80/160-GHz Transceiver and 140-GHz Amplifier in SiGe Technology

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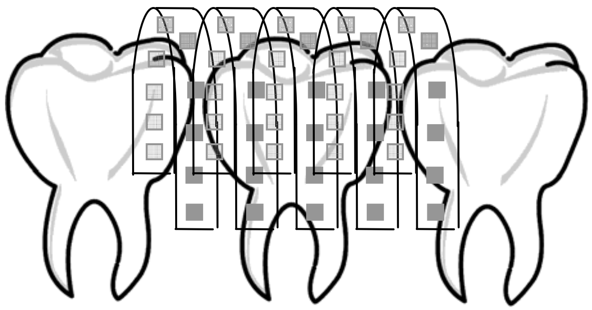
Outline

- Motivation
- Transceiver overview
- Circuit blocks
- Passives
- Measurement setup and results
- Conclusions and future work

Motivation

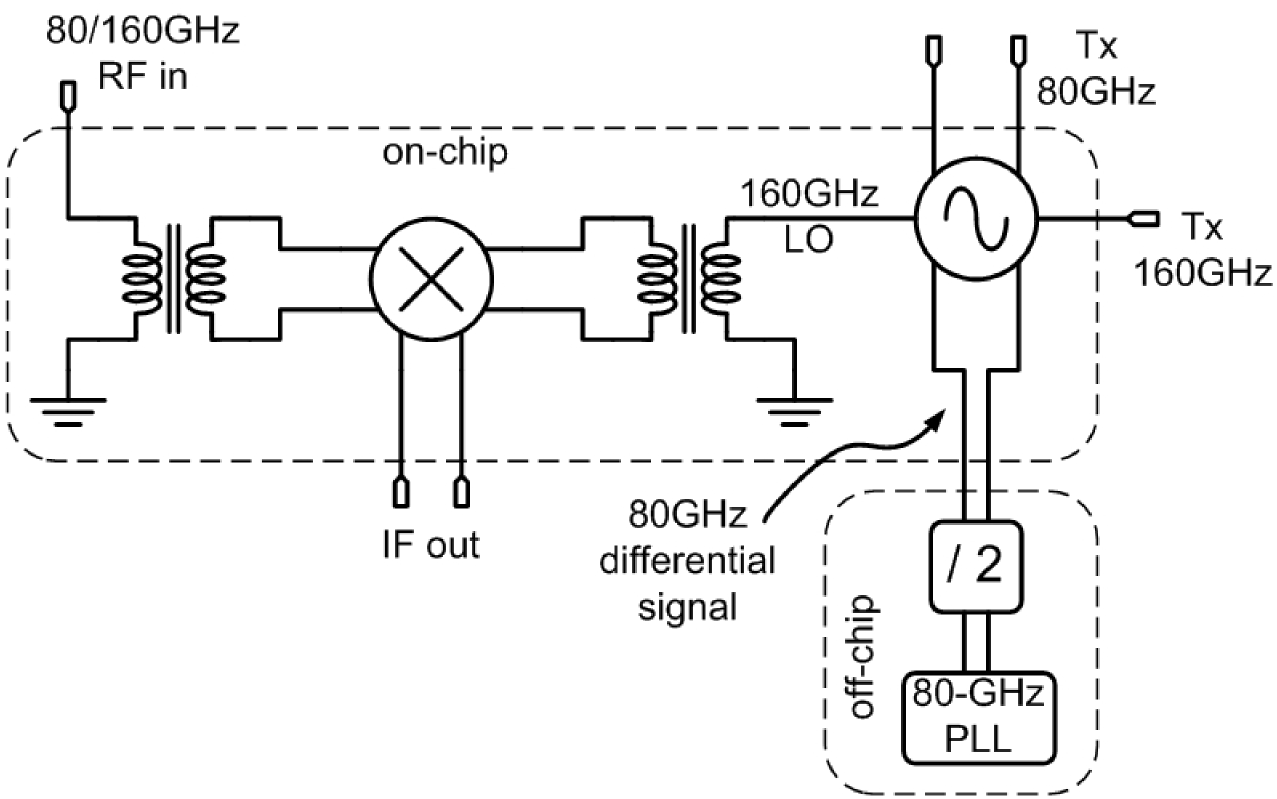
- High resolution imaging transceiver
- More information about the object due to different absorption in 80 & 160 GHz bands
- Possible astronomy imaging applications
  - ALMA† band 3: 84 - 116 GHz
  - ALMA band 4: 125 - 163 GHz
- Possible dental imaging applications

† Atacama Large Millimetre Array Radio Telescope project



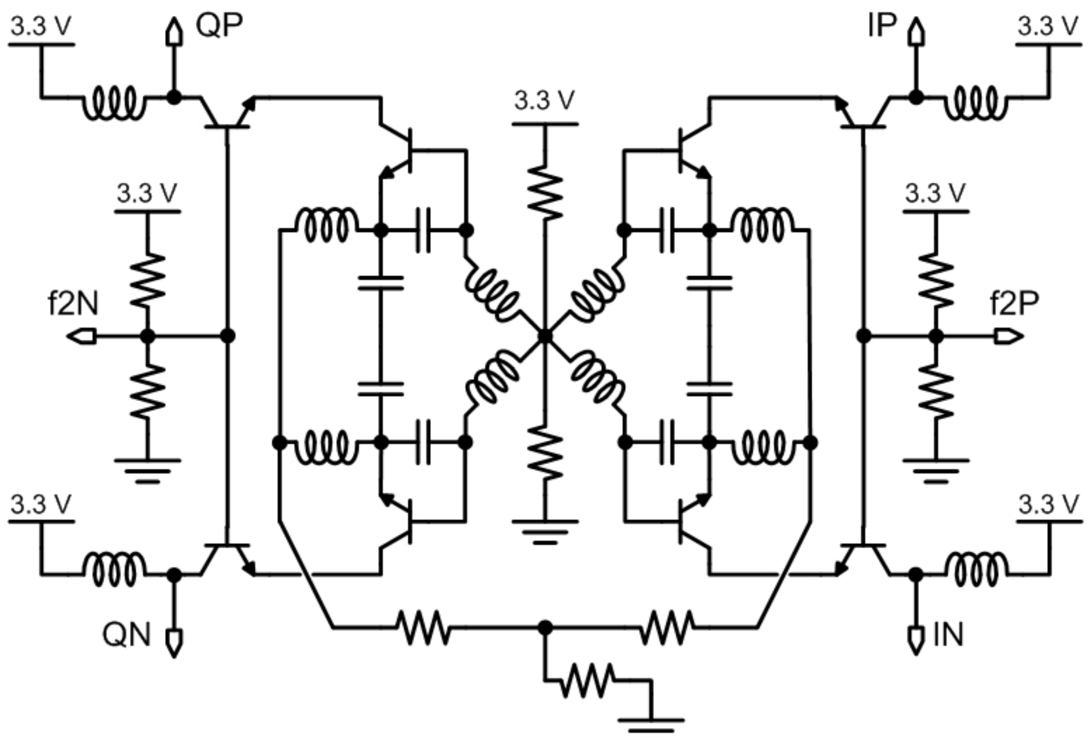
Transceiver Overview

- Transmit and receive in 80- and 160-GHz bands



80/160-GHz Oscillator

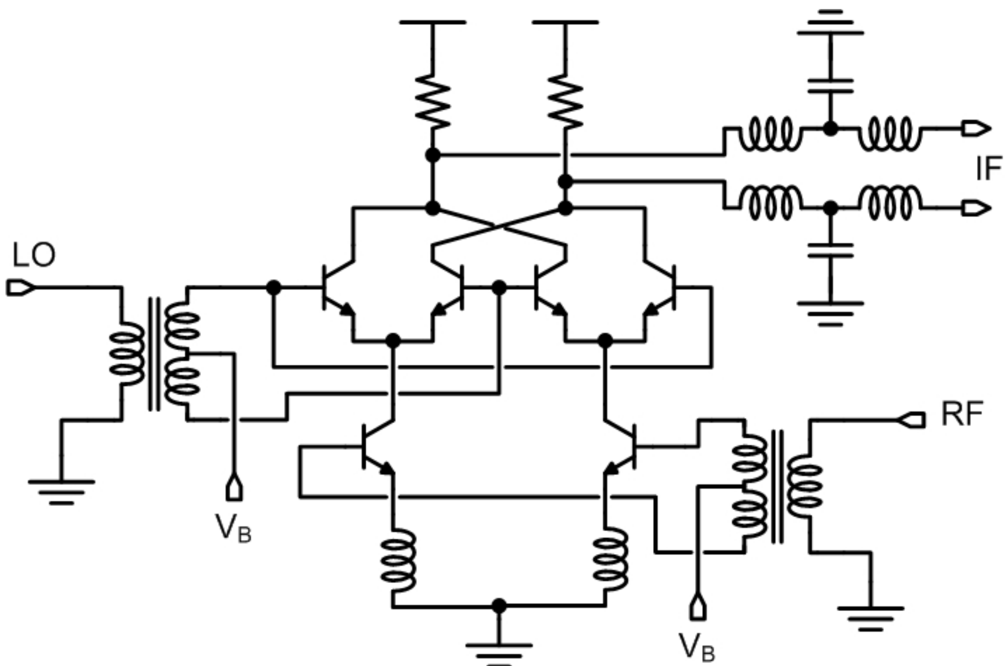
- 4 coupled Colpitts oscillators
- Differential @ 160 GHz, Quadrature @ 80 GHz



- peak-f_T bias
- 70mA, 3.3V

160-GHz Mixer

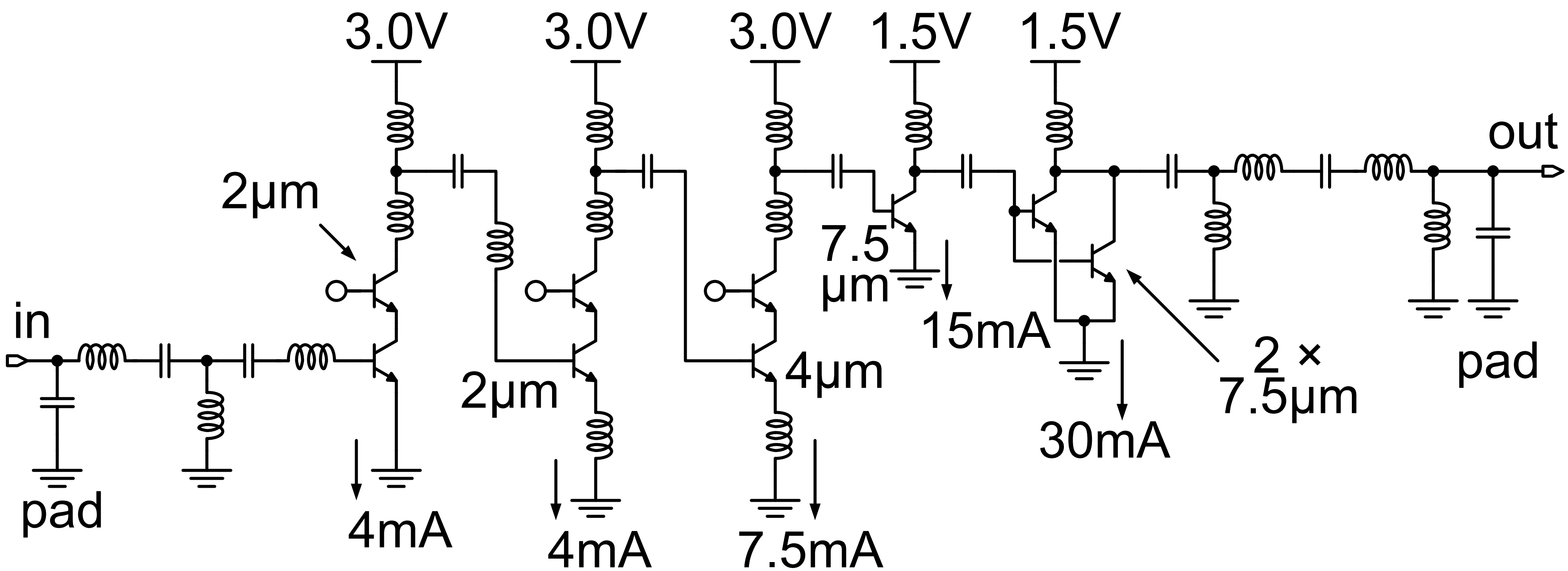
- Double-balanced Gilbert cell topology
- On-chip transformers employed at LO and RF



