Radiometer Testbed Development for SWOT

Pekka Kangaslahti, Shannon Brown, Todd Gaier, Douglas Dawson, Dennis Harding,

Lee-Lueng Fu, Daniel Esteban-Fernandez

Jet Propulsion Laboratory, California Institute of Technology

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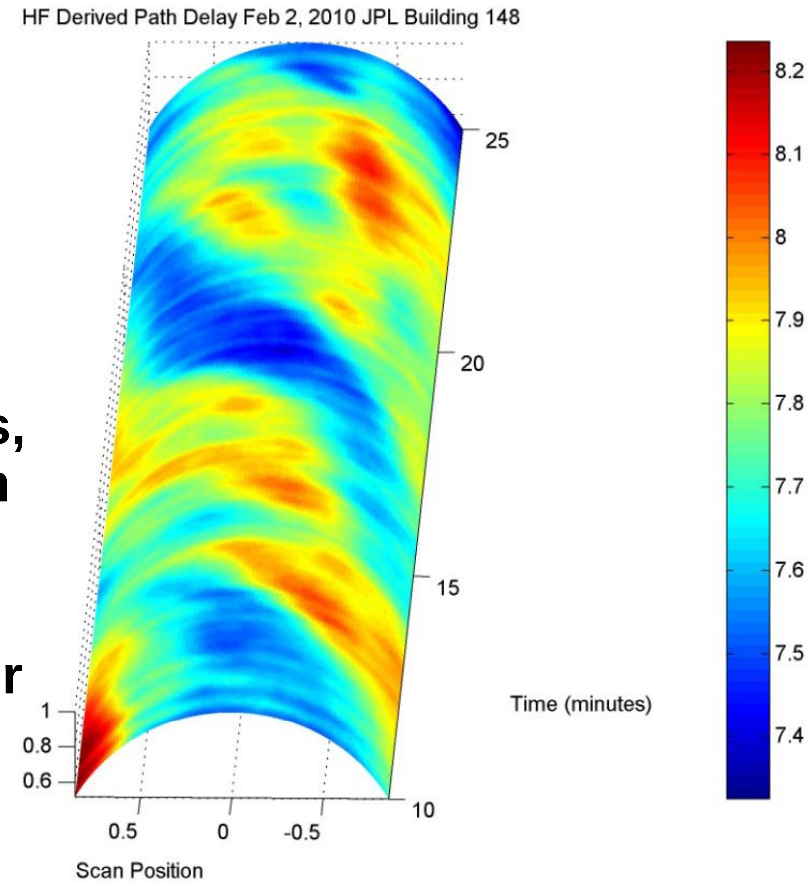
Outline

- Introduction
- LNA Modules
- Direct Detection Radiometers
- Internal Calibration
- Conclusions

