

LNA and Mixer for 122 GHz Receiver in SiGe Technology

Wolfgang Winkler, Wojciech Debski
September 2010

Silicon Radar GmbH
Im Technologiepark 25
15236 Frankfurt (Oder)
Germany

Outline

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

Possible Applications of SiGe ICs

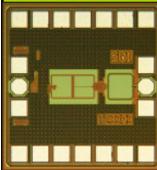
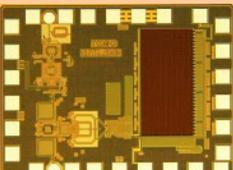
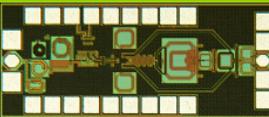
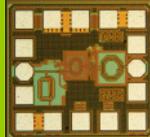
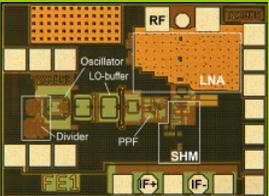
Communication	Radar	mmW / THz Imaging and Sensing
<p><u>Wireless:</u></p> <ul style="list-style-type: none"> • Personal and Local Area Networks (PAN/LAN) • Consumer Electronic • Wireless Backhaul • Inter-building communication, E-Band (71-76GHz, 81-86GHz) • Secure links and surveillance • <u>Space and inter-satellite communication</u> 	<p><u>Automotive:</u></p> <ul style="list-style-type: none"> • 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 	<p><u>Sensing:</u></p> <ul style="list-style-type: none"> • Earth sensing and climate control • Industrial process control • <u>Astronomy, microwave background</u>
	<p><u>Space / Avionics:</u></p> <ul style="list-style-type: none"> • <u>Aviation safety (94GHz)</u> • <u>Airport ground control (94GHz)</u> 	<p><u>Security:</u></p> <ul style="list-style-type: none"> • Non-invasive imaging • Drug and explosive detection
<p><u>Fiber / Digital:</u></p> <ul style="list-style-type: none"> • High-speed interconnects • Data switches, CDR, Mux, DeMux 	<p><u>Industrial:</u></p> <ul style="list-style-type: none"> • Distance measurement (24/122GHz) • Alarm system, motion detection, sports (24GHz) 	<p><u>Biotechnology:</u></p> <ul style="list-style-type: none"> • Medical imaging, tumor detection • genetic screening
<p><u>AD / DA Conversion</u></p>		

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			Standard-IC's	Communication-IC's
Pulse	FMCW <i>Complex</i>	FMCW <i>Simple</i>		
 <p>25GHz Pulse-Radar</p>	 <p>Single-Chip 24GHz Radar with integrated Ramp-generation</p>	 <p>Single-Chip-Radar 24GHz</p> 	 <p>Transmitter IC 24GHz FlipChip</p> <p>23 - 27GHz Ultra Wideband Receiver</p> <ul style="list-style-type: none"> • 60 GHz LNA • 60 GHz VCO • 60 GHz Power Amplifier 	<ul style="list-style-type: none"> • X-Band phased-array System • 60 GHz Frontend Communication IHP-IP's
	<p>122 GHz Frontend SUCCESS-Project</p>	 <p>122 GHz Frontend</p>	<ul style="list-style-type: none"> • 94 GHz LNA • 122 GHz LNA • 185 GHz VCO • 210 GHz Oscillator 	

