STANDARDS DEVELOPMENT FOR REMOTE SENSING AT MICROWAVE AND TERAHETZ FREQUENCIES

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Background

- NIST has a long history of microwave noise standards and measurements (radiometry in transmission lines).
- Recently we extended our work to include standards development for remote-sensing (measuring radiated power from thermal radiation), at both microwave and terahertz frequencies.

Artist's rendering of NPP satellite. From NPP website.

Motivation, Applications

- Microwaves can supplement optical measurements because they can see through clouds.
- Microwave radiometry important for weather & climate monitoring due to water and oxygen emission/absorption lines. (Oxygen is a good representative for "everything else.")

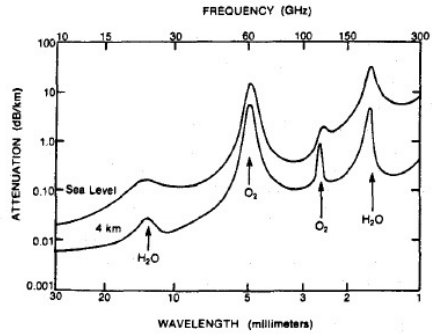
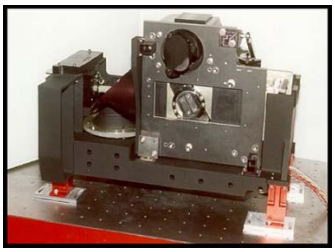
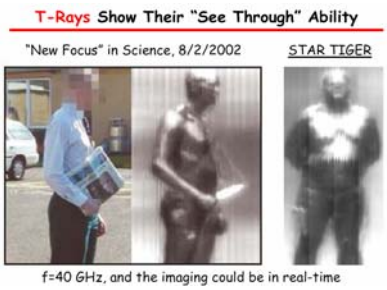


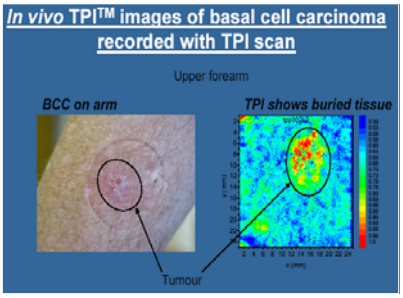
Fig. 1 - Atmospheric attenuation (after Rosenblum).

- Therefore, microwave radiometry important for:
  - sea surface temperature
  - sea surface wind
  - soil moisture
  - ice and snow cover
  - atmospheric water vapor profile
  - pressure and temperature sounding


CRIMMS instrument, which includes the Advanced Technology Microwave Sounder (ATMS). From NPOESS/CRIMMS website.

- Terahertz radiometry has important applications in
  - astronomy/astrophysics
    temperature of gas clouds in stellar formation, …)
  - security
  - biomedical imaging





Imaging of BCC by Teraview, Inc.
Provided by Dr. Peter H. Siegel @ CalTech

Need for Standards

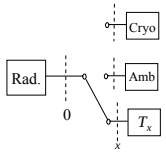
- National radiance standards and traceability exist for visible and infrared frequencies; not for microwave or terahertz.
- Visible & infrared radiance standards have proved very useful.
- Some applications do not need (terrestrial) absolute standards
  - can sometimes use cold space for calibration
  - relative measurements (e.g., cloud cover)
  - "vicarious" calibrations

- Many other applications do require absolute standards, & the need for standards is growing:
  - drive for lower uncertainties (± 0.5 K or lower), and difficulty verifying uncertainty claims
  - combining, comparing, and reconciling data from different instruments
    - different microwave instruments or
    - microwave instrument with infrared instrument, etc.
  - data over very long time periods (decades)
    - microwave radiometer compared with its successor, possible gap between radiometer and its successor
- Need a very stable, very accurate standard, based on fundamental physical principles.

