Towards 100+ GHz Electronics

Ekaterina Laskin, Sorin Voinigescu

University of Toronto

CMOSET 2007
Friday July 13, 2007

Outline

- Motivation
- Applications above 100 GHz
- System architectures
- Circuit examples
  - 65nm CMOS
  - SiGe HBT
- Summary

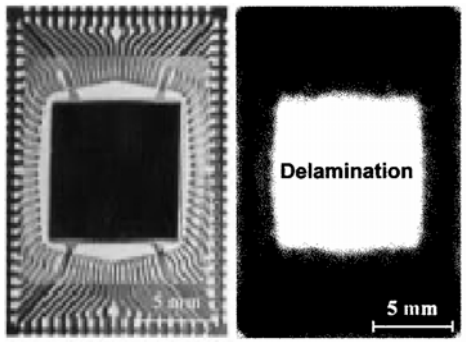
Motivation

- Why 100+ GHz?
  - Silicon transistors can now operate above 100GHz
  - Better resolution for imagers (~λ)
  - Larger BW → higher datarate
- Why CMOS / BiCMOS?
  - Can be integrated with signal processing
  - Integration of imaging arrays
  - Lower power
  - Lower system cost

Applications above 100 GHz

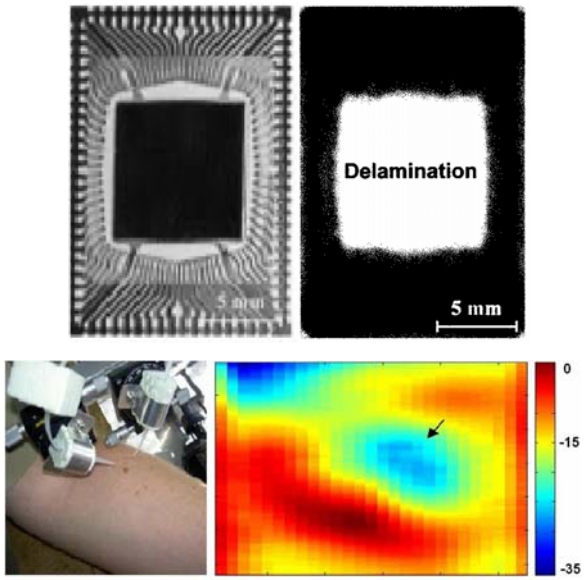
Applications above 100 GHz

- Industrial



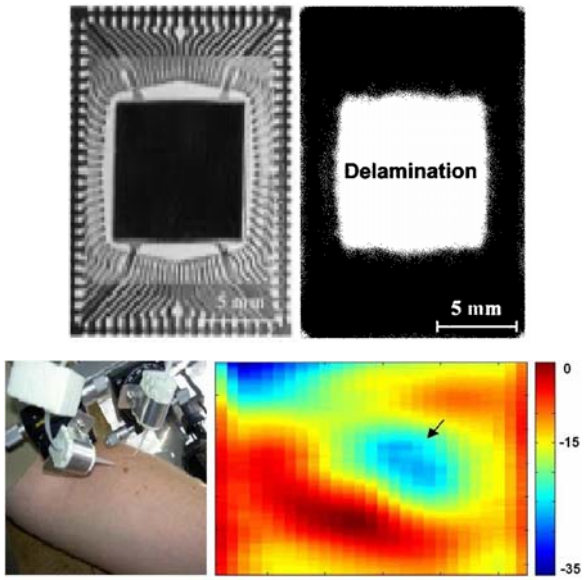
Applications above 100 GHz

- Industrial, medical



Applications above 100 GHz

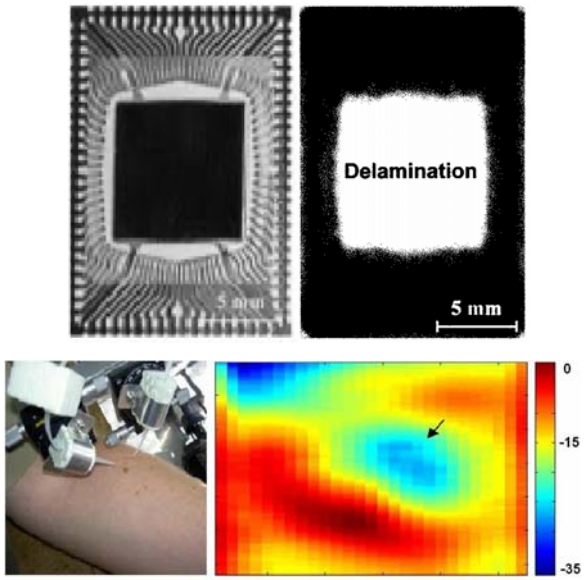
- Industrial, medical and security imagers



Applications above 100 GHz

- Industrial, medical and security imagers
- Possible radio astronomy applications
  - ALMA† band 3: 84 - 116 GHz
  - ALMA band 4: 125 - 163 GHz

† Atacama Large MM-Wave Array

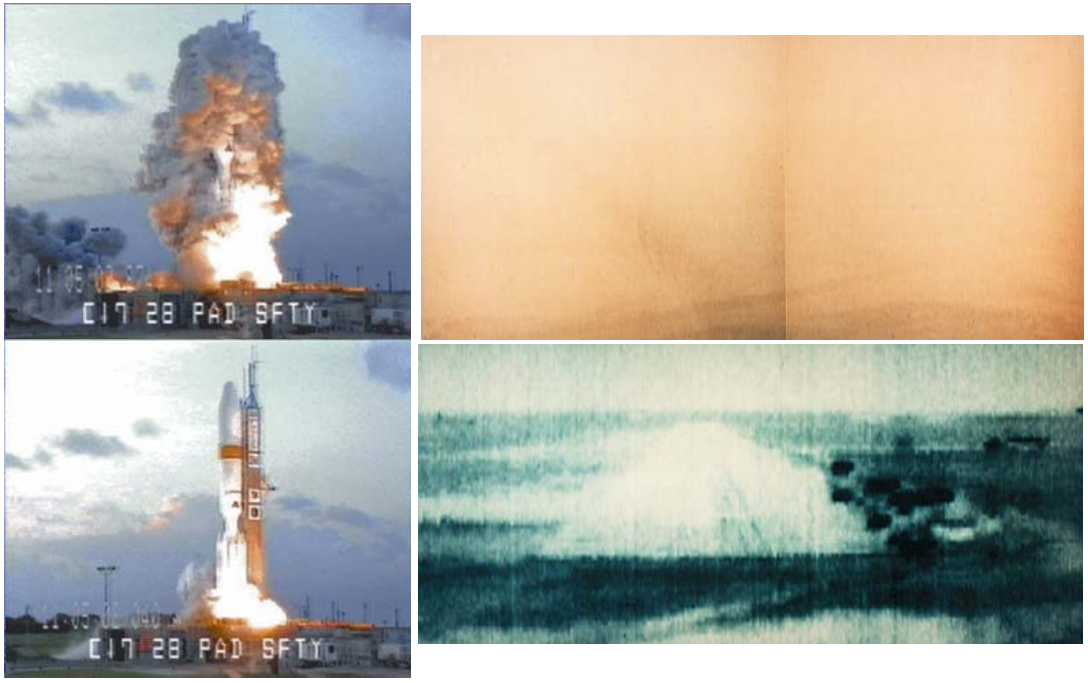


Applications above 100 GHz

- Night- and fog-vision cameras

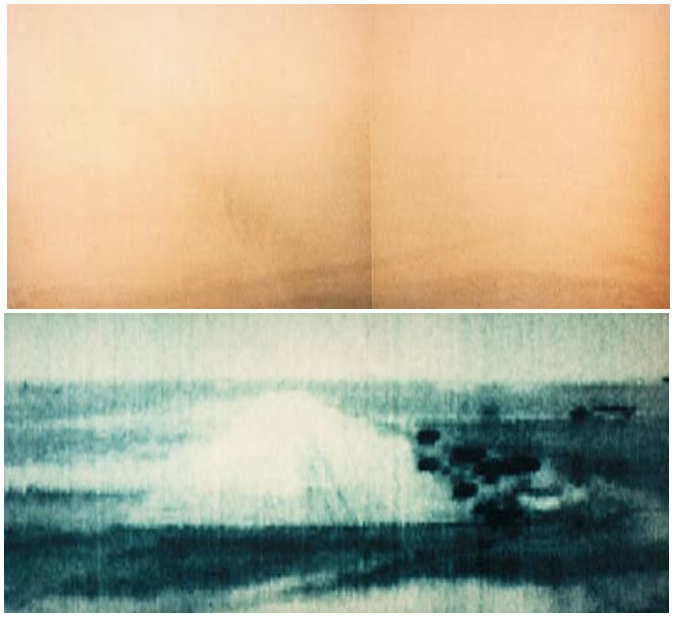
Applications above 100 GHz

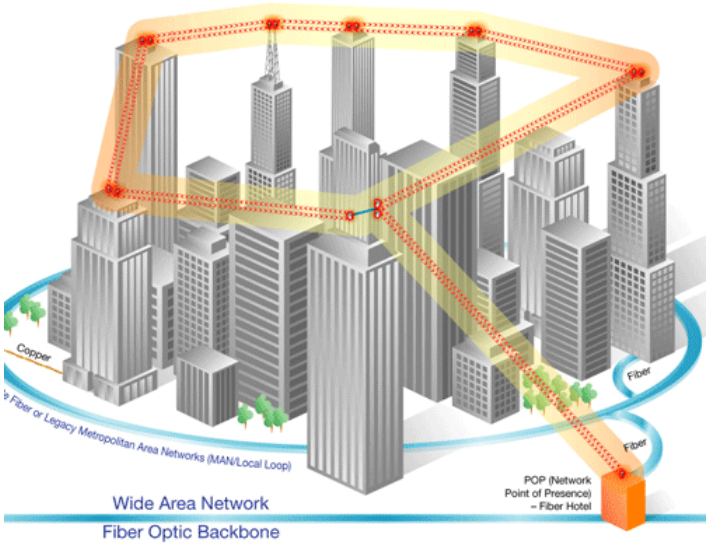
- Night- and fog-vision cameras



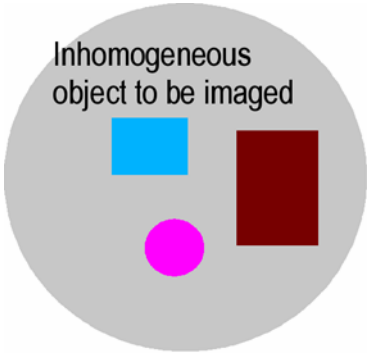
Applications above 100 GHz

- Night- and fog-vision cameras
- Wireless links with > 10 Gb/s datarate
  - Last mile, chip-to-chip