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

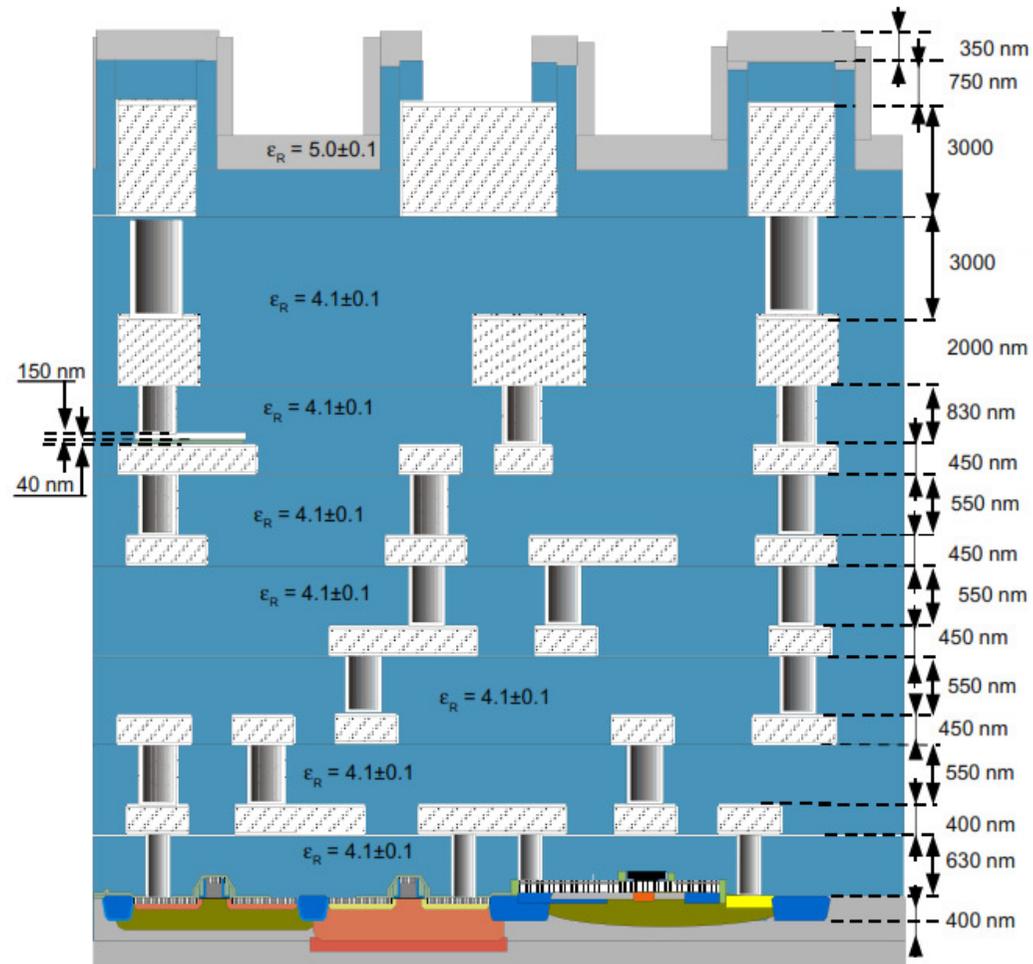
Technology: Devices

0.13 μ m SiGe BiCMOS technology of IHP SG13

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

Technology: Backend

Five / seven metal layers available



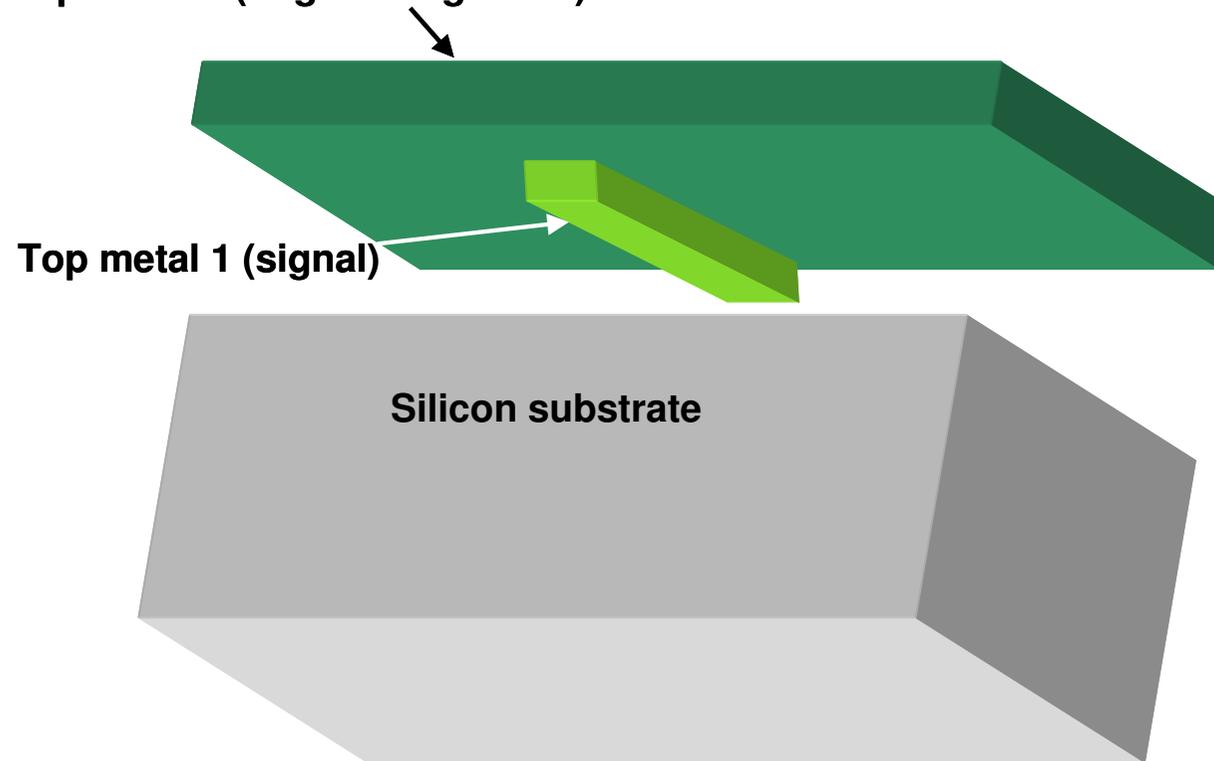