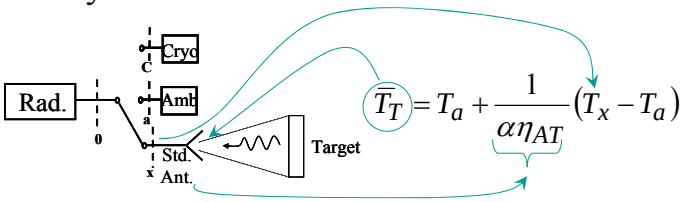
PLAN FOR A MICROWAVE BRIGHTNESS-TEMPERATURE STANDARD

Standard Radiometer

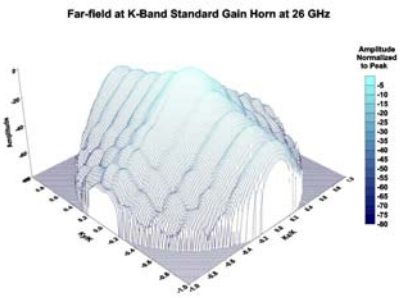
- In noise-temperature measurements in waveguides, use two primary standards and a linear radiometer to measure unknown noise source (DUT):

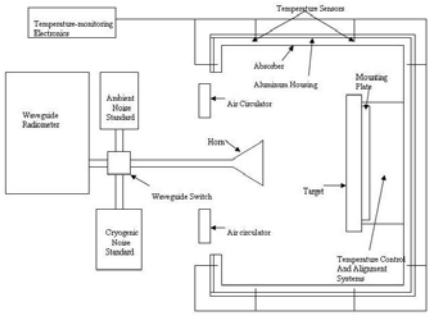


- For brightness-temperature measurement, replace DUT by characterized antenna:

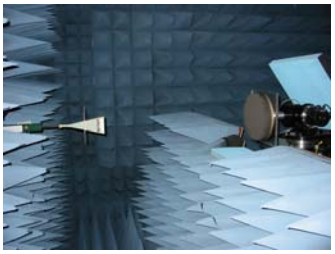


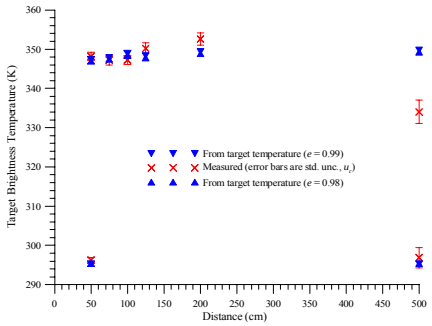
- Need:
  - Antenna pattern
  - Antenna losses
  - Controlled environment





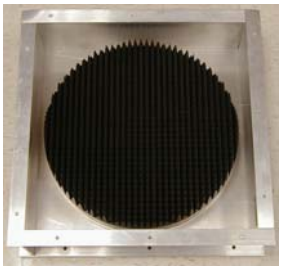
- Preliminary test:
  - Borrowed calibration target, monitored physical temperature, computed brightness temperature.
  - Measured brightness temperature in anechoic chamber, for different separation distances.
  - Compared.





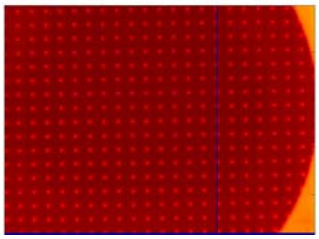
Standard Target & Hybrid Standard

- Most microwave remote sensing programs use a standard target, a blackbody radiator.

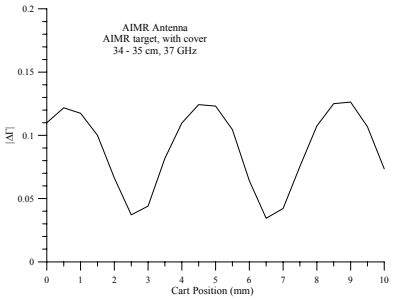


- Need to know
  - surface temperature and uniformity (thermometers embedded at a few locations in *back* of target)
  - emissivity (no generally accepted standard measurement method)
  - pattern (or near-field effects)

- Surface temperature & uniformity can be measured by IR imaging.



- Reflectivity of target can have significant effect (a few kelvins) for small separation distance.