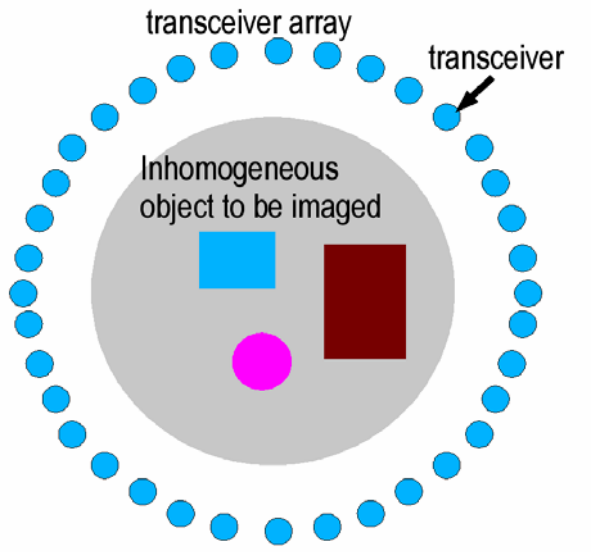




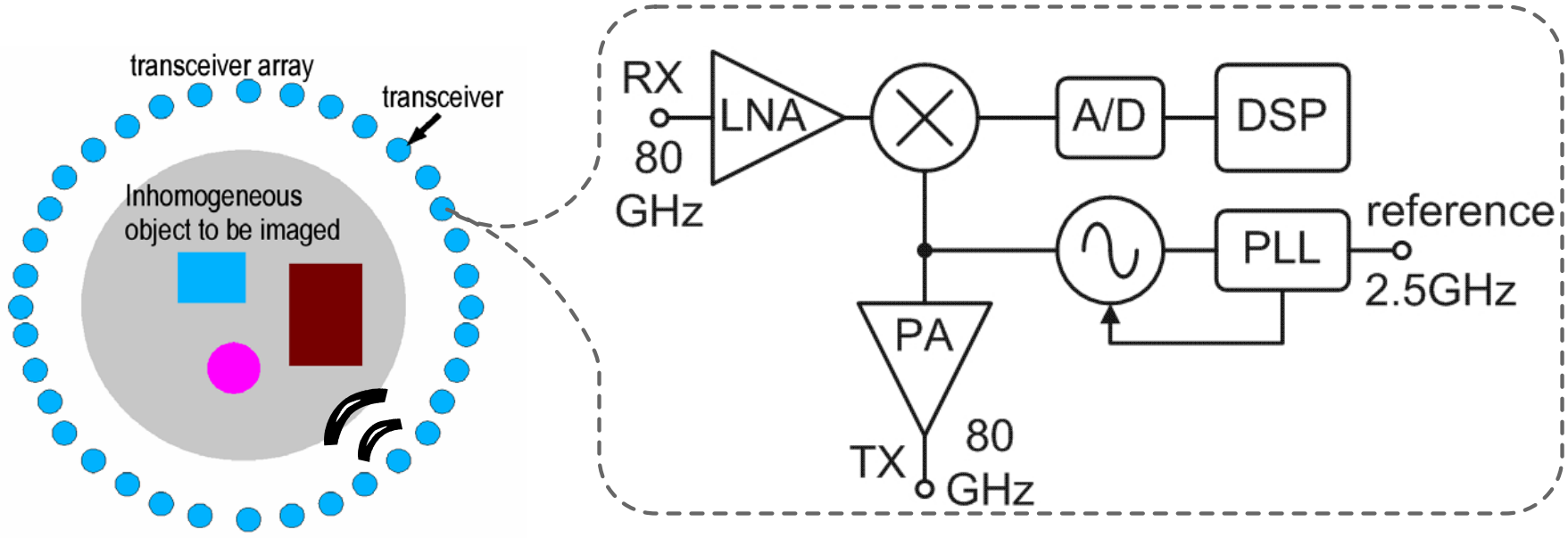
80-GHz Imaging Transceiver



80-GHz Imaging Transceiver

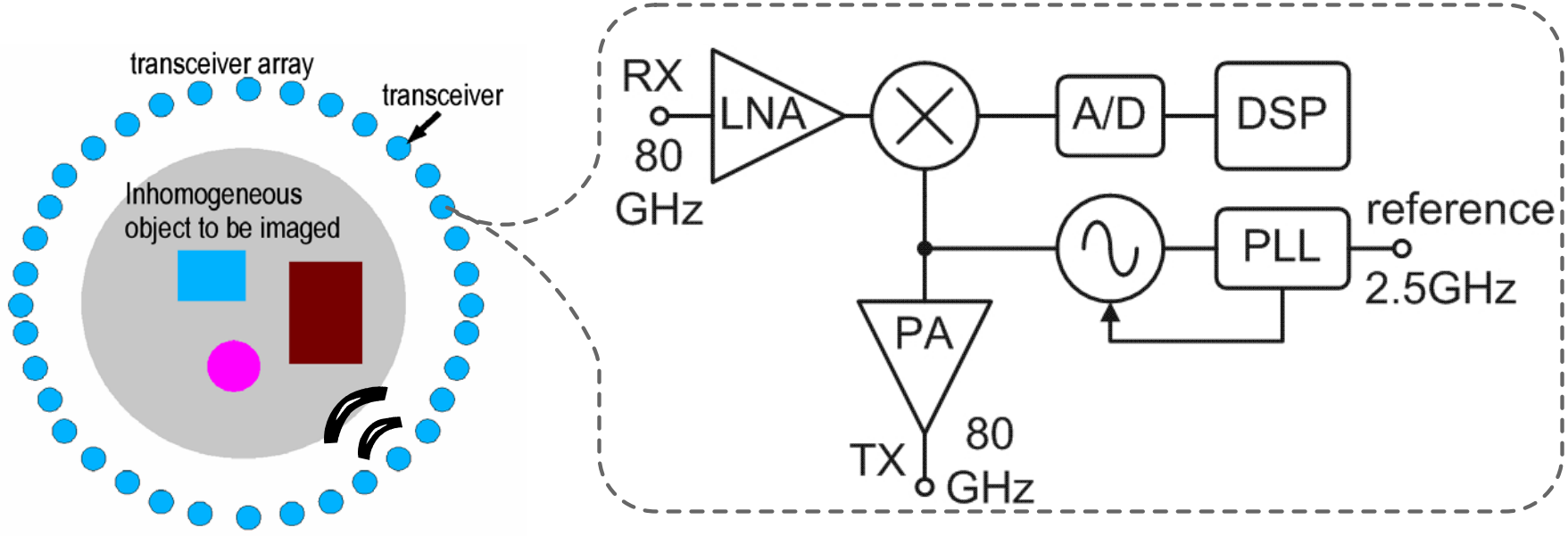


80-GHz Imaging Transceiver



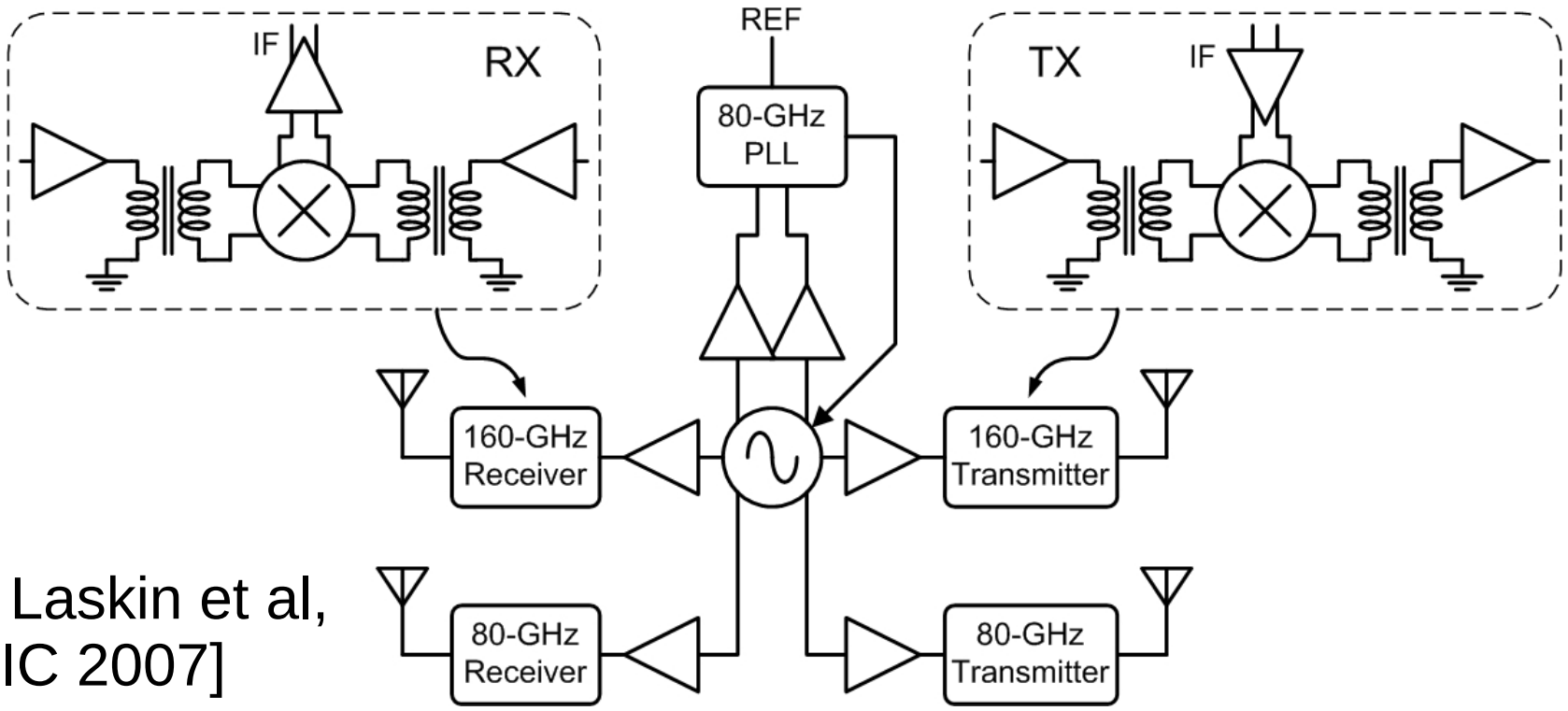
80-GHz Imaging Transceiver

- Crosstalk suppression by system architecture
  - Different frequencies in TX and RX modes
  - One TX on, all other TXRX in receive mode
- Need very low power for array integration



