LNA and Mixer for 122 GHz Receiver in SiGe Technology

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Outline

- Motivation
- SiGe Technology
- Transmission Lines
- Circuit Design
- Layout Design
- Measurements Results
- Conclusions

Possible Applications of SiGe ICs

Communication	Radar	mmW / THz Imaging and Sensing
Wireless: • Personal and Local Area Networks (PAN/LAN) • Consumer Electronic • Wireless Backhaul • Inter-building communication, E-Band (71-76GHz, 81-86GHz) • Secure links and surveillance • Space and inter-satellite communication	**Automotive:** • Long Range Radar (LRR) • Collision avoidance, ACC, (24/77GHz) • Short Range Radar (SRR) • Pre-crash detection, stop-and-go, lane-change assistant (23-27, 77-81GHz) • Road condition detection	**Sensing:** • Earth sensing and climate control • Industrial process control • Astronomy, microwave background
	Space / Avionics: • Aviation safety (94GHz) • Airport ground control (94GHz)	**Security:** • Non-invasive imaging • Drug and explosive detection
Fiber / Digital: • High-speed interconnects • Data switches, CDR, Mux, DeMux	**Industrial:** • Distance measurement (24/122GHz) • Alarm system, motion detection, sports …. (24GHz)	**Biotechnology:** • Medical imaging, tumor detection • genetic screening
AD / DA Conversion		

Ref.: U. R. Pfeiffer, et al., "Opportunities for silicon at mmWave and terahertz frequencies," *BCTM* 2008, pp. 149–156.

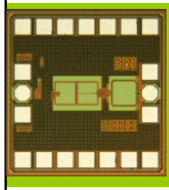
Overview of SR activities

Application →

Frequency ↓

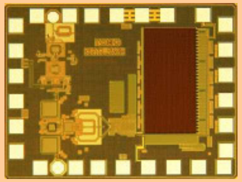
Radar-IC´s

Pulse



25GHz Pulse-Radar

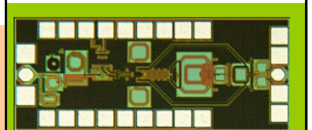
FMCW *Complex*



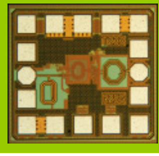
Single-Chip 24GHz Radar with integrated Ramp-generation

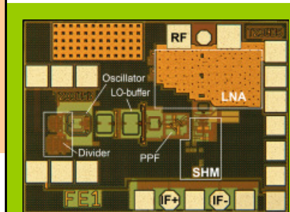
122 GHz Frontend SUCCESS-Project

FMCW *Simple*



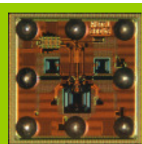
Single-Chip-Radar 24GHz





122 GHz Frontend

Standard-IC´s



Transmitter IC 24GHz FlipChip

23 - 27GHz Ultra Wideband Receiver

- 60 GHz LNA
- 60 GHz VCO
- 60 GHz Power Amplifier

- 94 GHz LNA
- 122 GHz LNA
- 185 GHz VCO
- 210 GHz Oscillator

Communication-IC´s

- X-Band phased-array System

- 60 GHz Frontend Communication IHP-IP´s

Pros and cons of SiGe-IC

Comparison valid for medium quantity, i.e. couple thousands up to (some) millions

IC Technology		other technologies		Silicon Radar
		GaAs, InP	CMOS (e.g. 90nm)	SiGe BiCMOS
Cost	Material cost	High	Medium	low
	Mask cost	medium	Very high	Medium
Technical Parameters	Integration feasibility	Low	Very good	(very) good
	HF-Noise	Very good	Good	good
	1/f Noise	Bad	Bad	Very good
	Breakdown Voltage	High	Medium	medium
	High frequency parameters f_T/f_{max}	Very good	Medium	Very good
	Radiation Hardness	Partly good	Bad	good
Overall estimation	Overall cost	Very high	High	Medium
	Technical Parameters	Good	Medium	Very good

