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

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Outline

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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 ($f_T > 550$GHz and $f_{\text{max}} > 1$ 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
• 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
• 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

180 GHz antenna with custom flange

Vector Network Analyzer Frequency Extender

ESTF 2010 B7P2
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 to 183 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.
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