80/160GHz Transceiver Array

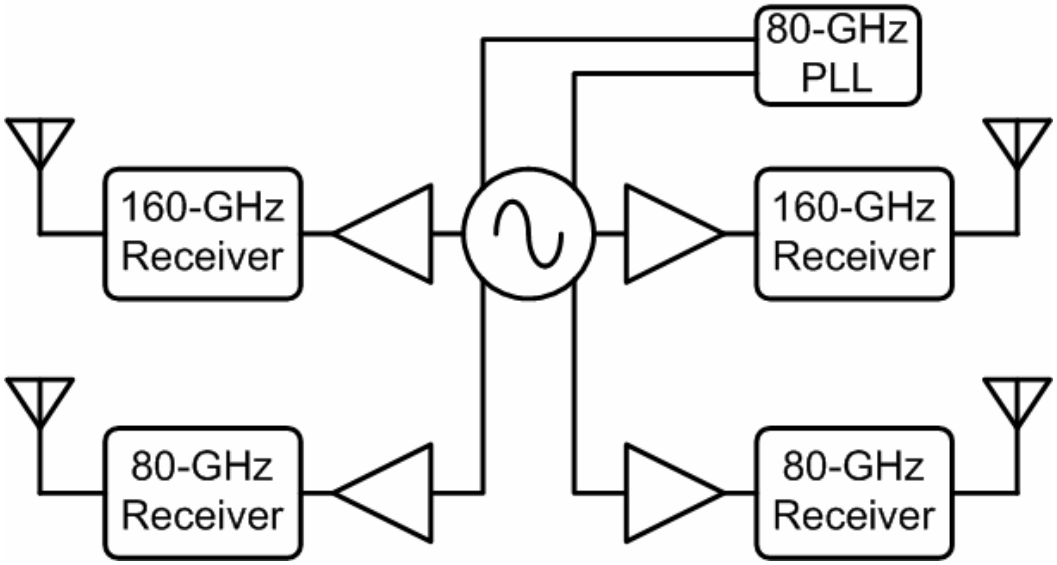
- Save power using 1 multi-signal VCO+PLL
- VCO signal distribution using transformers



[E. Laskin et al, RFIC 2007]

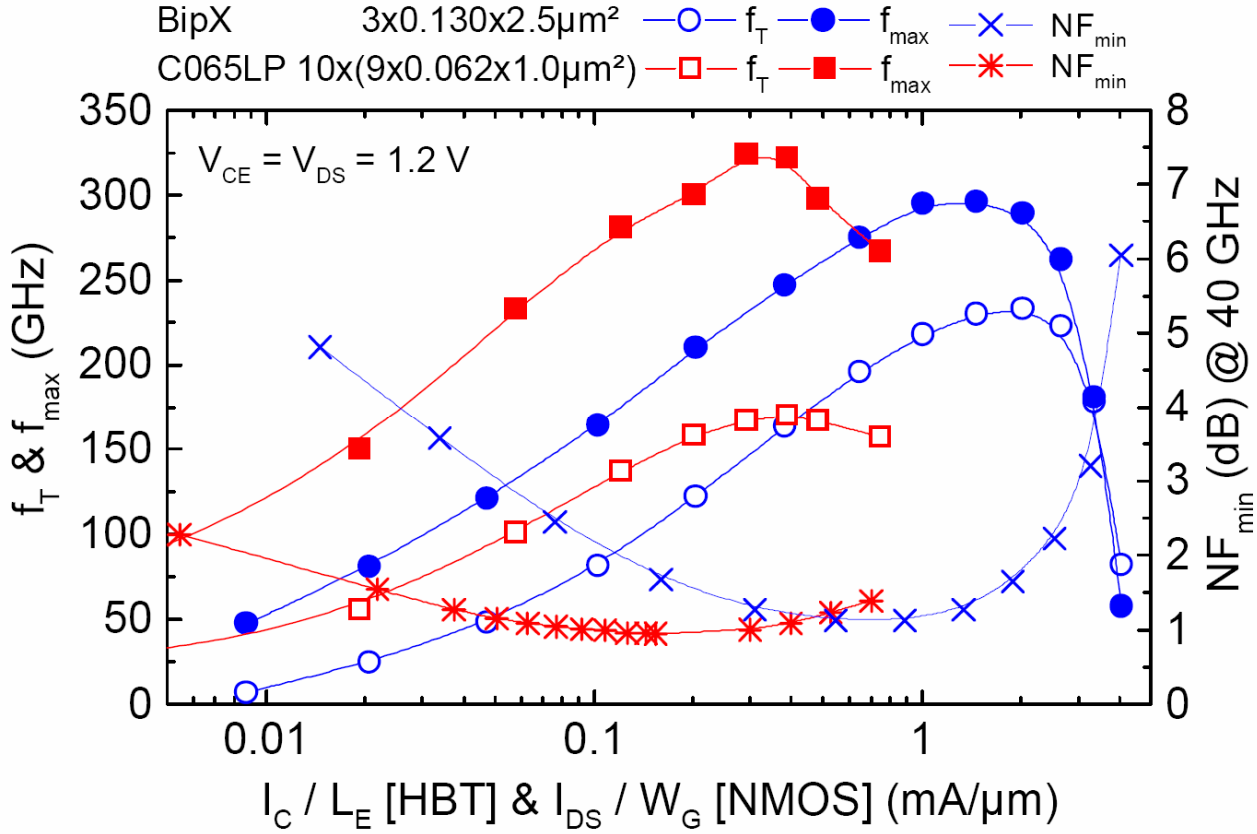
80/160-GHz Receiver Array

- Passive imaging receiver
- Suitable for implementation in CMOS



[74-94 GHz Receiver,
K. W. Tang, CICC 2007]

65nm NMOS vs. SiGe HBT

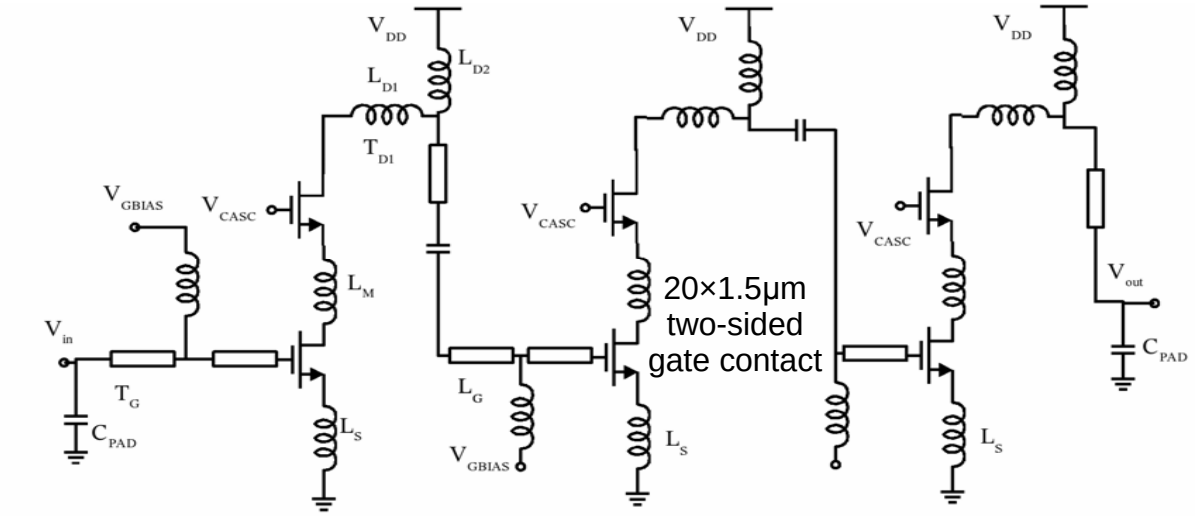


- Comparable high frequency performance

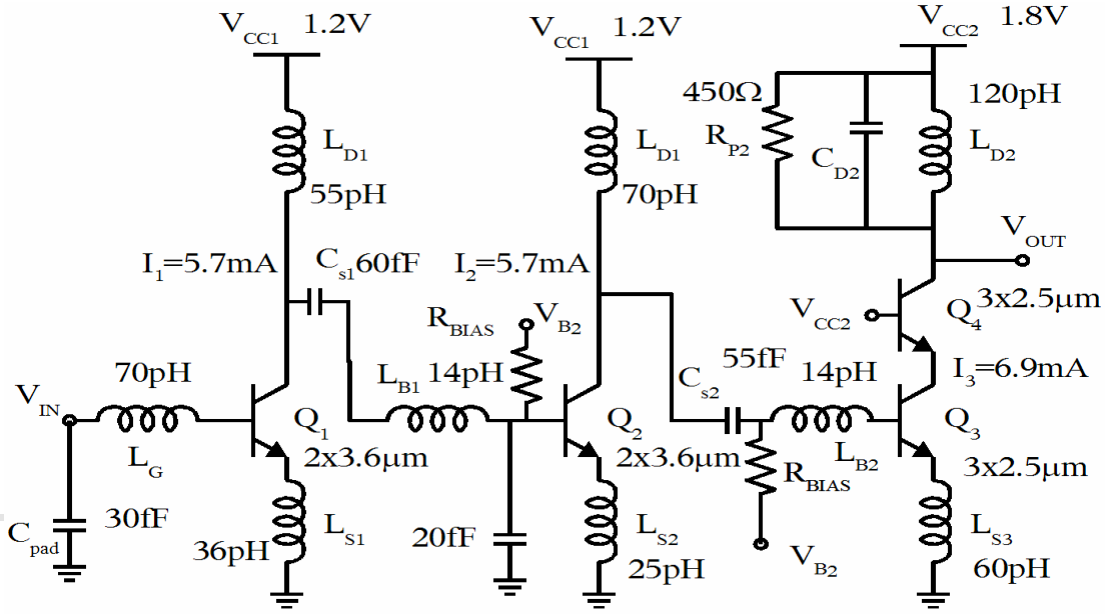
[P. Chevalier et al. CSICS-2006]

