Miniature MMIC Low Mass/Power Radiometer Modules for the 180 GHz GeoSTAR Array

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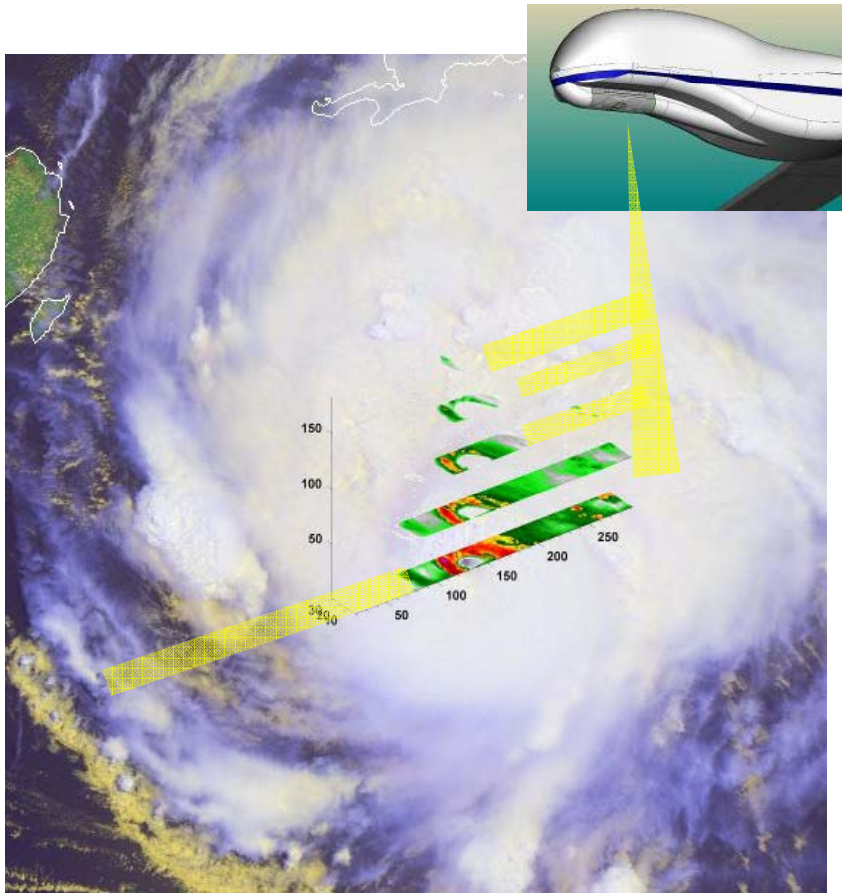
Outline

- Introduction
- Indium Phosphide MMICs
- Receiver Design
- Measured Results
- Conclusions

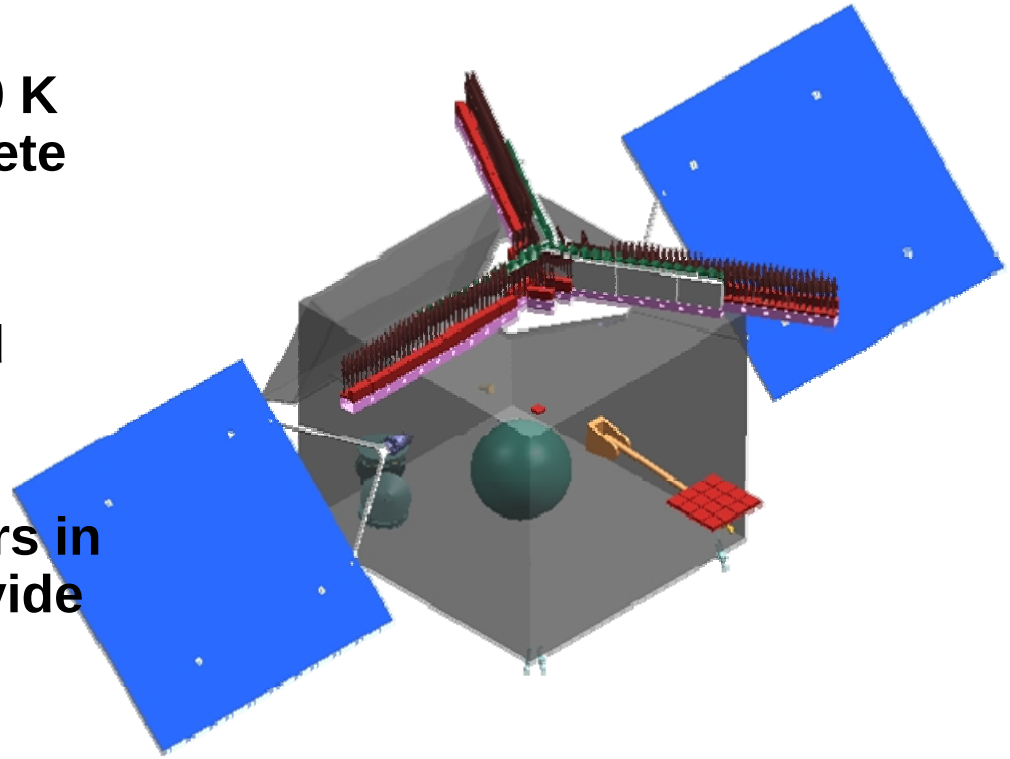
Introduction

- Weather forecasting, hurricane tracking and atmospheric science applications depend on humidity sounding of atmosphere
- Current instruments provide measurements from ground based, airborne and LEO satellites by measuring radiometric temperature on the flanks of the 183 GHz water vapor line.
- Developed miniature low noise receivers that will enable these measurements from a geostationary thinned array sounder



