A SiGe BiCMOS LNA for mm-Wave Applications

Christo Janse van Rensburg

Saurabh Sinha

Microelectronics & Electronics Group
University of Pretoria, South Africa

Monday, 19 October 2009

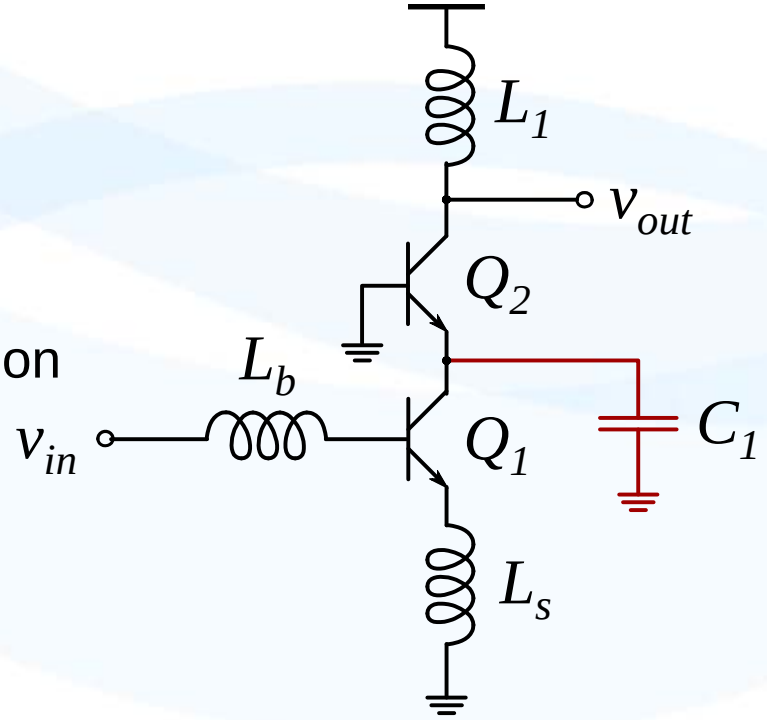
UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

E E C E

Departement Elektriese, Elektroniese & Rekenaar-Ingenieurswese
Department of Electrical, Electronic & Computer Engineering
Kgoro ya Merero ya Mohlagase, Elektroniki & Bointšinere bja Khomphutha

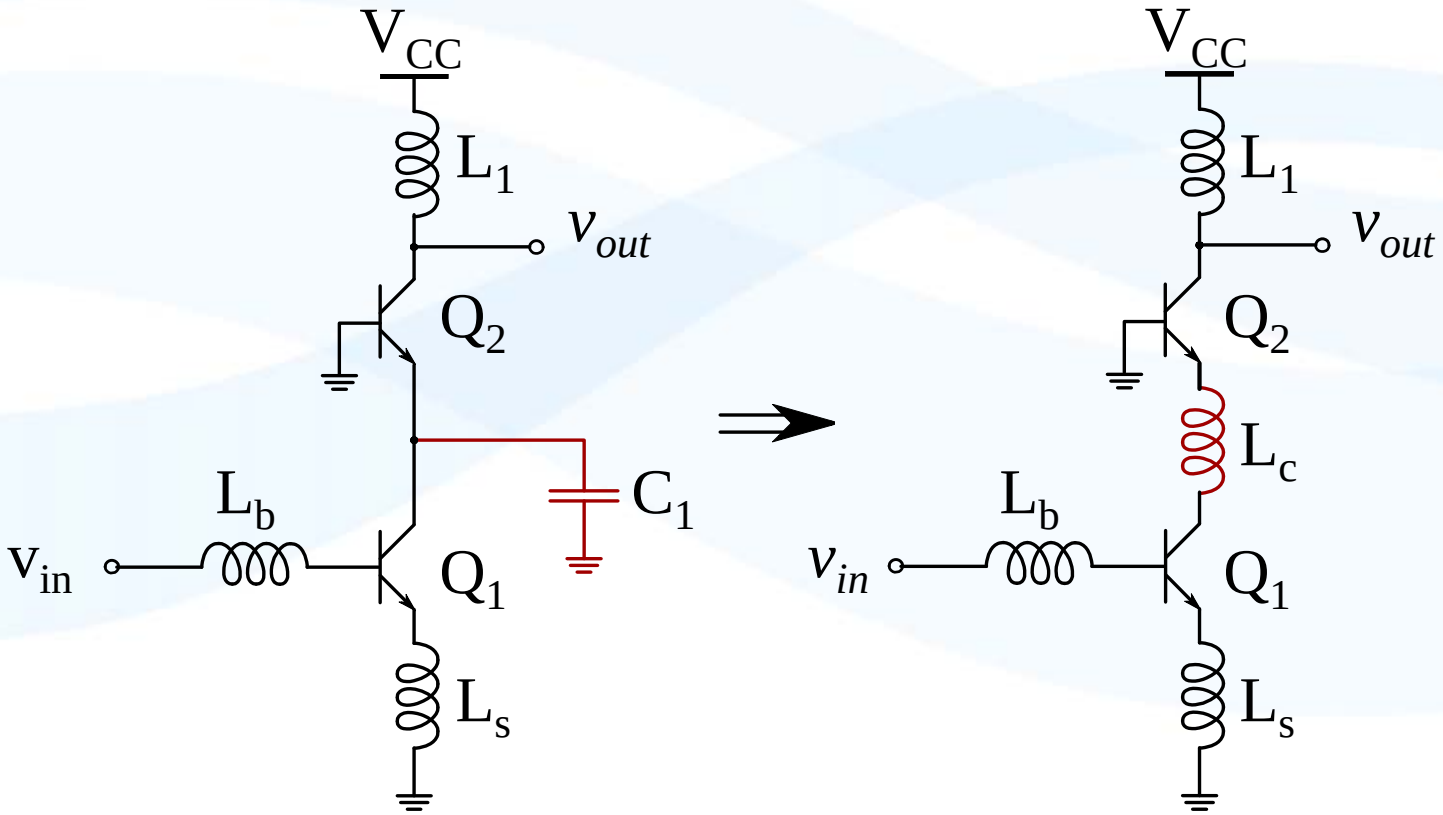
Introduction (1)