CMOS vs. HBT LNAs

65nm CMOS LNA (55 mW)



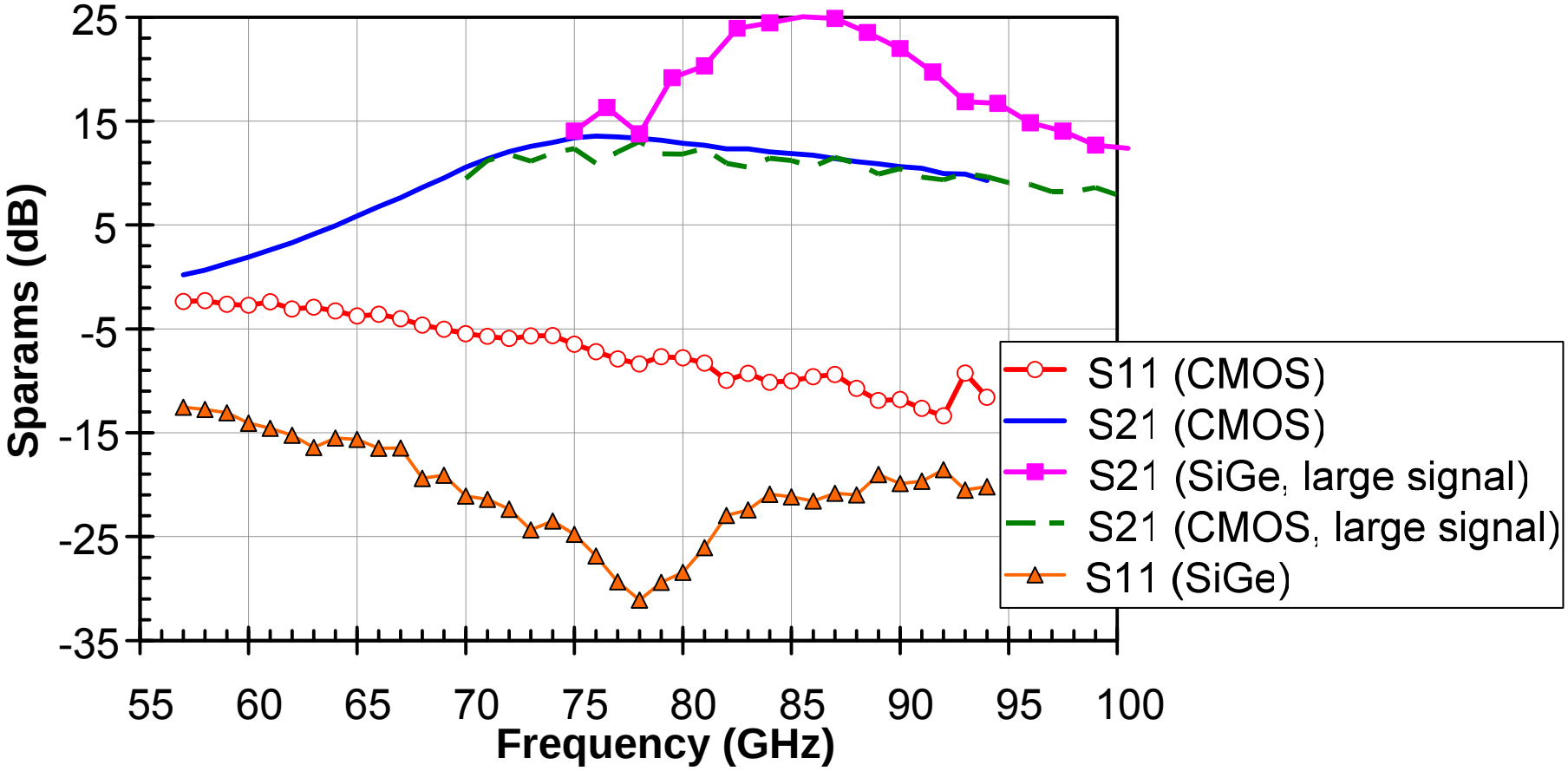
290-GHz SiGe HBT LNA (52 mW)



[S.T. Nicolson et al. IMS-07, CSICS-06]

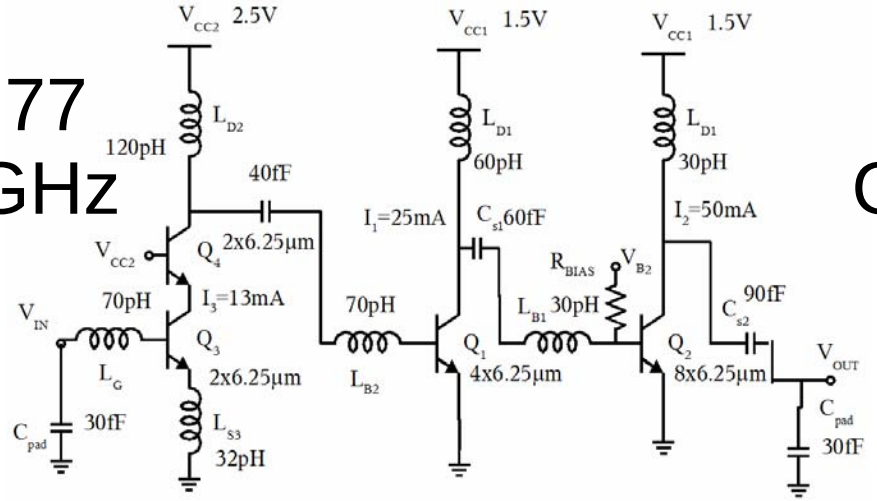
CMOS vs. HBT LNAs

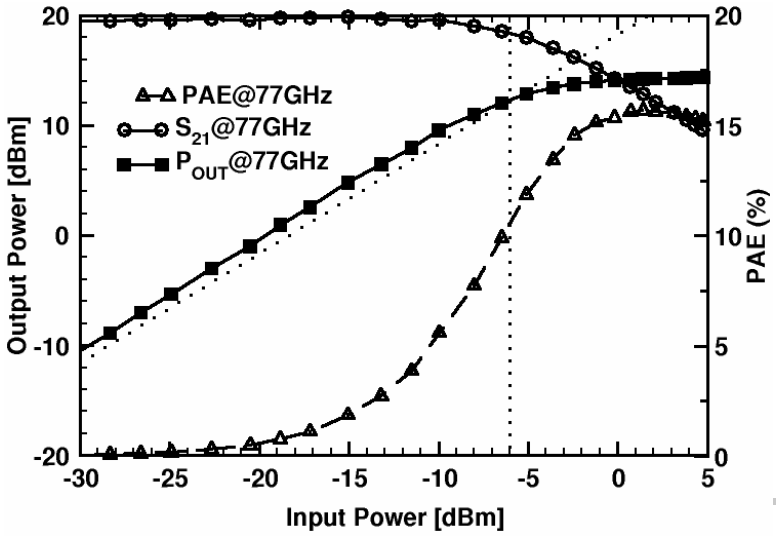
- CMOS gain and output power is lower than SiGe