Introduction

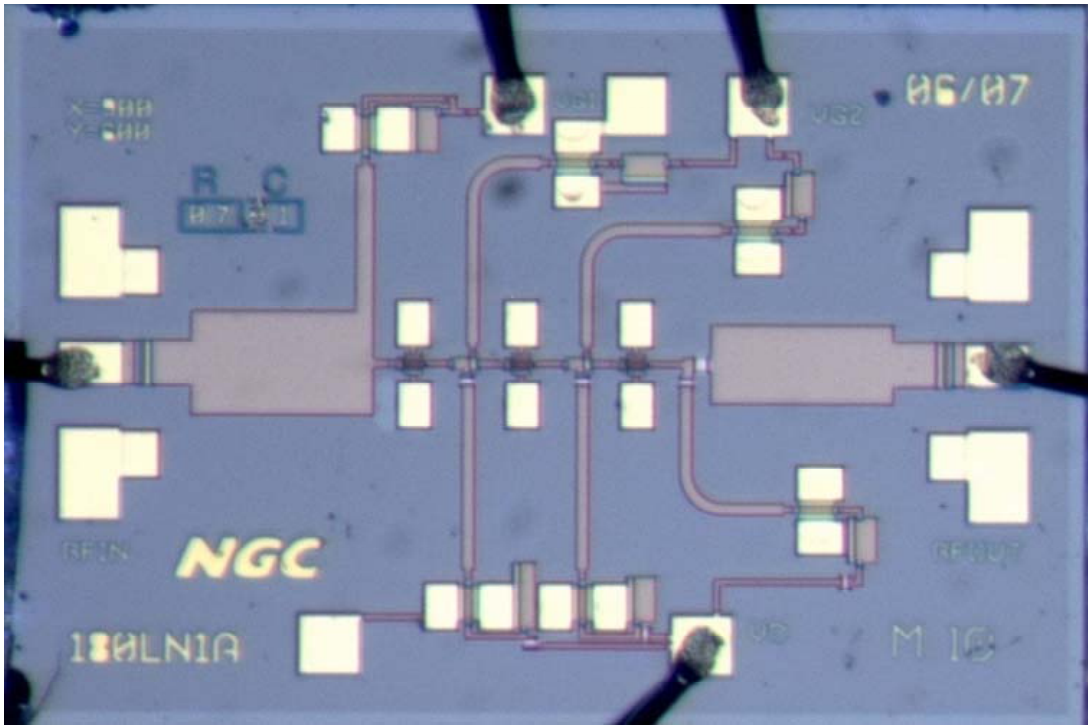
- Demonstrated a noise temperature NT=400 to 450 K (NF=3.8 to 4.1) for a complete I-Q receiver
- Receiver operates with Pdc=24mW, weighs 3g and requires a local oscillator power of PLO=+3dBm
- Hundreds of these receivers in GeoSTAR instrument provide humidity profiles of the sounding area every 15 minutes with a 25 km resolution



Indium Phosphide MMICs

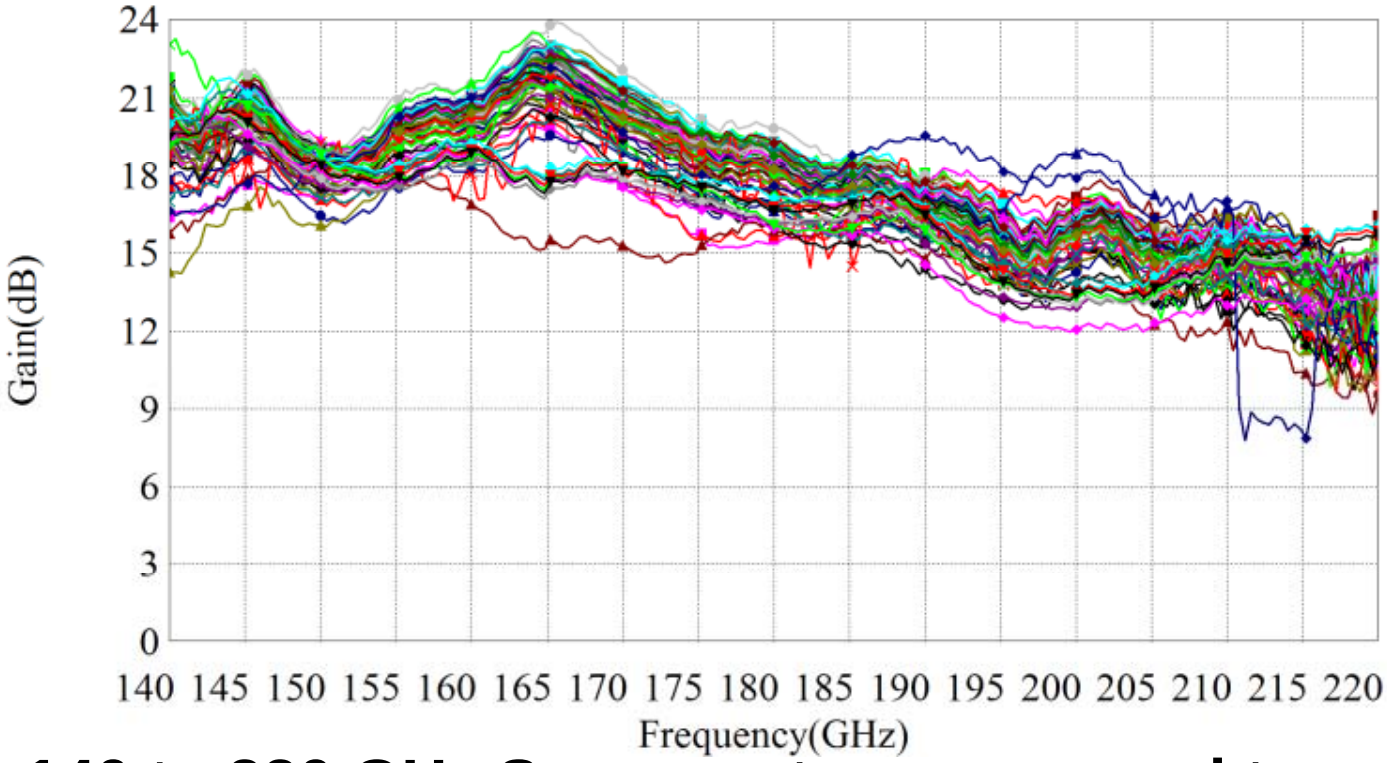
- Development based on a high performance 35 nm gate length InP HEMT (f_T > 550GHz and f_{max} > 1 THz)
- LNA MMICs have three common source stages, passive circuitry microstrip transmission lines on the 2 mil thick InP substrate
- MMIC second harmonic I-Q mixer implemented as a resistive balanced mixer on the LNA wafers
- Two wafer runs completed (with cost-sharing)

