A Broadband Direct Conversion Transmitter/Receiver at D-band Using CMOS 22nm FDSOI

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Outline

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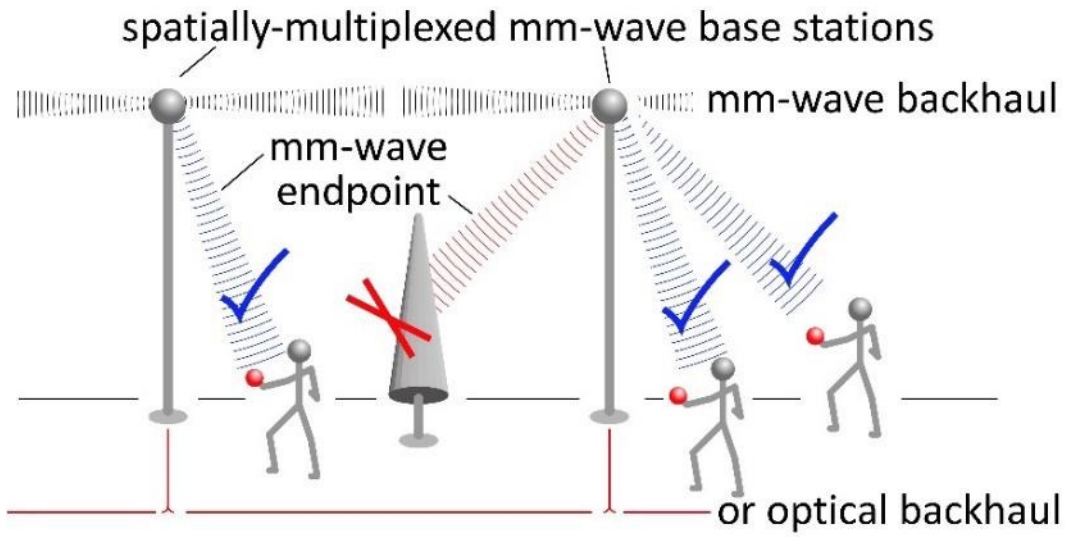
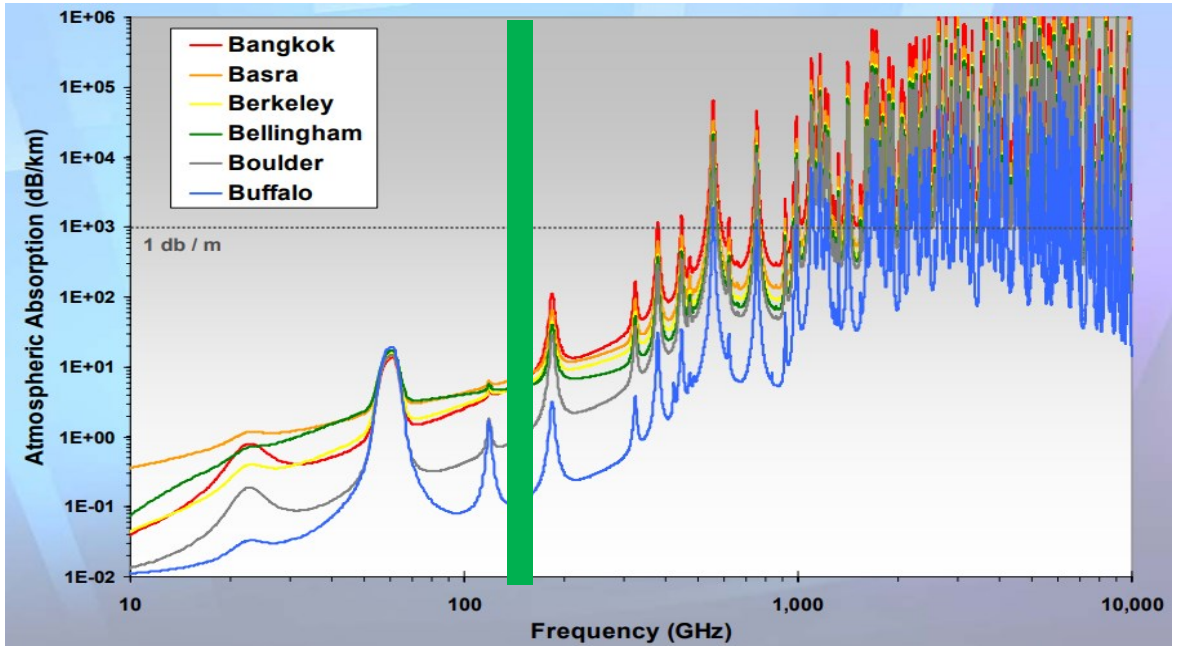
Motivation and Applications





[M.Rosker, IMS2007]

Millimeter waves:

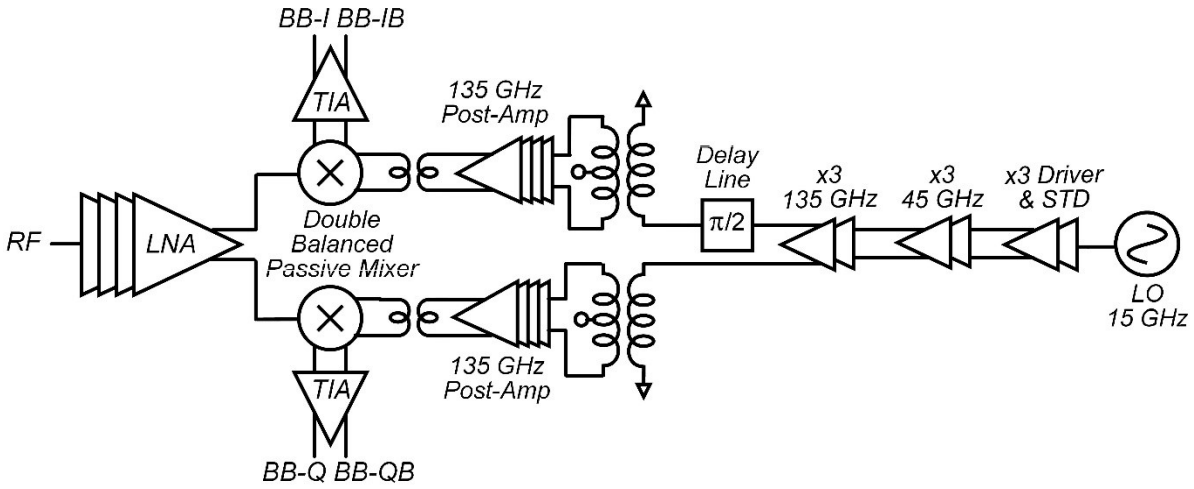
Large available spectrum.

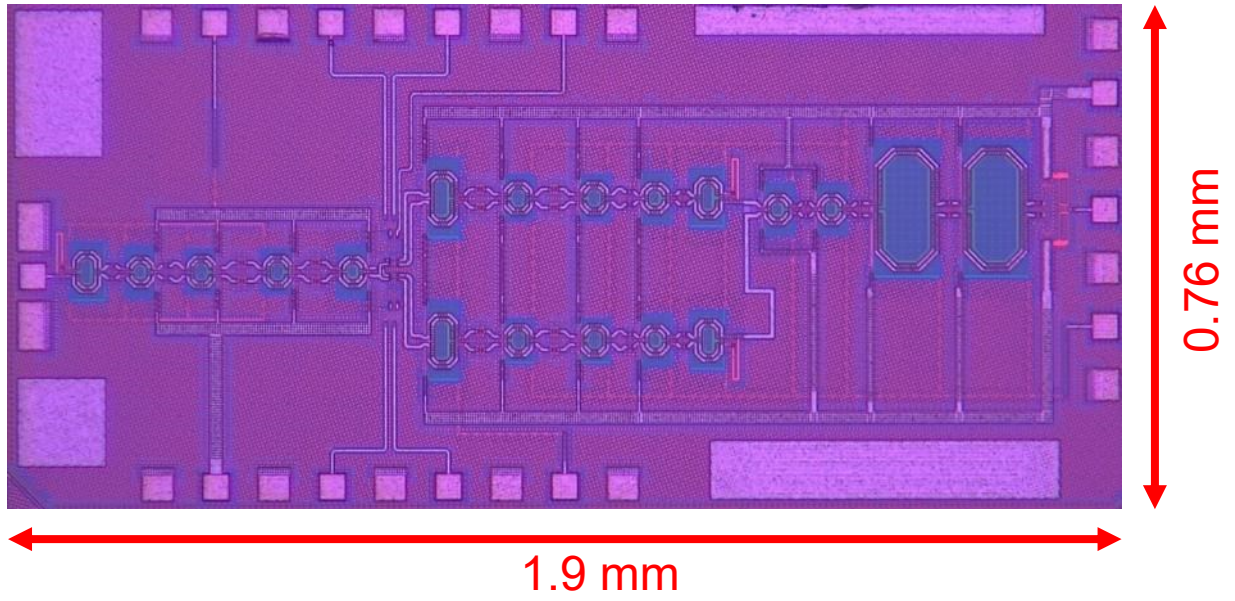
Massive # of parallel channels, multiple independent beams.