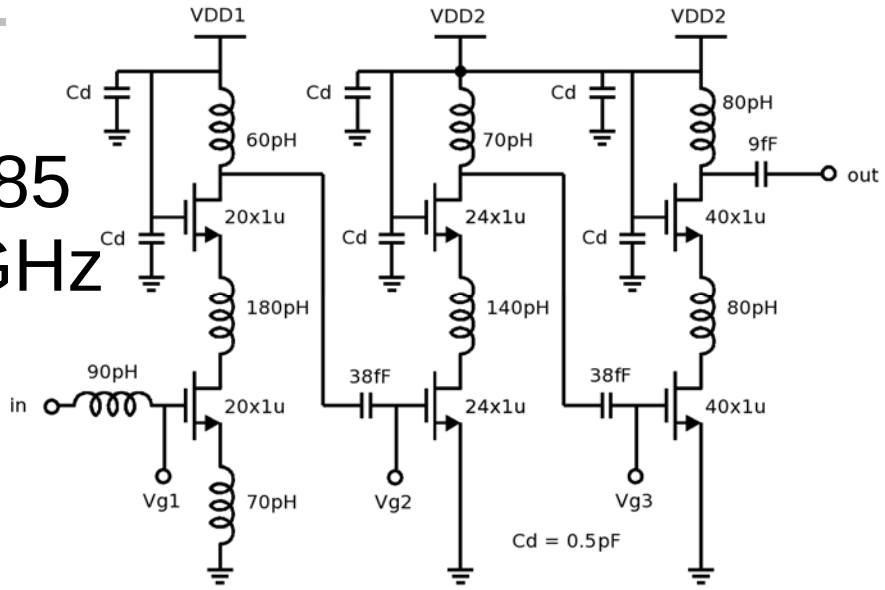
HBT vs. CMOS PAs

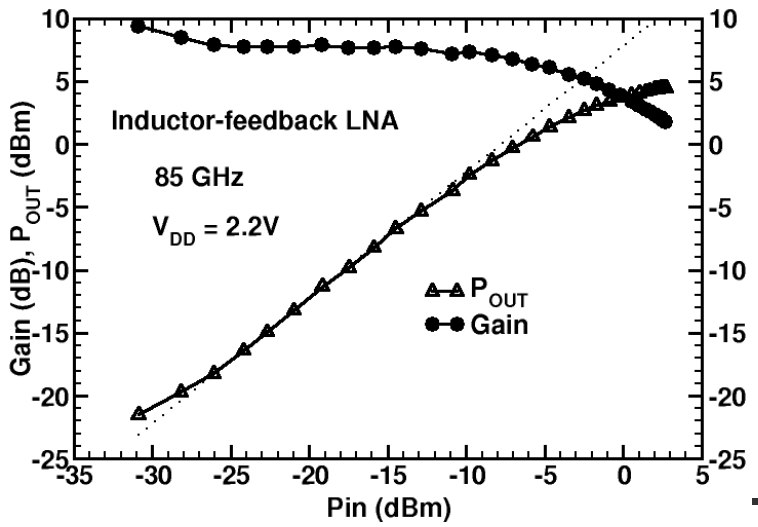
77 GHz





85 GHz

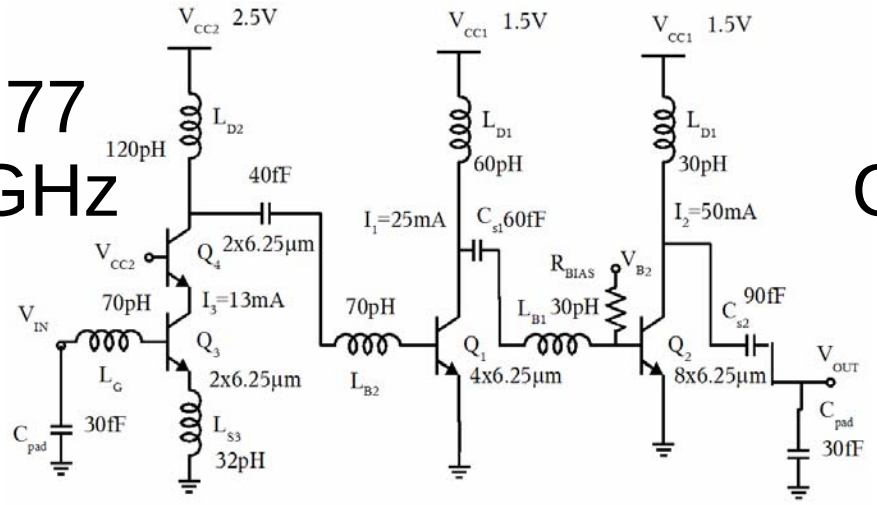




[M. Khanpour, CICC-07]

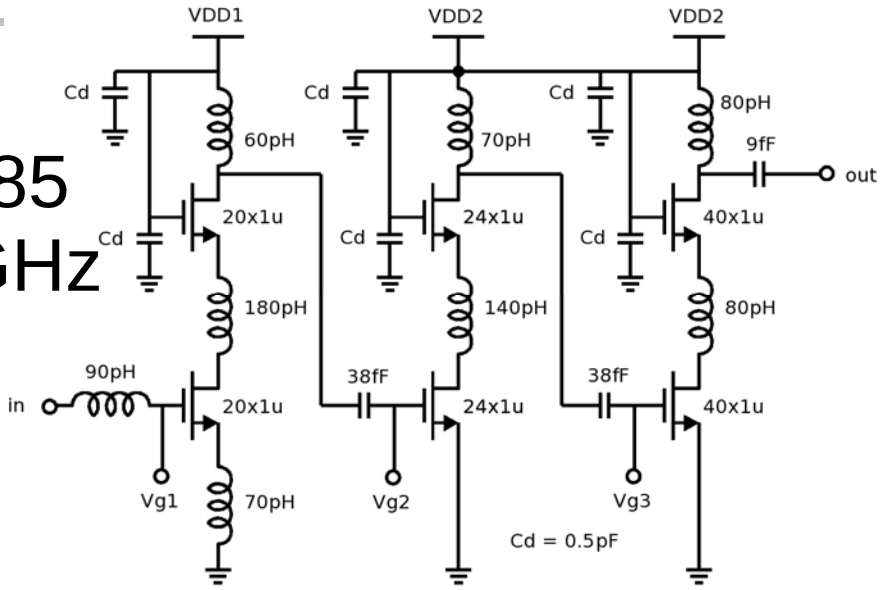
HBT vs. CMOS PAs

77 GHz



- G = 19 dB
- OP_{1dB}= 12 dBm
- P_{SAT}= 14.6 dBm
- PAE = 15.5%
- P_{DC}=161 mW

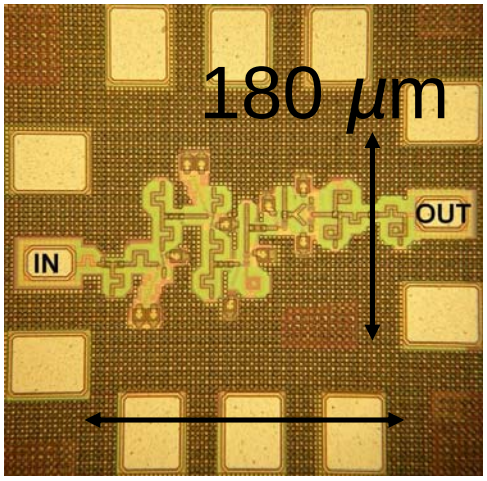
85 GHz

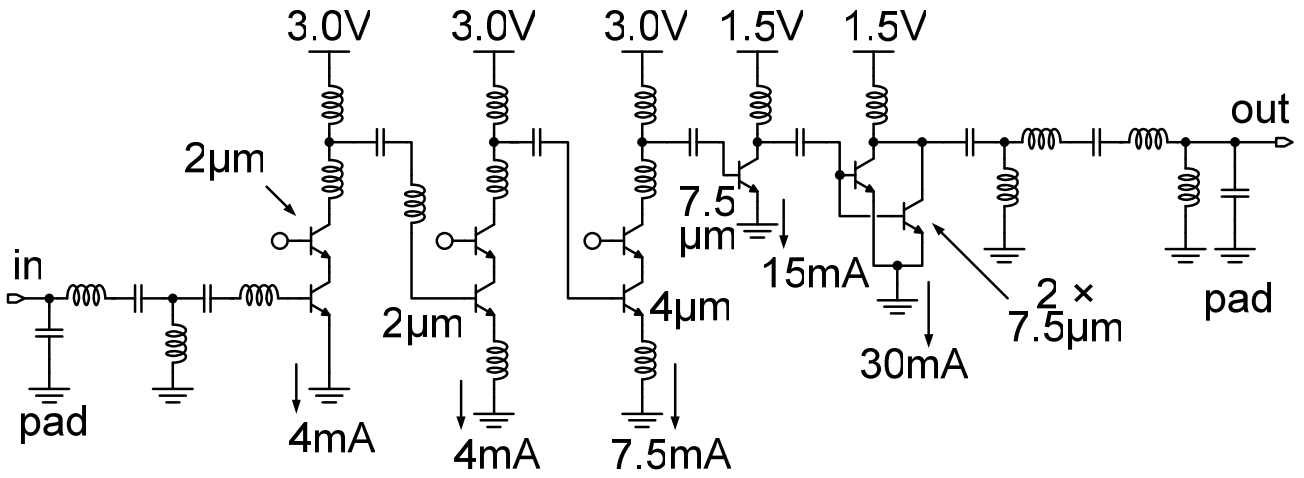


- G = 7 dB
- OP_{1dB}= -1 dBm
- P_{SAT}= 5 dBm
- P_{DC}=55 mW

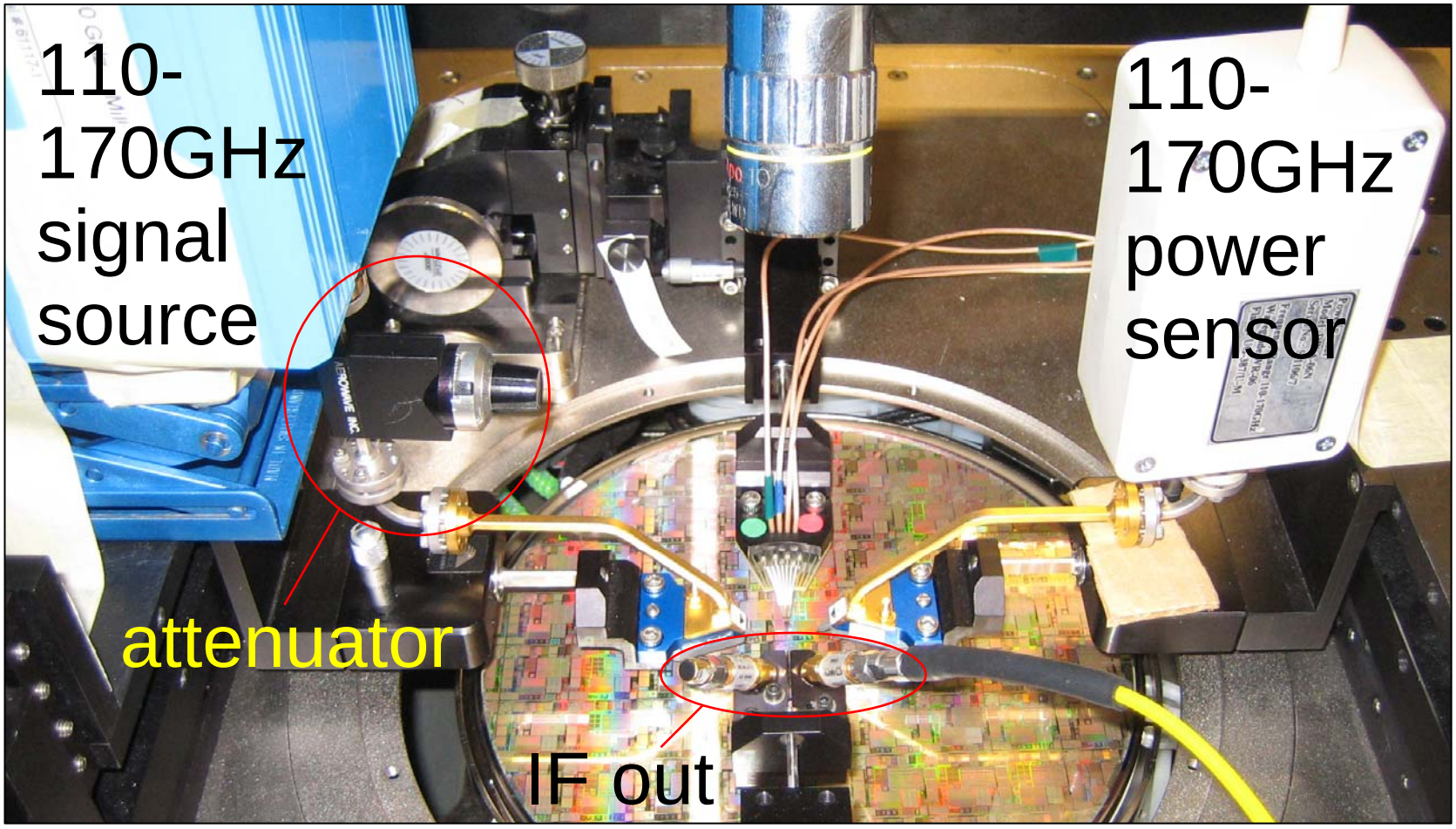
140-GHz Amplifier

- Cascodes → gain, CE stages → output power
- $R_E+R_B \approx 50\Omega$ → No input degeneration
- Degeneration in 2nd stage for interstage matching
- Ratioed inductors, split loads for gain invariability
- Biased at peak-f_{MAX} for max power transfer