- peak-f_T bias
- 15mA, 3.3V

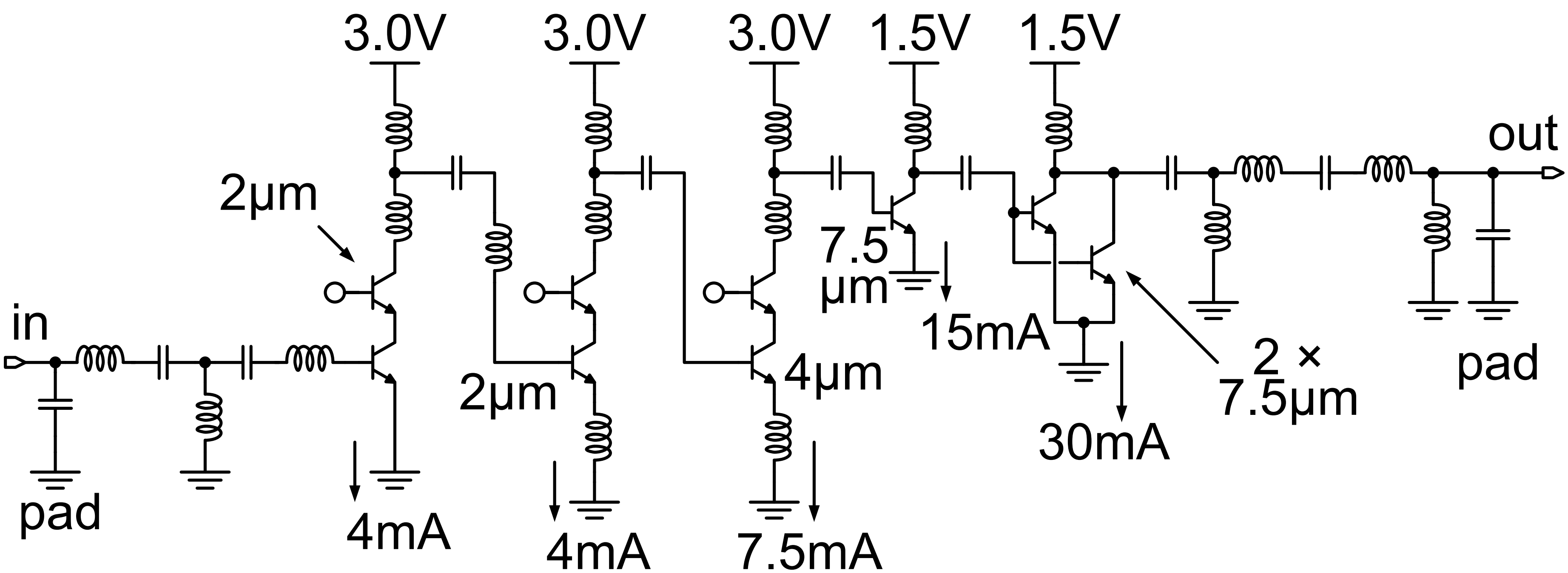
140-GHz Amplifier

- Cascodes → gain, CE stages → output power
- At 140GHz $R_E+R_B \approx 50\Omega$ → No input degeneration



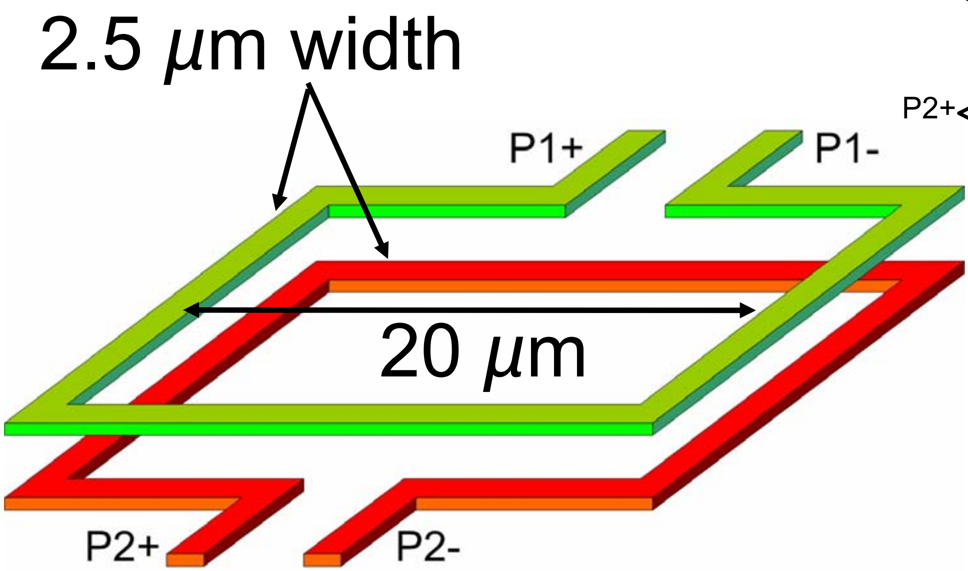
140-GHz Amplifier

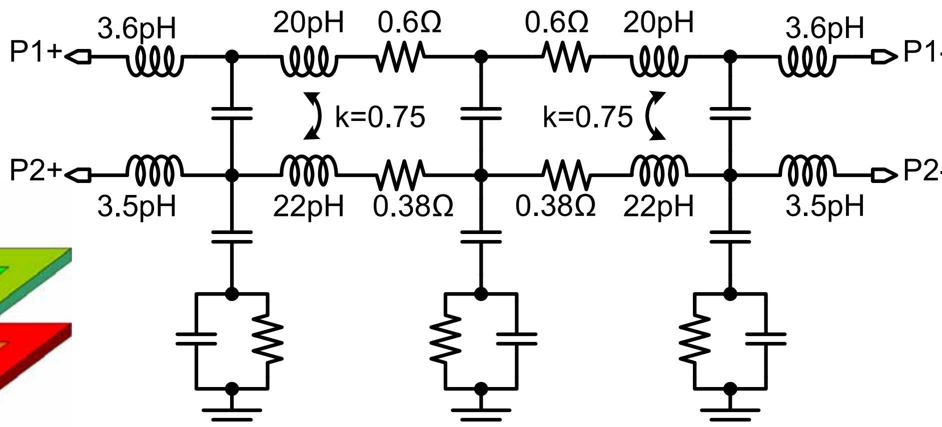
- Degeneration in 2nd stage for interstage matching
- Ratioed inductors and split loads for gain control
- Biased at peak-f_T for max power transfer



160-GHz Transformer

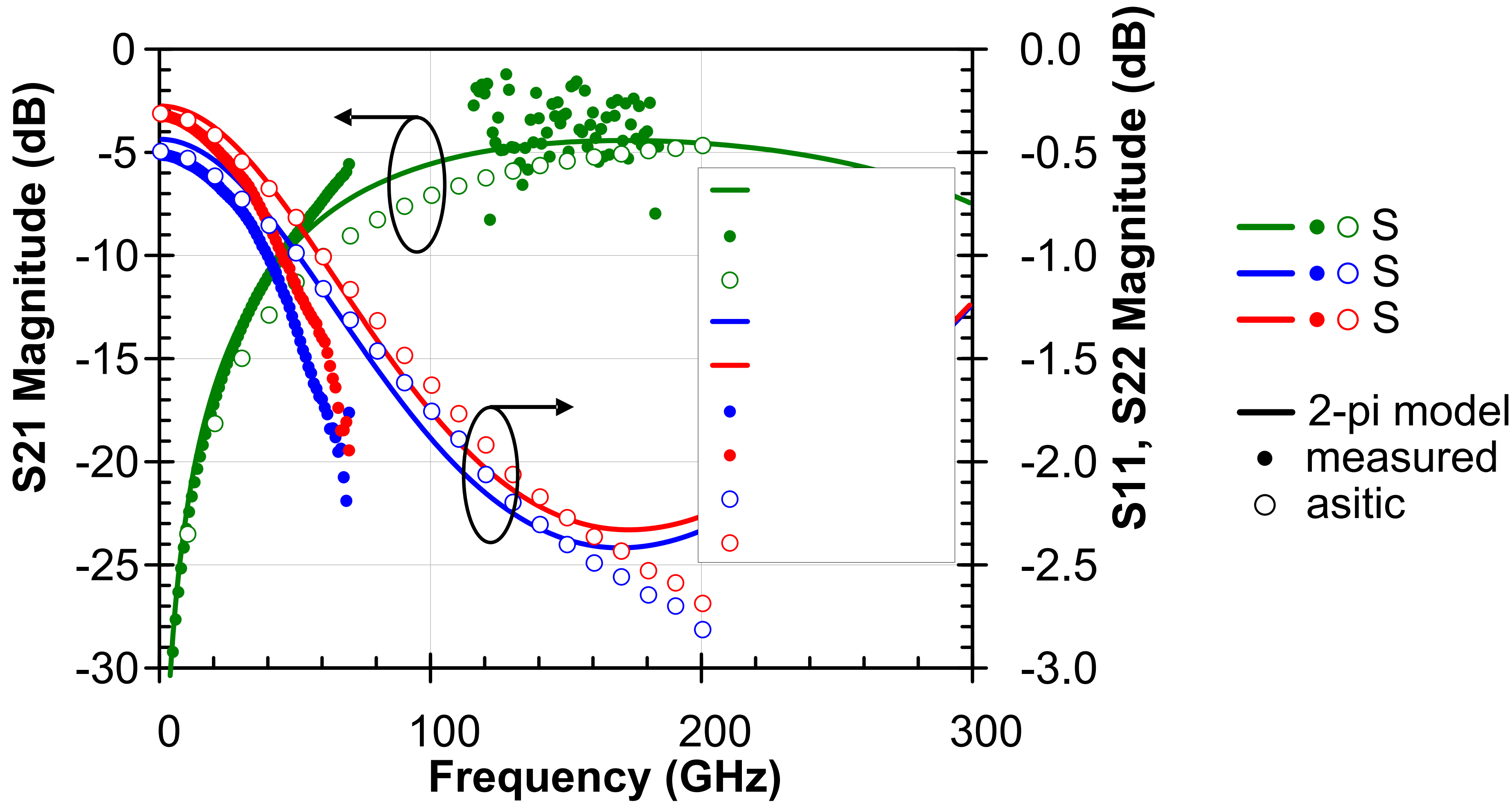
- Top 2 metal layers of a standard backend
- Optimized for lowest loss at 160 GHz
- 2-pi model used includes substrate model