Why 135GHz- band?

Less attenuation compared to its neighbor frequency bands.

Receiver Architecture





Direct conversion receiver:

Wideband fully differential LNA.

Double balanced passive mixer.

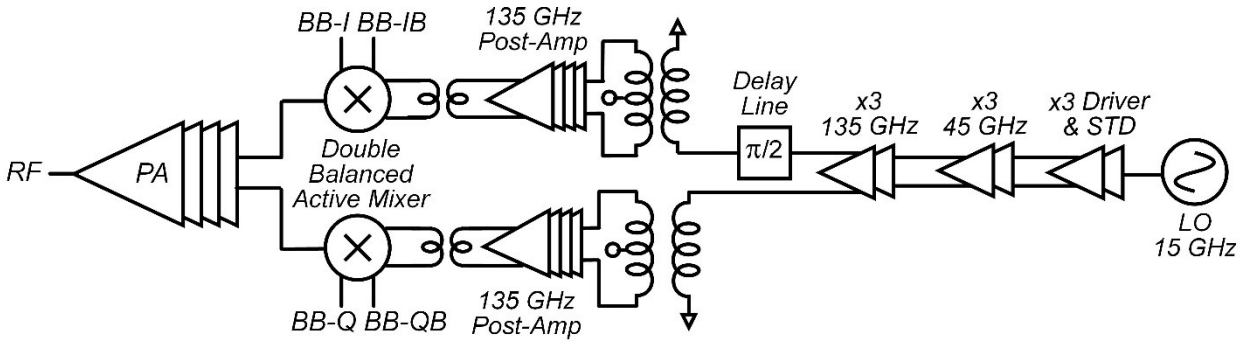
Broadband pseudo-differential transimpedance amplifier (TIA).

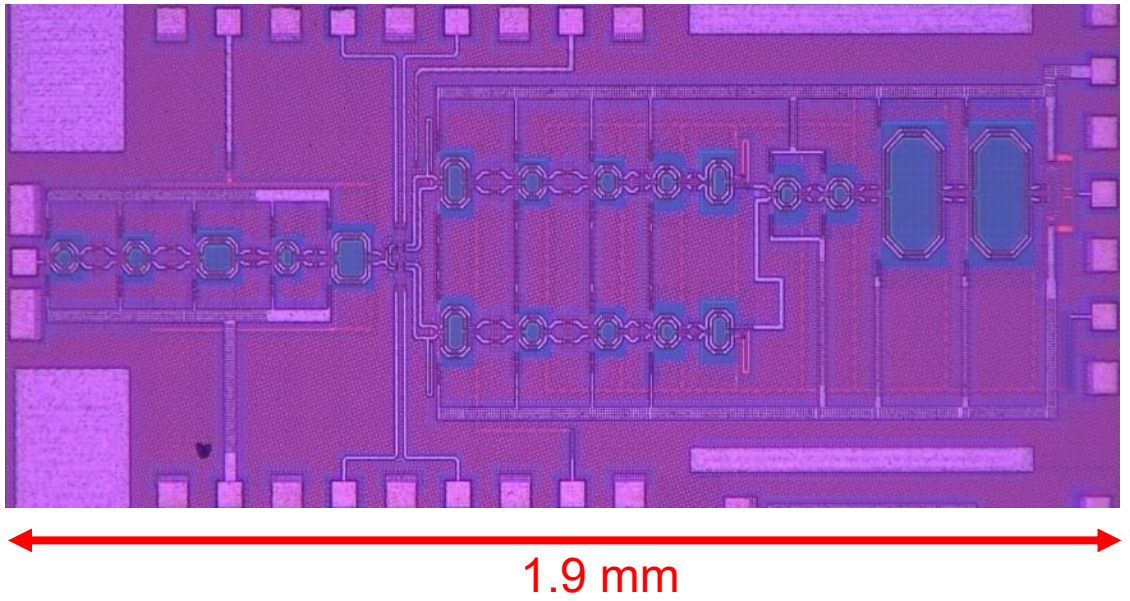
9:1 LO frequency multiplier (15GHz→ 135GHz):

two cascaded limiting amplifiers as triplers.

λ/2 transmission Line to generate LO (I,Q) signals.

Transmitter Architecture





Direct conversion Transmitter:

Active double balanced Gilbert cell.

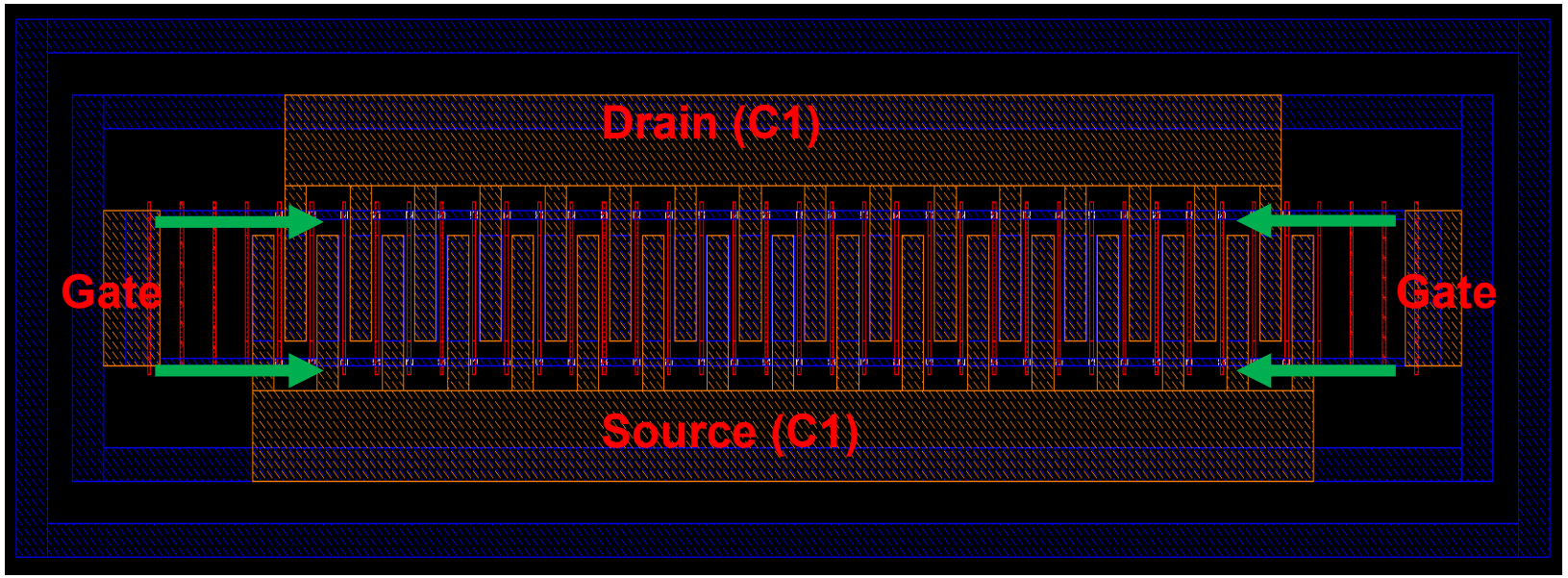
Wideband fully differential driver amplifier.