Transmission Lines: Possible structures

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

Transmission Line Construction in LNA

Top metal 2 (large-area ground)



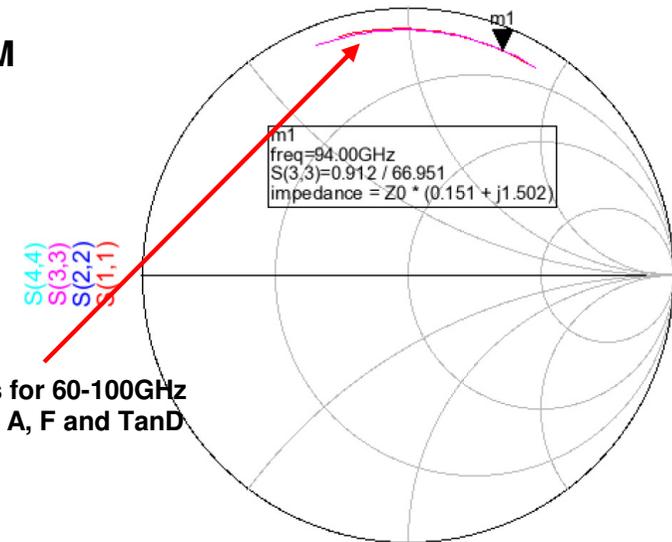
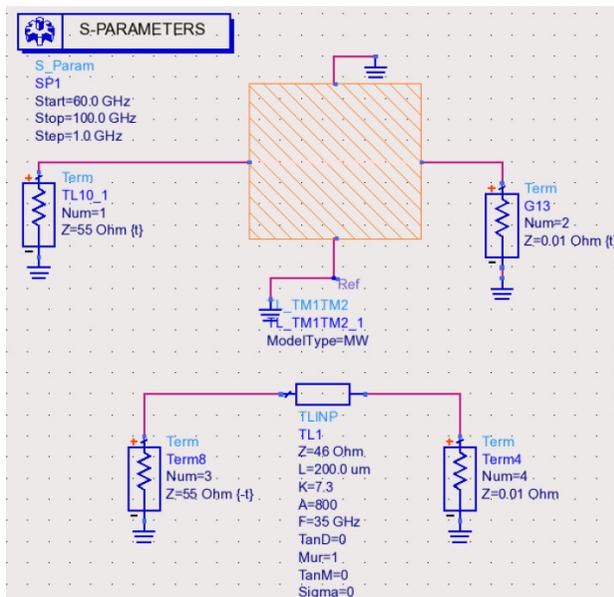
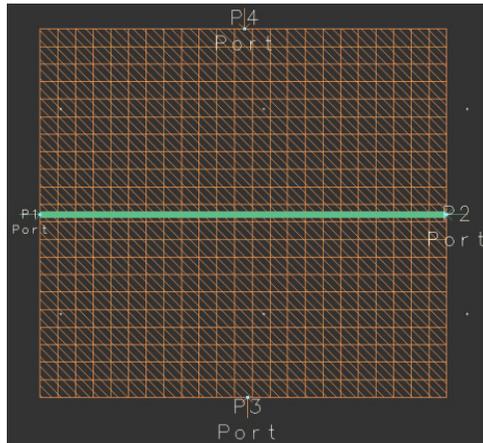
Top metal 1 (signal)