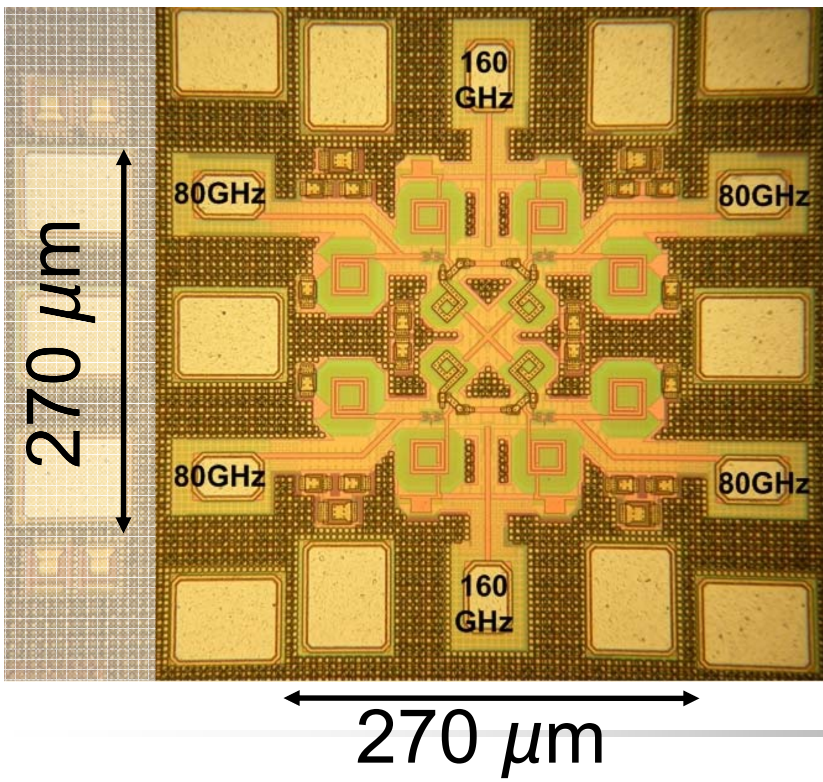
model from ASITIC

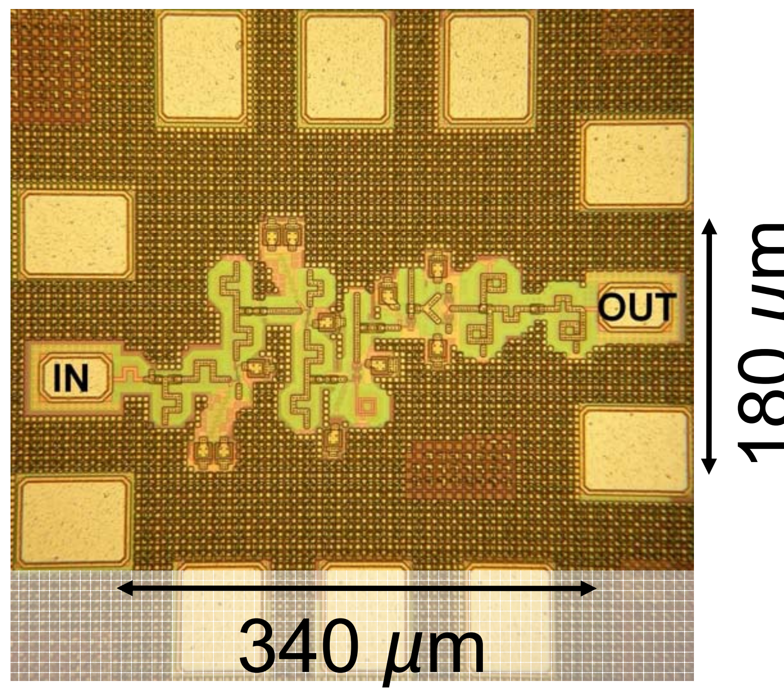
Transformer Meas. vs. Sims



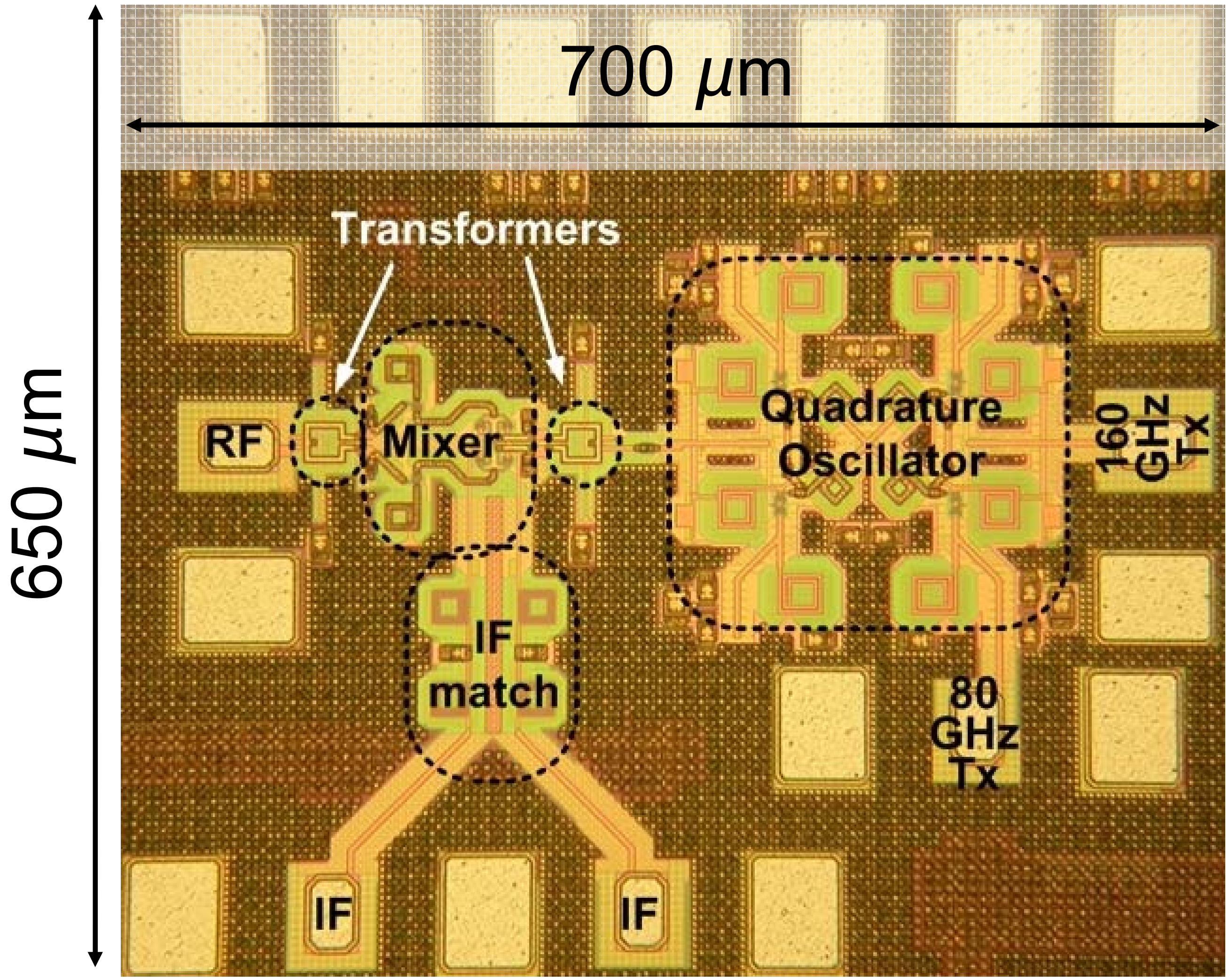
Fabrication

- STM 130nm SiGe HBT with BiCMOS9 backend
- f_T=230 GHz, f_{MAX}=300 GHz, + process splits