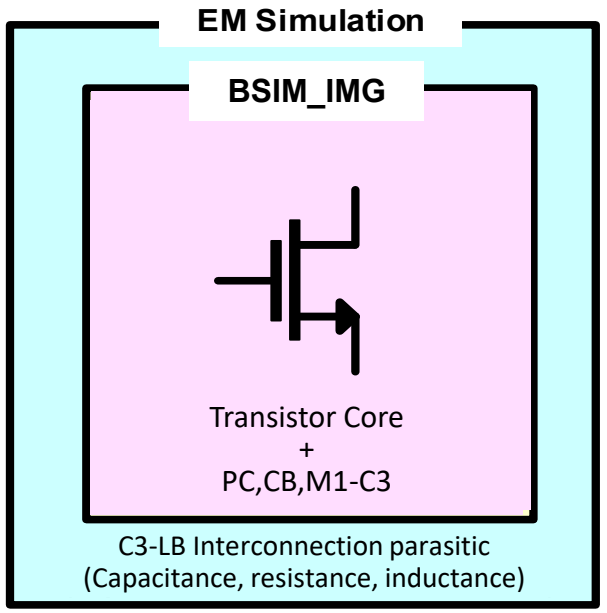
9:1 LO frequency multiplier (15GHz→ 135GHz):

two cascaded limiting amplifiers as triplers.

λ/2 transmission Line to generate LO (I,Q) signals.

Technology Characterization





SLVT device with 32 fingers.

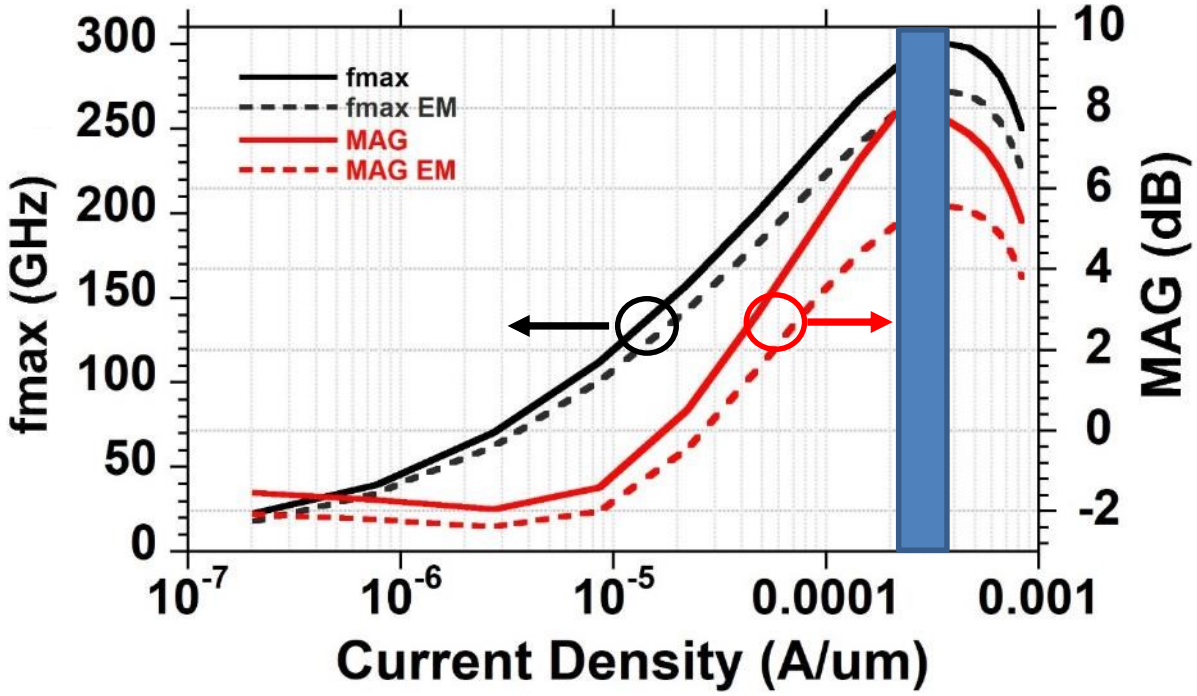
Gate finger pitch is (2xCPP) 2:1 above minimum:

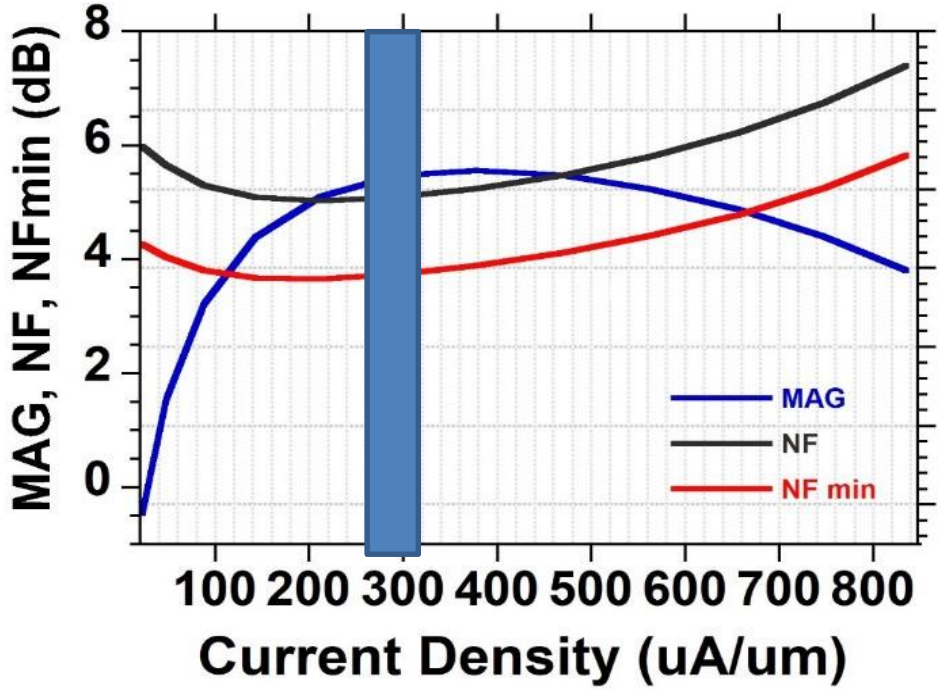
Allows placement of sufficient number of vias.

Satisfy electro-migration limits, when operating at 0.3mA/µm at 110^0C.

Minimize C_{ds} and C_{gs} overlap capacitance.

