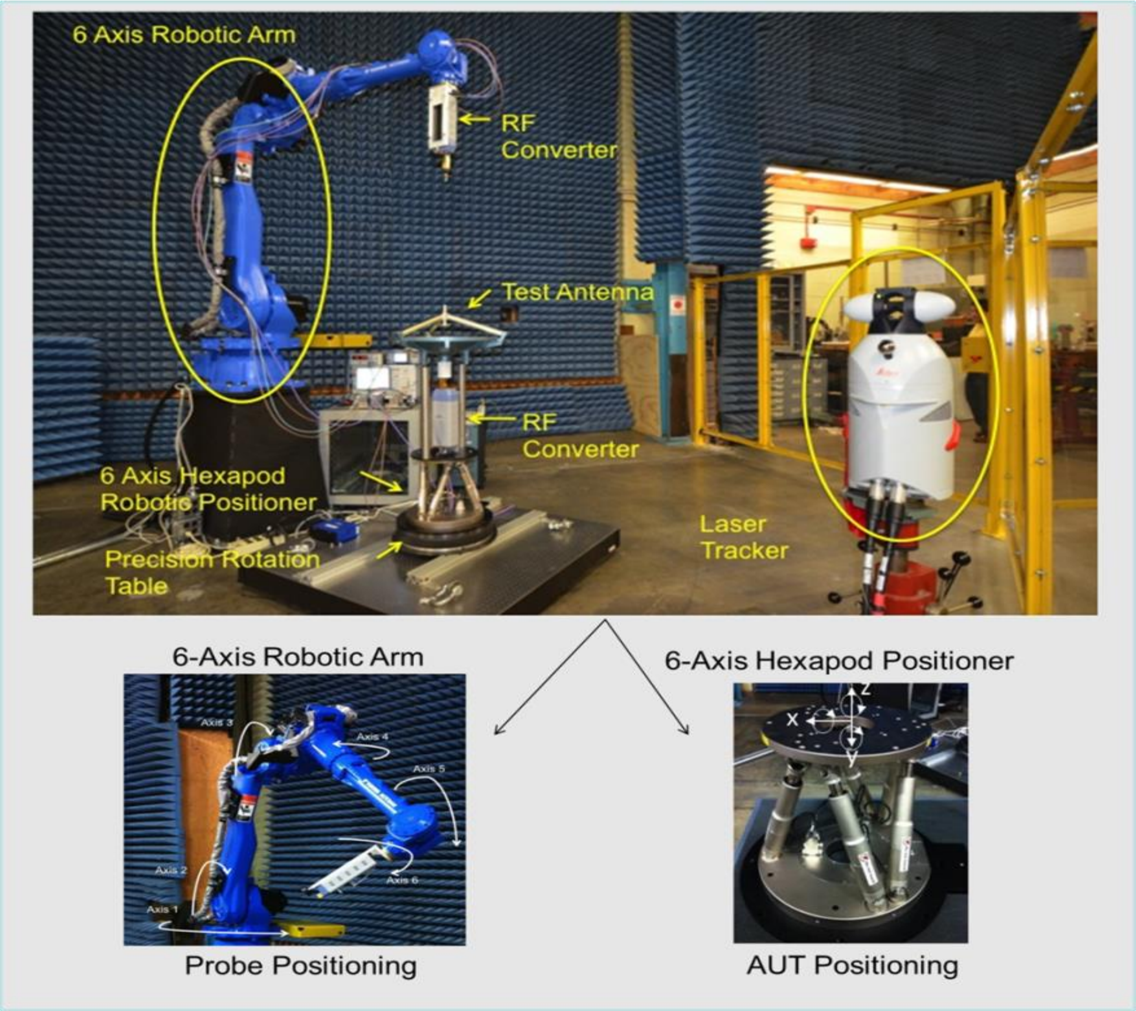
Robotic Range

- >180º meas. range
- Laser tracker provides dynamic positioning error correction of 22 μm ($\lambda/50$ @ 270 GHz)
- Able to accommodate up to 1 m^3 and 30 kg mass; e.g., ATMS-sized instrument
- 110-183 GHz Operational
- Up to 500 GHz capability with existing hardware
- Ideal for CubeSat-type instruments