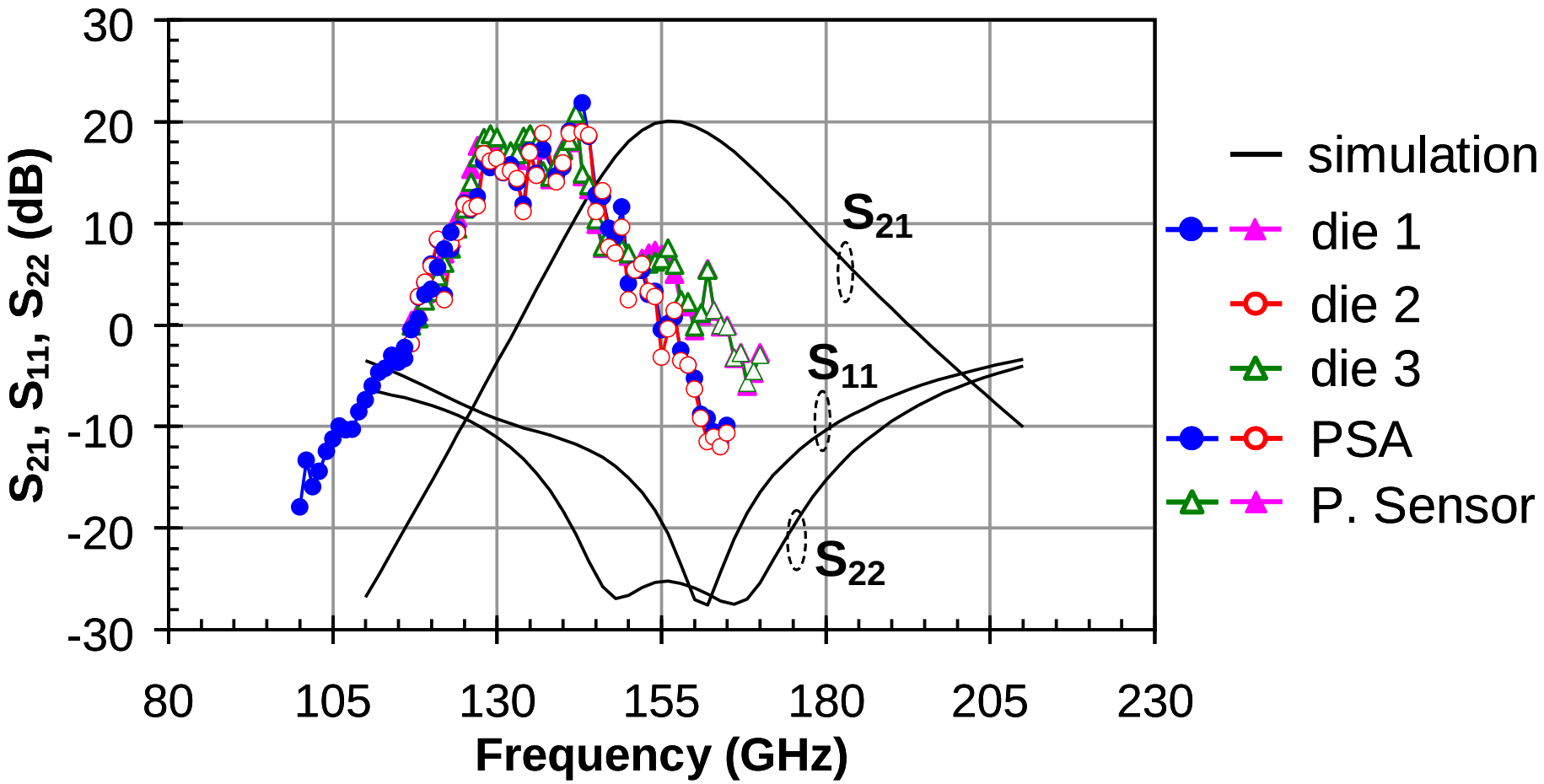




170-GHz Measurement Setup

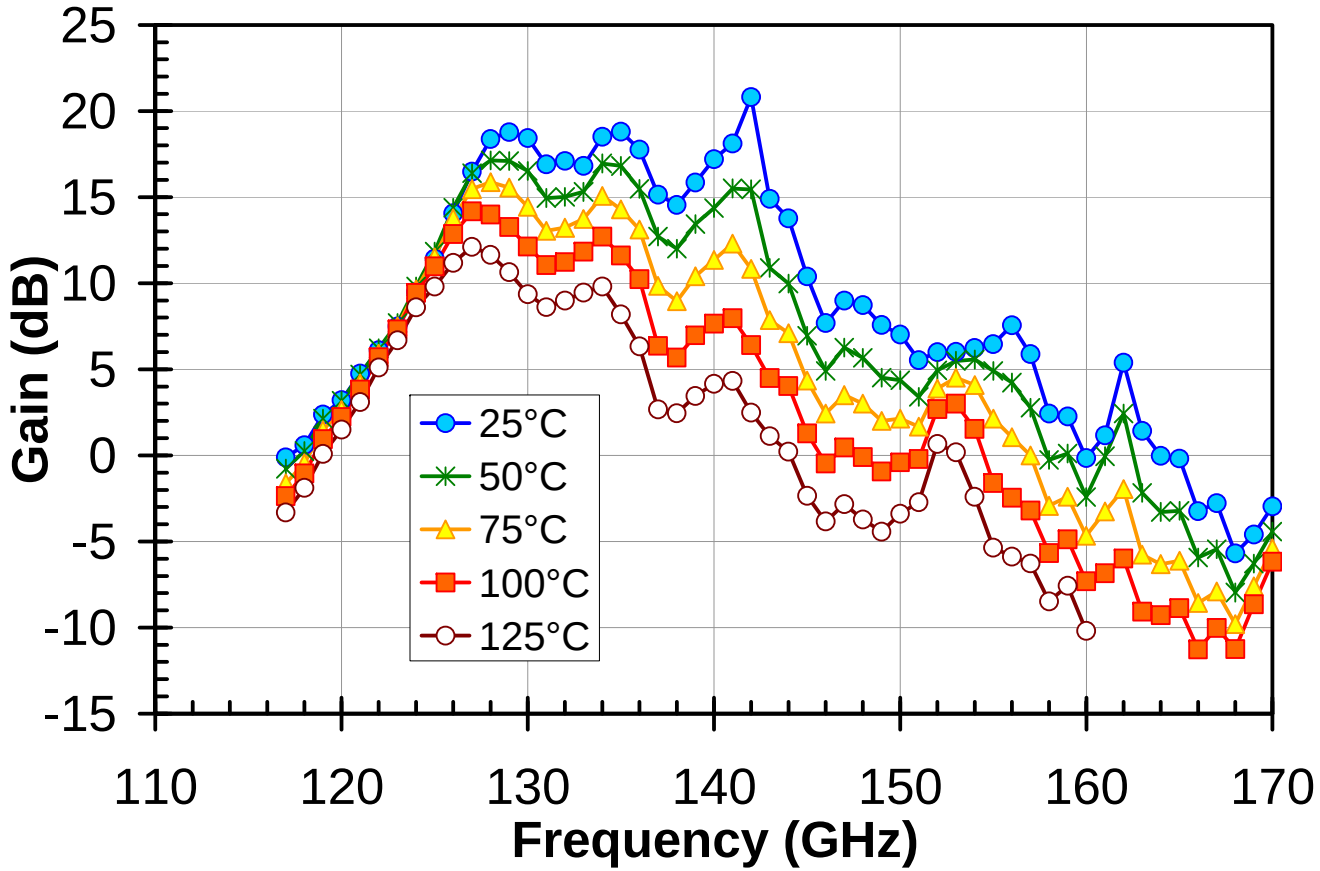


Amplifier - Measured vs. Sim

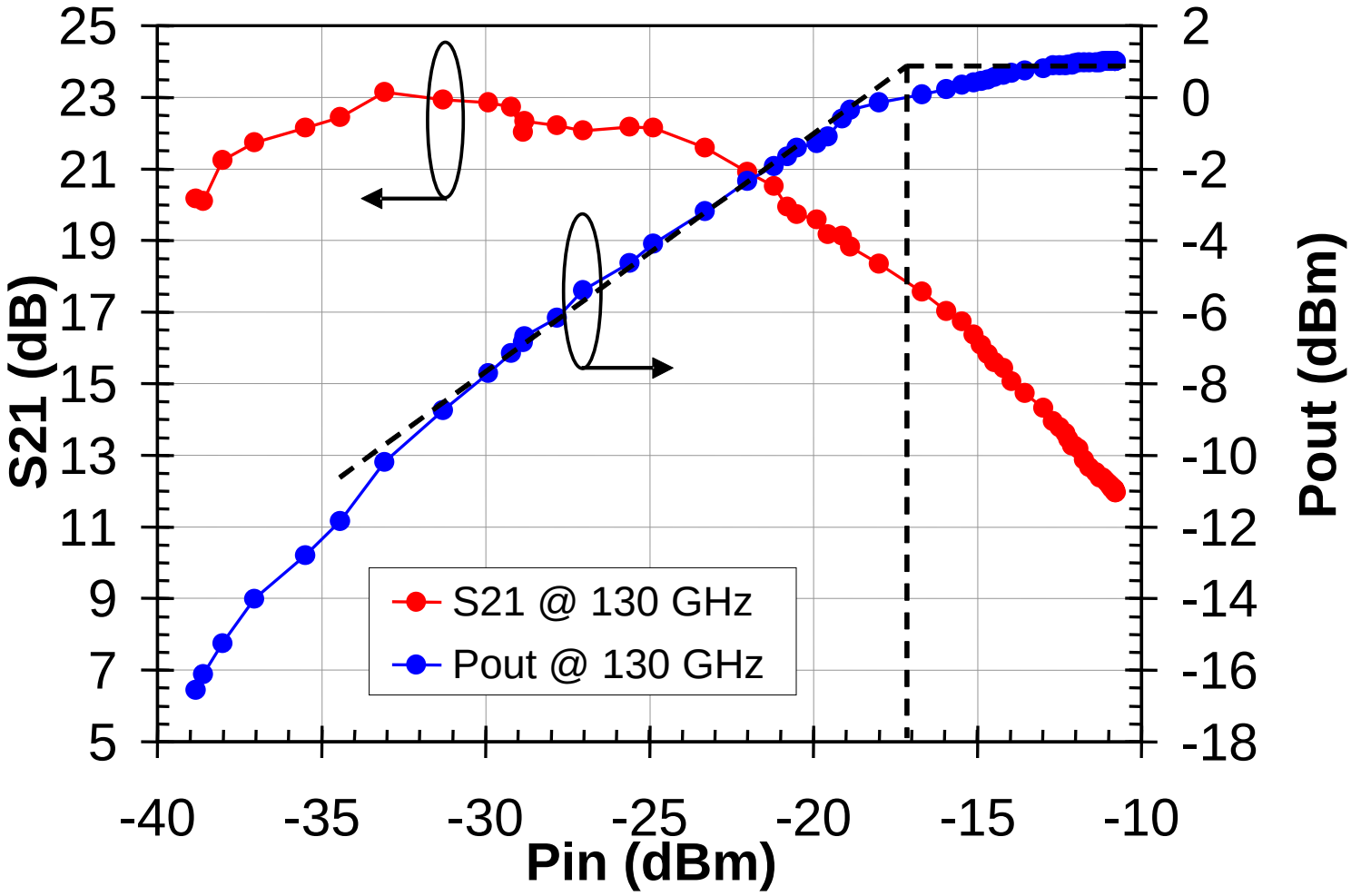


Amplifier Over Temperature

- Nominal wafer, measured using power sensor