Technology Characterization





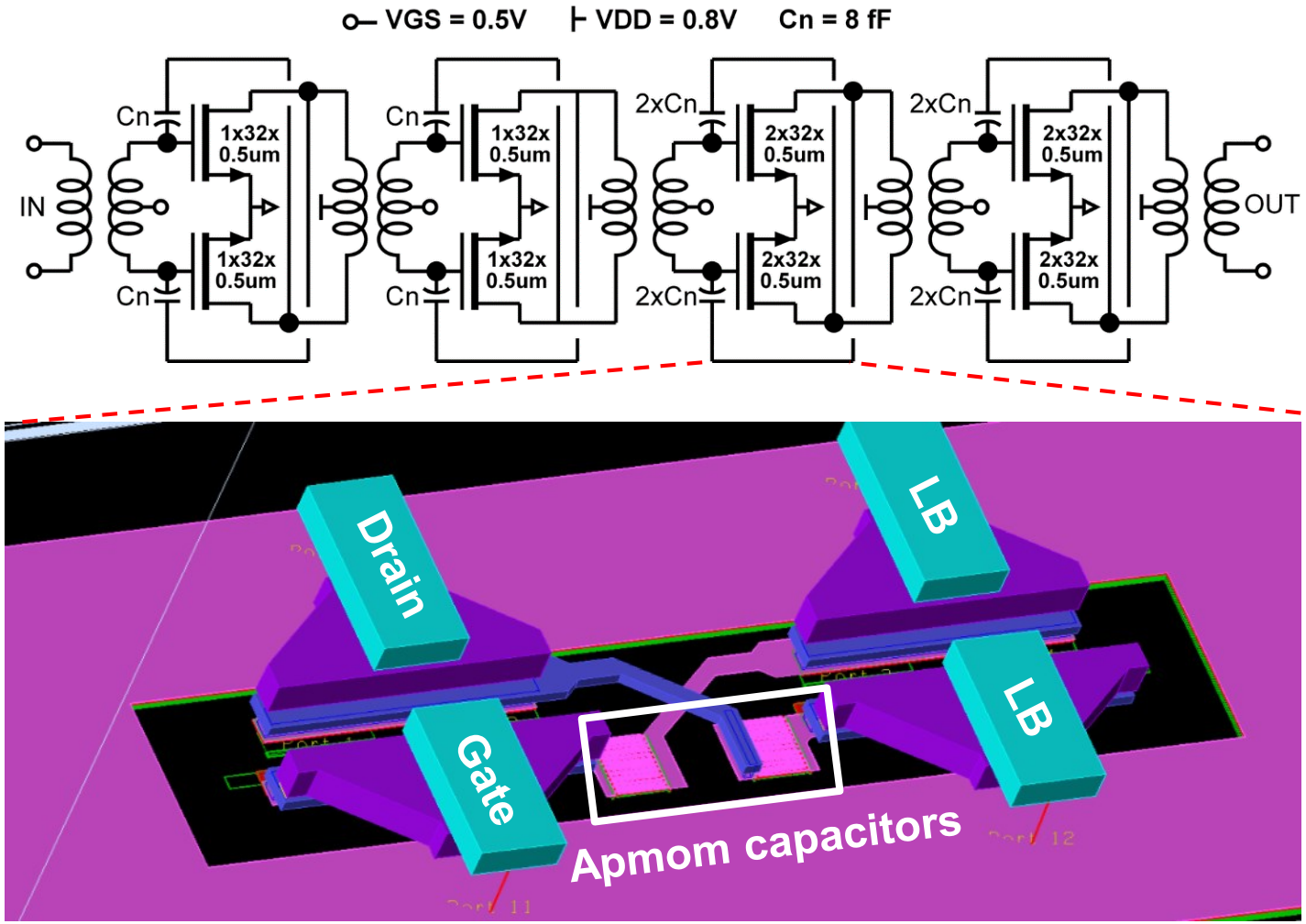
At current density of 0.3 mA/µm

f_{max} ~ 300GHz referenced to bottom Metal Layer (M1).

f_{max} ~ 250 GHz referenced to top Metal layer (LB/ Aluminum).

G_{max} = 5.5 dB and NF_{min} = 3.9 dB @ 135 GHz.

Circuit Design- LNA/PA



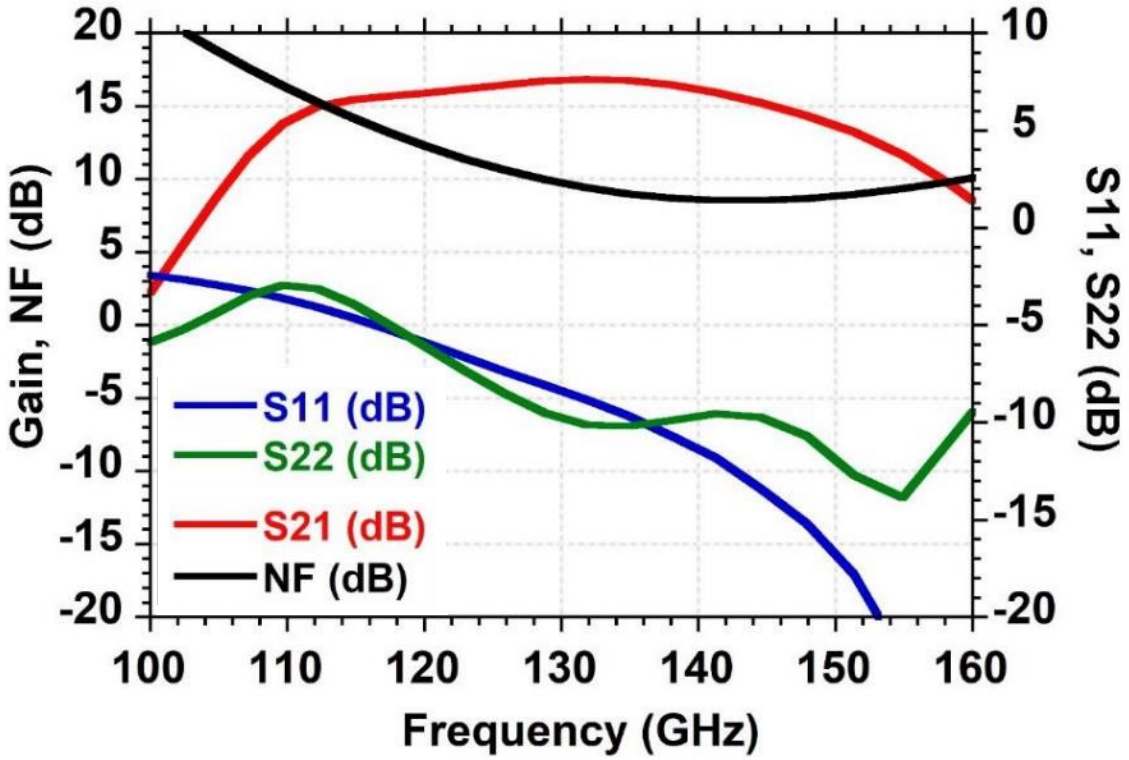
4-stage differential CS amplifier
Capacitive neutralization.

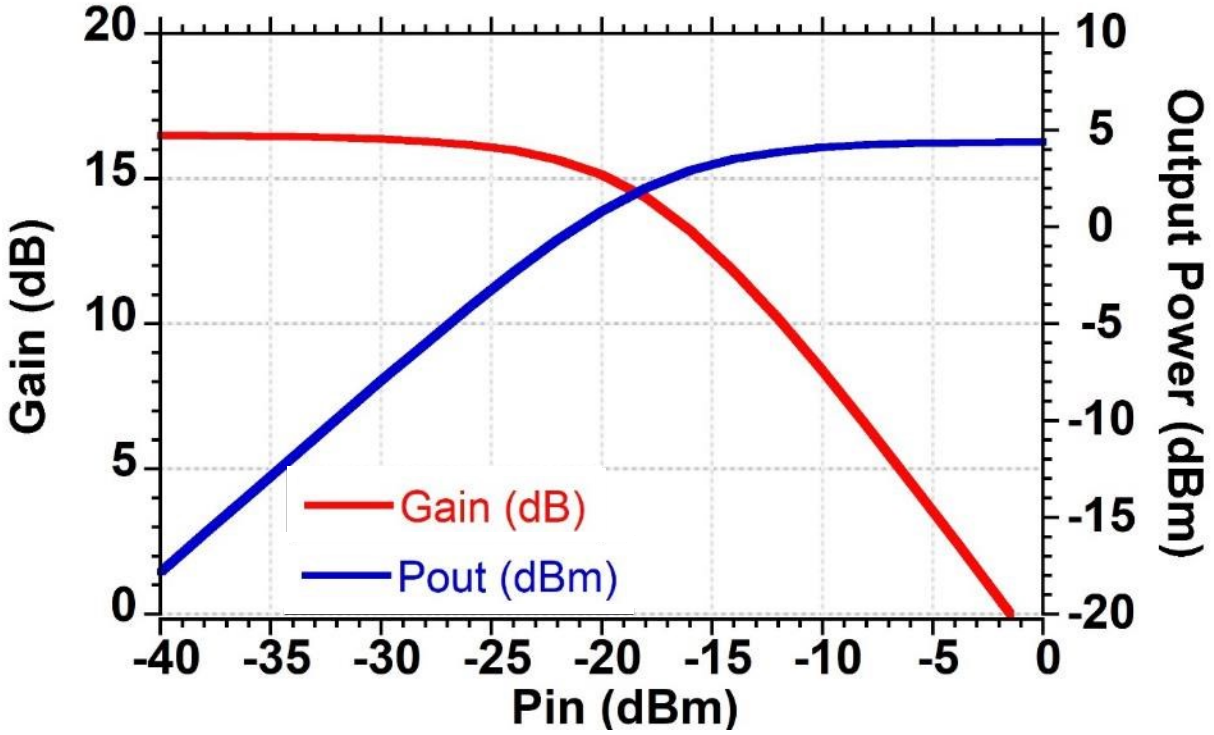
First stage optimized for Noise Figure.

Last stage tuning: maximum P_{out}.

Staggered inter-stage tuning
→wider bandwidth.