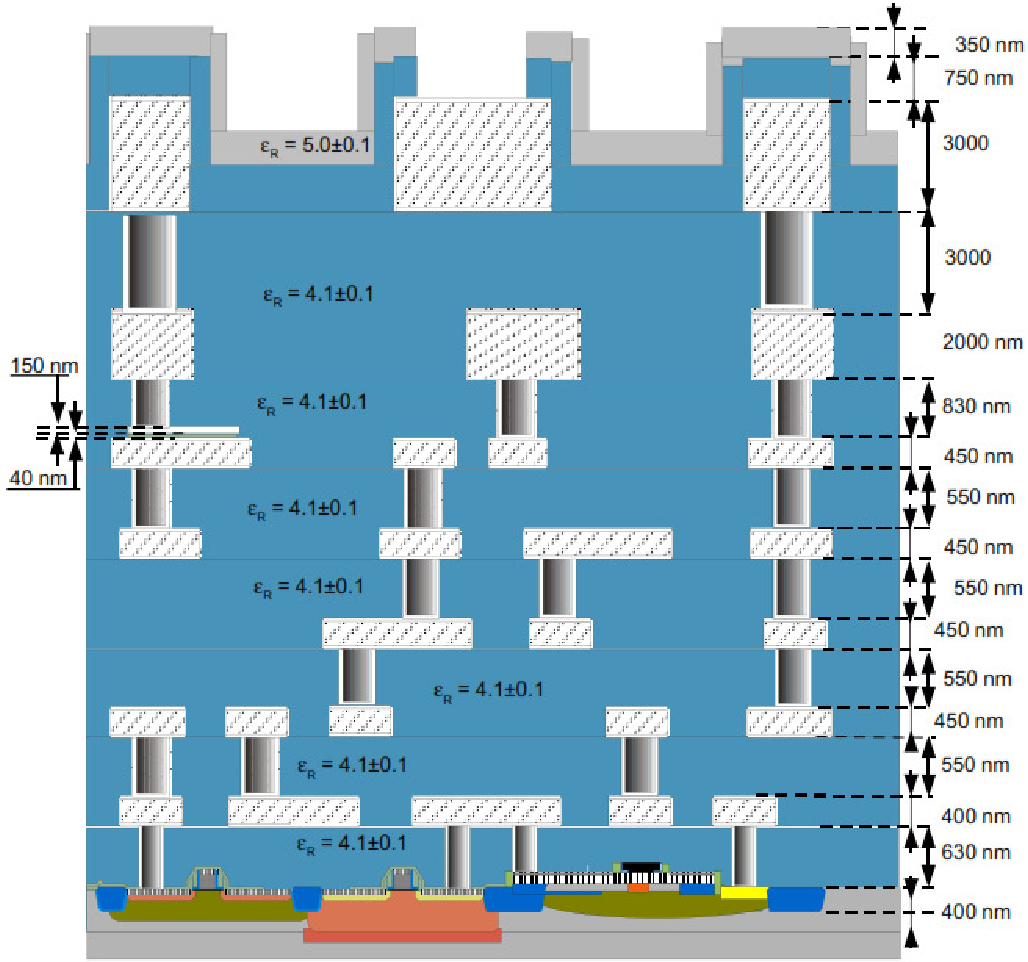
Technology: Devices

0.13µm SiGe BiCMOS technology of IHP SG13

Device	Parameter	Value
NPN1	peak ft/fmax	250 /300 GHz
	B_{VCEO} / B_{VCBO}	1.75V / 5.5V
NPN2	peak ft/fmax	45/120 GHz
	B_{VCEO} / B_{VCBO}	4V / 16V
MIM capacitor	Unit capacitance Temperature coeff. Breakdown voltage	C' = 1.5 fF/µm^2 < 3.6 ppm/grd 23 V
Resistors	Sheet resistance	R_{sil}= 7 Ω, R_{ppd}= 335 Ω, R_{high}= 750 Ω