See the video! http://nist.gov/pml/electromagnetics/rf_fields/robot-arm-aids-antenna-calibration.cfm

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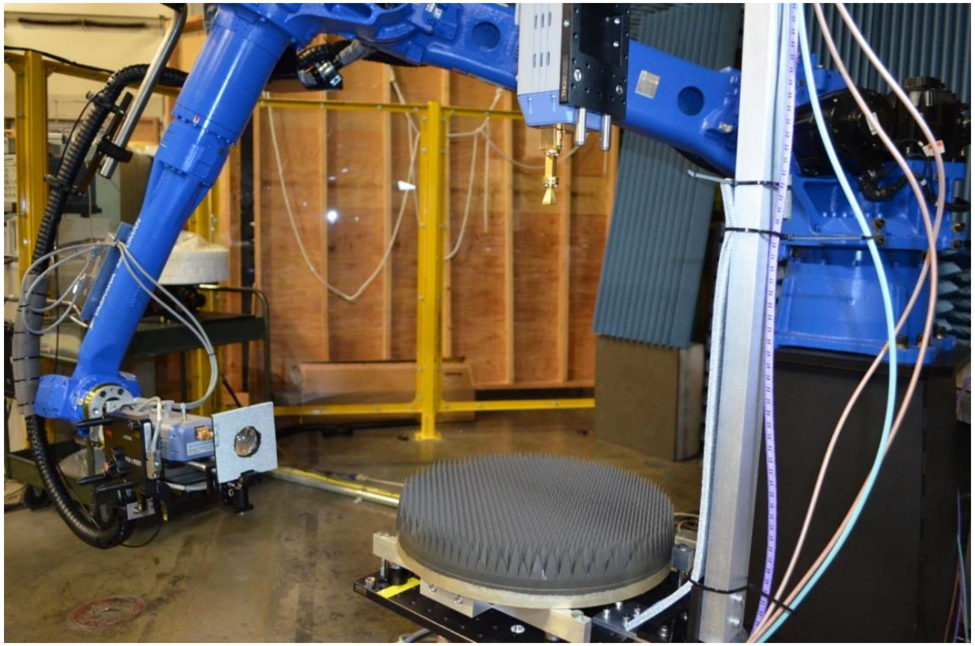
Scattering (BRDF) Measurements

- We are using the CROMMA to measure bi-static and mono-static reflections from the NIST black-body target.
  - Range of measurable target reflectivity: 0 to -60 dB.
    - Limited by system losses (30 dB) and dynamic range (90 dB).
  - Target is at the center of the scanning arc, illumination is aligned to the center of rotation.



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Summary & Plans

- T_B standard radiometer demonstrated at NIST
  - Initial development 18-26.5 GHz band; 12 to 65 GHz now, with plans to build 75-110 GHz rad.
  - Next: Demonstrate practical cal. transfer to flight instrument, FY15/FY16
- Primary standard target
  - Potential reduction in uncertainty (goal ~0.25-0.5 K)
  - Provides a means for checking and transfer
  - Modeling & design nearing completion
  - Fabricate & test target FY15-16
- Ocean salinity

GPS-RO and Tb Standards

- GPS-RO is SI-traceable through *freq. stds.*
  - Still requires modeling to get to T, H
  - Only at 1.2 and 1.6 GHz
  - Spatial coverage: 8-25 km alt., 300 km area, ~1 km height resolution
  - Creates reliable long-term RO data record
- Radiometry can be SI-traceable with Tb stds.
  - No modeling for T (for known ε); other EDRs not so
  - Broad freq. coverage: 1-65 GHz now, more (higher) soon
  - Creates reliable long-term Tb data records
- Comparable uncertainties achievable with GPS-RO or radiometry; ~1 K (single retrieval)

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