LNA/PA Simulation



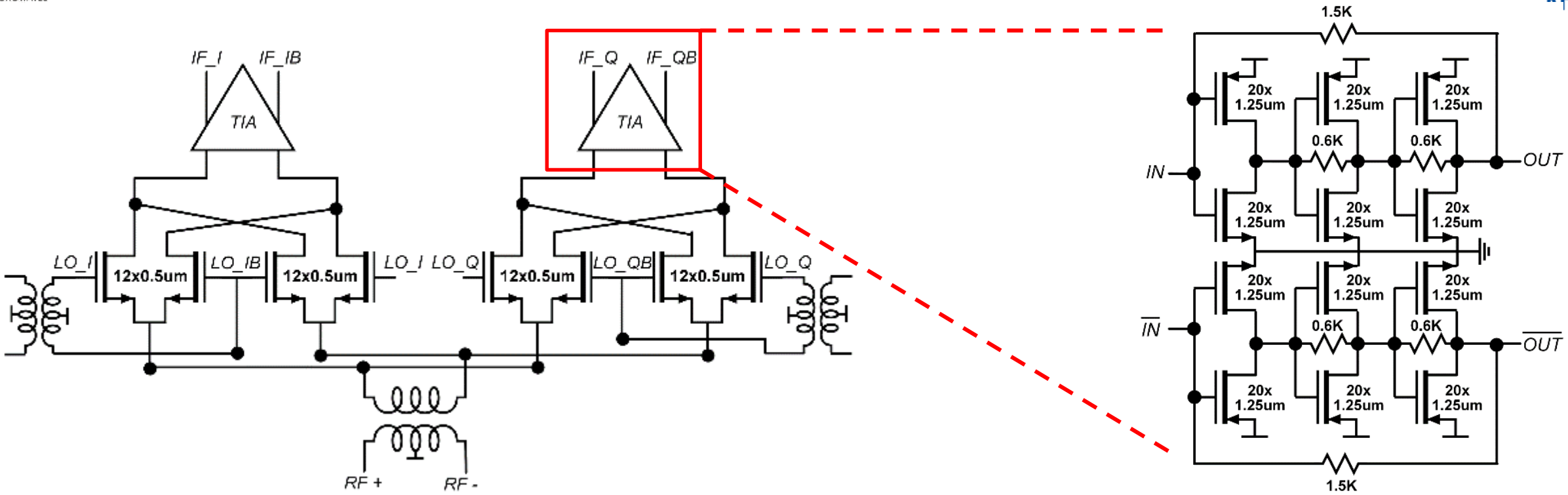


Simulated S_{21} is 16dB with 40GHz 3-dB BW.

P_{sat} is 4.5dBm, while P_{1dB} is 1.8dBm.

Power consumption: 0.8V, 60mA →48mW.

Circuit Design- Down Conversion Mixer

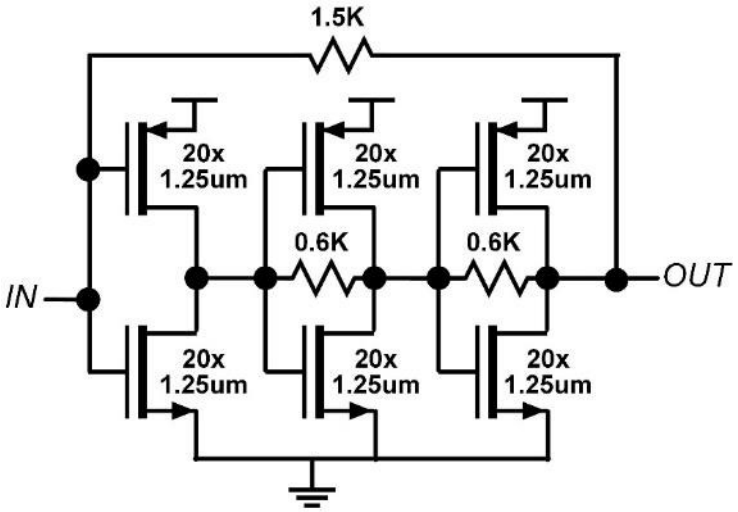


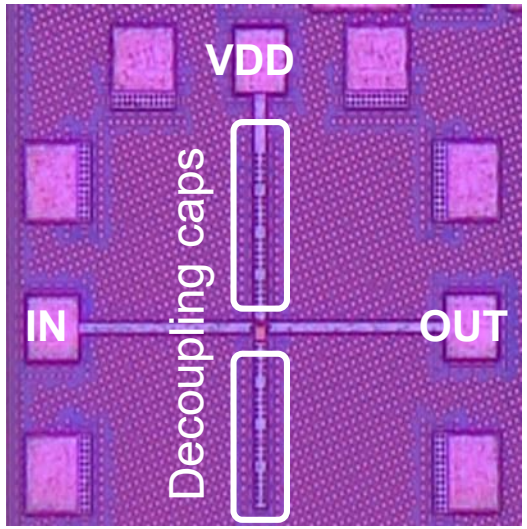
Double balanced passive mixer → high input dynamic range.

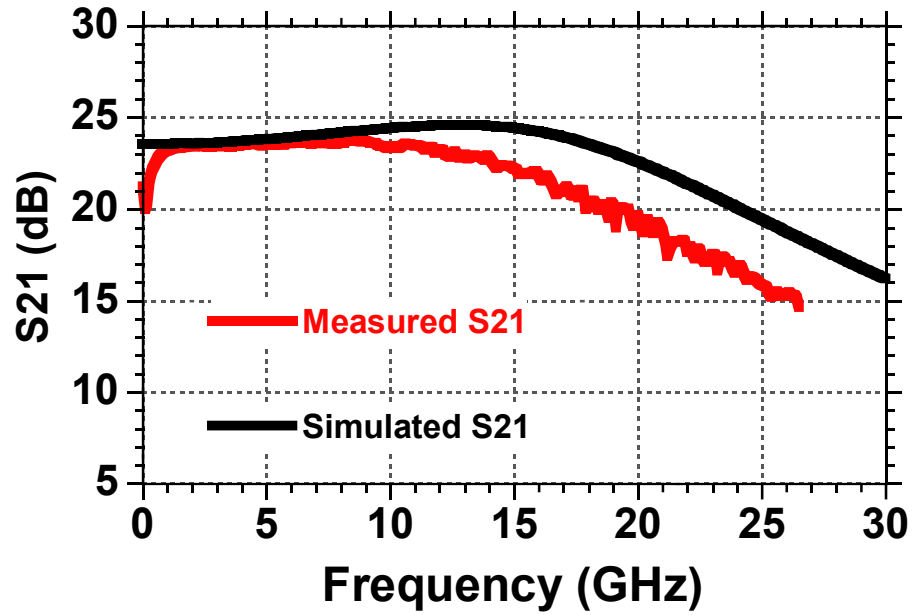
LO (I,Q) signals converted to differential form by transformers.

Baseband (I,Q) mixer outputs DC-coupled to TIA.

Circuit Design- Transimpedance Amplifier







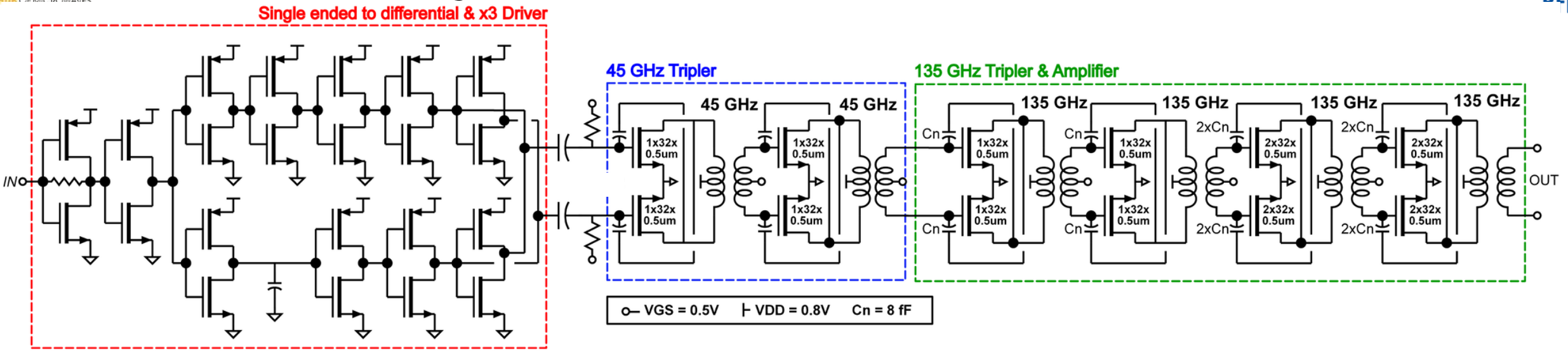
24dB gain, measured and simulated.