Technology: Backend

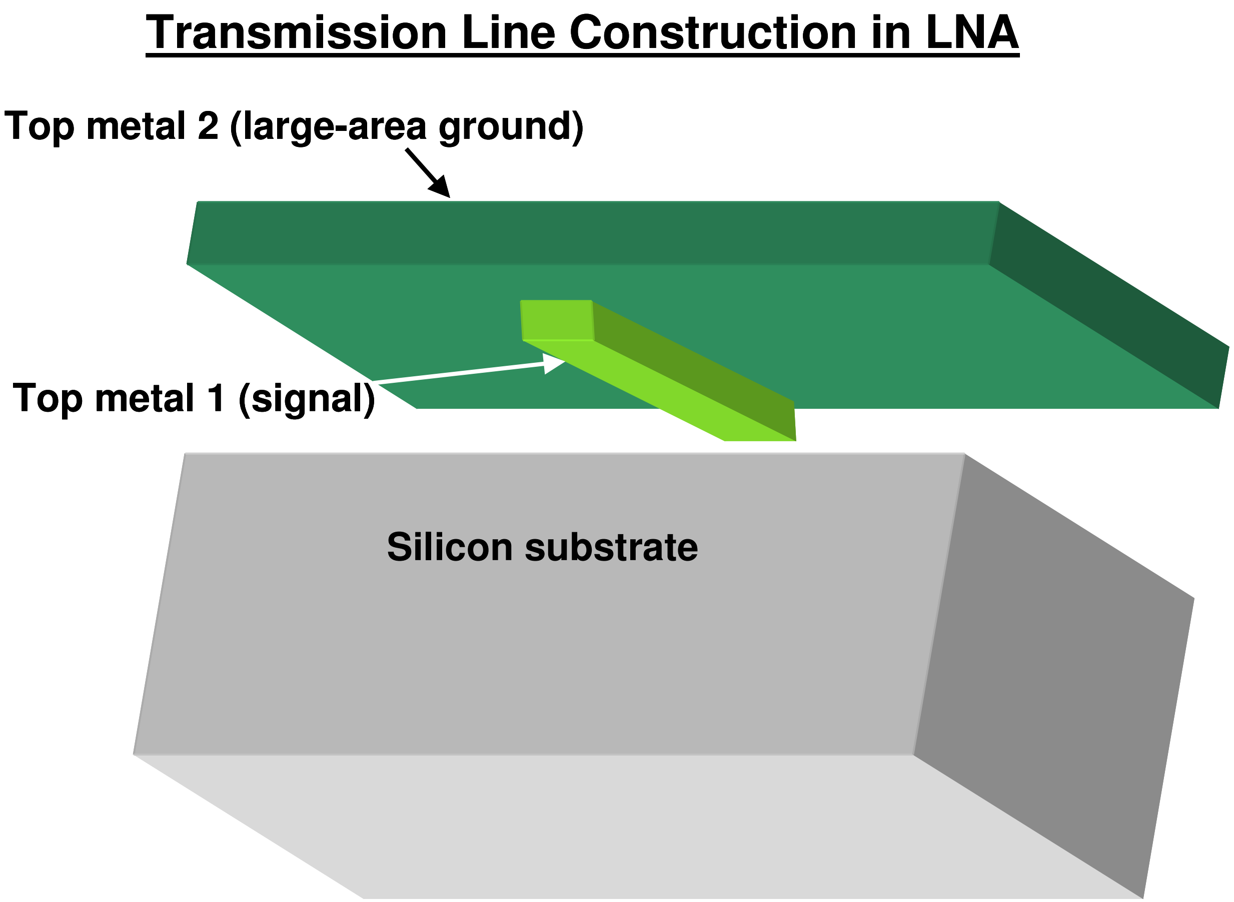
Five / seven metal layers available



Transmission Lines: Possible structures

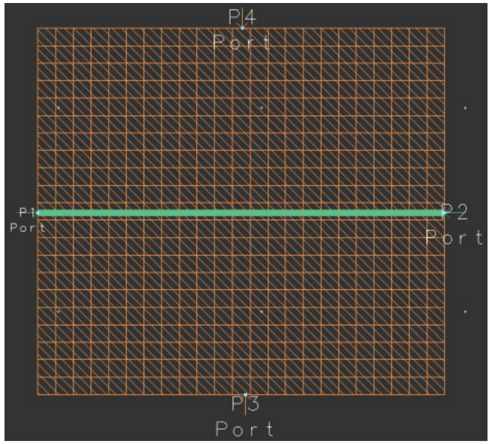
TL Type	Advantage	Disadvantage
CPW	Low loss	Undesired modes possible Large area on chip
Microstrip TM2-M1	Often used element Good modeling	Broken ground plane in the design, thin gnd plane
Slow wave TL	Compact design	Modeling? Problems at higher frequencies
New TL: „inverted TL“ TM1-TM2	Nearly ideal ground plane on chip	TM2 layer spent for gnd Cut outs for inductors and transformers
…		