Indium Phosphide MMICs



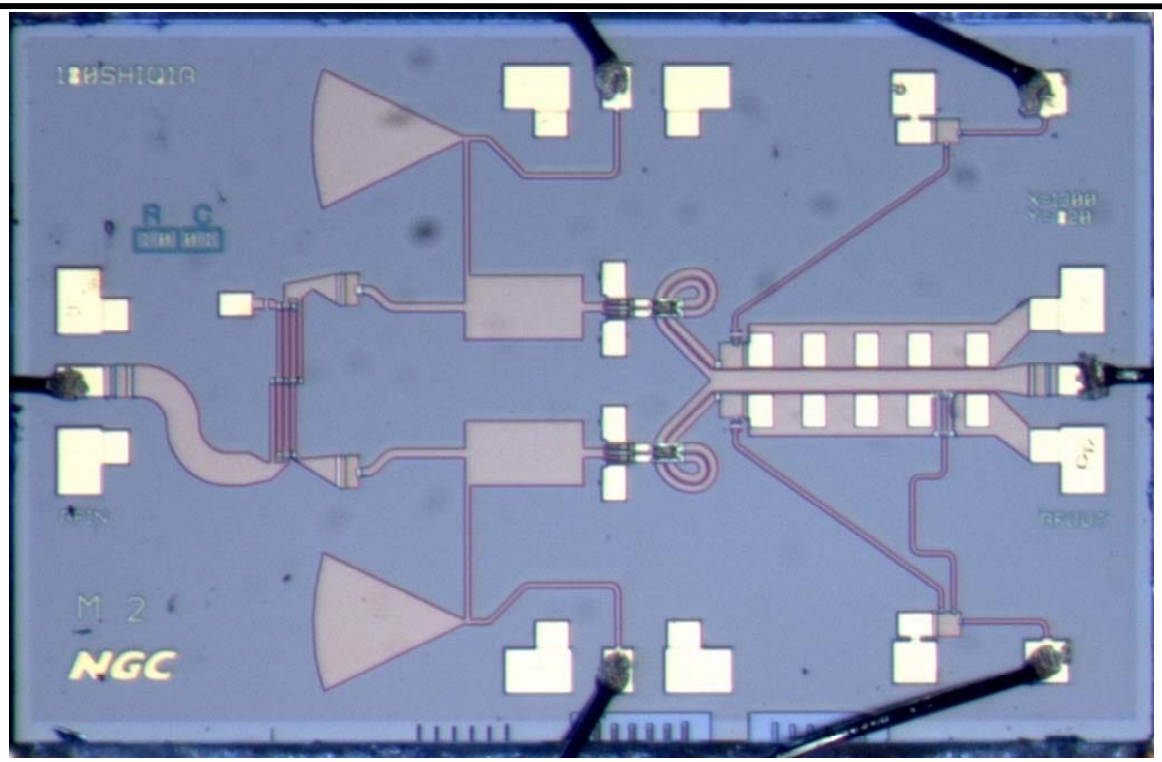
- Low Noise Amplifier MMIC area is 900 x 600 um2
- Three stage design, each transistor has two gate fingers, for a total of 30 um gate periphery

Indium Phosphide MMICs



- 140 to 220 GHz S-parameters measured to screen the LNA MMICs
- The LNAs had 16 to 21 dB of gain at 165 to 183 GHz frequency range

Indium Phosphide MMICs



- The mixer has I and Q outputs
- Operates at second harmonic of the LO frequency
- MMIC area is 1100 x 820 um^2.

Receiver Design

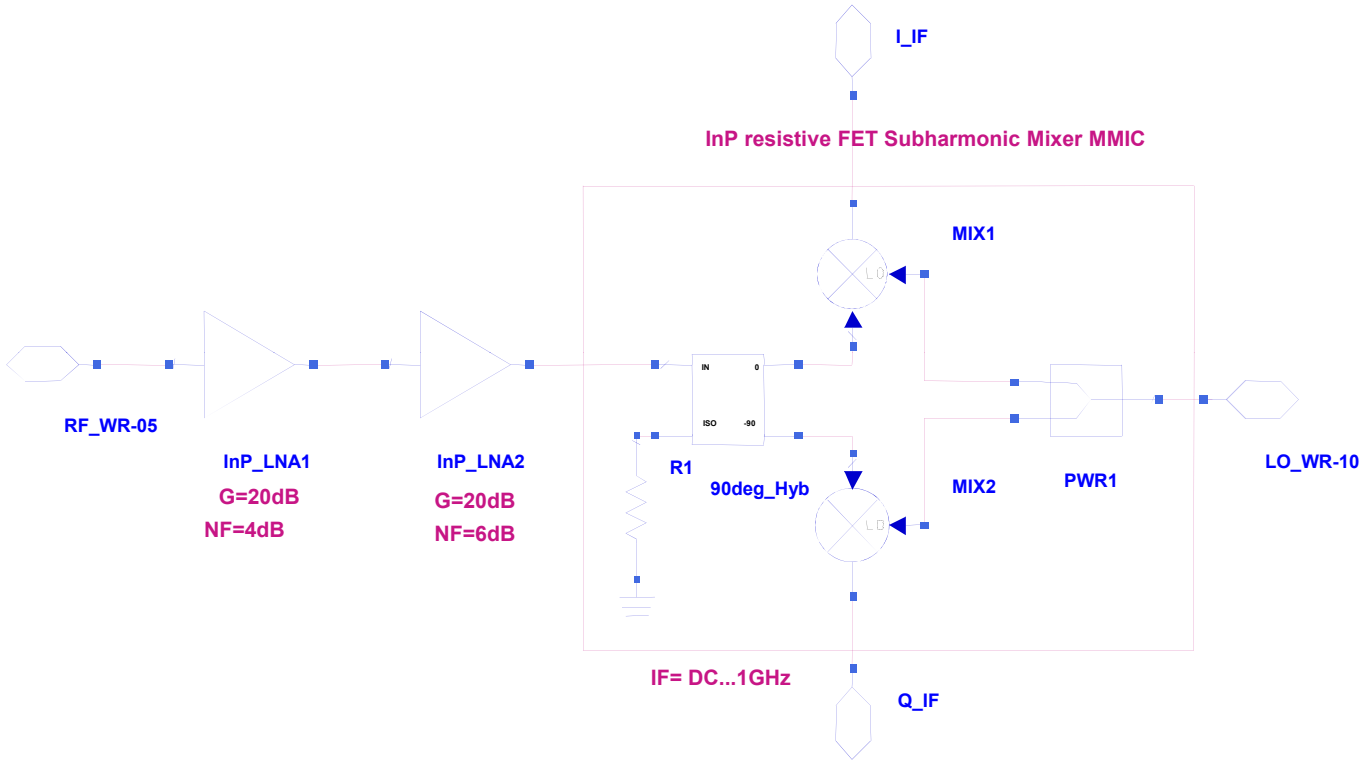
GeoSTAR receivers will be produced in volume