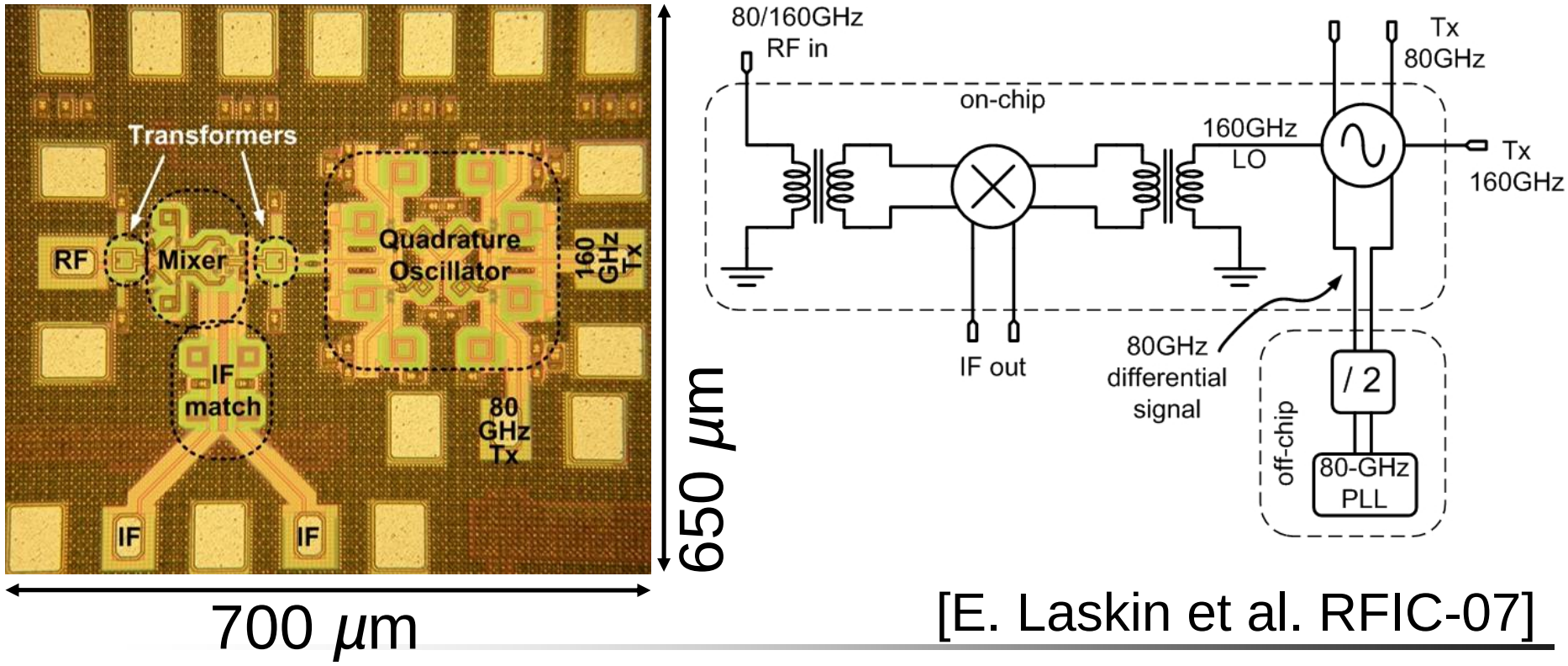


Amplifier Linearity - 130GHz



80/160-GHz Transceiver

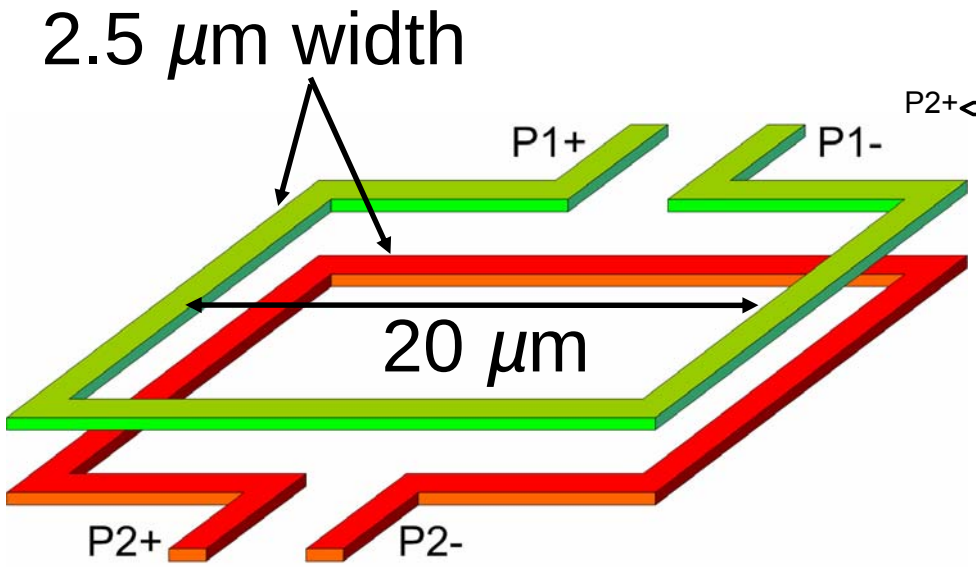
- Transmit and receive simultaneously in 80- and 160-GHz bands

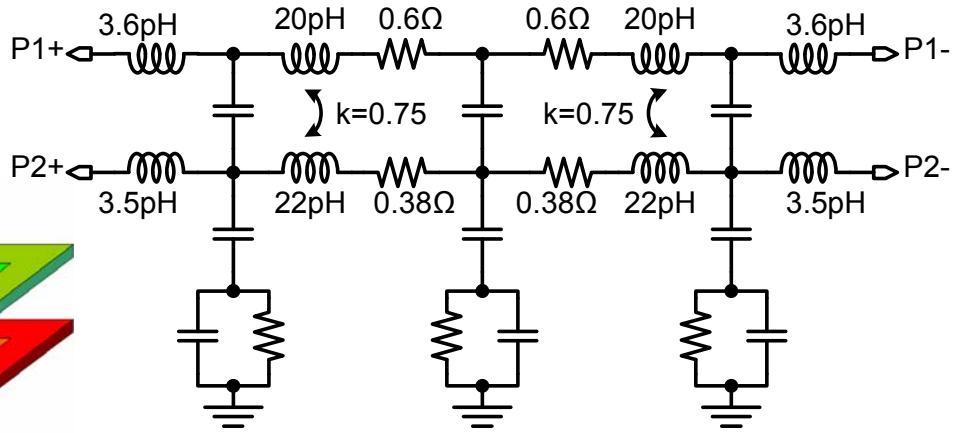


[E. Laskin et al. RFIC-07]