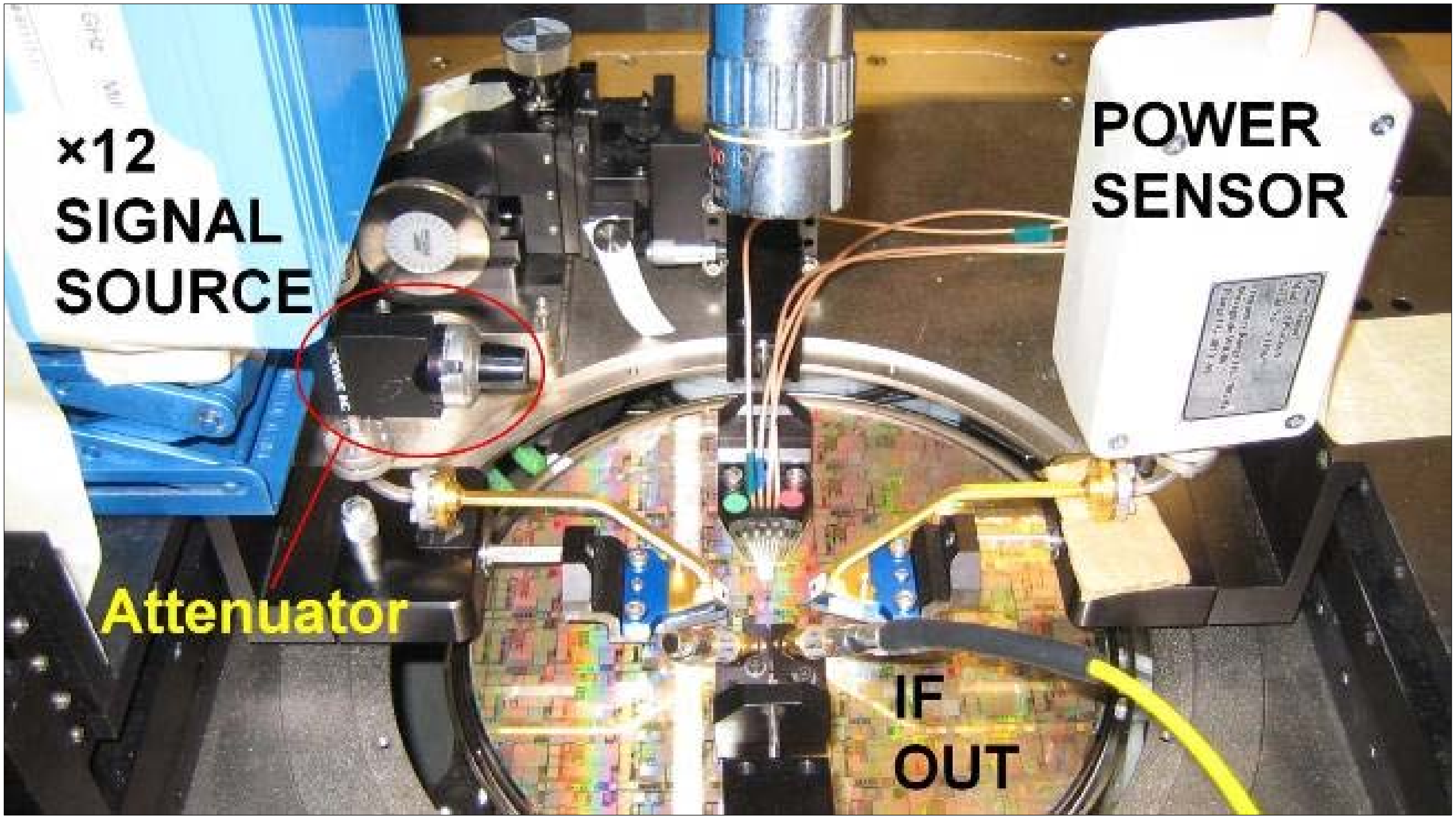




80/160-GHz Transceiver

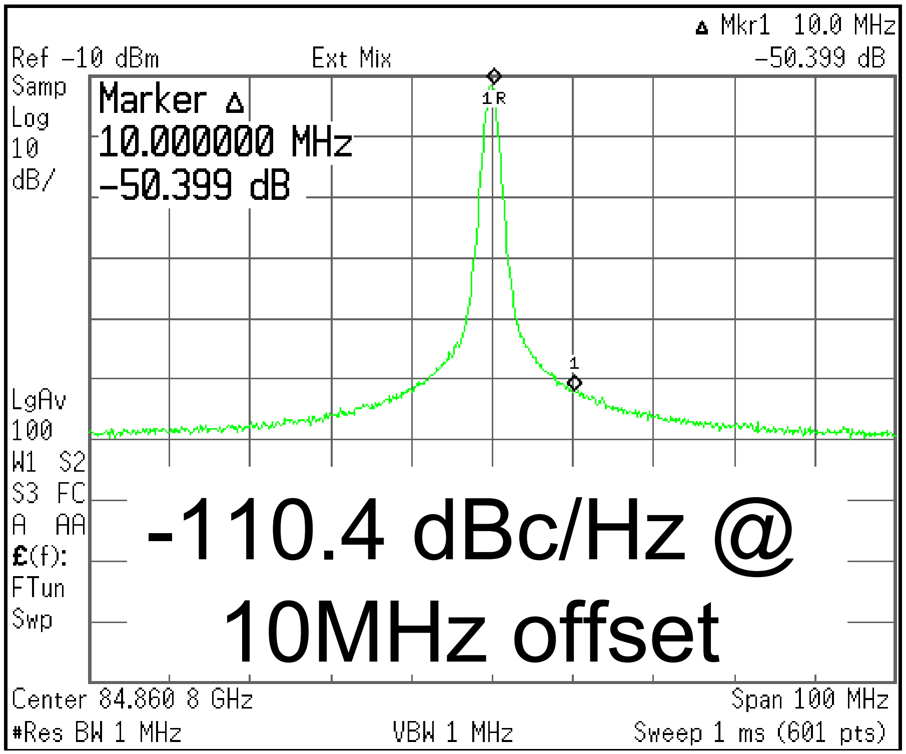


Measurement Setup

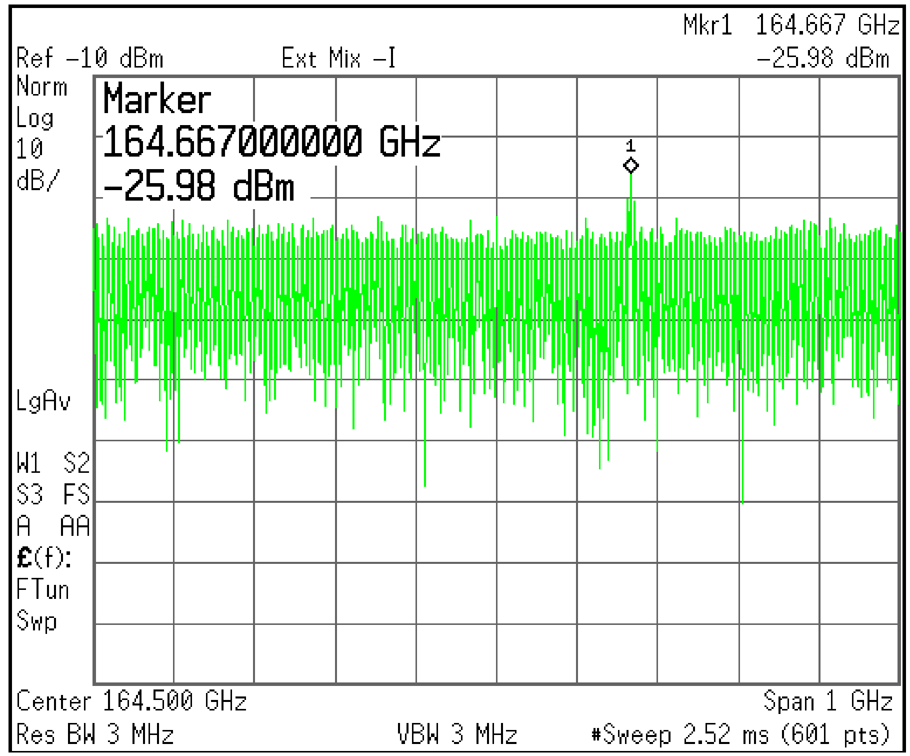


Results - Oscillator Breakout

80-GHz Output:



160-GHz Output:



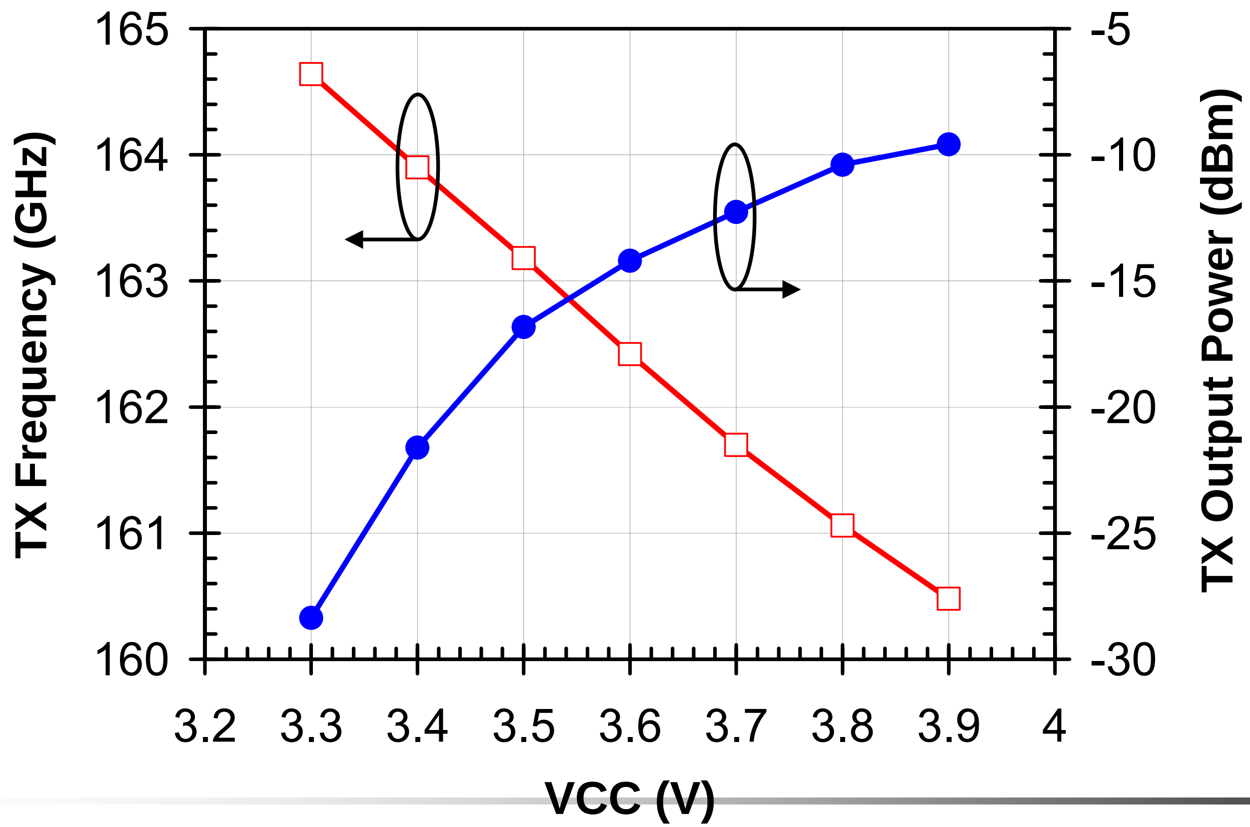
low-noise power supply

losses not deembedded

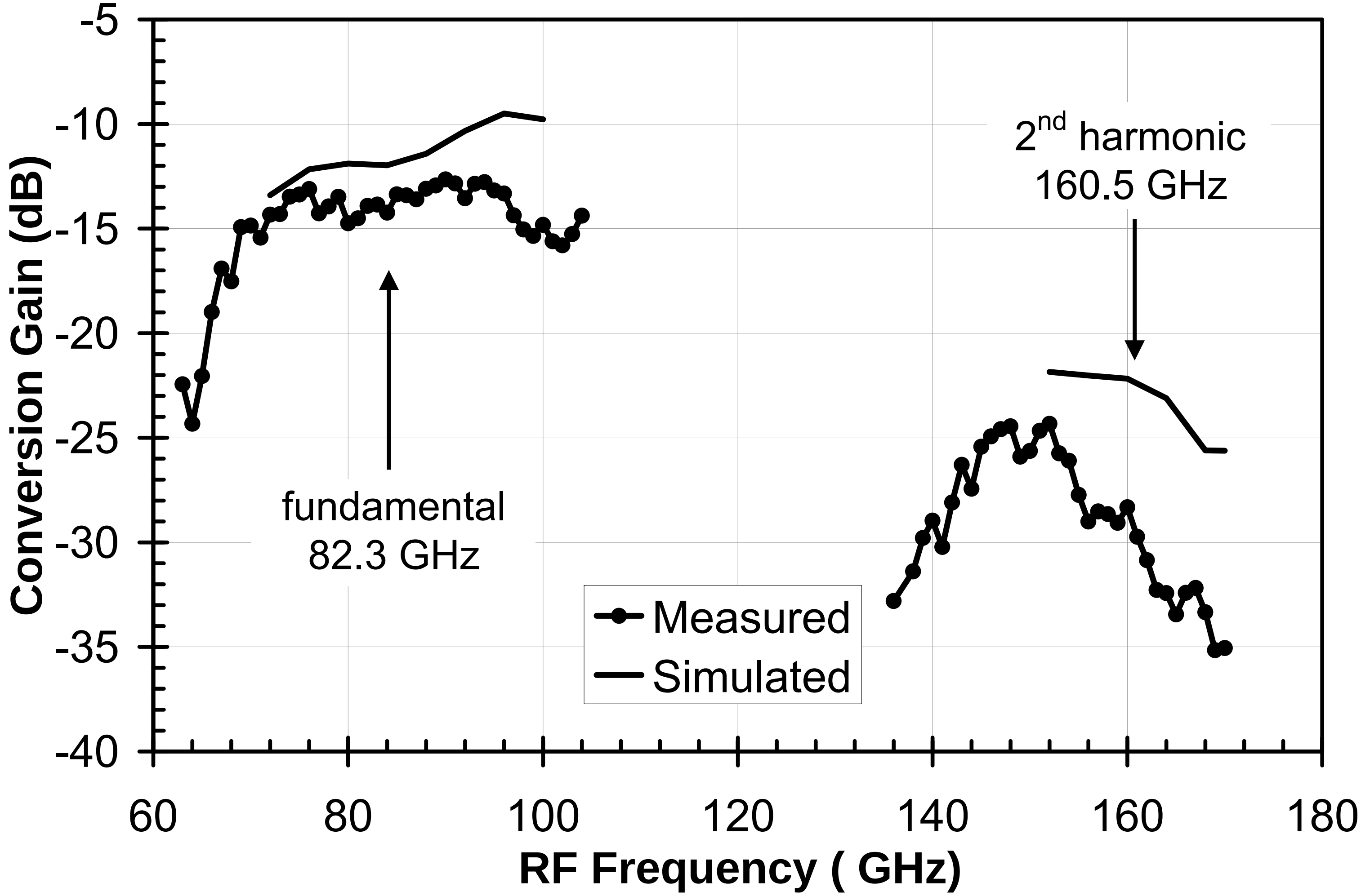
improper bias (60 mA)