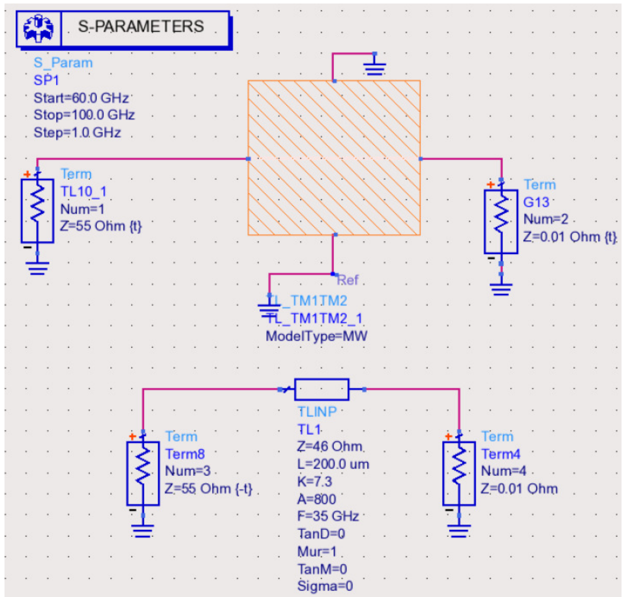
Inverted Transmission Line Structure

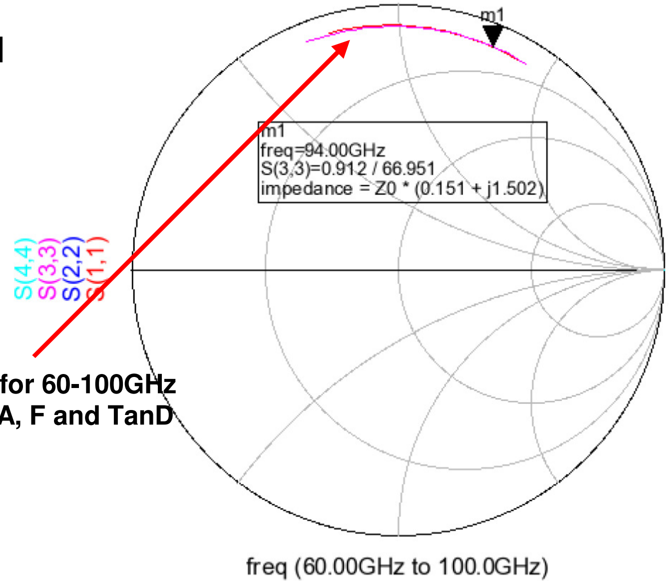


Modeling Transmission Line

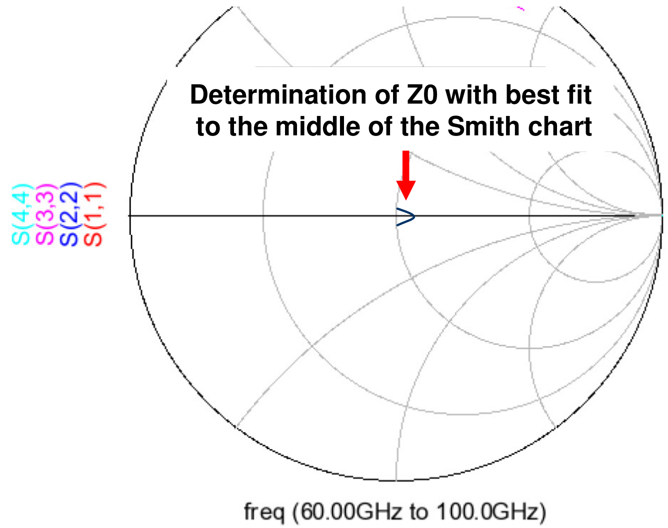
Planar 3D-simulation of the transmission line using MOMENTUM
Line length: 200µm, Frequency: 60GHz-140GHz