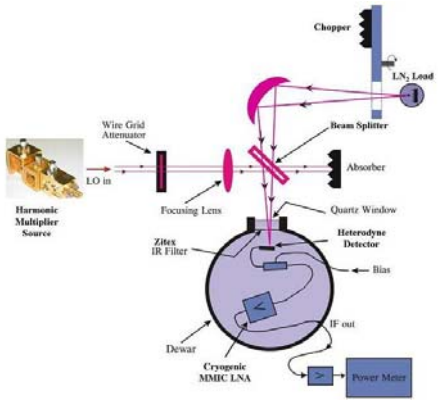
- For a standard target, need:
  - sufficient distance between target and antenna
  - metrology for measuring emissivity of target
    - Use a standard radiometer
      - Target in far-field but fills antenna FOV (preferred method)
      - Target in far-field but doesn't fill FOV; requires careful alignment and η calculation
    - Measure specular and diffuse reflectance (as with THz target)
    - Use a short (flat metal plate) as reference for target reflectivity
  - characterization of surface temperature.
- Have suggested a "hybrid" standard, which would consist of a standard radiometer + a standard target.
  - Would reduce uncertainties somewhat
  - Greater flexibility
  - More robust (and credible).

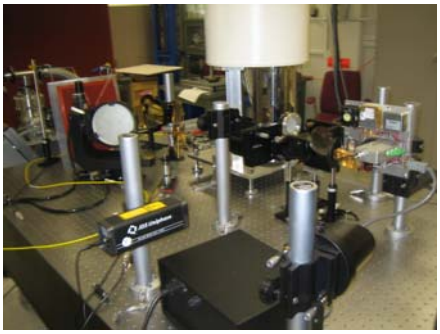
TERAHERTZ NOISE STANDARD & MEASUREMENT

Approach

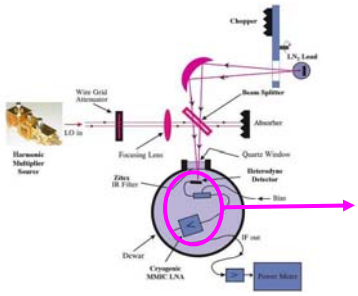
- Unlike the microwave case, we do not have a history of noise measurements at terahertz frequencies. Need both a standard and a detector/receiver.
- The NIST Terahertz Technology Project has developed a terahertz receiver built around a hot electron bolometer (HEB) mixer, which they use in an imaging system.
- So, use or copy that receiver, and develop a terahertz noise standard.