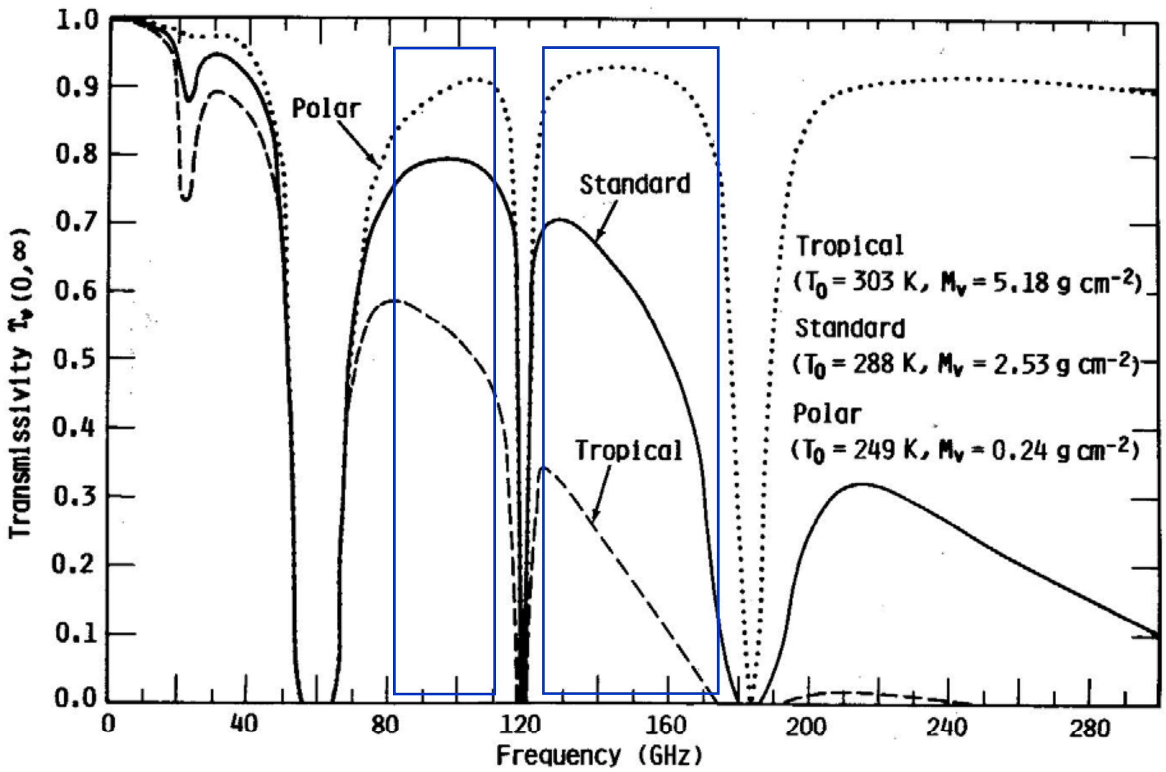
Introduction

- **Conventional altimeters include nadir looking co-located 18-37 GHz microwave radiometer to measure wet tropospheric path delay**
- **High-frequency window channels, 90, 130 and 166 GHz are optimum for improving performance in coastal region**
- **Channels on 183 GHz water vapor line are ideal for over-land retrievals.**



•Path Delay derived from 113 and 166 GHz channels over JPL – 2/2/2010

Introduction



- **Window channels (blue boxes) have wide bandwidth and large contrast in water vapor signal**

Introduction

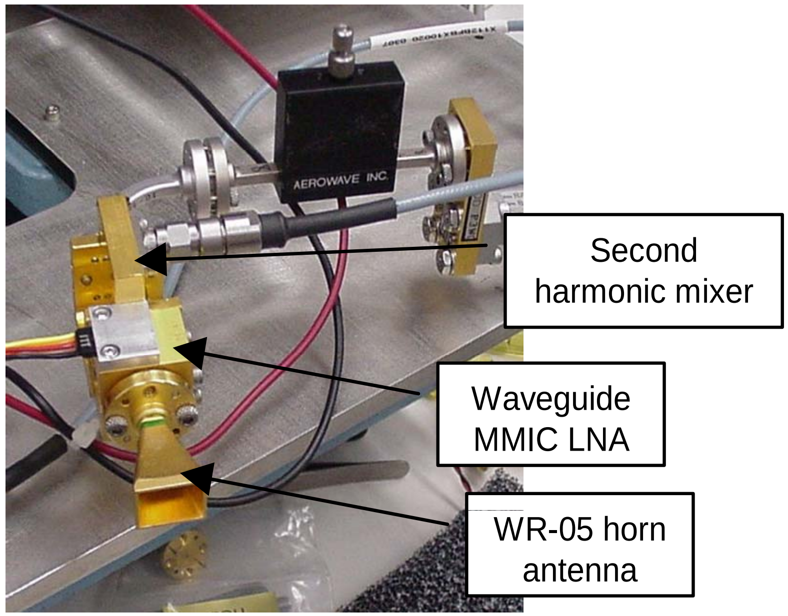
- **Fixed radiometer field-of-view and no moving parts requires internal calibration**
  - **Examples:**
    - **Dicke load and cold sky horn (Topex, ERS-1,2)**
    - **Dicke load and noise diodes (Jason-1, Jason-2)**
- **Stability of internal calibration references for frequencies > 90 GHz must be characterized**