Silicon substrate

Modeling Transmission Line

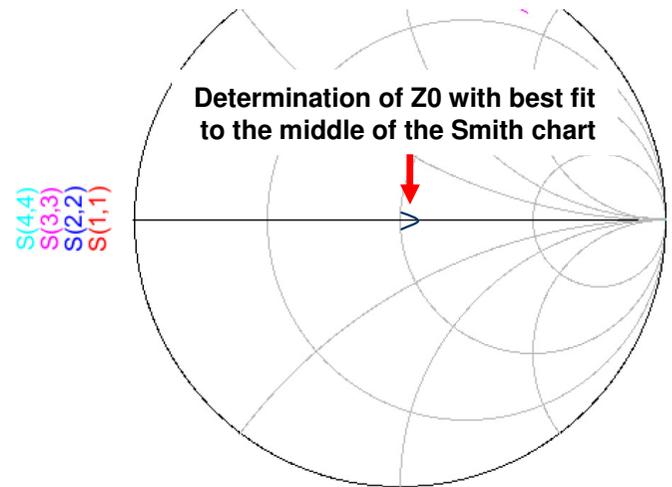
Planar 3D-simulation of the transmission line using MOMENTUM

Line length: 200 μ m, Frequency: 60GHz-140GHz



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

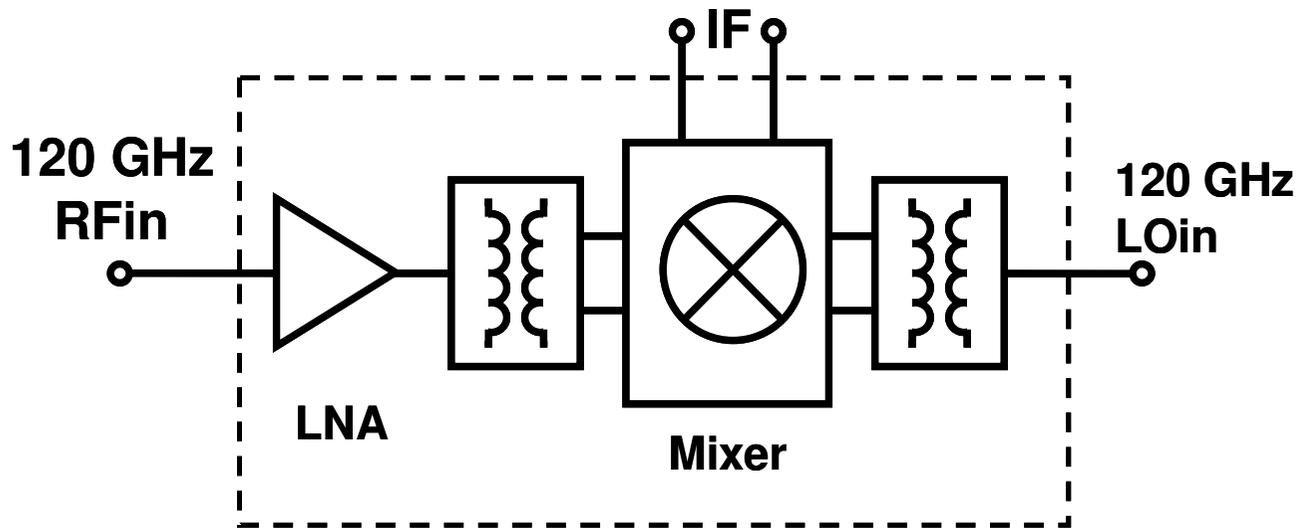
freq (60.00GHz to 100.0GHz)