- Substrate losses particularly problematic at mm-Wave frequencies
  - Substrate conductivity
  - High frequency capacitive effects
- Performance of the cascode configuration vanishes at high frequency
  - Shunts the AC current to ground
  - Reduces gain
  - Output stage increases noise



Introduction (2)

- A possible solution:

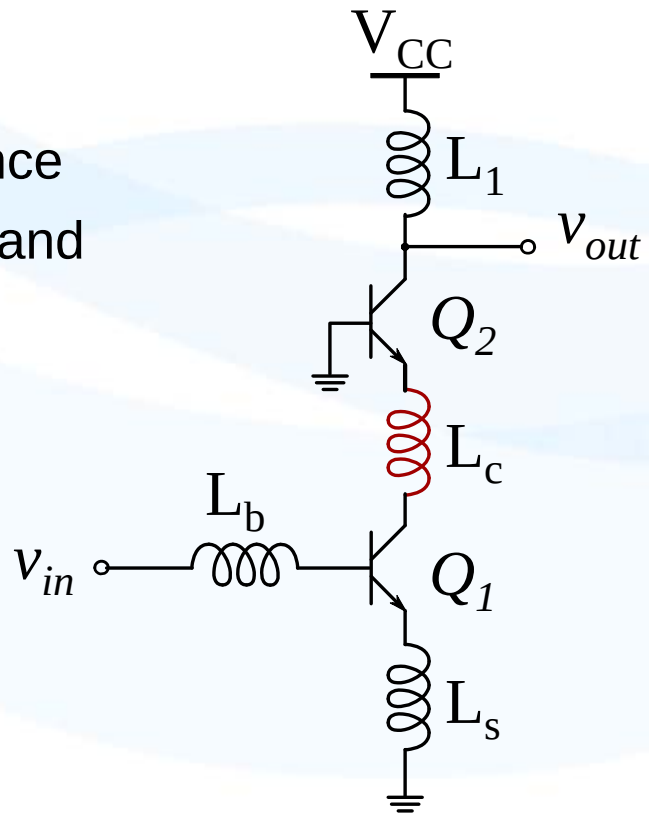


Introduction (3)

Research problem formulation:

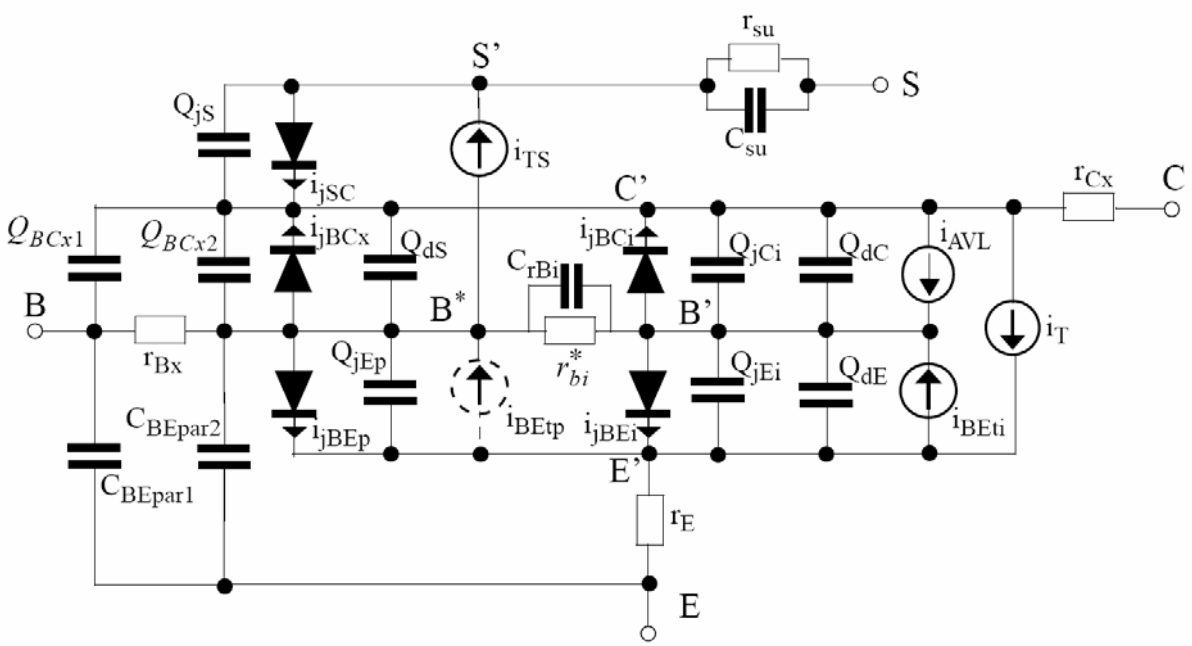
Negative impact of poor inductor performance

- Inductors L_b and L_s are part of a narrowband matching network
  - Low *Q* degrades noise figure
  - Noise figure degraded by 10 % [1]
- Inductor L_c fails to cancel the parasitic capacitance



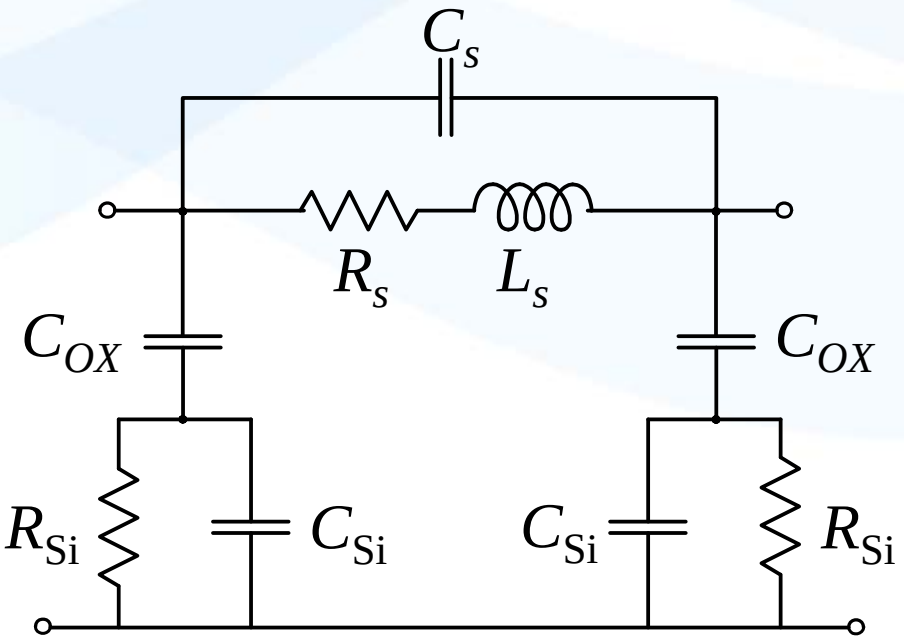
Substrate effects (1)

- HICUM
  - Substrate effects in transistors
  - Modelled as a simple RC network



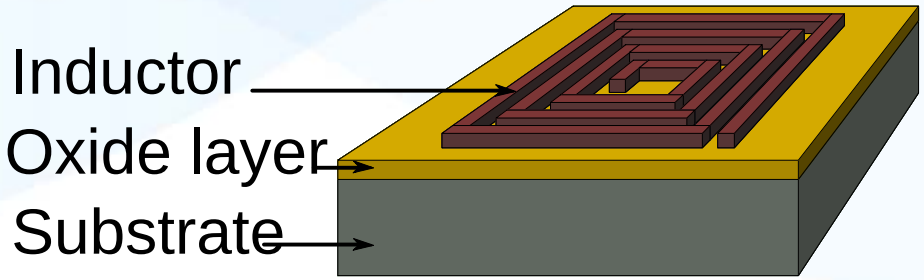
Substrate effects (2)