- **Test bed being developed to characterize stability of internal calibration sources between 90-180 GHz**
  - **RF switches**
  - **Active Sources (e.g. noise diodes)**
  - **Inherent stability of Low Noise Amplifiers**

LNA Modules

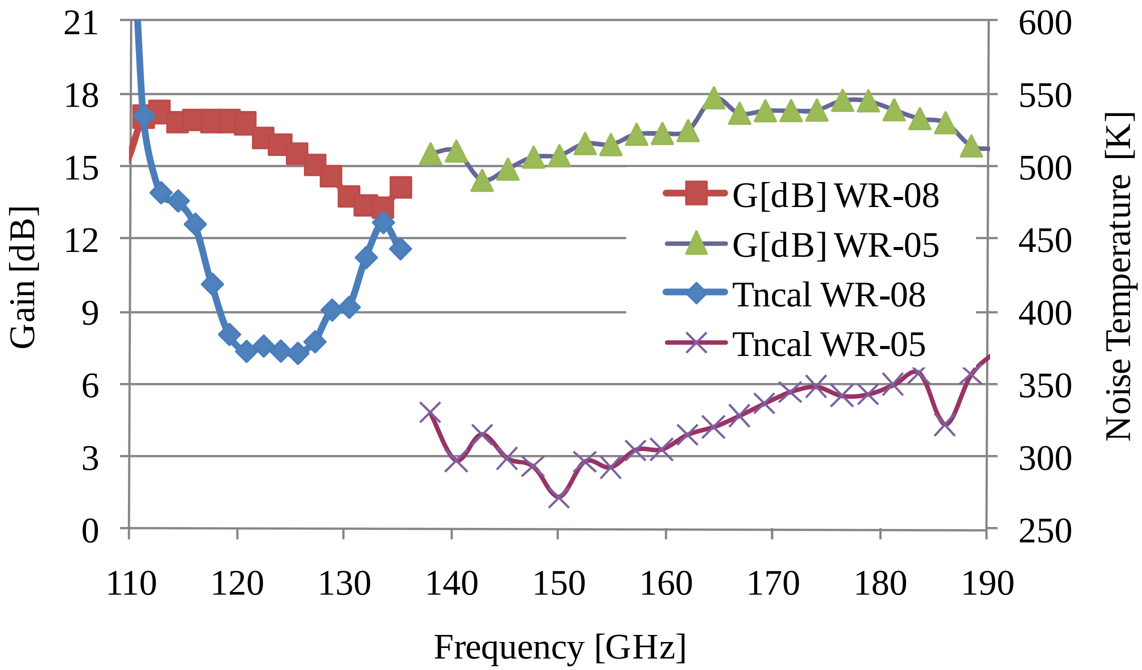
- Development based on a high performance 35 nm gate length InP HEMT (f_T > 550GHz and f_{max} > 1 THz)
- LNA MMICs in the 35 nm process were fabricated in previous projects
- LNA module development included housing and microstrip to waveguide transition design
- Transitions included matching networks to compensate for the wirebonds