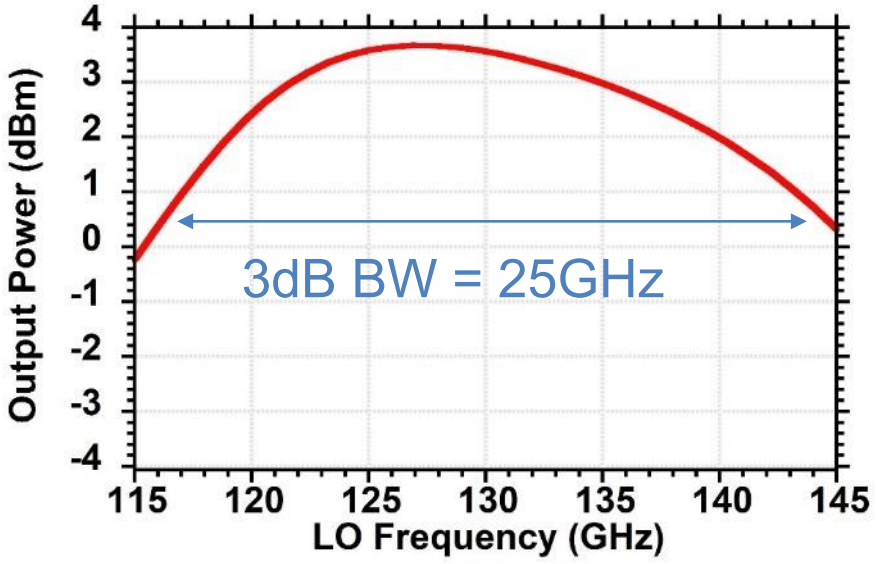
17GHz bandwidth measured; 22GHz simulated.

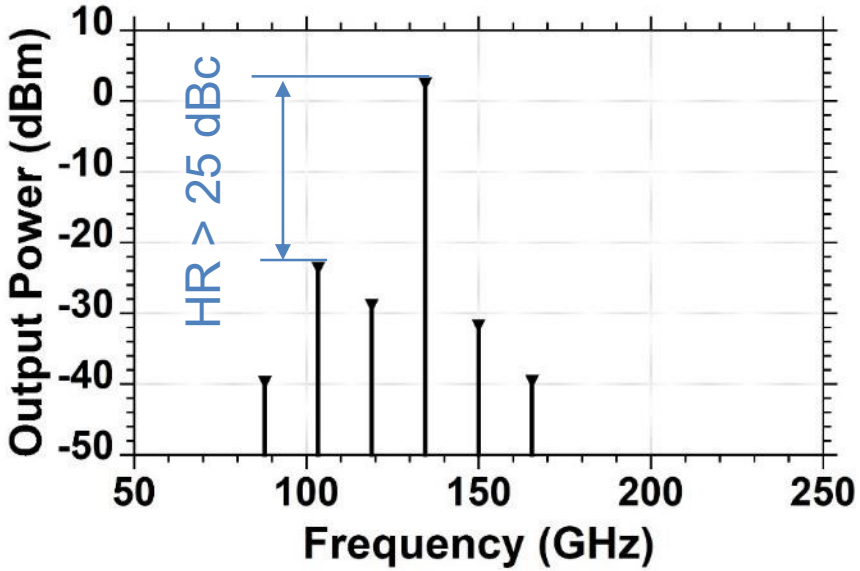
Gain notch due to power supply resonance.

No gain notch in fully receiver (differential signal path).

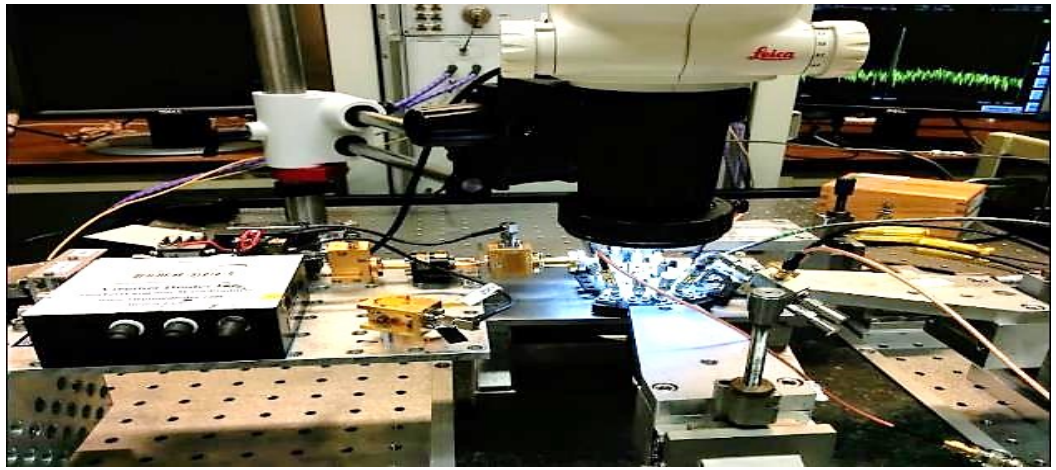
Frequency Multiplier Simulations

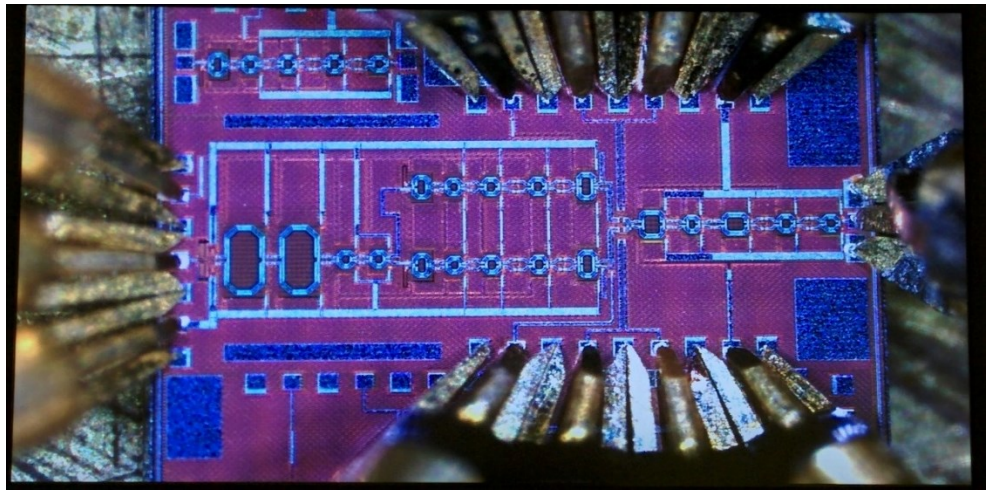






Receiver Measurements





Test Setup:

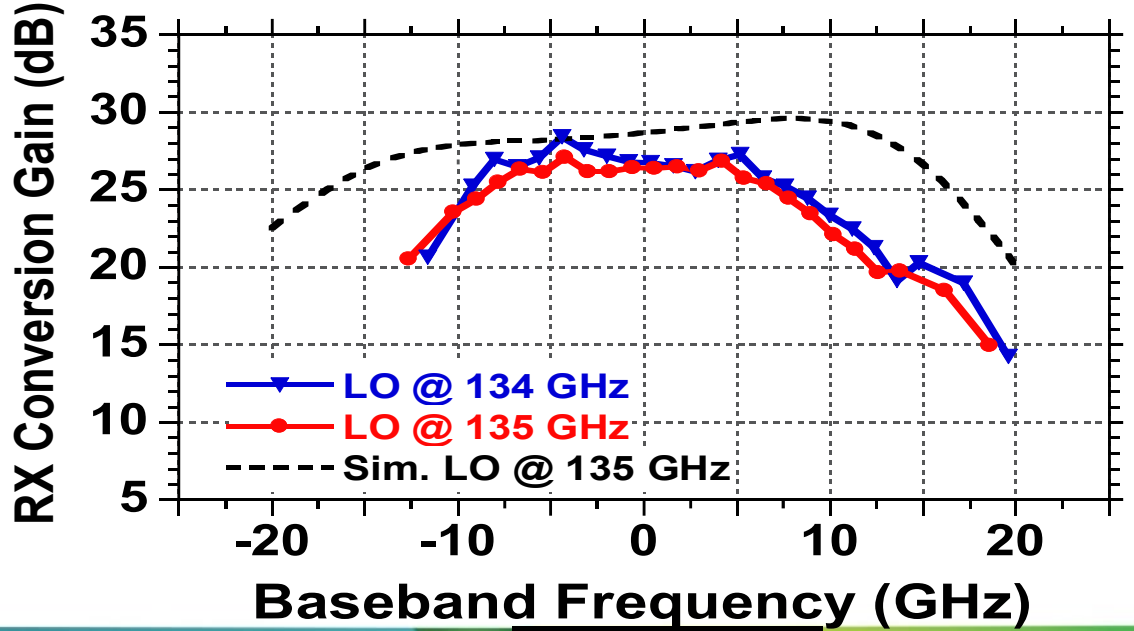
Input signal source: Virginia Diode AMC333.