- number of MMICs and substrates in each receiver has to be minimized
- receivers have to be planar to enable automated assembly

Performance has to be state-of-the-art (or better)

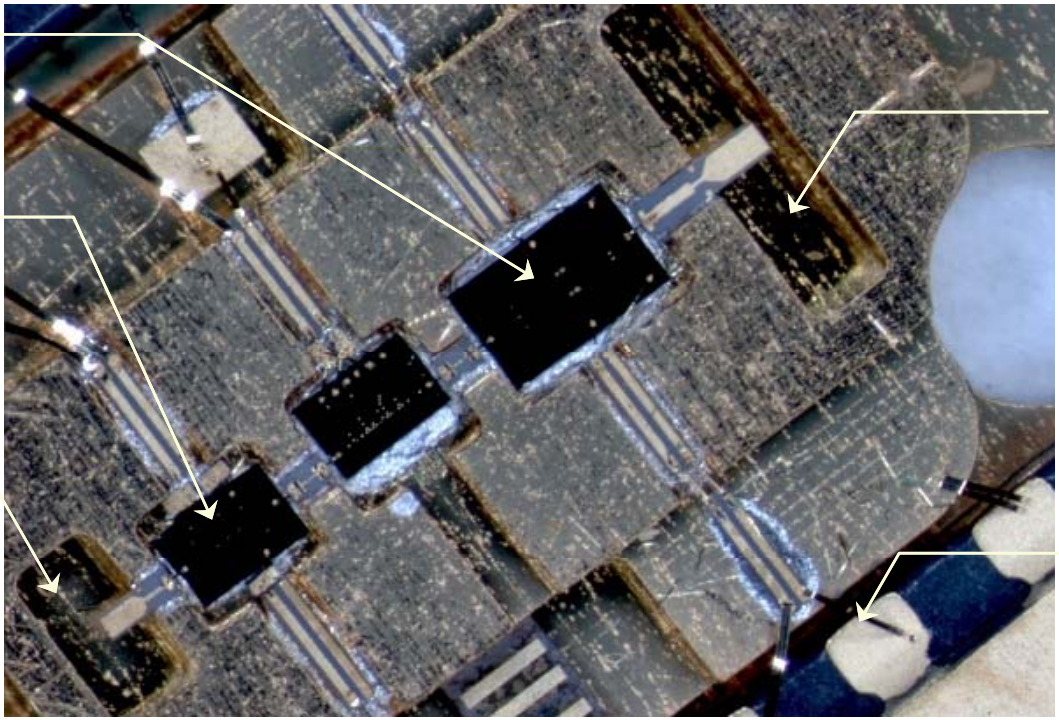
- receiver noise increases integration time and thus the temporal coverage will be reduced
- receiver noise temperature of 400K reduces the integration time to 15 minutes for four channels in the new 4-row array configuration
- receiver has to operate with very low Local Oscillator (LO) power to reduce the DC power consumption of the LO distribution network

Receiver Design



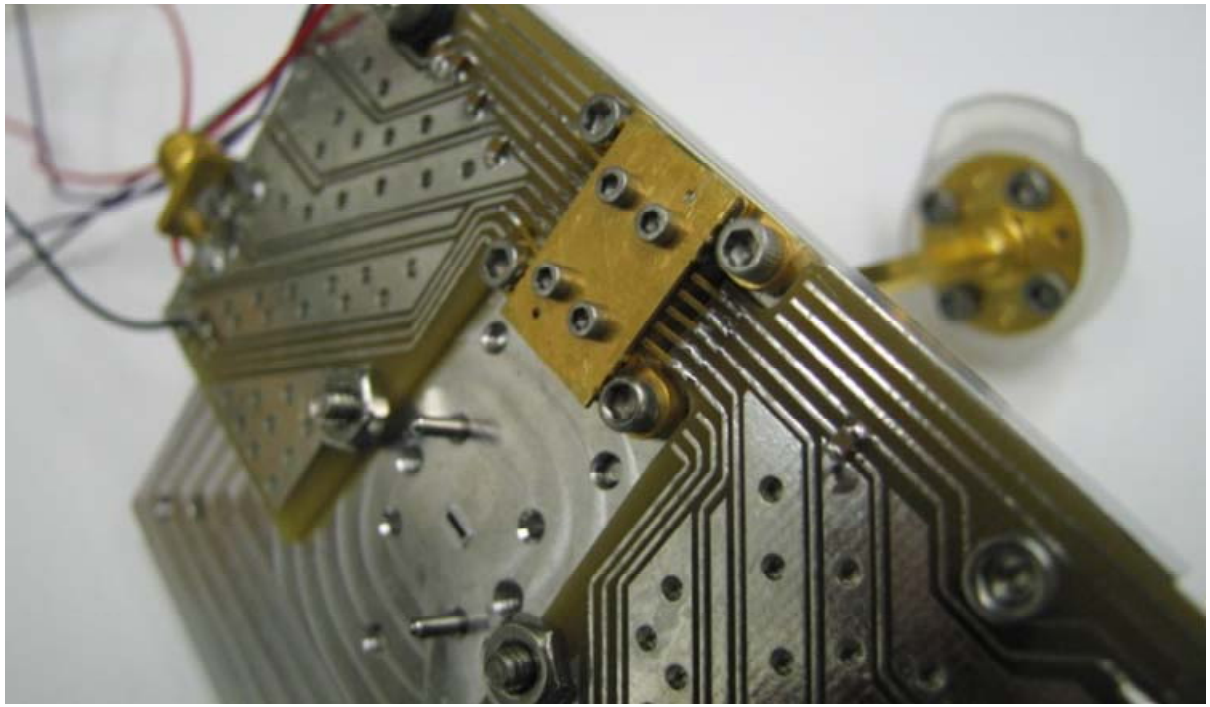
- **Direct conversion approach minimizes radiometer complexity and enables narrowband measurements of upper and lower sideband signals**