LNA Modules



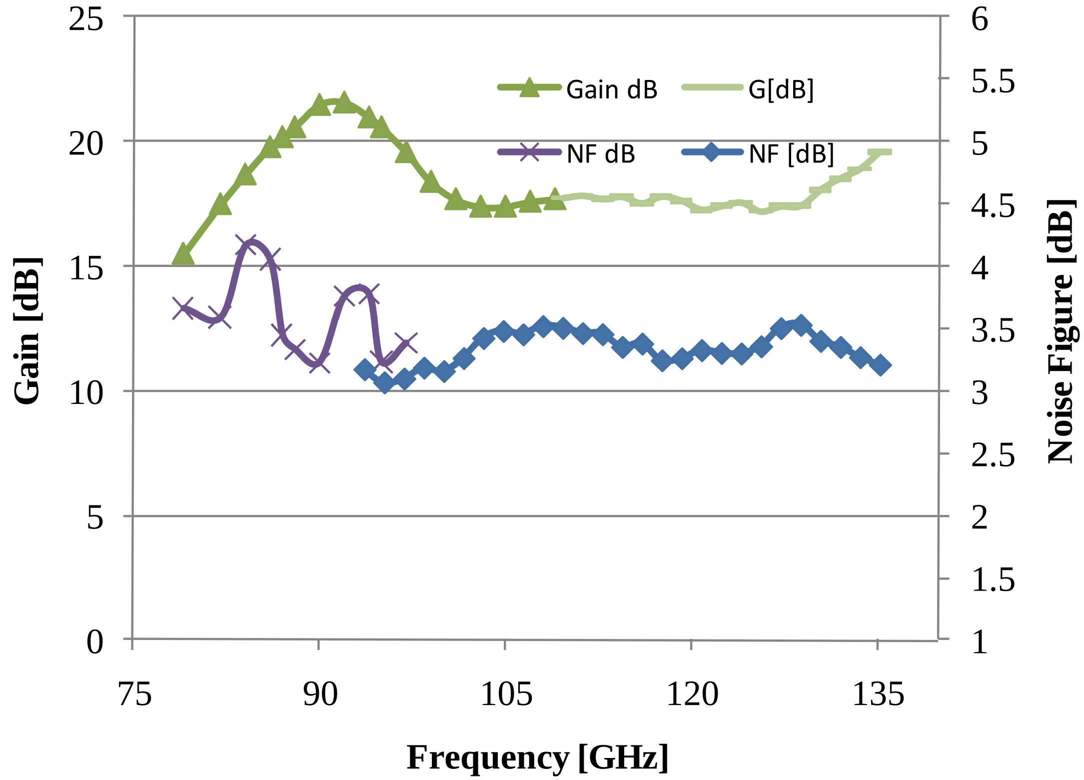
- **Testing of noise temperature and gain**
- **Y-factor hot/cold load testing with absorber at room temperature and liquid nitrogen temperature**

LNA Modules



- First MMIC LNA type was packaged in WR-05 and WR-08 housings to characterize it over broadband
- Record low noise temperature of 300 K at 150 to 160 GHZ frequency range

LNA Modules



- **Second MMIC LNA type was packaged in WR-08 and WR-10 housings to characterize it over broadband**
- **Suitable for the 130 GHz radiometer testbed**

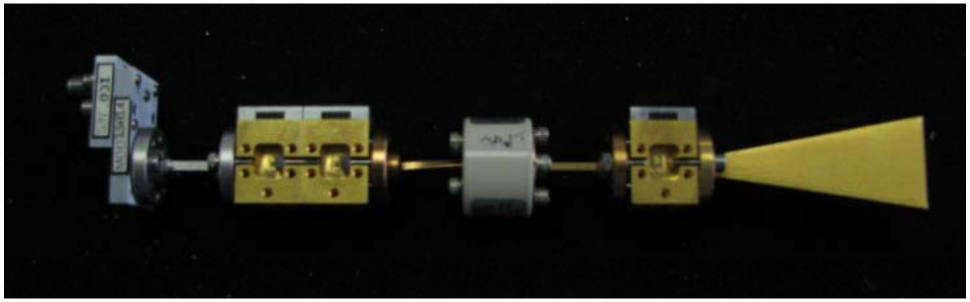
Direct Detection Radiometer Testbeds

These LNA modules enabled us to design direct detection radiometer test beds.

- do not require local oscillators
- operate with very low DC power.
- The radiometers are a cascade of two or three LNA modules, band definition filter and detector.