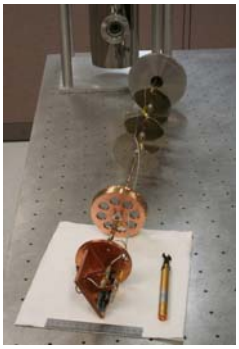
Full System

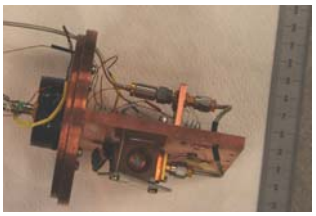




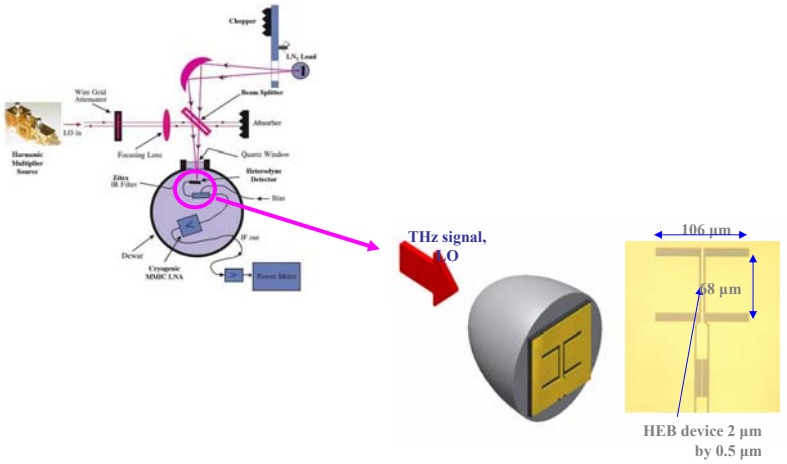
Inside the Cryocooler



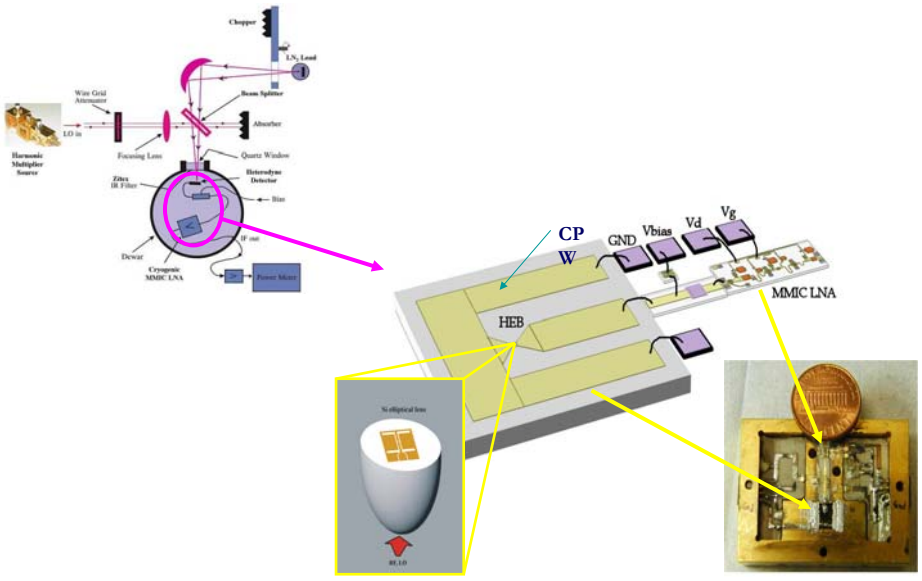




Adapter & Detector

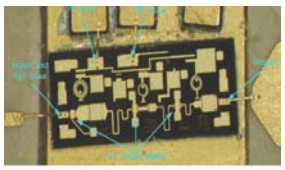


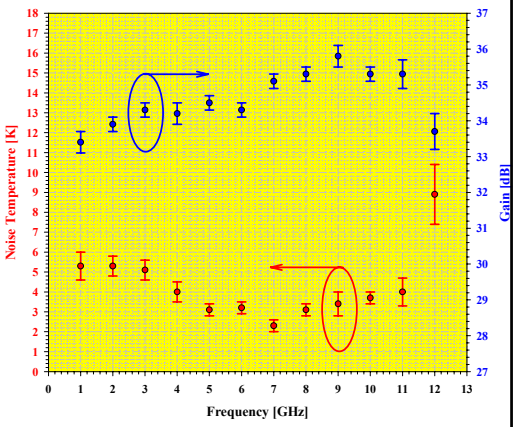
Mixer Block Integration



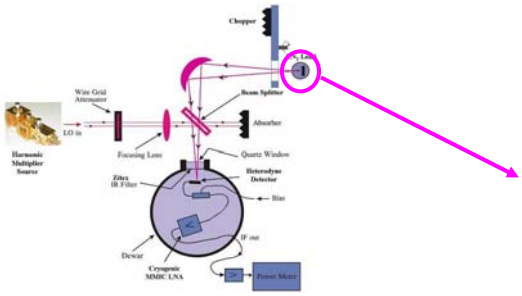
LNA Performance

Developed by Dr. Sander Weinreb's group at JPL/Caltech

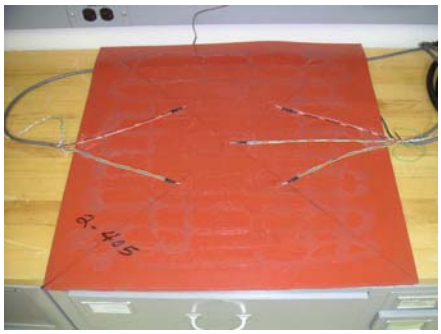




Variable-Temperature Standard



- Hot circulating oil, ~ 23 ˚C – 240 ˚C
- Back surface instrumented with RTDs surrounding image area.
- One front-side RTD (moveable)
- NIST Physics Lab measuring the total reflectance (= 1 – emissivity)



STATUS & PLANS

- Microwave radiometer-calibration effort has been suspended. If funding becomes available, we will proceed with the standard-radiometer development, and possibly the hybrid standard work.
- The terahertz noise work is proceeding. We expect to make the first measurements later this year.

Acknowledgement

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