TIA outputs terminated by 50Ω.

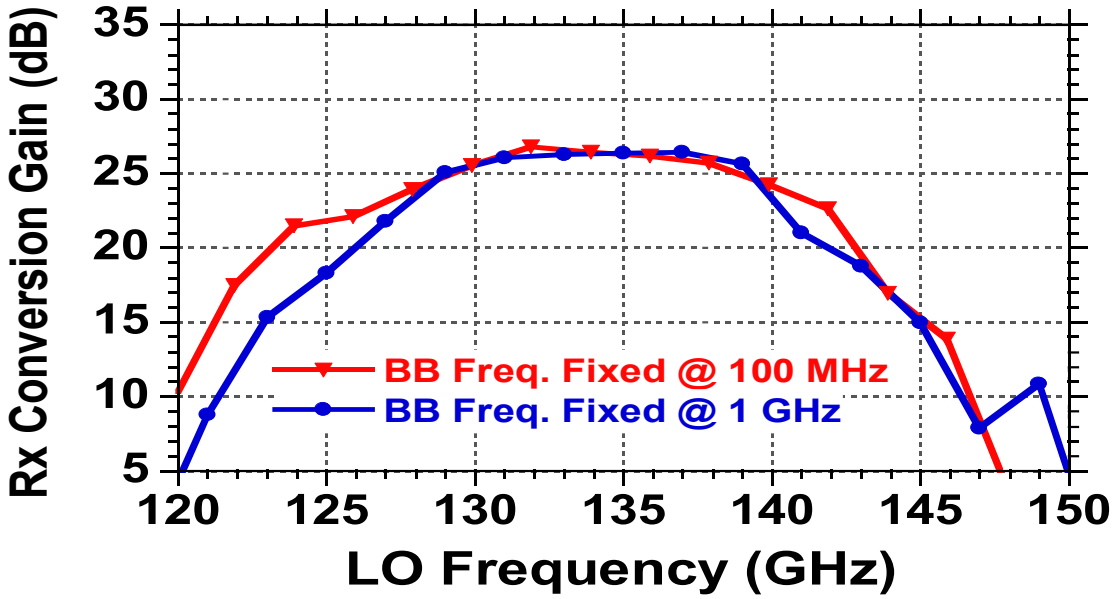
Characterization:

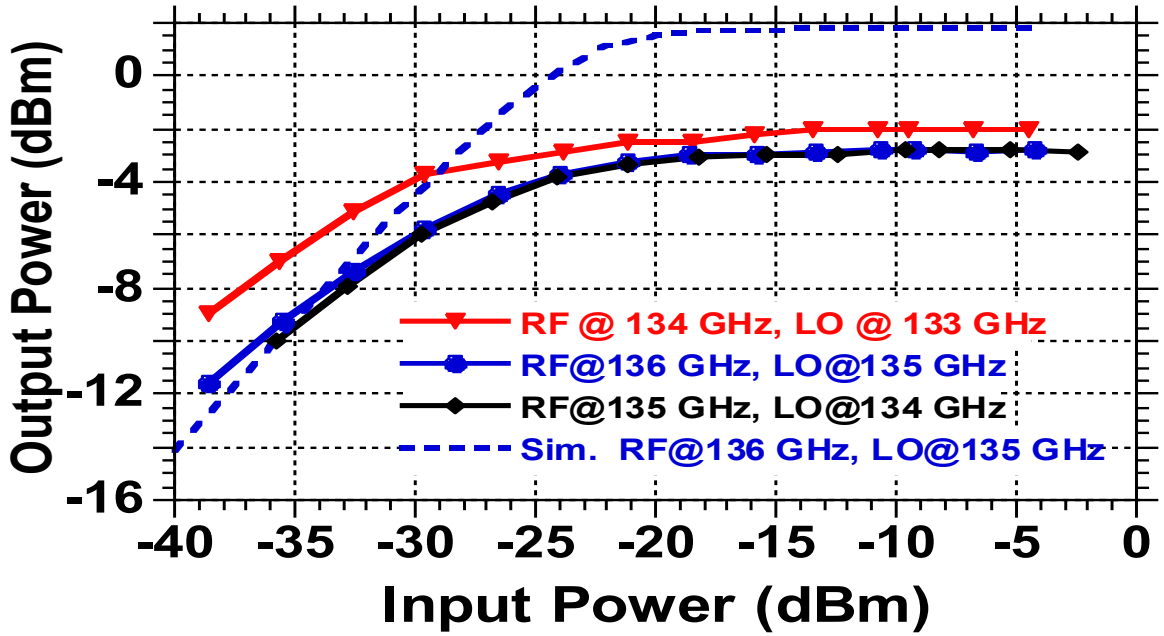
Conversion gain=27dB.

20GHz Rx modulation BW with Fixed 135GHz LO.



Receiver Measurements

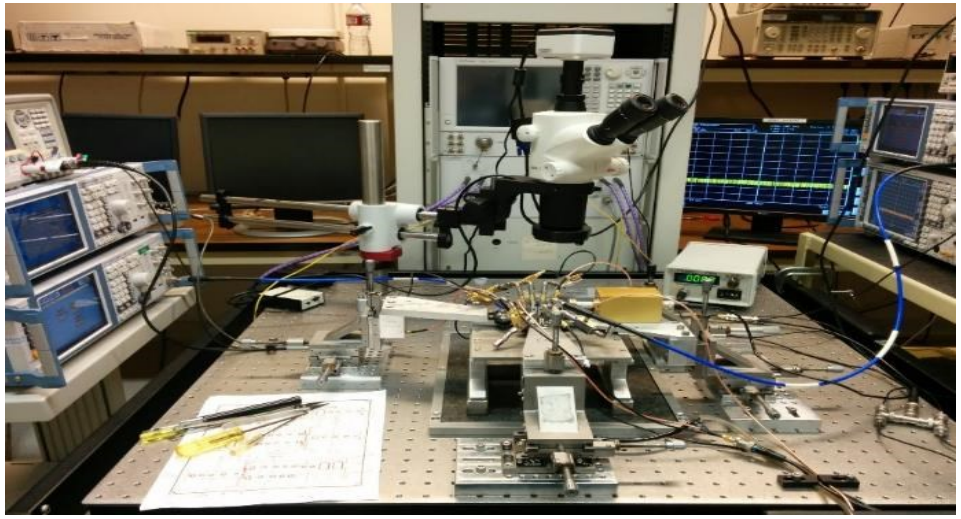


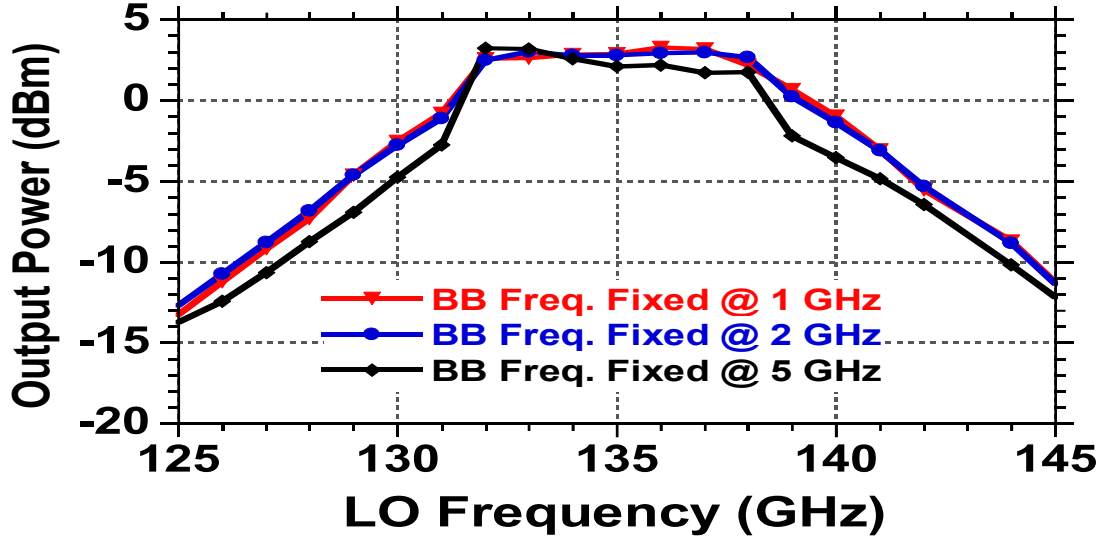


10GHz RX tuning range, limited by LO tuning range.