Direct Detection Radiometer Testbeds

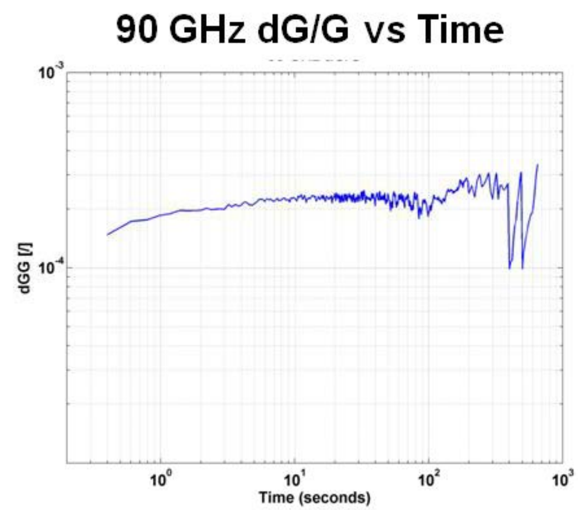
	92 GHz	130 GHz	166 GHz
Gain	40dB	40dB	45dB
Receiver NT	340 K	340 K	455 K
Bandwidth	10%	10%	10%
DC Power	40mW	40mW	60mW

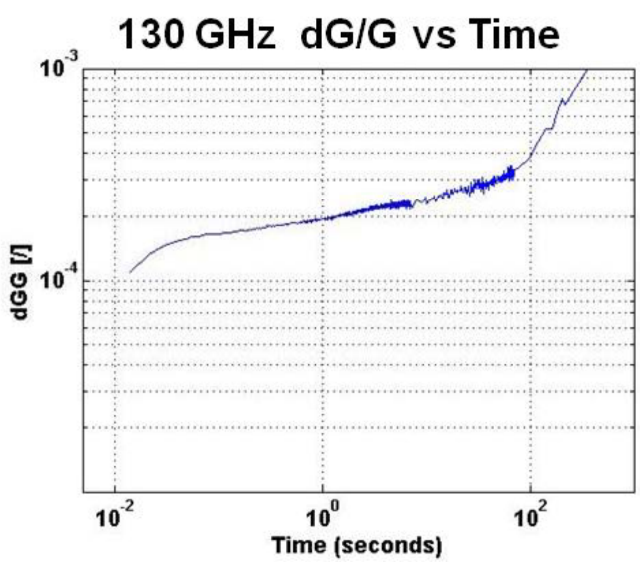


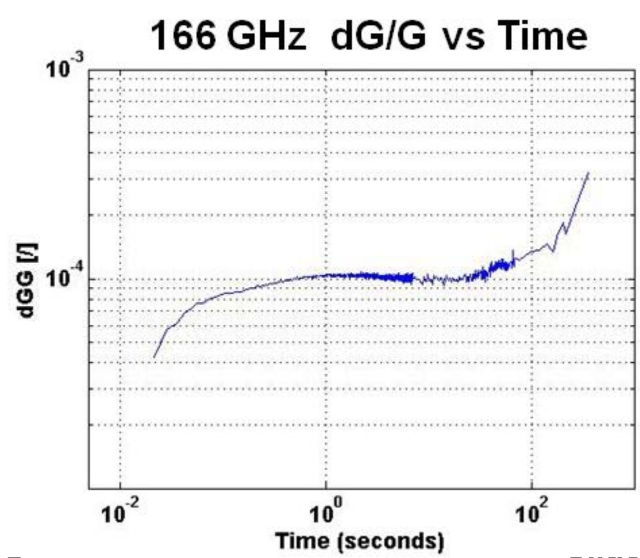
- **Direct detection approach minimizes radiometer complexity**

Direct Detection Radiometer Testbeds

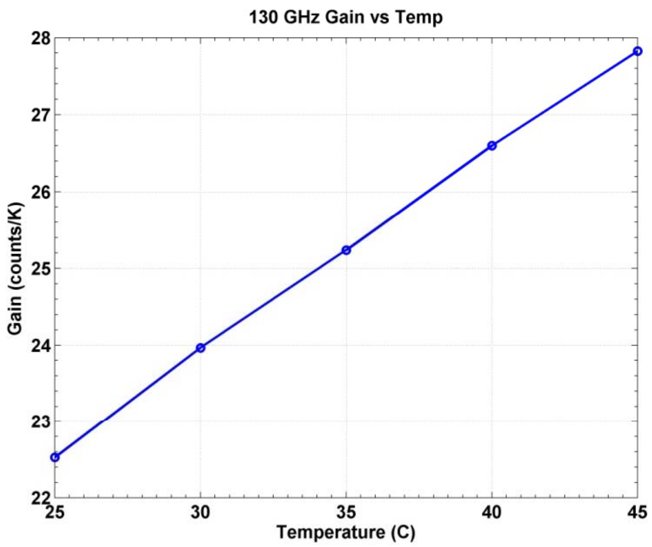
- **Inherent stability of LNA tested to give dG/G at stable temperature**
- **Receivers exhibit dG/G ~ 2e-4 or better to 30s**