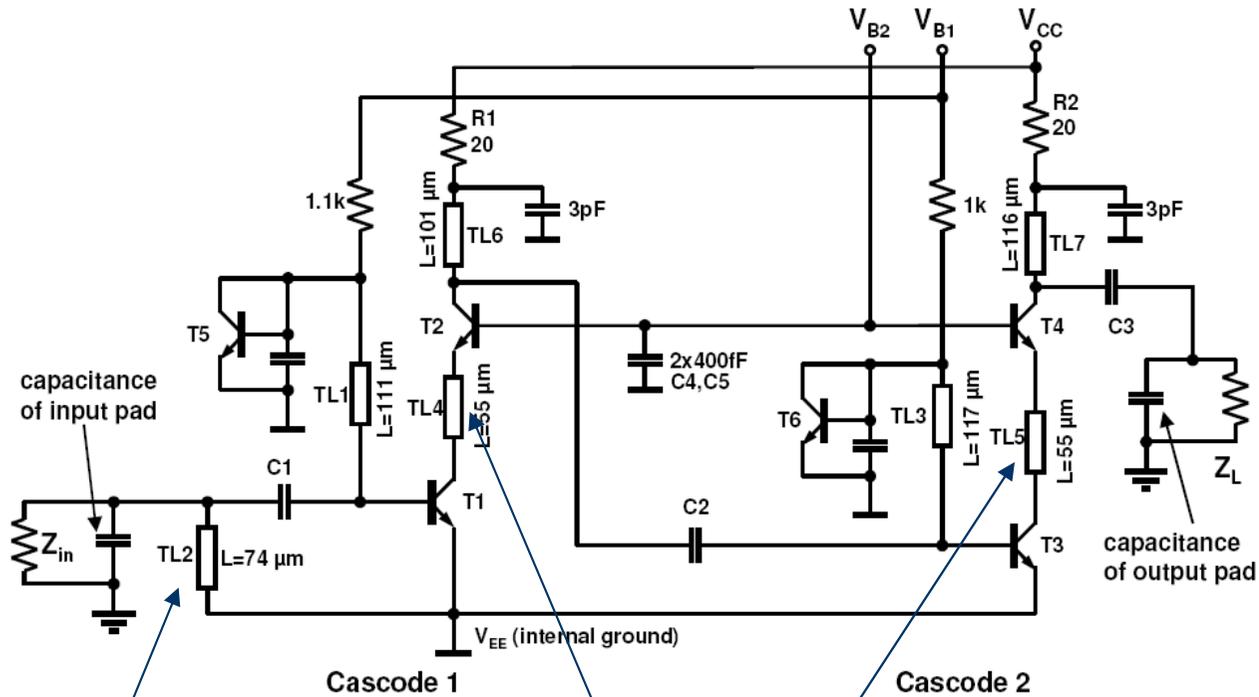
Determination of Z0 with best fit
to the middle of the Smith chart

freq (60.00GHz to 100.0GHz)

Circuit Design: 120GHz Frontend.