Receiver Design



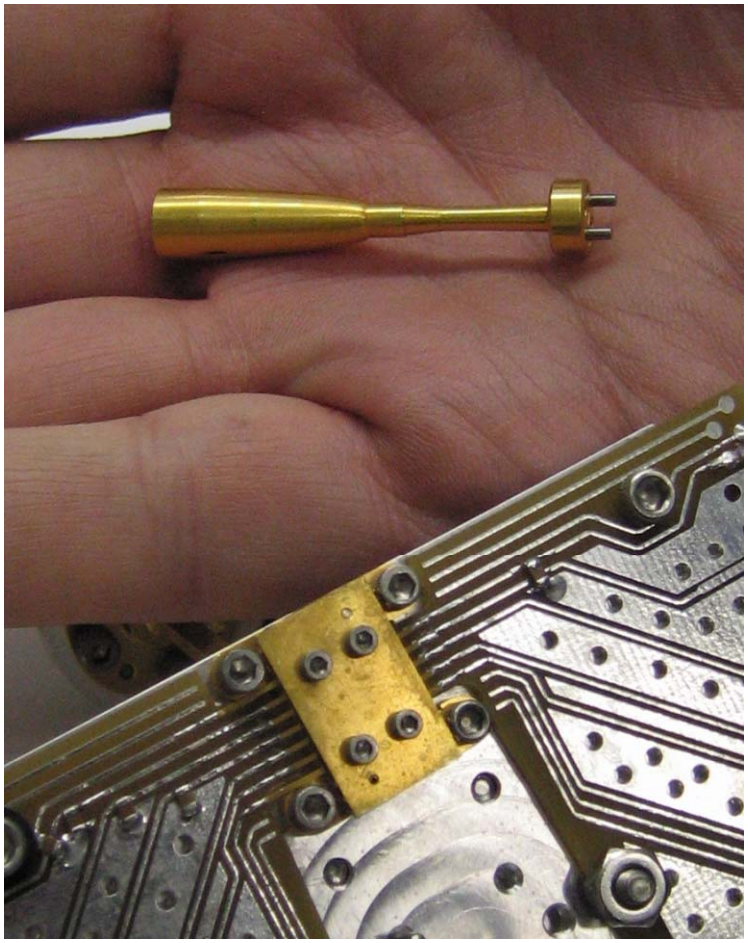
- RF input waveguide WR-05
- LO waveguide reduced height WR-10
- Waveguide to microstrip transitions, interconnect lines have matching circuits for wirebonds

Receiver Design



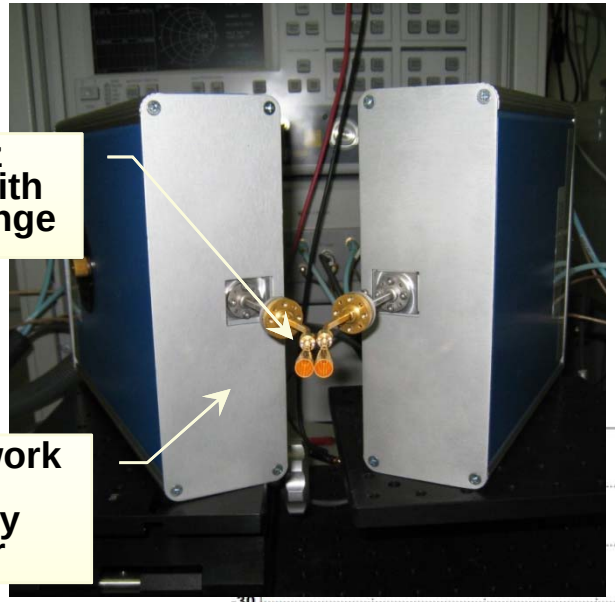
- Receiver module on the testing platform
- 180 GHz RF signal fed through the platform
- LO waveguide flange is on the platform, and the bias and IF lines are on FR-4 PCB