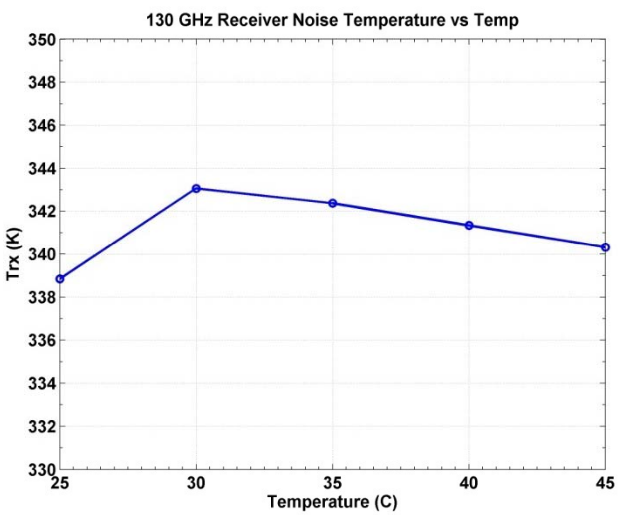


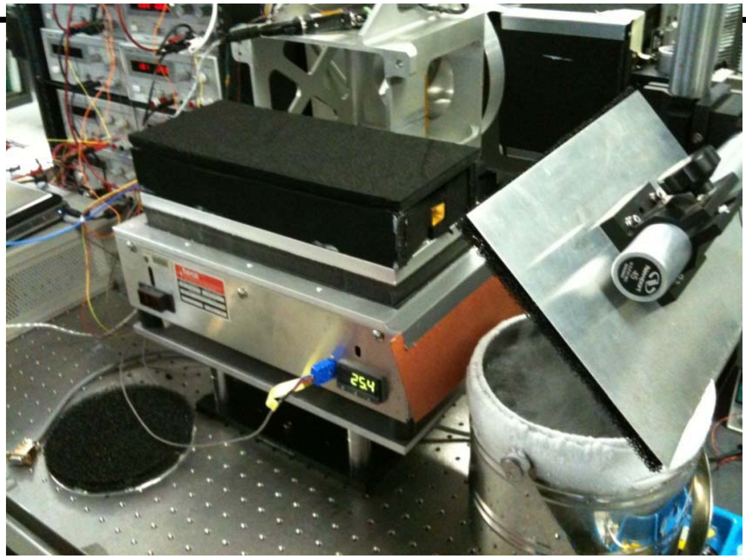




Direct Detection Radiometer Testbeds

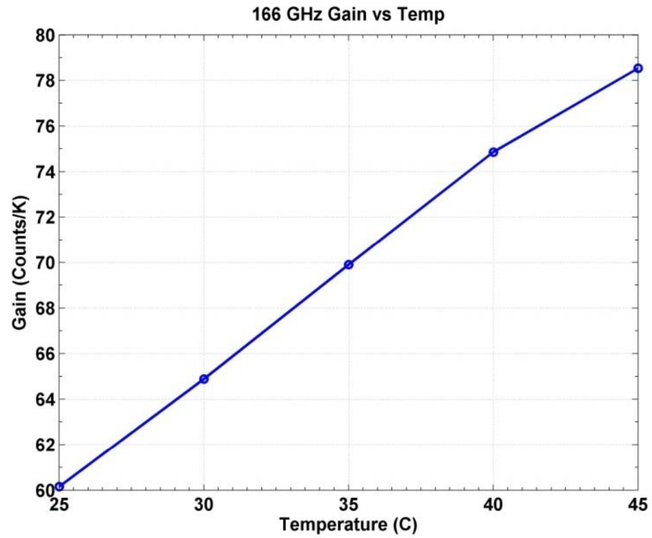


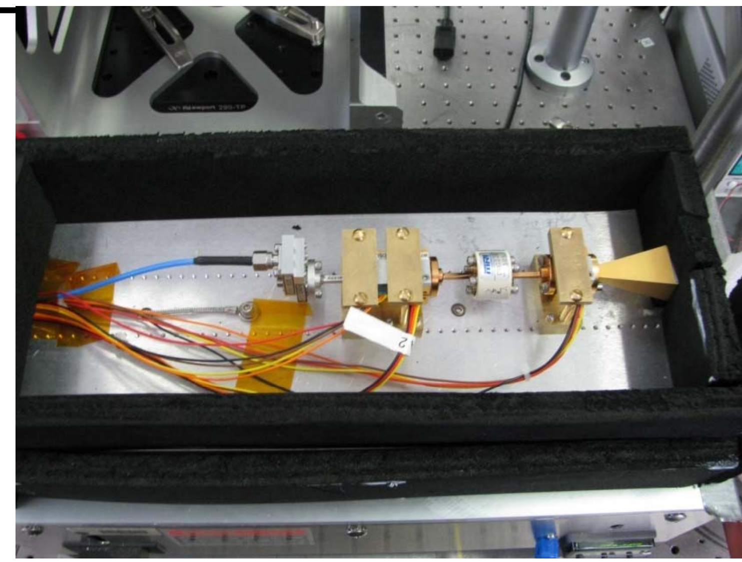


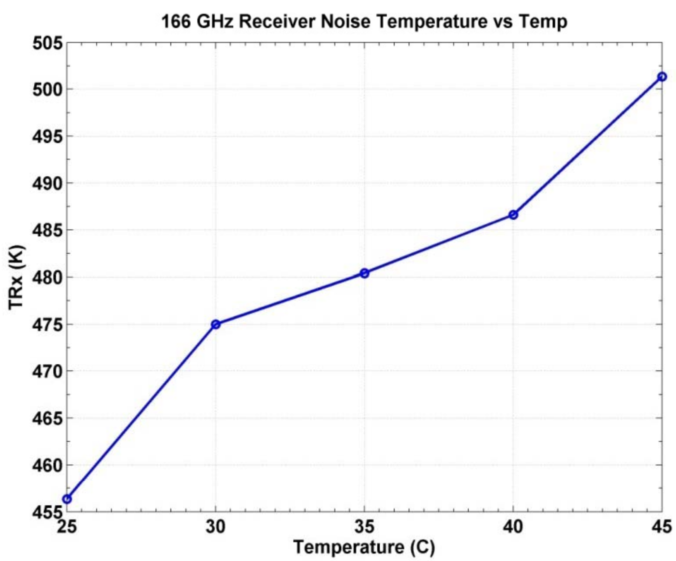


- **TEC used to cycle receiver over temperature**
- **LNAs exhibit low temperature dependency**
  - **Gain temperature coefficient of 1%/C (0.04dB/C)**
  - **Receiver noise temperature also stable over temperature**

Direct Detection Radiometer Testbeds







- **166 GHz LNAs also exhibit low temperature dependency**
  - **Gain temperature coefficient of 1.3%/C (0.06dB/C)**
  - **Receiver noise temperature changes at 2K/C**

Internal Calibration

- **Measurement noise depends on scene NEDT and noise from calibration**
  - **Can determine requirements for internal calibration sources**