Circuit Design of LNA

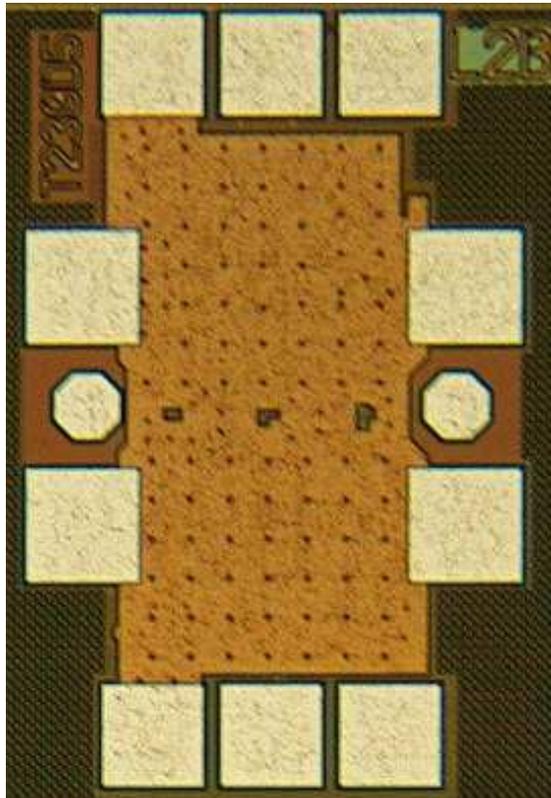


Input matching incl. ESD protection

improved matching between CE and CB stage

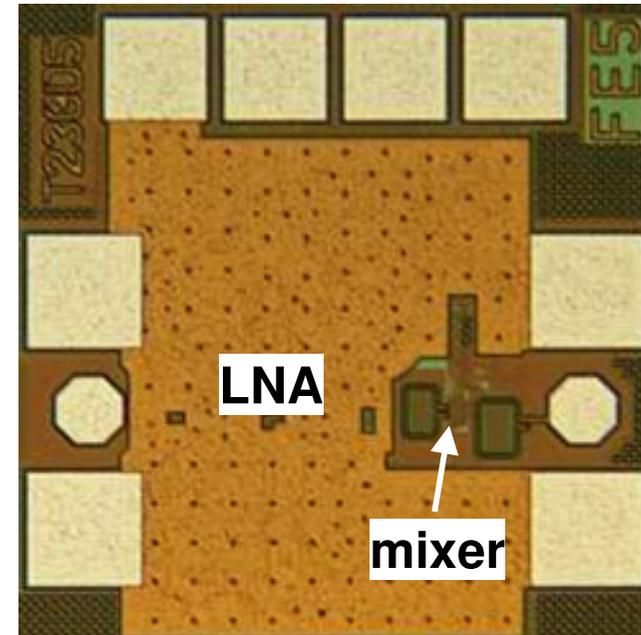
LNA and Frontend Layouts

Chip photo of the LNA test-structure



0.45 x 0.65 mm²

Chip photo of the 120 GHz frontend

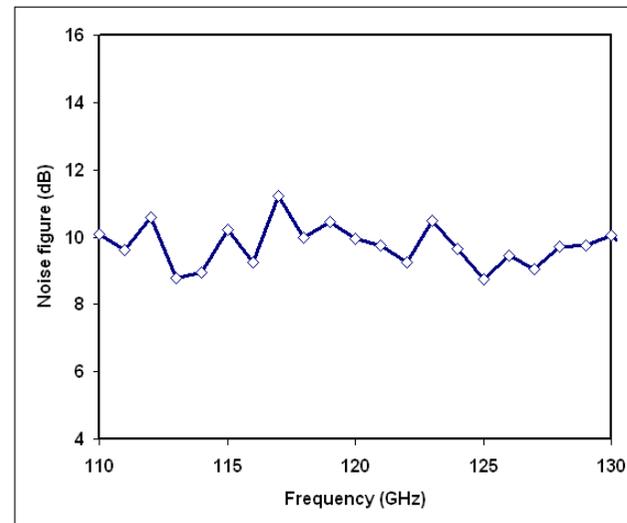
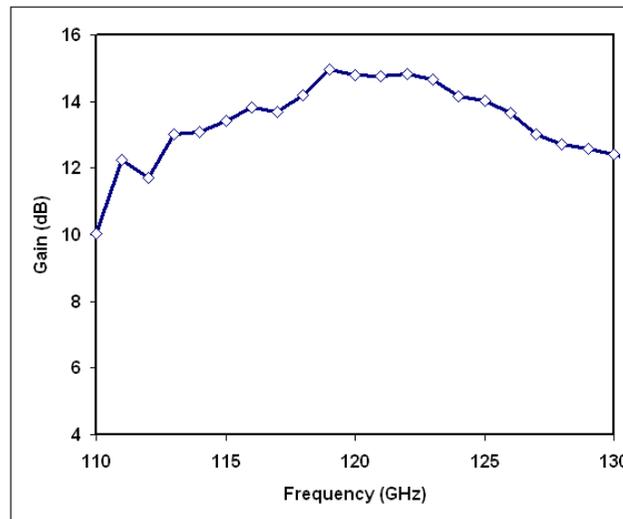