- Inductors
  - Also modelled as a RC network
  - Substrate coupling reduces the *Q*-factor and f_{sr}
  - Electric field penetrates the substrate causing severe energy loss



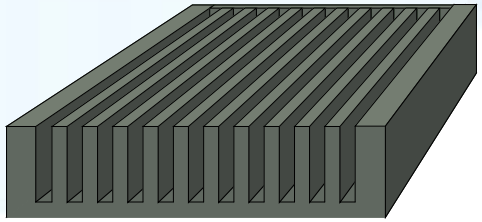
Inductors for mm-Wave applications (1)

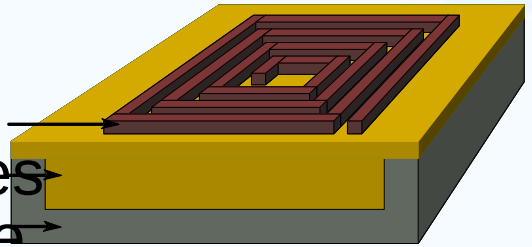
- Spiral inductors / transmission lines
  - On the Silicon substrate
  - Substrate losses becomes severe
  - Degrades Q and f_{sr}
  - Several techniques to improve inductor performance



Inductors for mm-Wave applications (2)

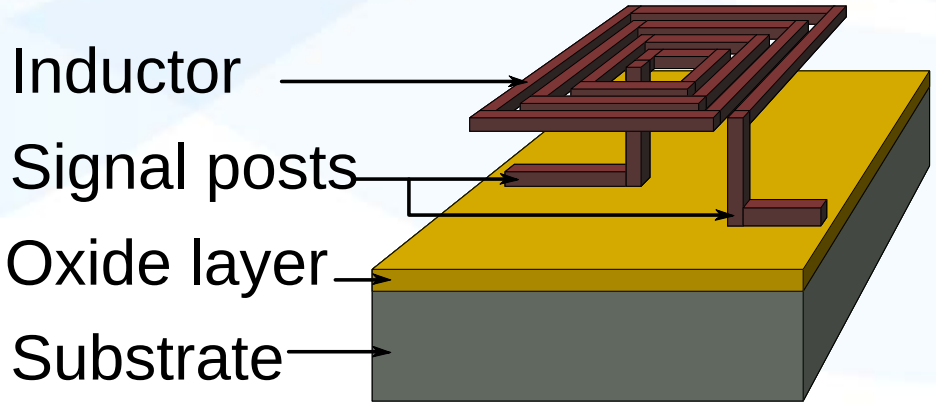
- MEMS technology
- Substrate trenches / bulk micromachining
  - Create thick trenches in the Silicon substrate
  - Oxidation process creates a thick oxide layer
  - Improves inductor – substrate isolation
  - Improves Q and f_{sr}





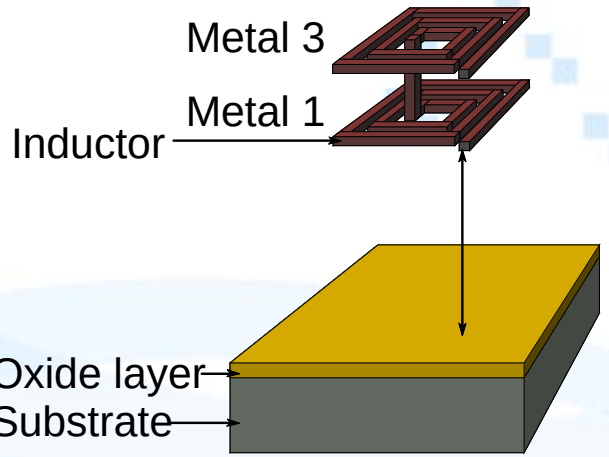
Inductors for mm-Wave applications (3)

- MEMS technology
  - Fabrication further away from the substrate
  - Tuneable
  - Structural support
  - Applications in the RF range



Inductors for mm-Wave applications (4)