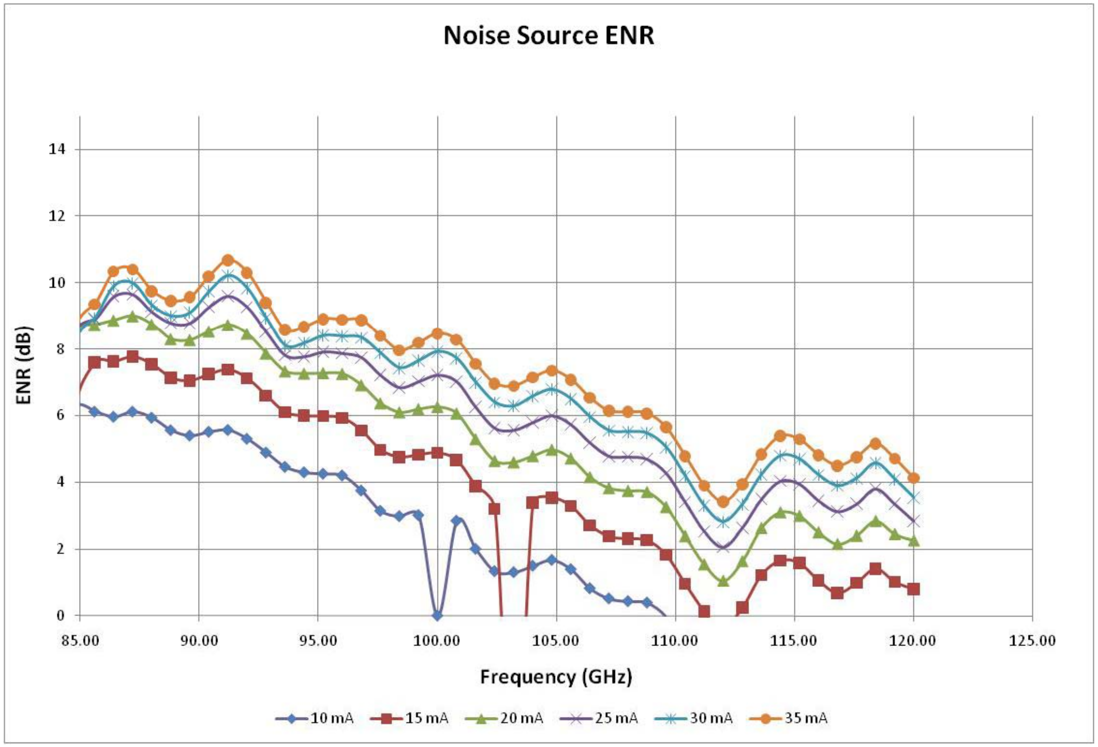
$$\Delta T_A{}^2(\tau_A, \tau_{Cal}) = \left\{ NE\Delta T^2(\tau_A) + \Delta T_{Cal\_white}{}^2(\tau_{Cal}) + \Delta T_{Cal\_Systematic}{}^2(\tau_{Cal}) \right\}$$

Measurement noise (K) for different calibration source temperature differences based on LNA stability measurements

Cal TB difference	90 GHz	130 GHz	166 GHz
20	0.13	0.13	0.16
50	0.11	0.11	0.093
150	0.10	0.10	0.083
300	0.10	0.10	0.082

Internal Calibration

- **WR-10 packaged AMR noise diode ENR vs frequency and current**
- **Good ENR at reasonable current up to 120 GHz**
- **WR-10 package design unmatched**
  - **166 GHz WR-05 package will need to be matched to get sufficient ENR**



Conclusion

- The developed MMIC LNAs had the lowest reported noise figure at 160 GHz frequency band of receivers operating at ambient temperature.
- The developed 166, 130 and 92 GHz radiometer testbeds have small size, very low power consumption and mass, because of the direct detection mode of operation
- Demonstrate and test critical technologies for the SWOT radiometer development
- MMIC LNA modules and radiometer testbeds were developed in ESTO IIP-07 task "Ka-band SAR Interferometry Studies for the SWOT Mission".
- The LNAs were also integrated in the airborne High Altitude MMIC Sounding Radiometer (HAMSR) that was developed under the IIP-98 and currently is funded to be installed onto the Global Hawk UAV for participation in NASA's Genesis and Rapid Intensification Processes (GRIP) hurricane field experiment in the summer of 2010

Acknowledgement

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