0.55 x 0.60 mm²

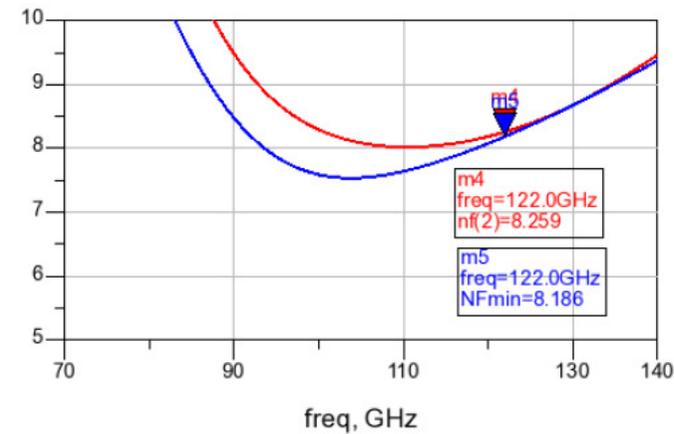
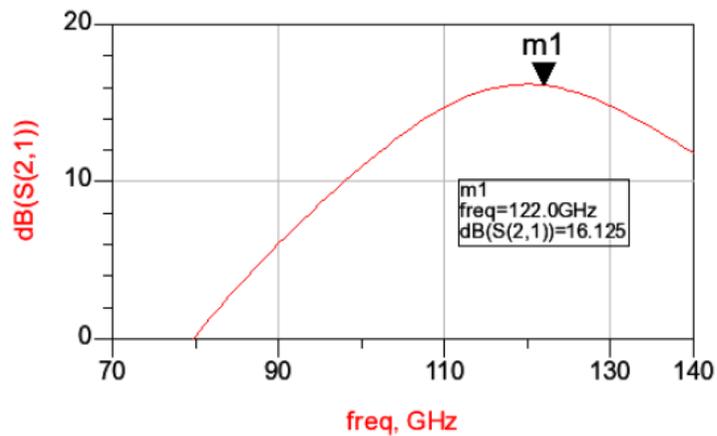
LNA Measurement Results

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

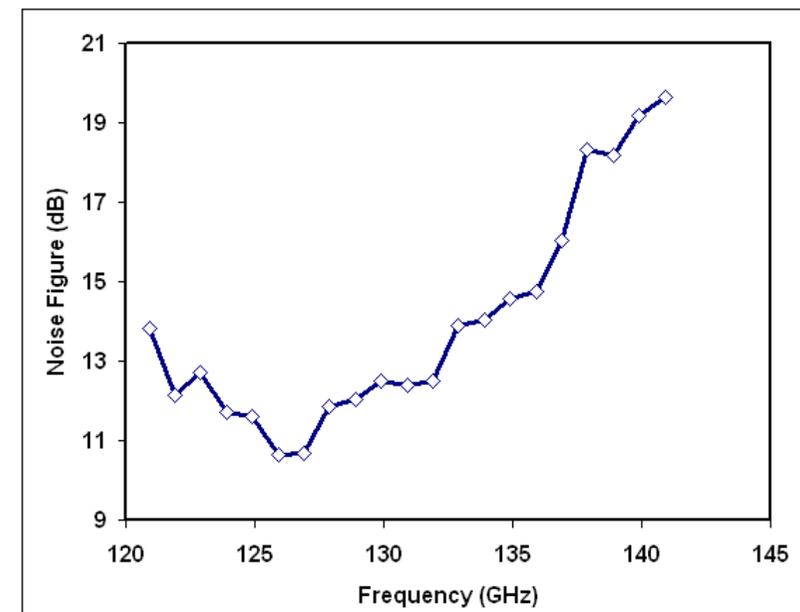
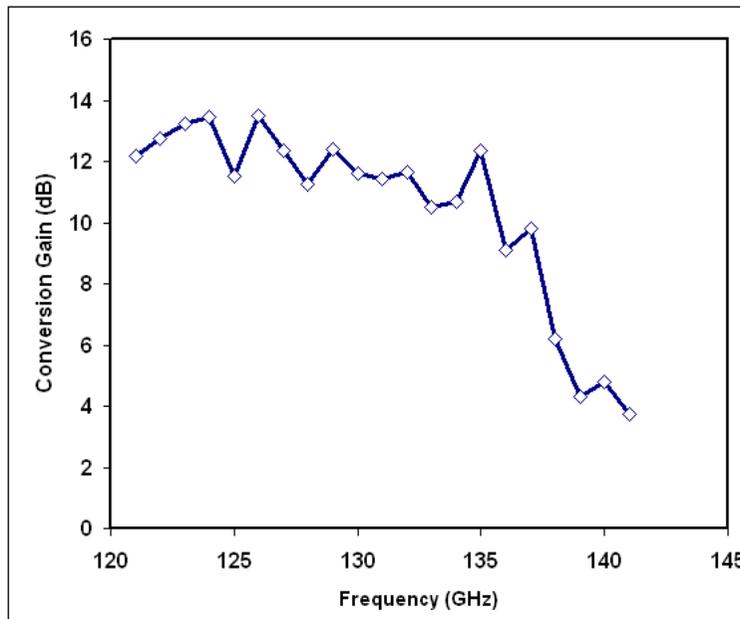


simulated



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!