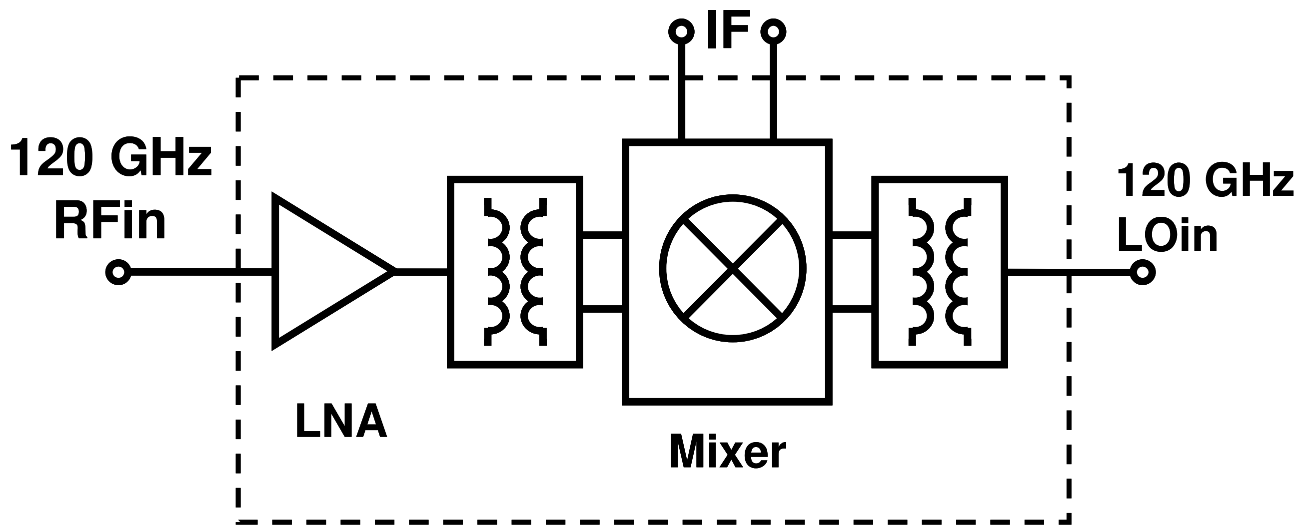


Best fit of the curves for 60-100GHz
Gives parameters K, A, F and TanD

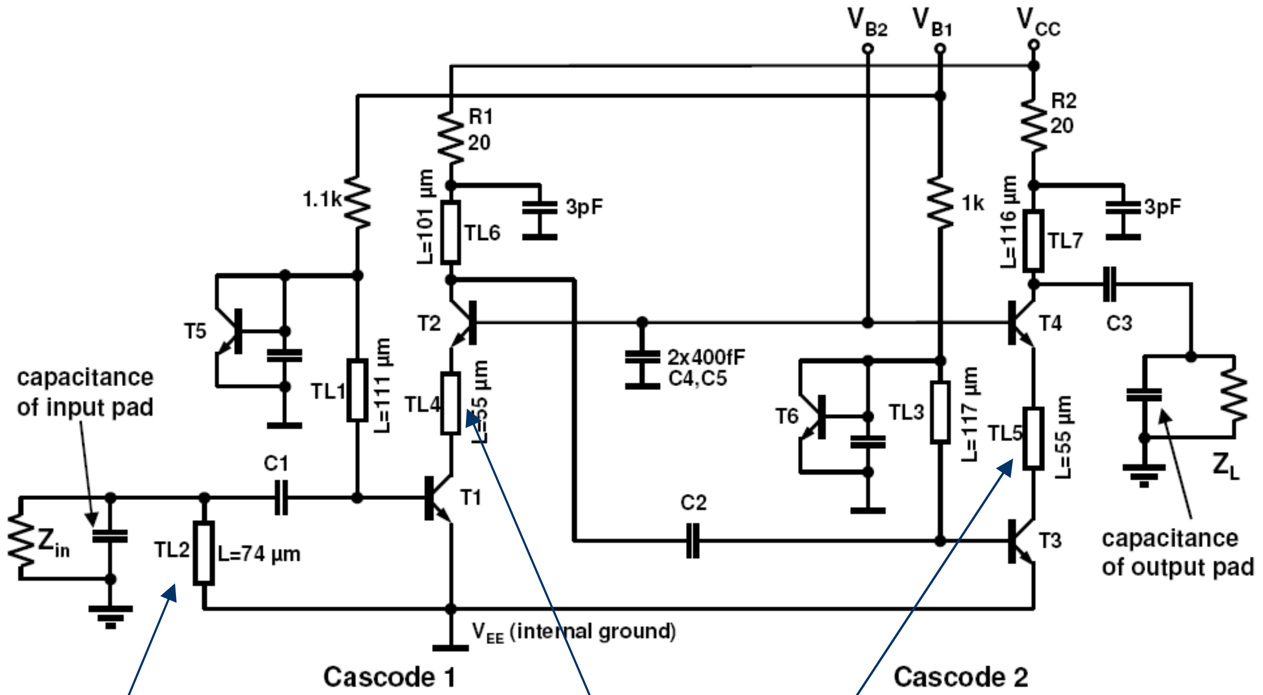


Determination of Z0 with best fit
to the middle of the Smith chart

Circuit Design: 120GHz Frontend.