Transmitter Output Power

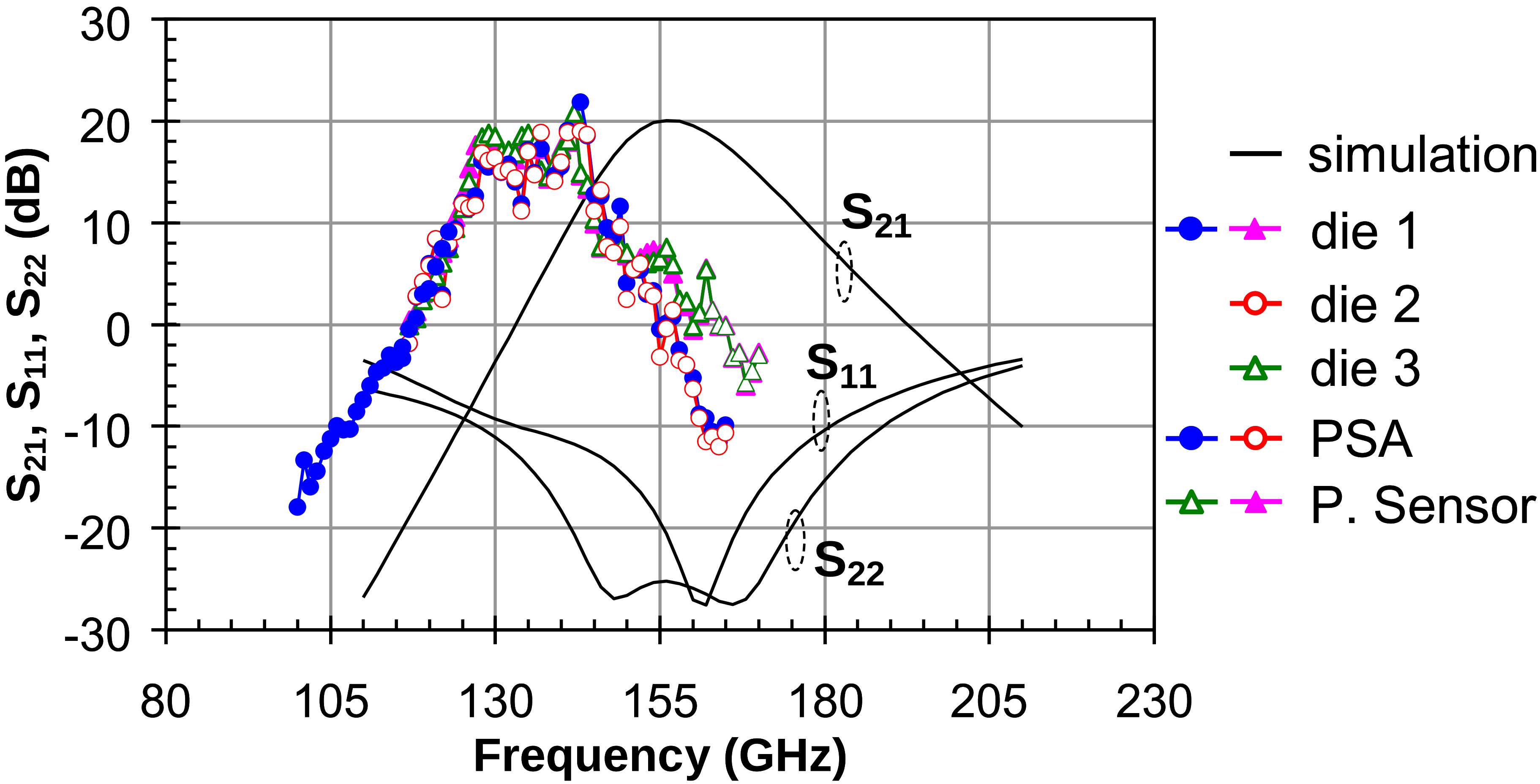
- Single-ended TX power increases with VCC
- Measured using the power sensor