P_{1dB} =-30dBm (compression due to TIA).

Transmitter Measurements





Test Setup:

Output power measured with PM4 power meter.

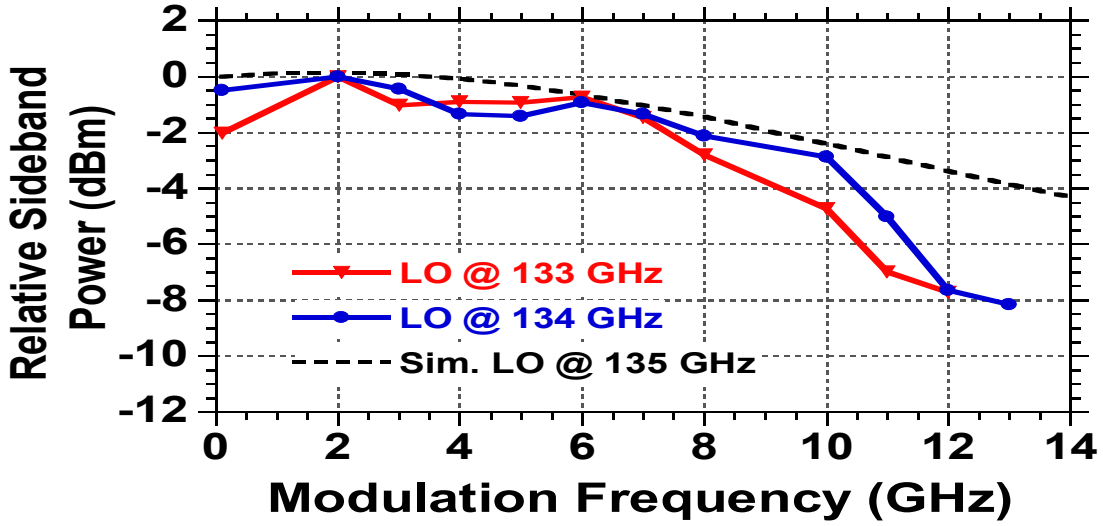
Baseband I /Q signal input power =-3dBm

Characterization:

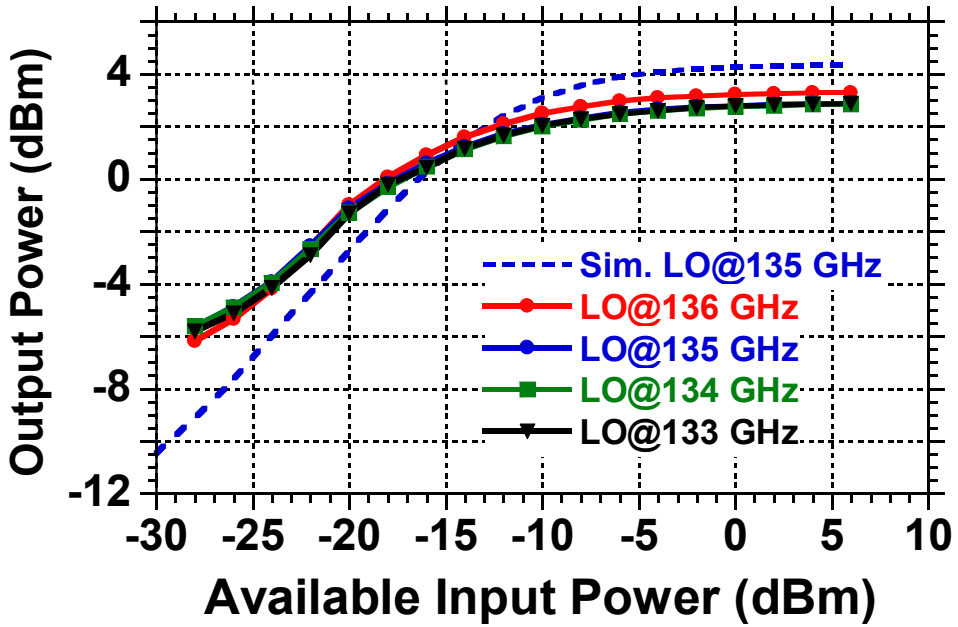
P_{sat}= 2.8dBm.

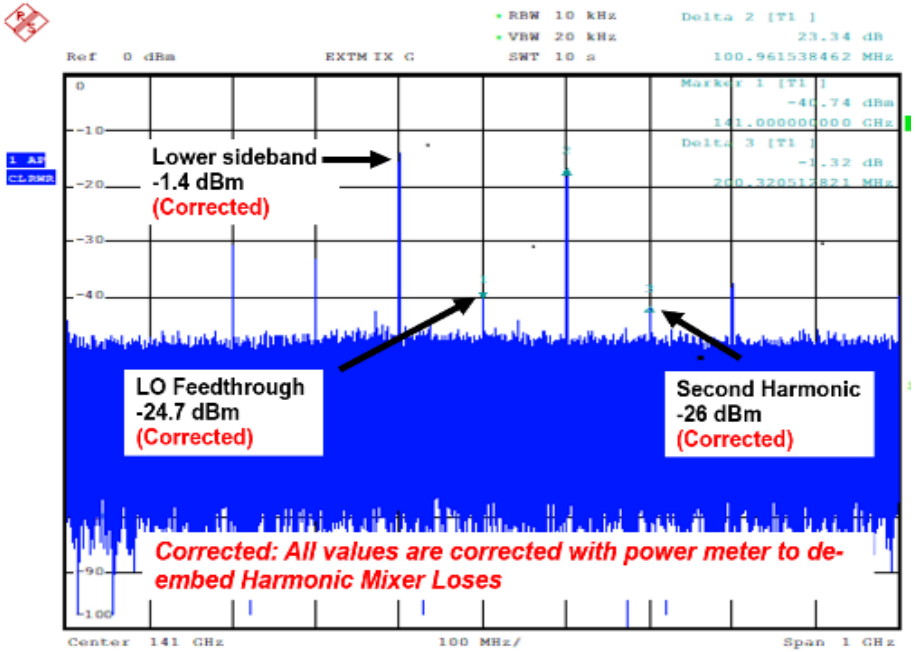
8GHz Tx tuning range, Limited by LO tuning.

8GHz S.S.B Modulation BW.



Transmitter Measurements





Gain compression characteristics shows 18dB gain.

~ -6dB LO leakage at low input power.

Tx output spectrum with correct DC biasing shows:

LO suppression= 23dB.

2nd harmonic rejection=24dB.

Comparison with state of the art

	T. Heller, MTT 2016	A. Simsek, BCICTs 2018	Y. Yang, RFIC2014	C. Lee, RFIC 2018	This Work
Technology	28nm CMOS	40nm SOI-CMOS	45nm CMOS	40nm CMOS	22nm SOI-CMOS
Frequency (GHz)	102-128	140	155	118	135
Conversion Gain (dB)	36-38	18 Rx ? Tx	23 Rx ? Tx	13 Tx	27 Rx 18 Tx
Modulation 3dB-Bandwidth (GHz)	18 Rx	12 Rx 8 Tx$^{\$\$}$	9 Rx ? Tx	14 Tx	20 Rx 8 Tx$^{\$\$}$
NF (dB)	8.4-10.4	5.5*	20*	-	8.5*
Pdc (mW)	51	125 Rx 120 Tx	345 Tx/Rx	271	198 Rx 196 Tx
Tx Psat (dBm)	NA	-2	-10	4.5	2.8
Integration	Rx	Tx/Rx	Tx/Rx	Tx	Tx/Rx

*simulated, $^{\$\$}$single sideband

Conclusion

D-band broadband transmitter and receiver.

22nm FDSOI CMOS .

Receive channel: 27dB gain, 20GHz 3-dB bandwidth.

Transmit channel: 18dB gain, 2.8dBm saturated output power.

Power consumption (0.8V supply):
- transmitter 196mW,
- receiver 198mW.
- both dominated by the LO multiplier (137mW).

Questions