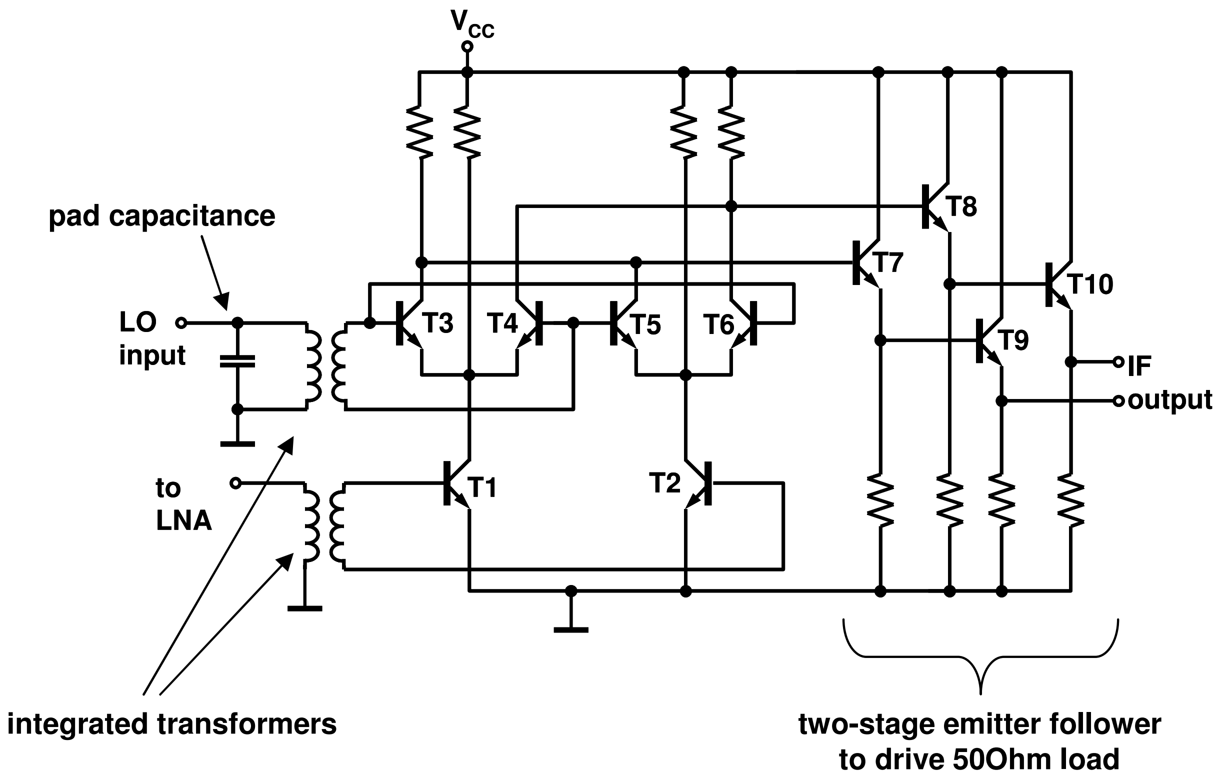
Circuit Design of LNA



Input matching incl. ESD protection

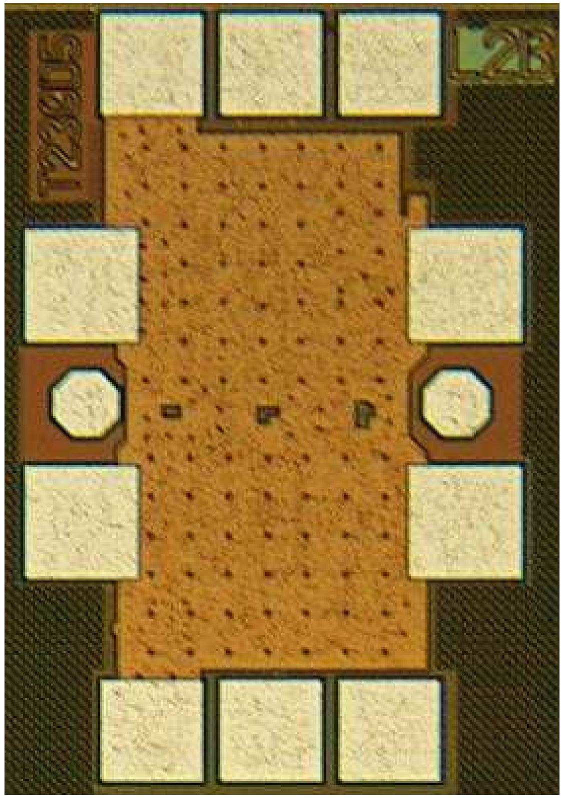
improved matching between CE and CB stage