Receiver Design

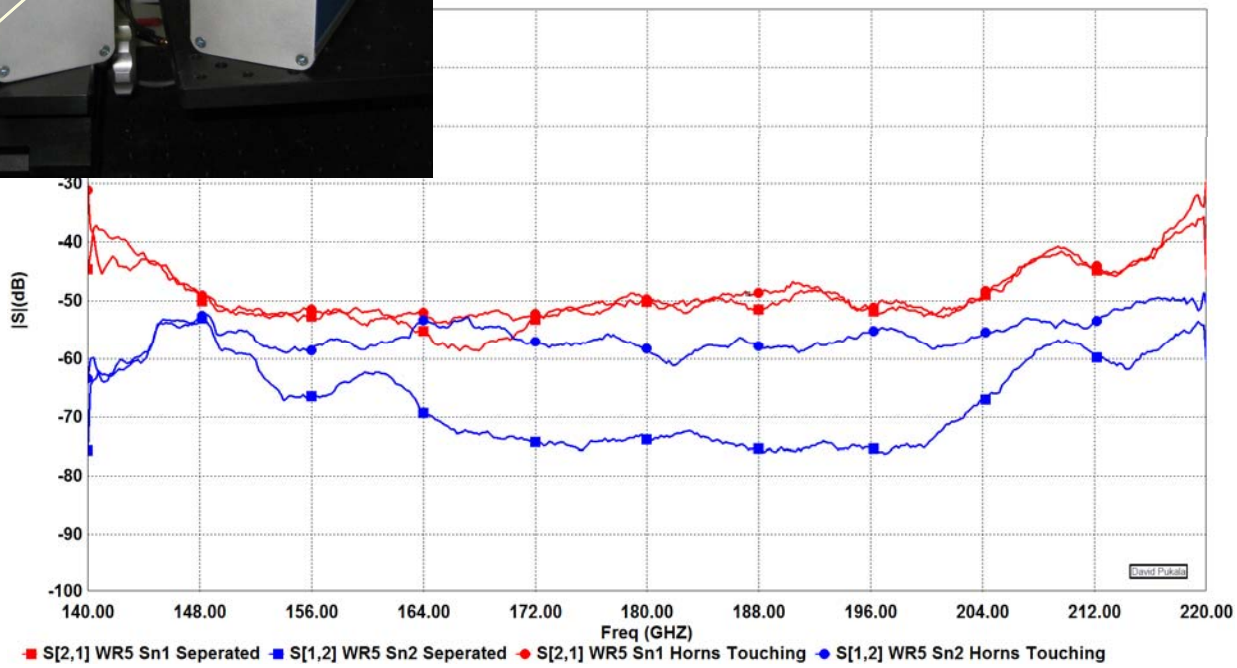


- Receiver module on the testing platform
- Parabolic potter horn antenna

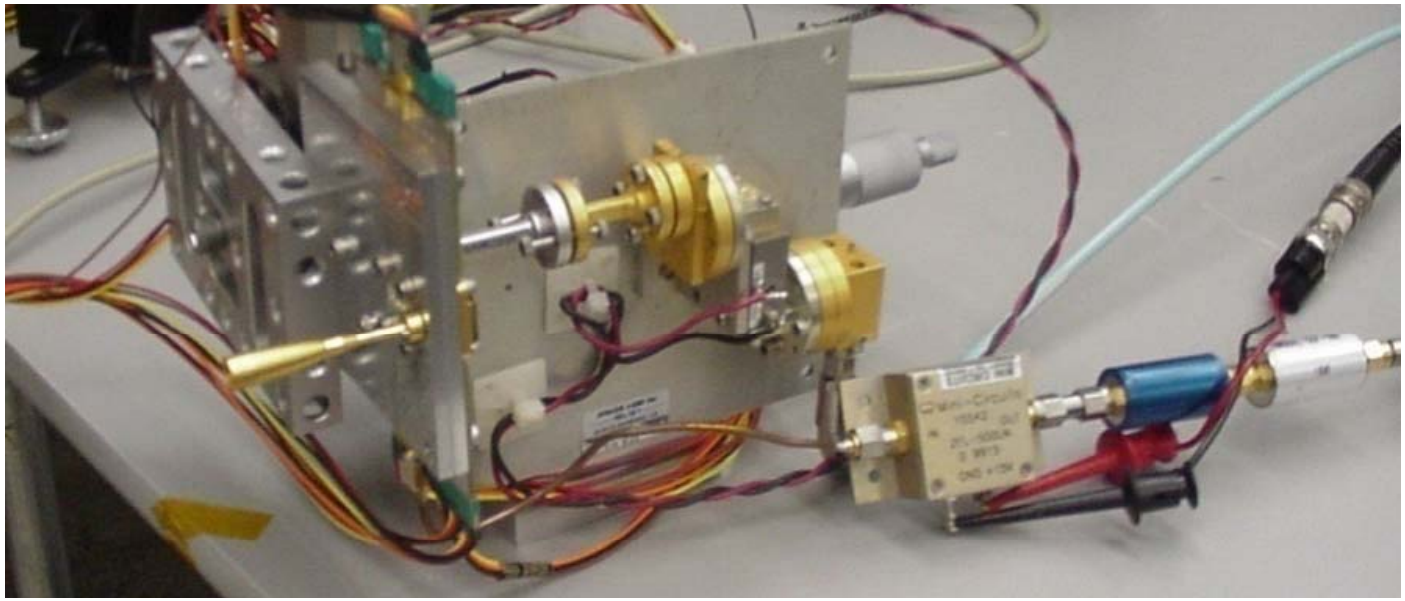
Receiver Design



- High Antenna to Antenna isolation of 72 dB
- Antennas placed side by side in this measurement
- High isolation is required to reduce correlated noise