Results - Receiver

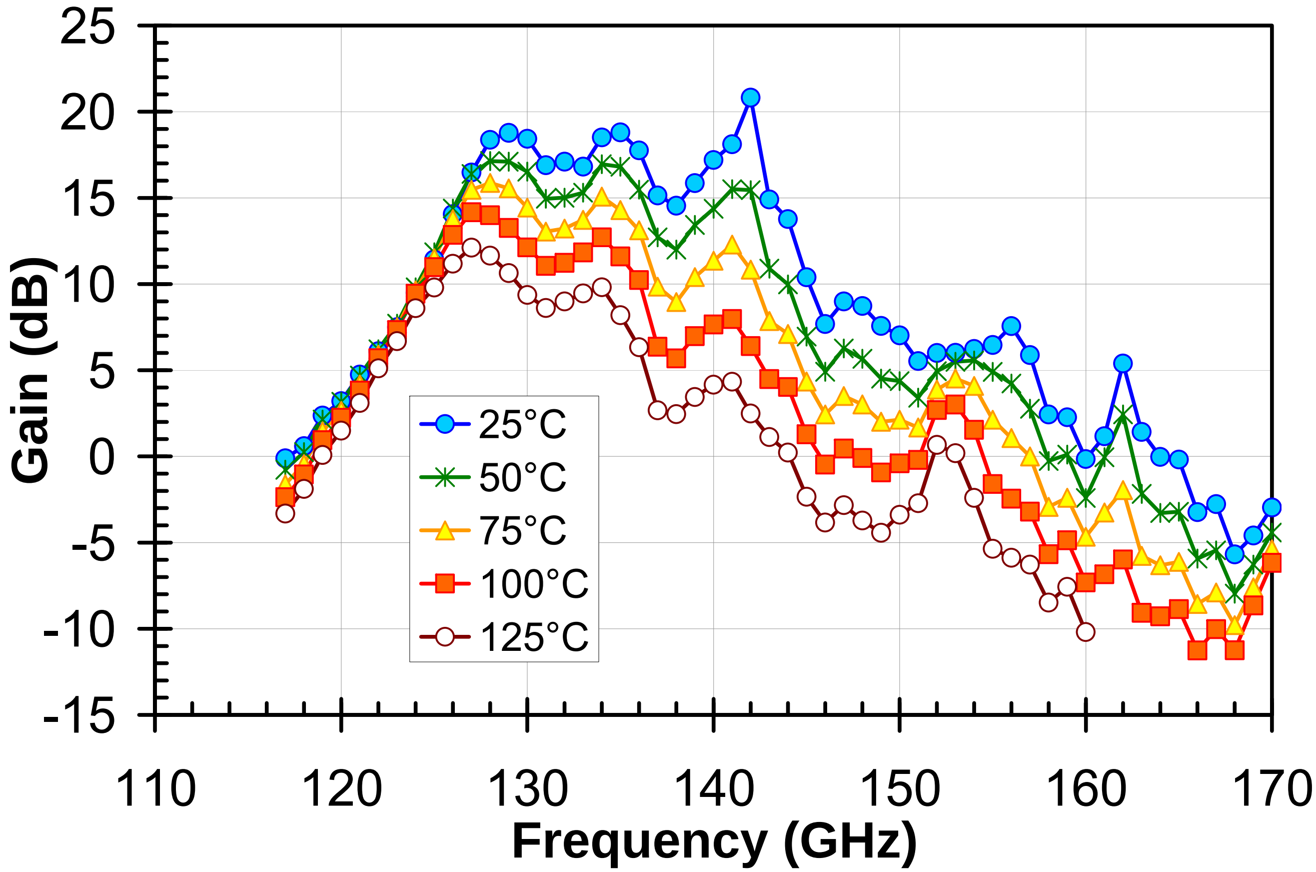


Amplifier - Measured vs. Sim



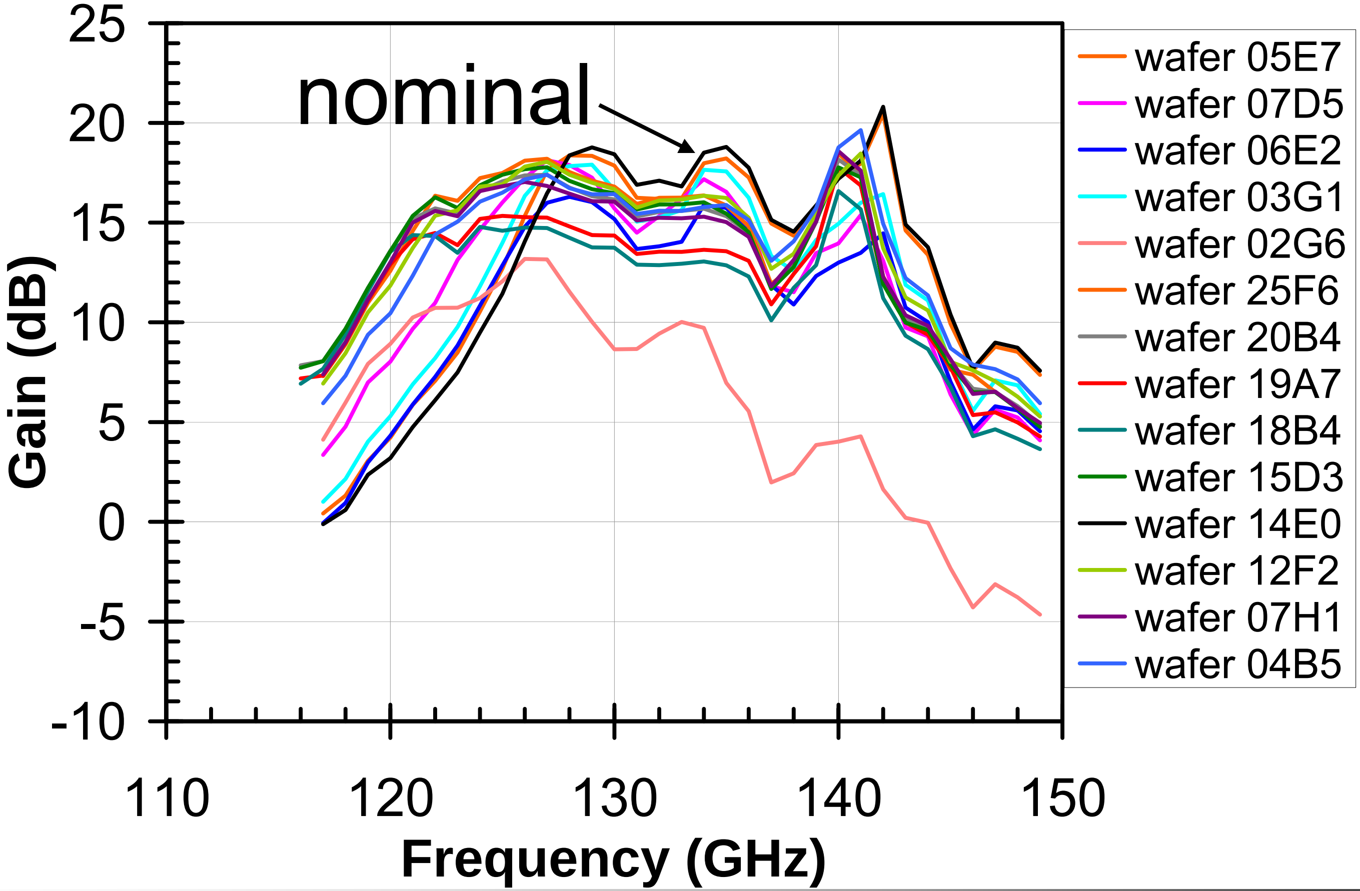
Amplifier Over Temperature

- Nominal wafer, measured using power sensor

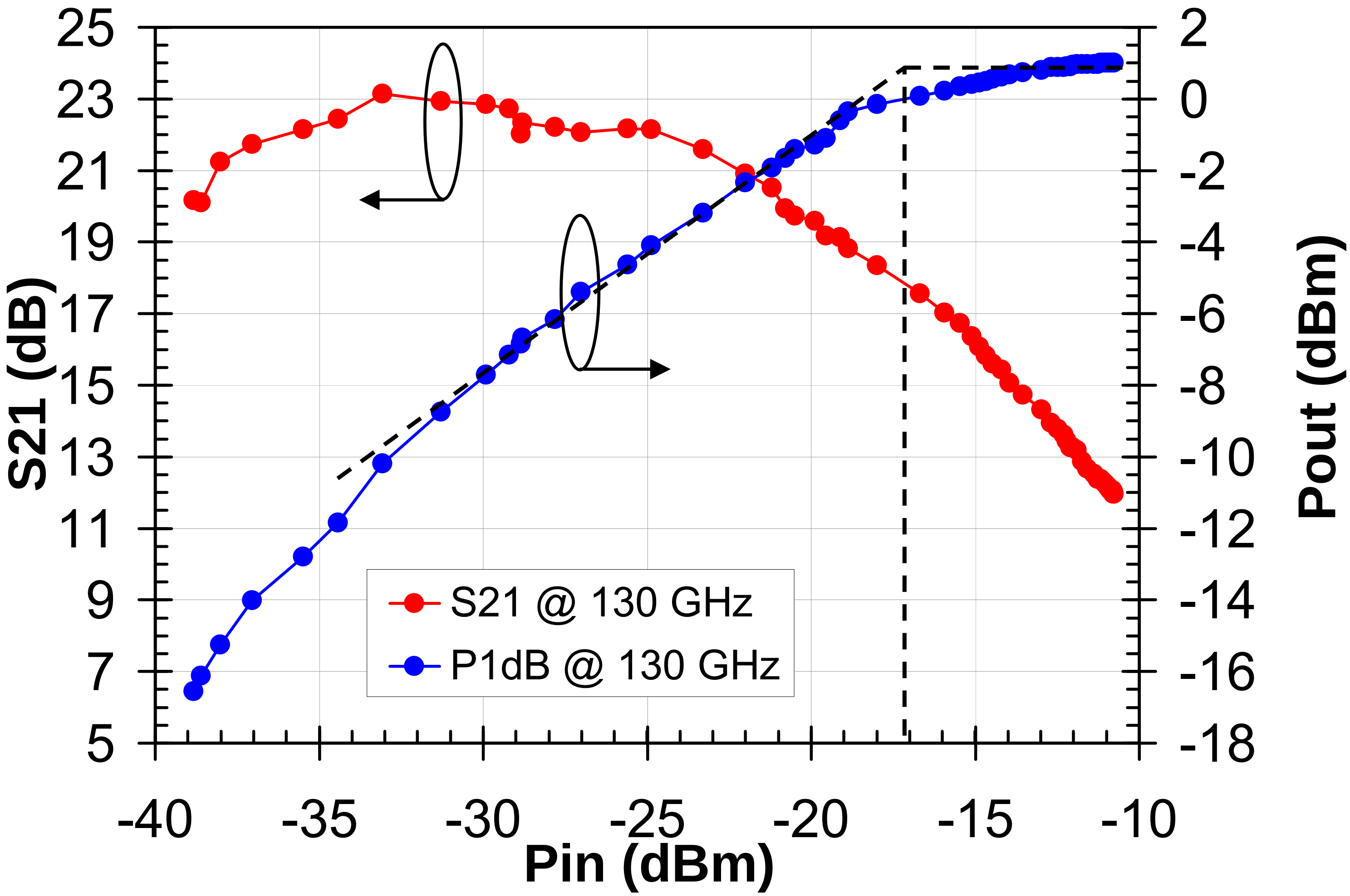


Amplifier Process Splits

- Same die location on 14 wafers with varied f_T/f_{MAX}



Amplifier Linearity - 130GHz



Conclusions

- First 80/160 GHz imaging transceiver
- First oscillator with a differential signal at 160GHz, -10 dBm output power
- First 140-GHz amplifier in silicon with gain > 15 dB, Psat = +1dBm
- Highest frequency monolithic transformer designed and verified up to 180 GHz

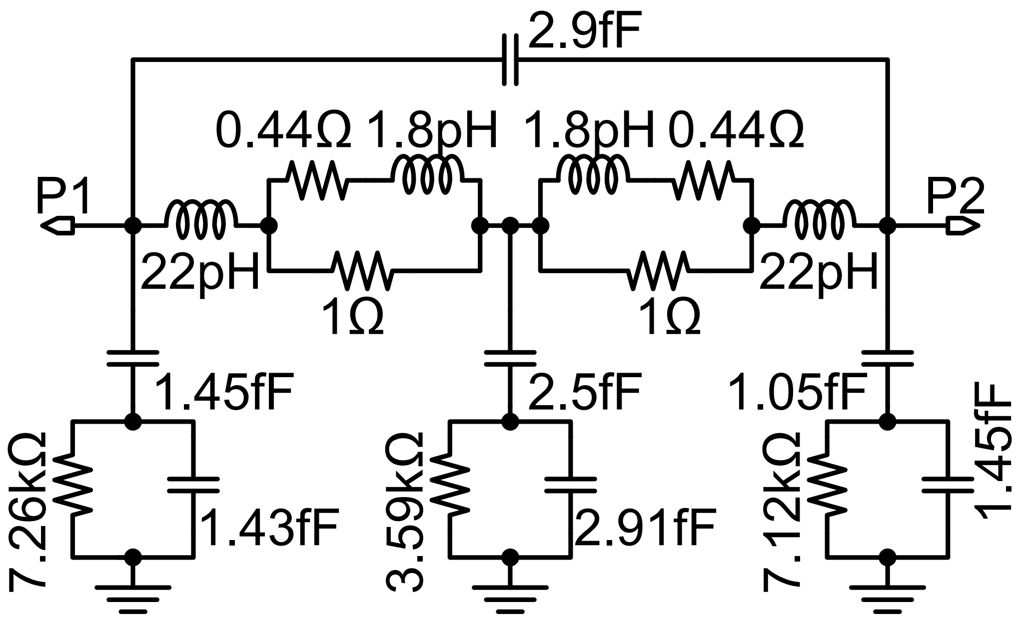
Acknowledgements

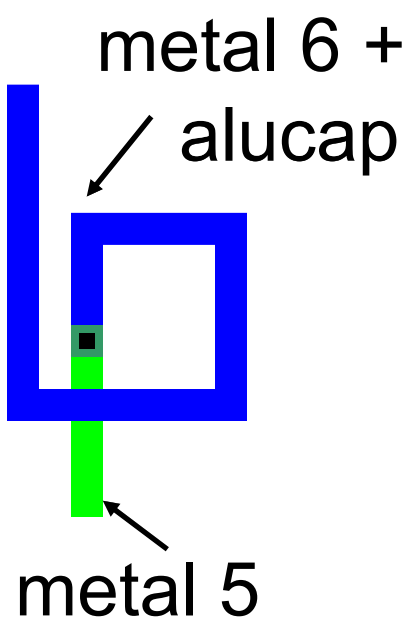
- CITO, NSERC for funding
- STMicroelectronics for fabrication
- ECTI, CFI, OIF for equipment
- Jaro Pristupa and CMC for CAD support