Circuit Design of Mixer



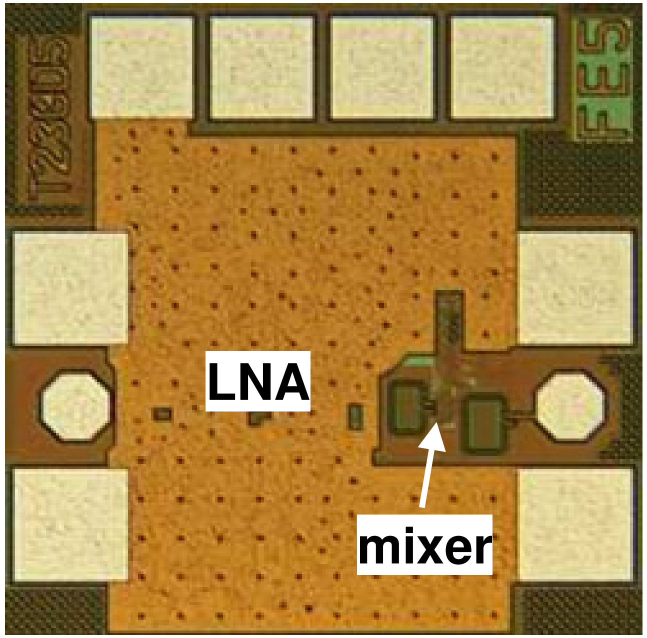
LNA and Frontend Layouts

Chip photo of the LNA test-structure



0.45 x 0.65 mm²

Chip photo of the 120 GHz frontend

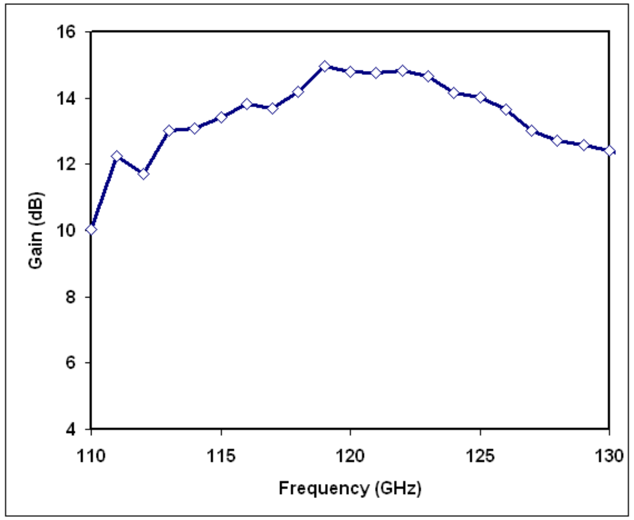


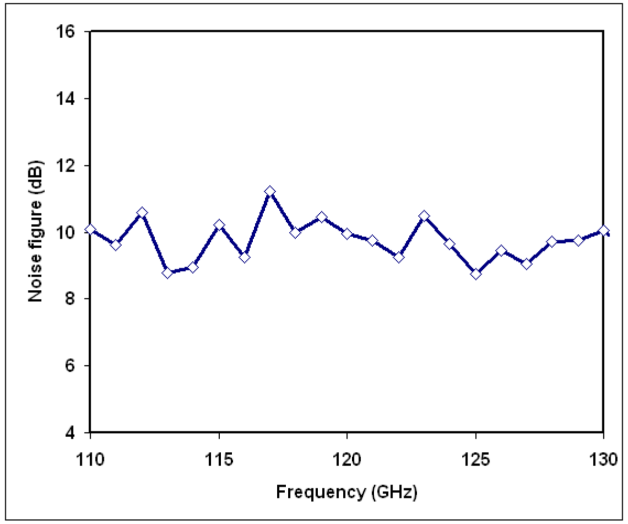
0.55 x 0.60 mm2

LNA Measurement Results

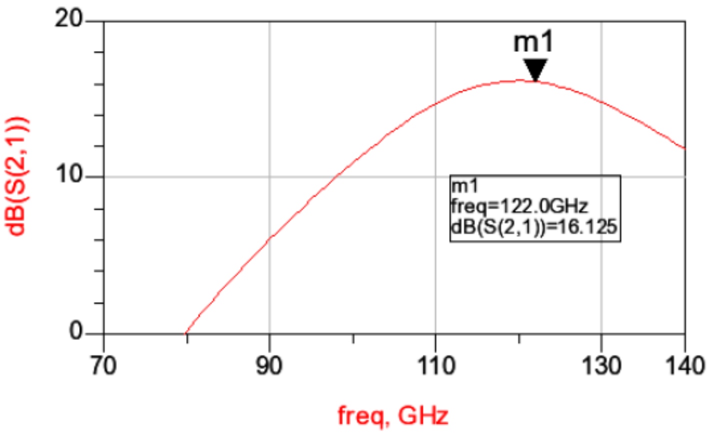
Parameter	Measurement	Simulation
V_{CC}	3.5 V	3.5 V
I_{CC}	17.7 mA	15 mA
gain @ 122 GHz	14.8 dB	16.1 dB
NF @ 122 GHz	< 10 dB	8.3 dB