160-GHz Transformer

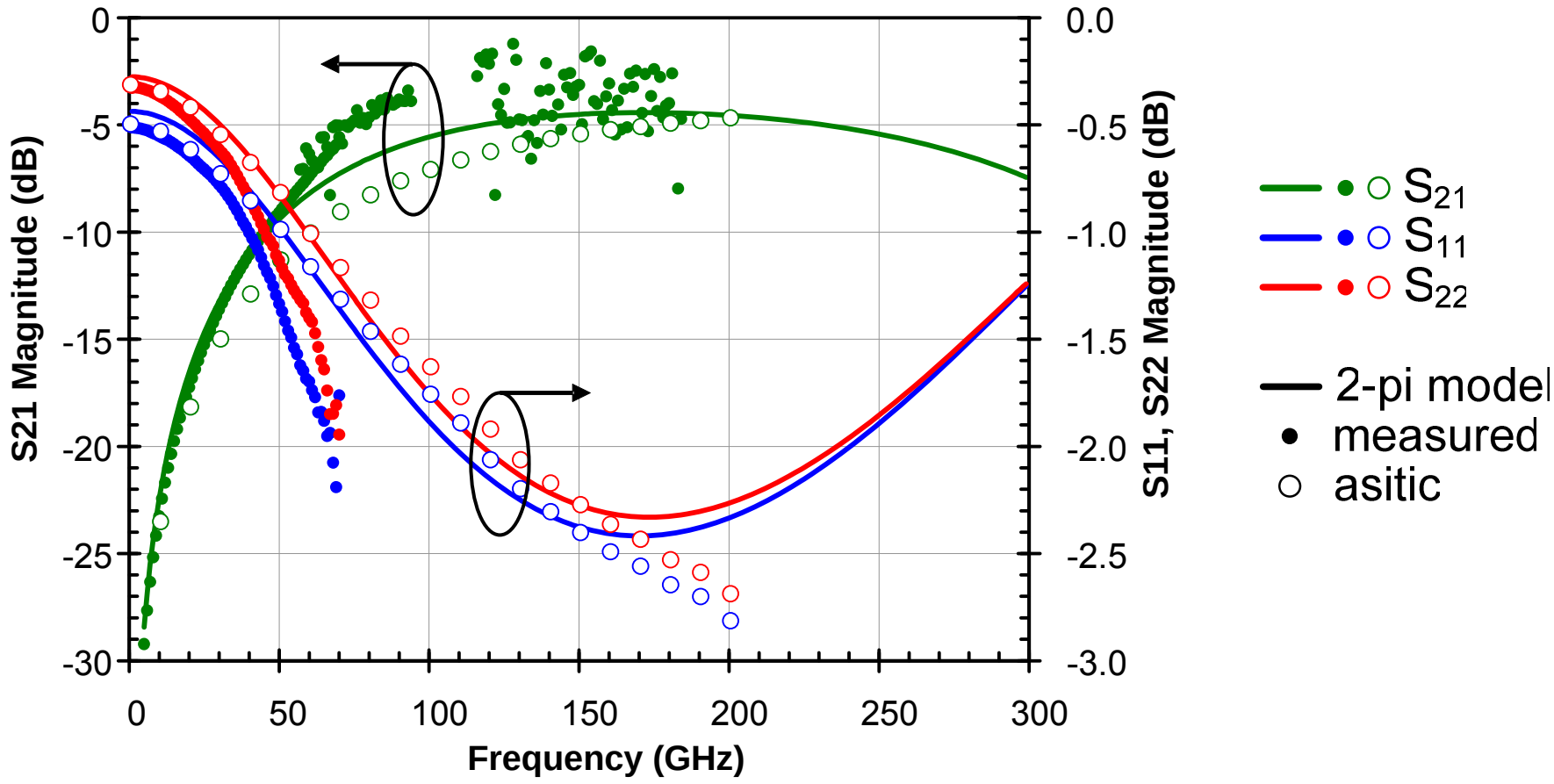
- Top 2 metal layers of a standard backend
- Optimized for lowest loss at 160 GHz
- 2-pi model includes substrate model





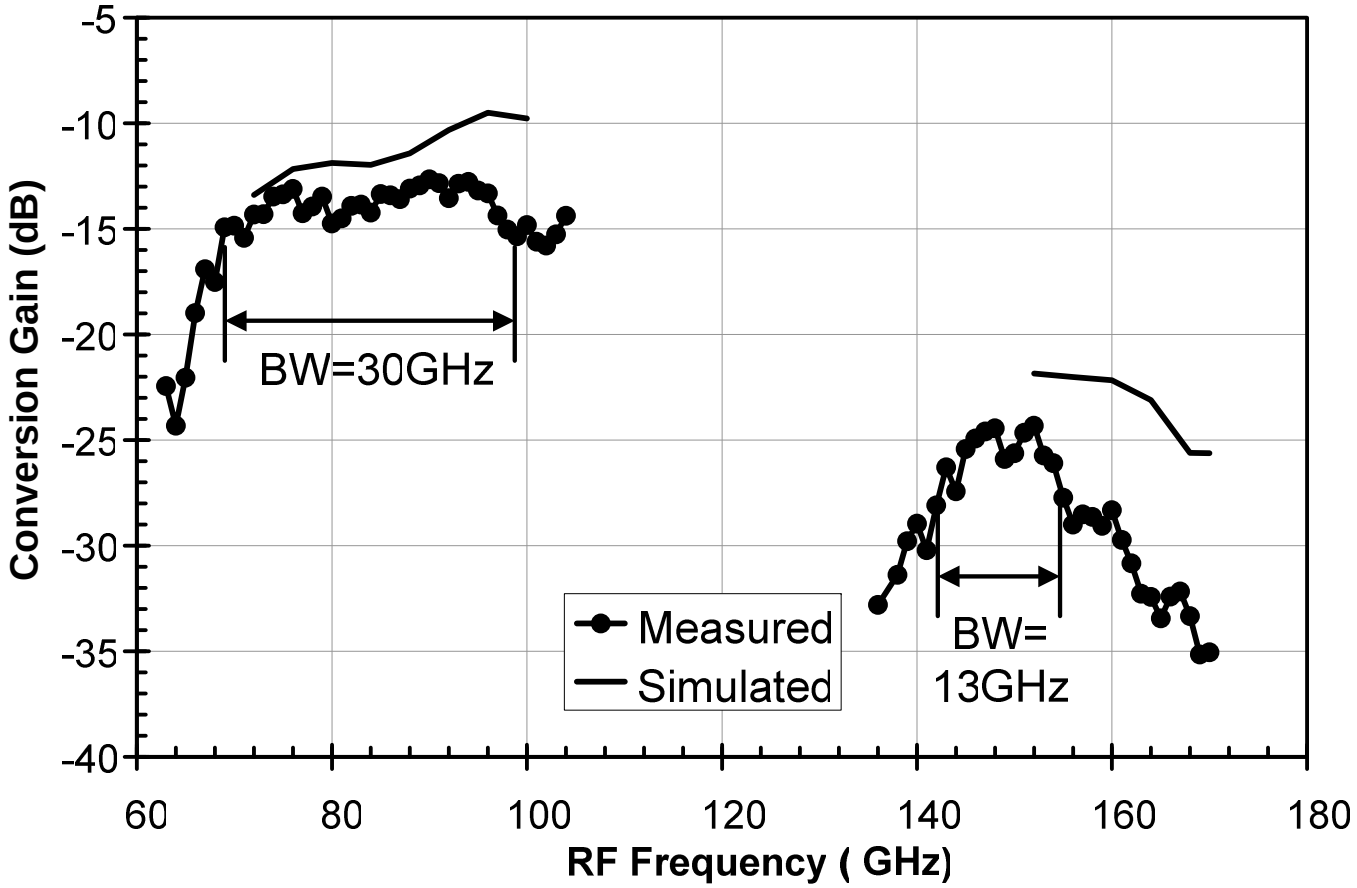
model from ASITIC

Transformer Meas. vs. Sims



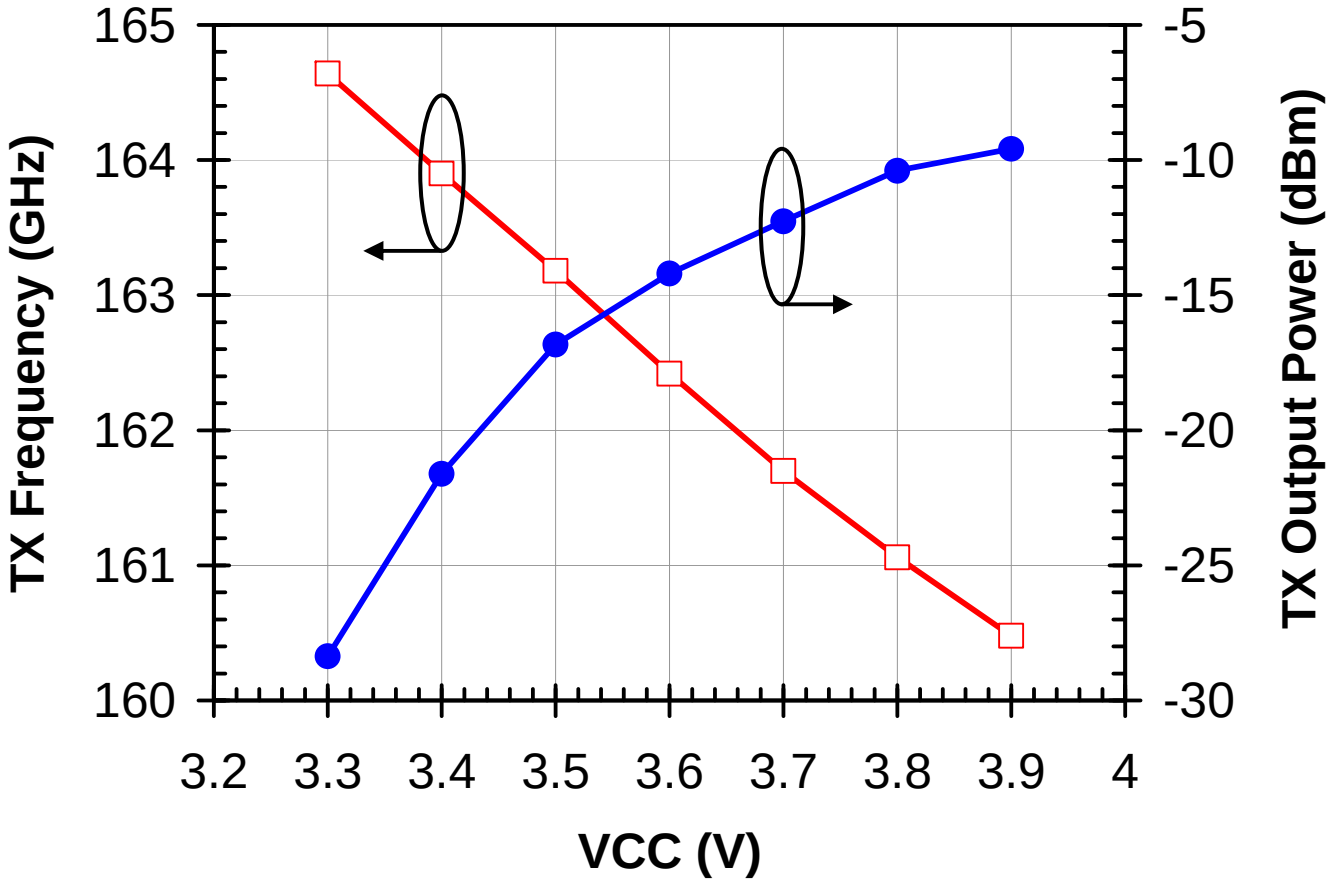
80/160-GHz Transceiver

- Receiver conversion gain:



80/160-GHz Transceiver

- Single-ended TX power increases with VCC



Conclusions

- Many applications above 100GHz for CMOS/SiGe
- CMOS & SiGe devices are capable of 100+ GHz
- Circuits demonstrated at & above 100 GHz
- Integrated 80/160GHz transceiver in silicon

Acknowledgements

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