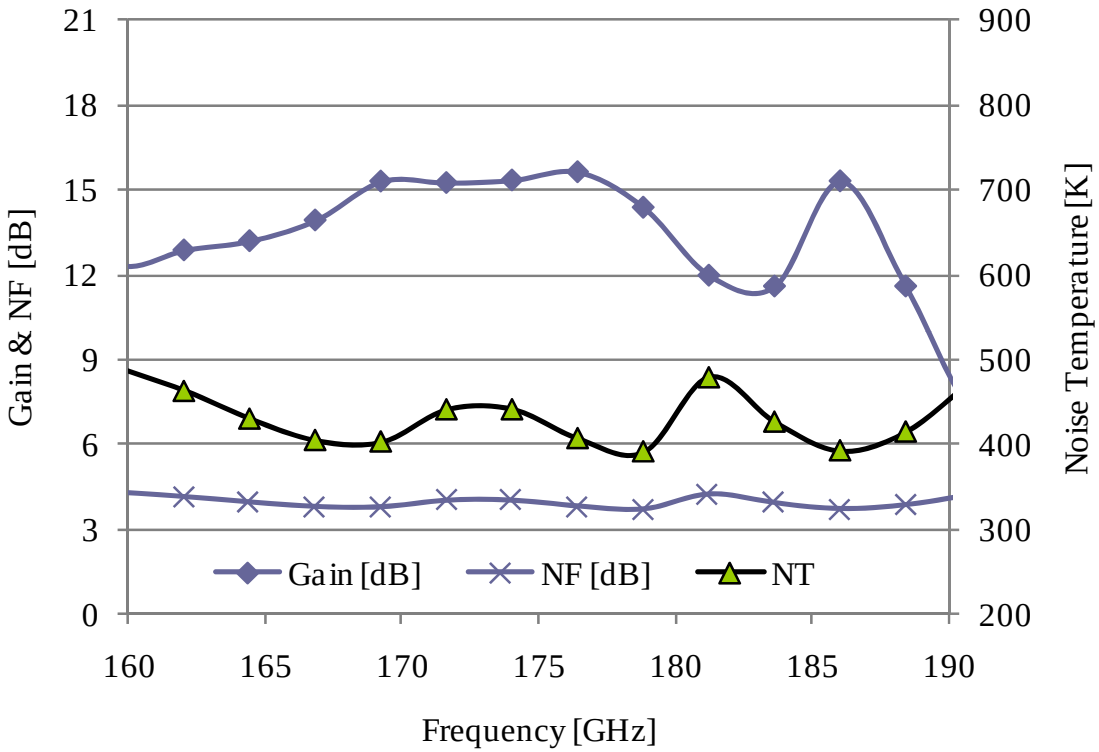


Measured Results



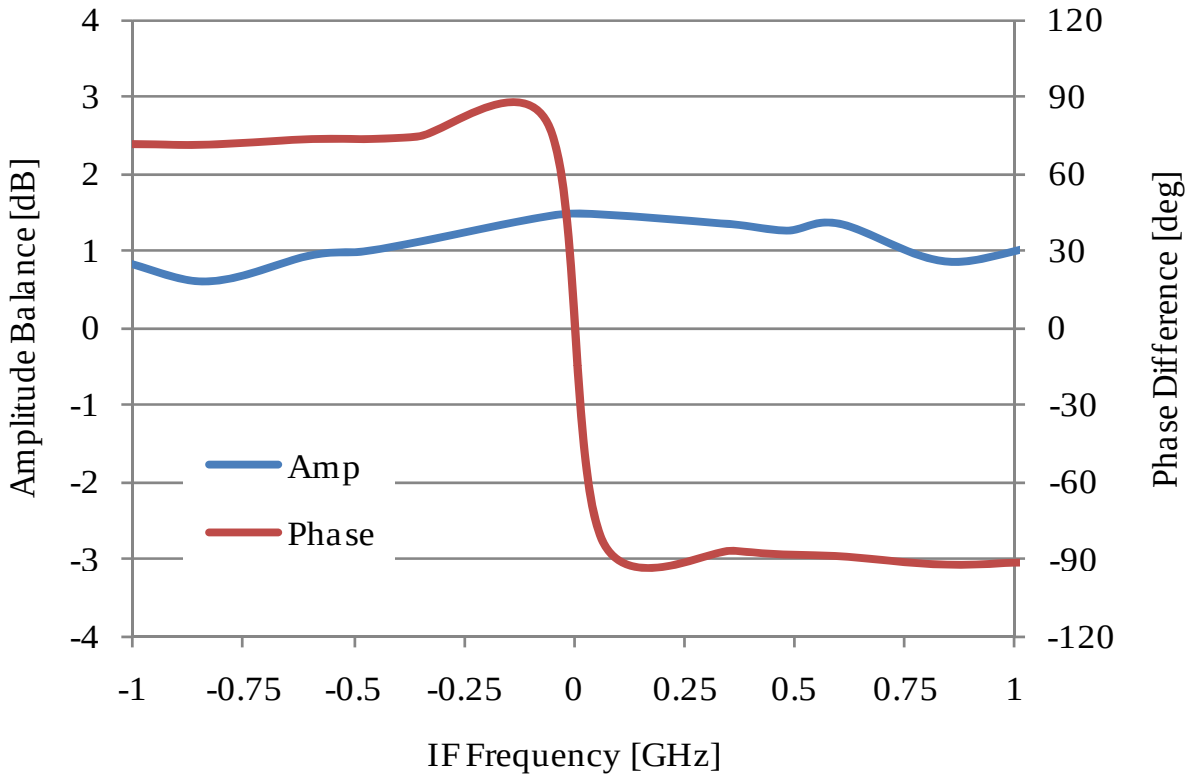
- Testing of the noise figure of the receiver with the developed potter horn antenna at the input
- Absorber used as hot (295 K) and cold noise source (78 K) in the Y-factor measurements