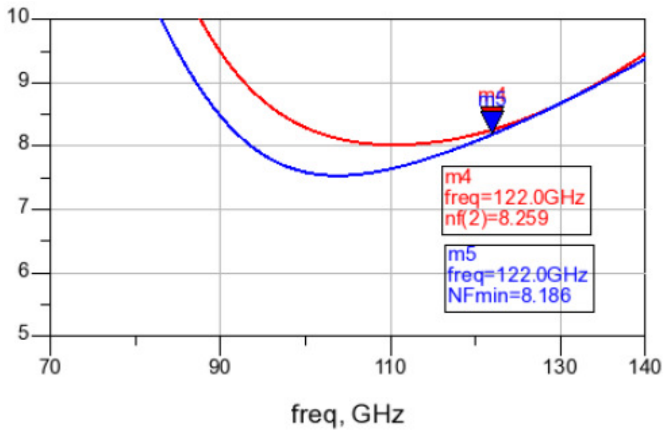
measured





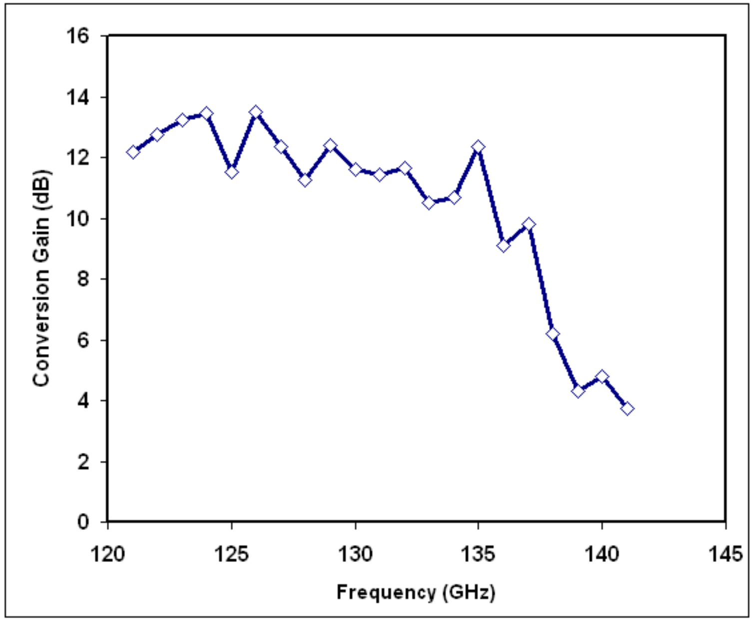
simulated

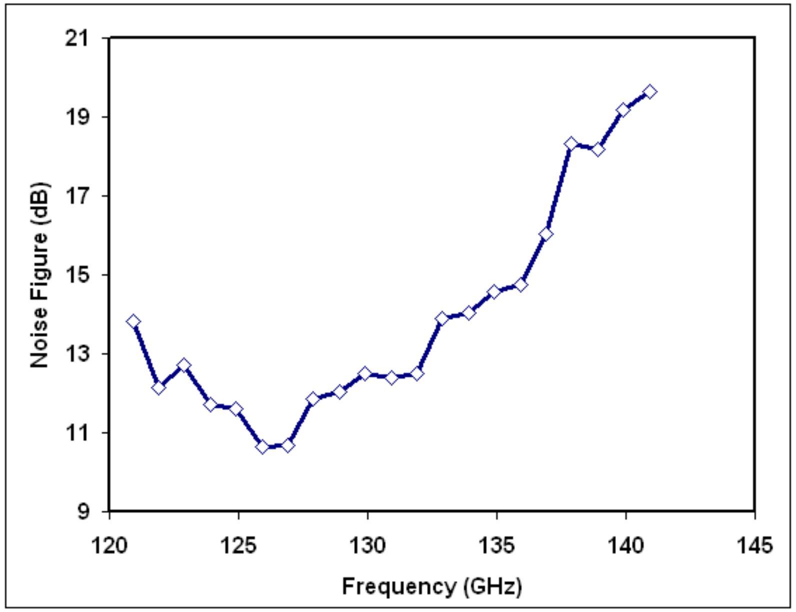




Frontend Measurement Results

Parameter	Measurement	Simulation
V_{CC}	3.5 V	3.5 V
I_{CC}	47mA	44 mA
conversion gain @ f_{RF}=121-29 GHz	12 dB	16 dB
NF @ 121-129 GHz	< 12.7 dB	< 11 dB





Conclusions

- New type of integrated transmission line proposed
- Modeling by using TLINP in ADS
- 122GHz amplifier and Frontend designed and measured
- Good match between measurement and simulation
- Proof of concept with LNA and mixer at 122GHz
- Capabilities of silicon-based technologies to operated at frequencies over 100GHz demonstrated

Acknowledgements

- IHP pilot line for excellent fabrication of the chips
- Mr. Hermann Massler (IAF) for noise measurement

Thank you!