Extra Slides

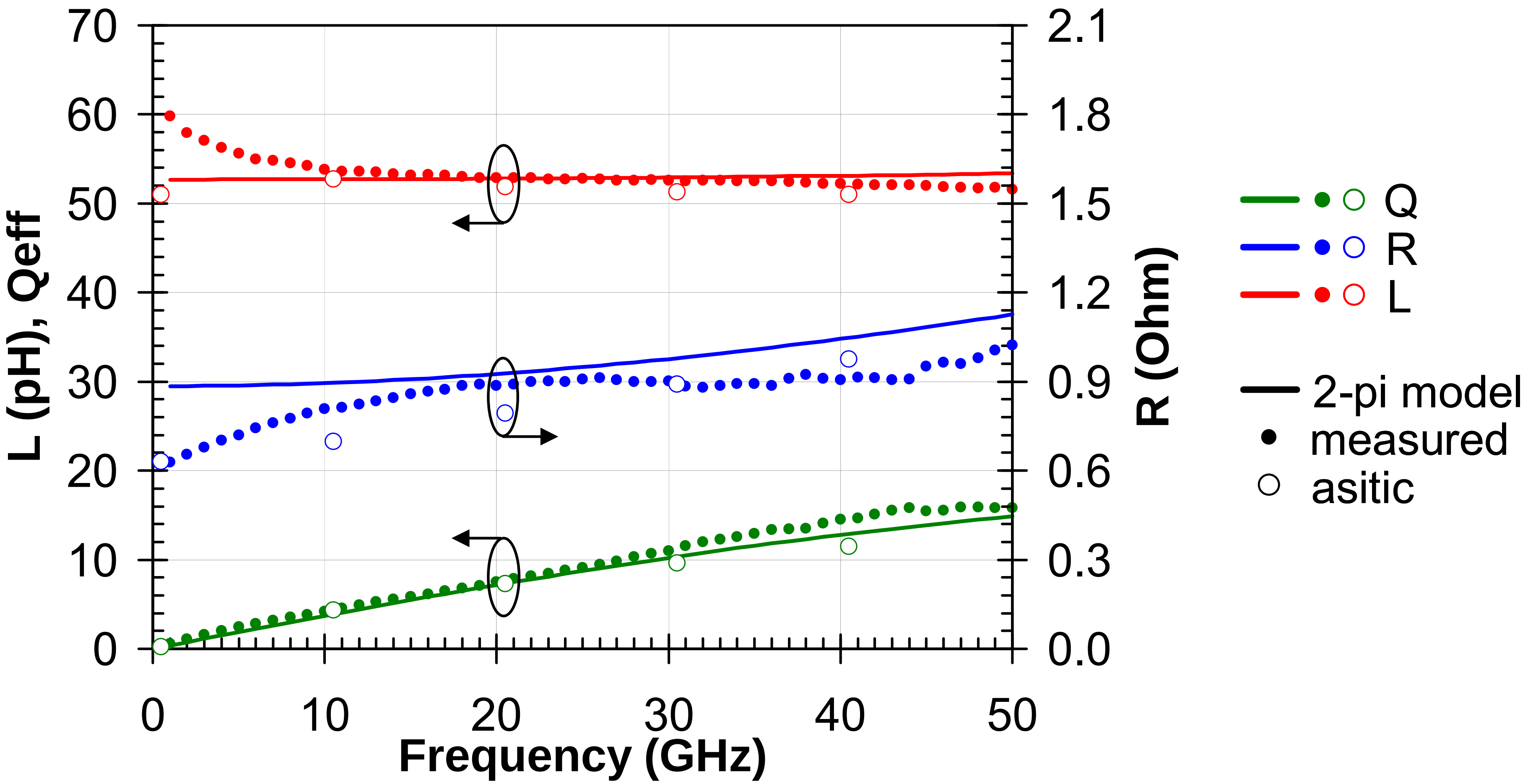
Inductor Design and Modeling

- 44-pH inductor for the oscillator tank
- Shunted top metals for low loss
- Designed using ASITIC, SRF > 400 GHz



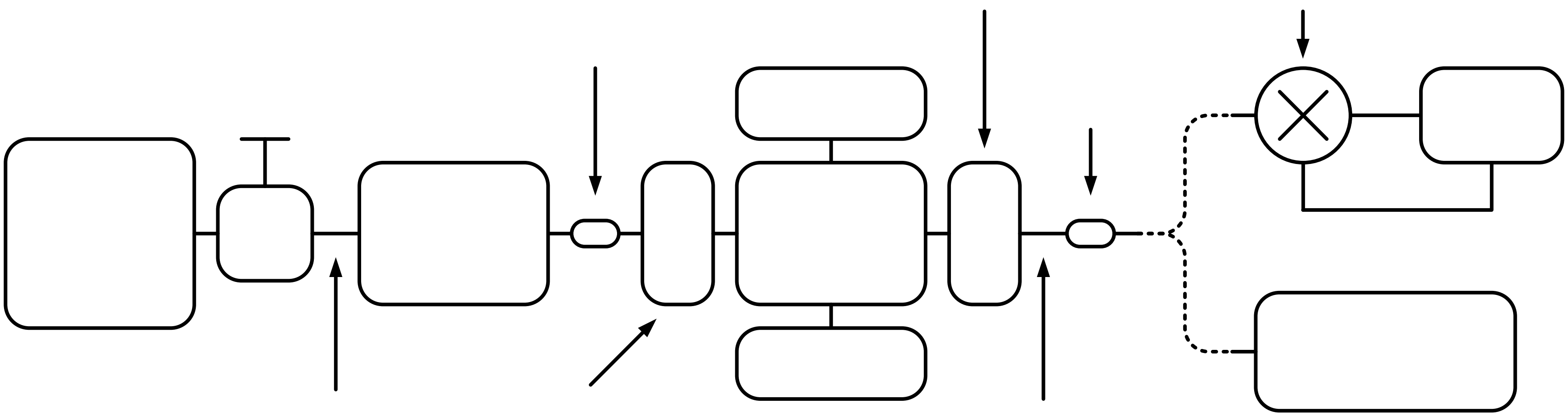


Inductor Model Verification



Measurement Setup

- On-wafer with waveguide probes
- ×12 multiplier signal source → harmonics
- PSA+mixer or power sensor at output



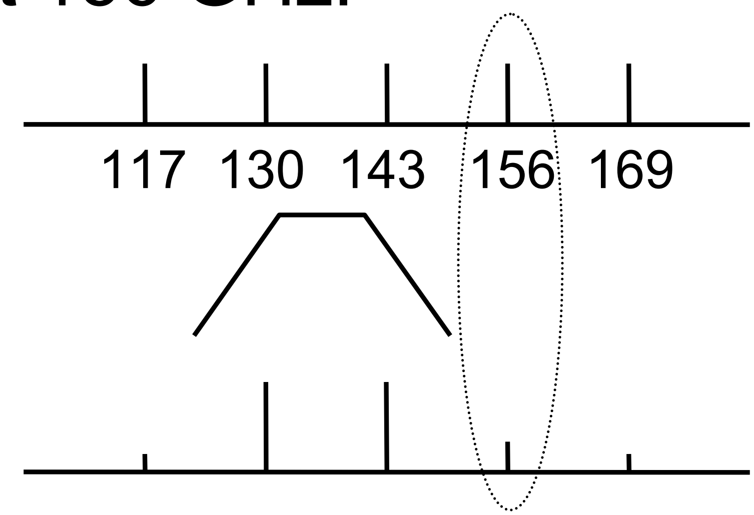
Measurement Setup

- Multiplier produces harmonics of input frequency
- Power sensor integrates power of all harmonics
- PSA allows reading power of only one harmonic
- Example measurement at 156 GHz:

input spectrum from ×12:

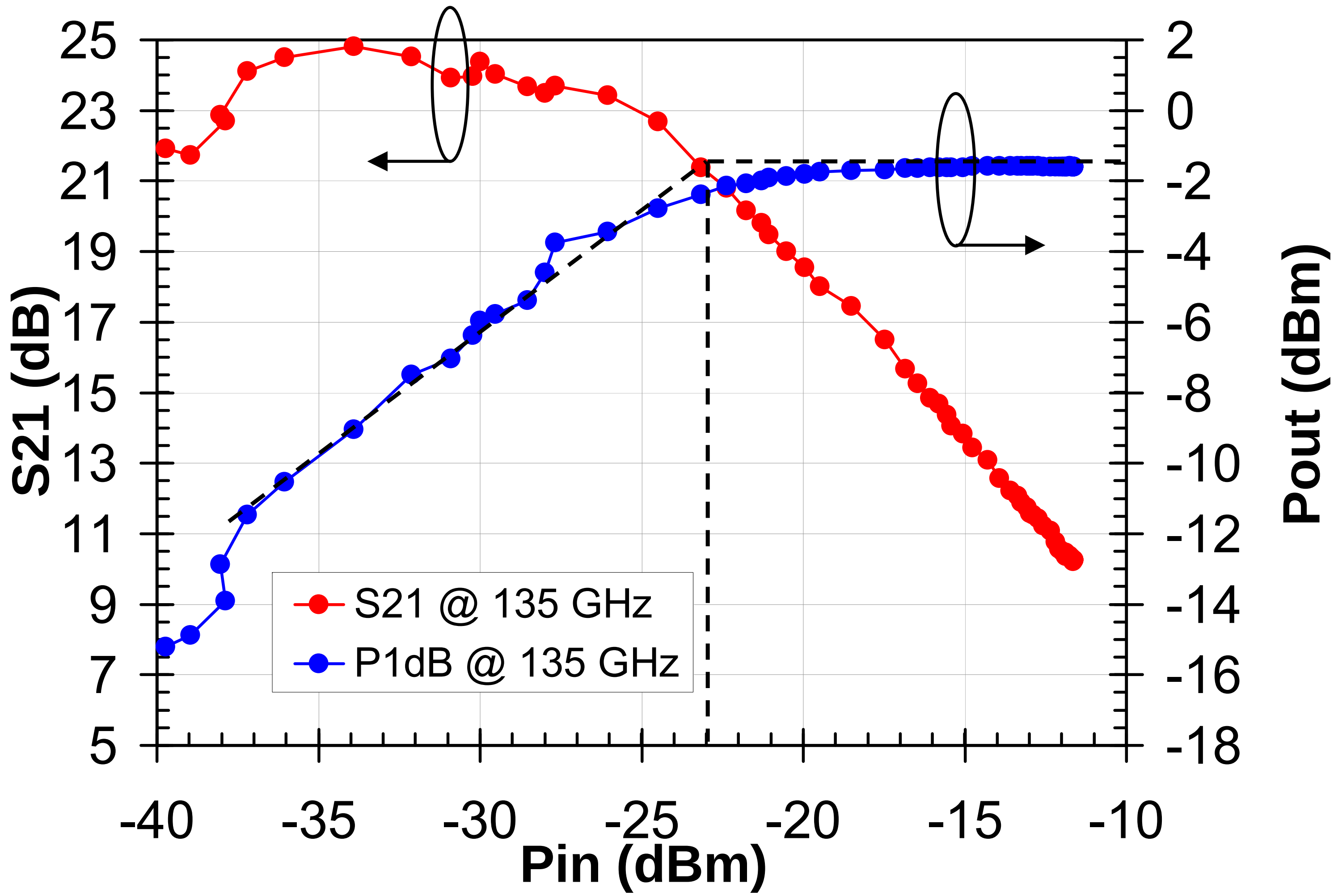
amplifier:

output spectrum:

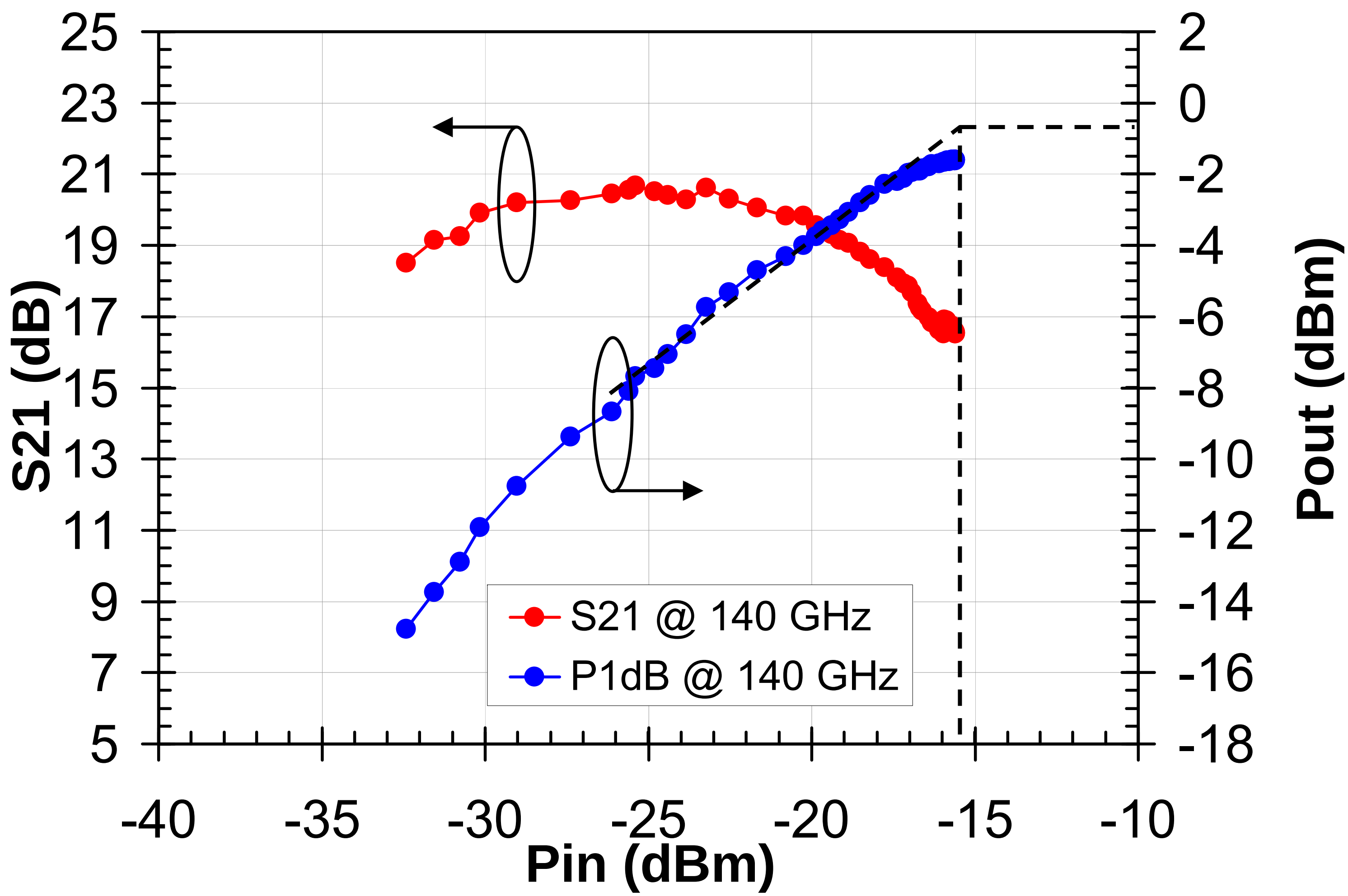


- Power sensor reading includes amplified signals

Amplifier Linearity - 135GHz

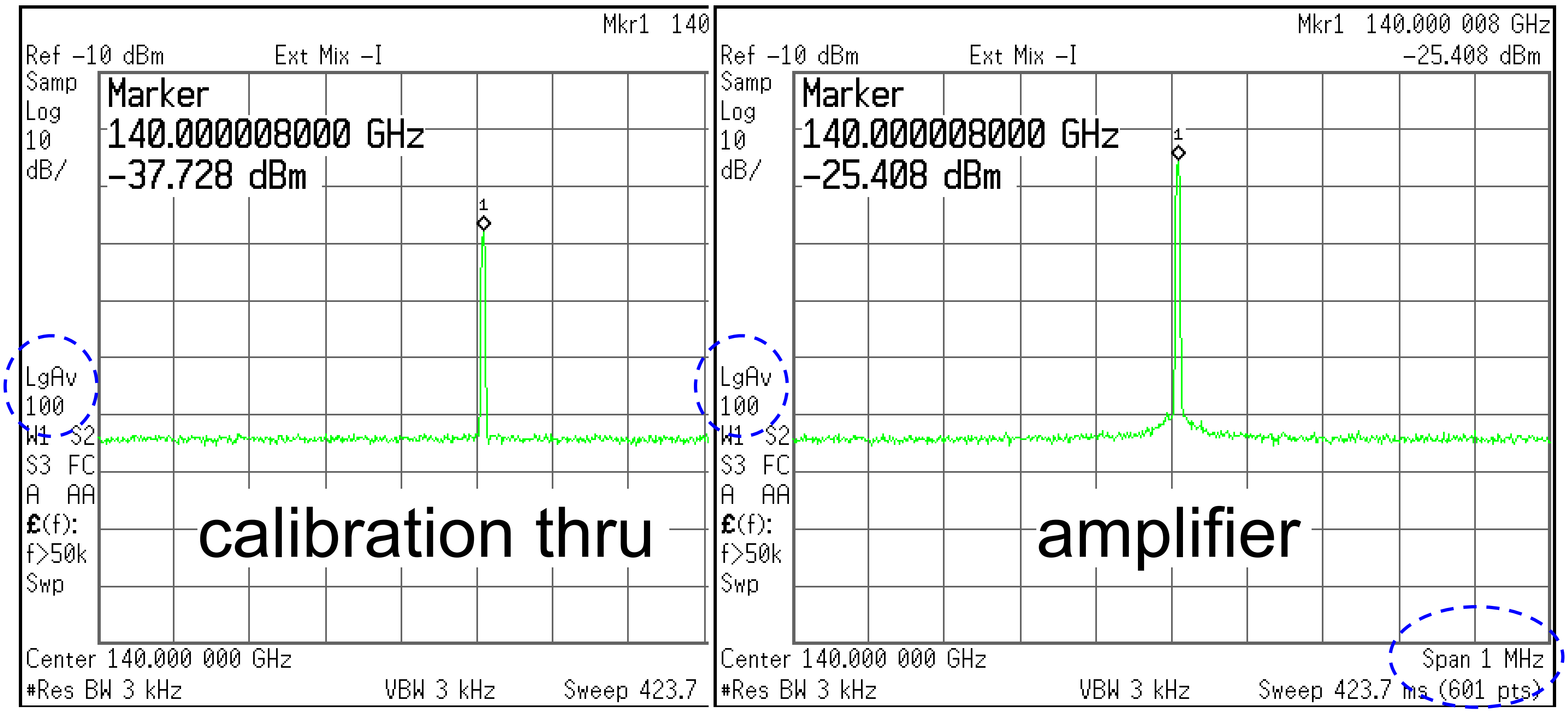


Amplifier Linearity - 140GHz



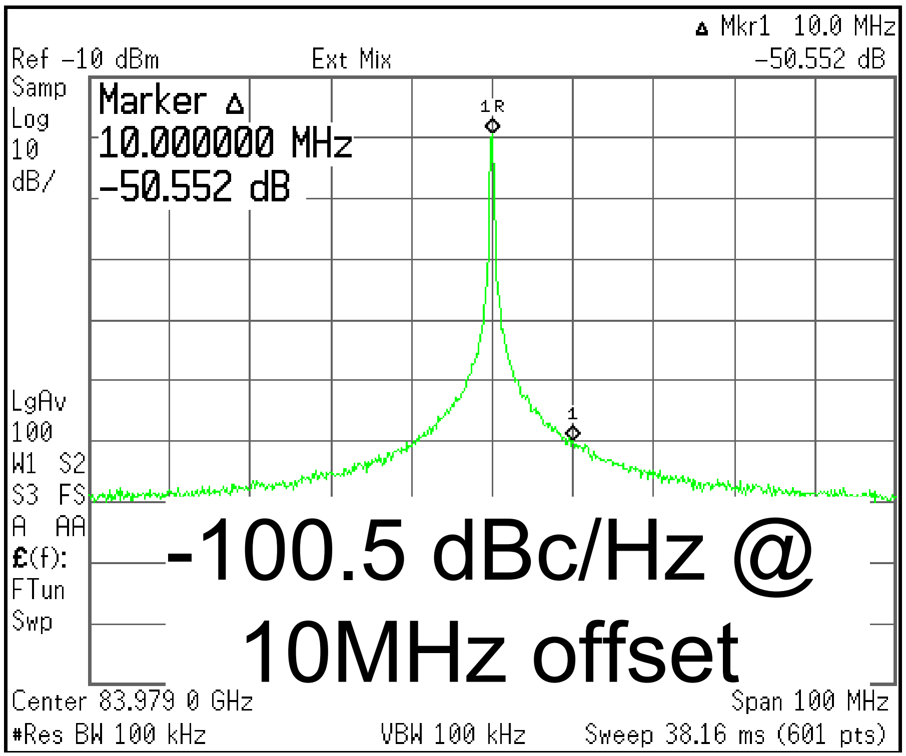
Amplifier Measurements

- Zoom to 1MHz BW, 100 averages



Results - Transmitter

80-GHz Output:



low-noise power supply

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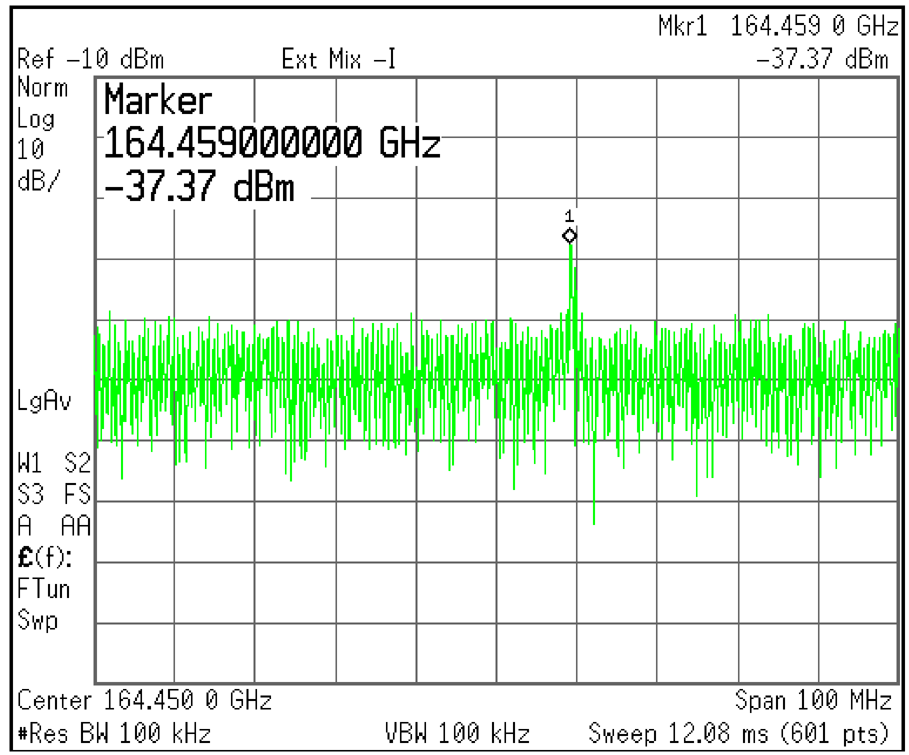
160-GHz Output:



losses not deembedded