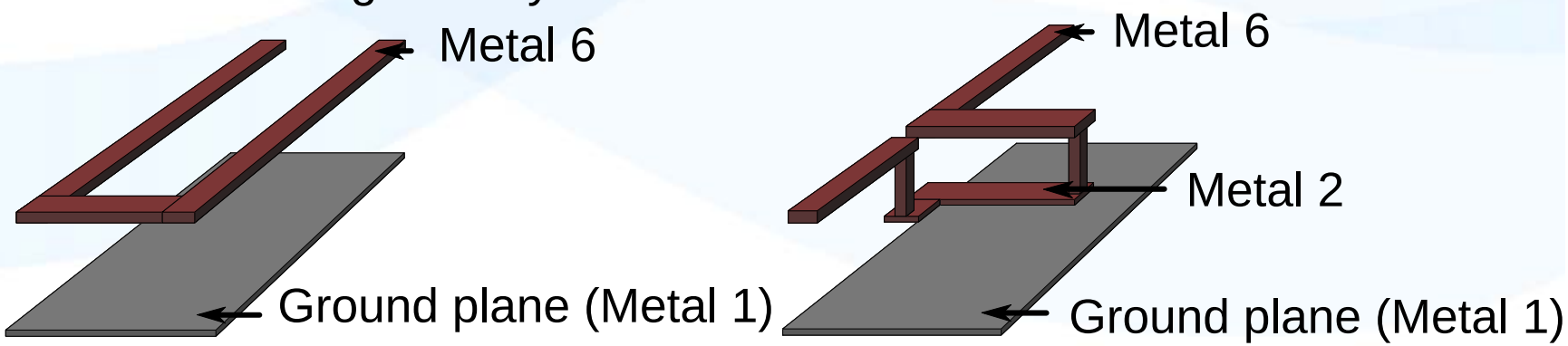
- Metal layers
  - Inductor footprint is minimized by reducing the diameter and line-width
  - Fabricate using the metal layers to further reduce substrate coupling
  - Stacked inductors further reduce footprint area
  - Ground plane beneath the inductor simplifies inductor model



	Inductance	Area	Q	#Metal layer(s)	Type
[2]	140 pH	29 µm × 29 µm	>20 above 40 GHz	9	Planar
[3]	420 pH	30 µm × 30 µm	13 @ 40 GHz	5,6	Stacked
[3]	420 pH	21 µm × 21 µm	>15 above 50 GHz	4,5,6	Stacked
[4]	380 pH	26 µm × 26 µm	11 @ 40 GHz	5,6 with ground plane	Stacked

Inductors for mm-Wave applications (5)

- Transmission lines can also provide an equivalent on-chip inductance
- Prominent advantage is using a ground plane
- Line length can be prohibitively long
  - Folded transmission line geometry
  - Series-stub geometry



Conclusion

- LNA performance is sensitive to inductor performance
- HICUM is able to accurately determine transistor losses
- Substrate losses reduces the Q and f_{sr} of the inductor
- Various techniques and methods exists to increase inductor performance
- Preferred inductor solution whether spiral inductors or transmission lines

References

[1] S.P. Voinigescu *et al.*, “A Scalable High-Frequency Noise Model for Bipolar Transistors with Application to Optimal Transistor Sizing for Low-Noise Amplifier Design”, *IEEE Journal of Solid-State Circuits*, vol. 32, no. 9, pp.1430-1439, September 1997.

[2] T. Yao *et al.*, “Algorithmic Design of CMOS LNAs and Pas for 60-GHz Radio”, *IEEE Journal of Solid-State Circuits*, vol. 42, no. 5, pp. 1044-1057, May 2007.

[3] T.O. Dickson *et al.*, “30-100-GHz Inductors and Transformers for Millimeter-Wave (Bi)CMOS Integrated Circuits”, *IEEE Trans. on Microw. Theory Tech.*, vol. 53, no. 1, pp. 123-133, January 2005.

[4] M.Q. Gordon, T. Yao and S.P. Voinigescu, “65-GHz Receiver in SiGe BiCMOS Using Monolithic Inductors and Transformers”, *Digest: Silicon Monolithic Integrated Circuits in RF Syst.*, San Diego, pp.265-268, 18-20 January 2006.

Feedback/Questions

Christo Janse van Rensburg
Carl & Emily Fuchs Institute for Microelectronics
Dept.: Electrical, Electronic & Computer Engineering
University of Pretoria
Pretoria 0002
SOUTH AFRICA

E-mail: ChristoJVR@ieee.org

Acknowledgements

The authors would like to thank the Federal Ministry for Education and Research (BMBF), Germany and National Research Foundation (NRF), South Africa for sponsoring travel, subsistence and related costs towards “exchange” stay in Germany.