Measured Results



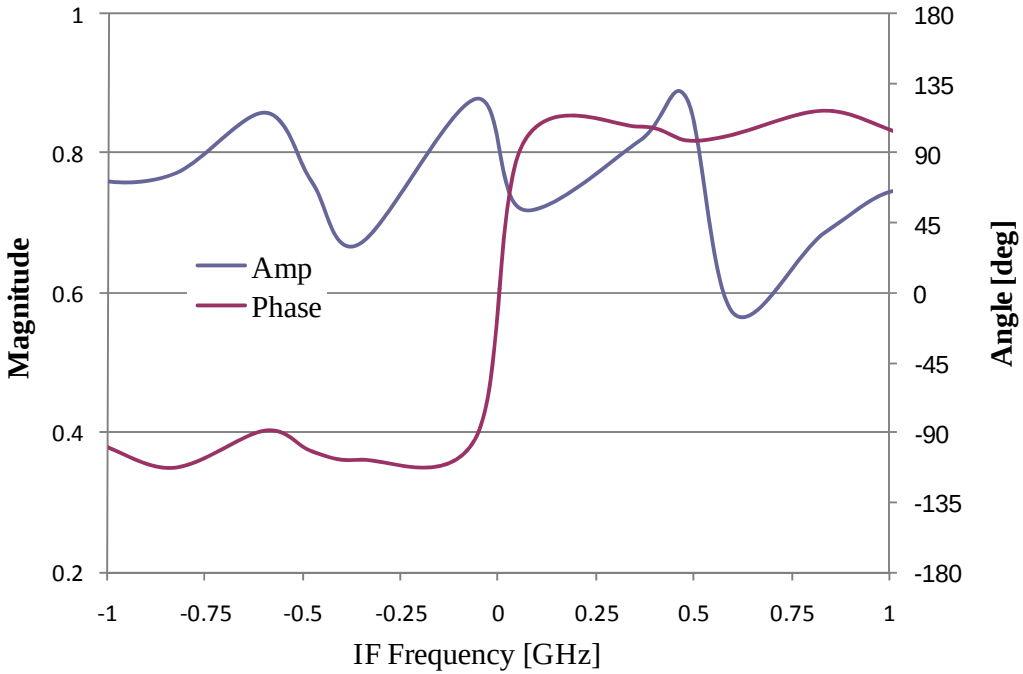
- **Measured results for MMIC receiver on the testing platform (input waveguide and antenna included)**
- **The noise temperature is between 400 and 450 K over the 165 to183 GHz frequency band**

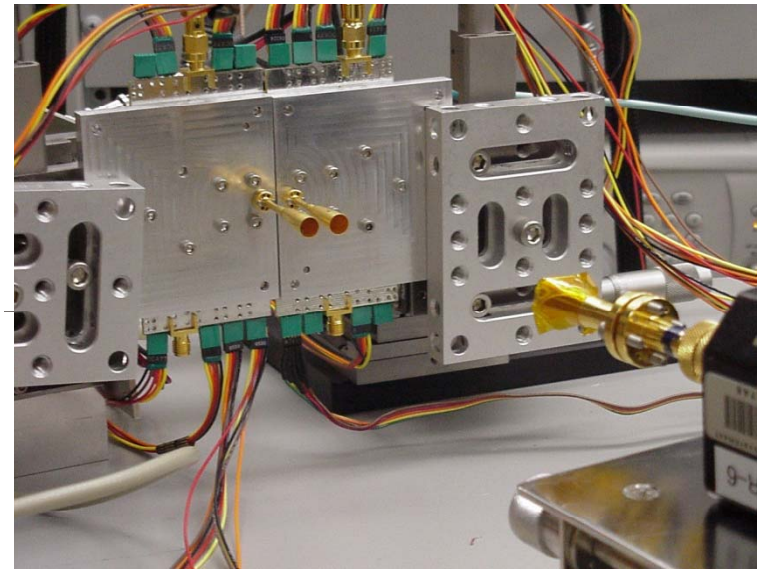
Measured Results



- **IF frequency range of the system 10 MHz to 500 MHz.**
- **The receiver has a flat phase and amplitude response**

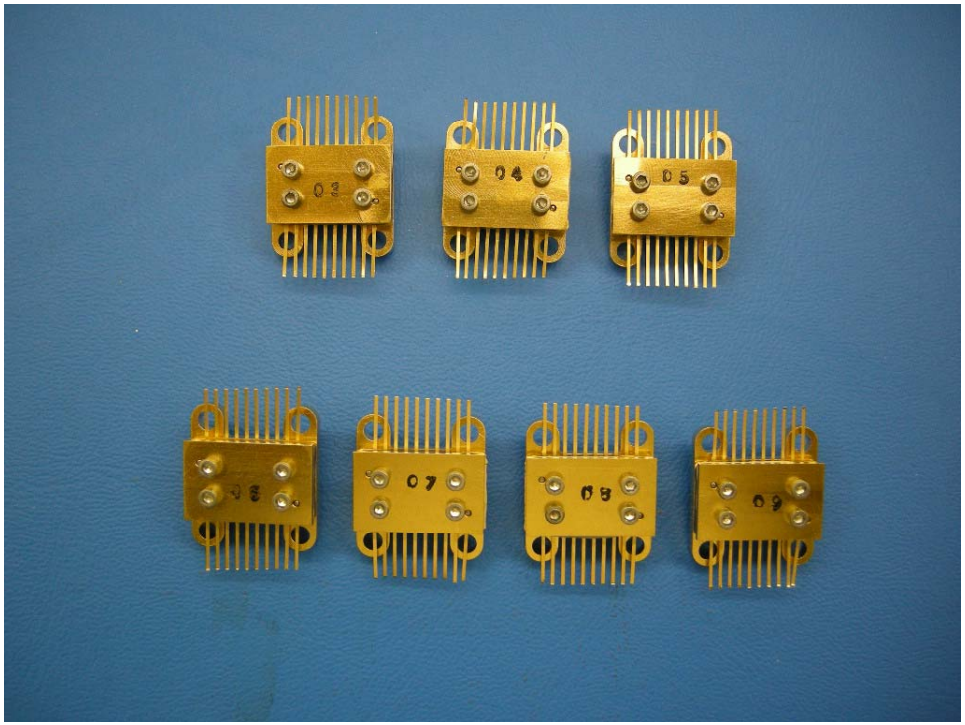
Measured Results





- IQ correlation was measured using a multiplied CW source
- The change in IQ correlation was characterized vs. IF frequency of the modules

Measured Results



- **Currently in production mode to build 48 receivers**

Conclusion

- Demonstrated the lowest noise figure MMIC I-Q receiver at 180 GHz frequency band that operates at room temperature
- Miniature size and very low power consumption and mass, all desirable features for large arrays
- Enabling technology for the geostationary thinned array radiometer (GeoSTAR) instrument for humidity sounding of the atmosphere

Acknowledgement

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