Practical experiences from realistic inductor and capacitor models in circuit synthesis

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- About Optenni Lab and circuit synthesis
- Ideal vs. realistic component models
- Observations from vendor supplied component models
- Effects of layout

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Optenni Lab

- Worldwide leading solution for circuit synthesis for antenna and RF applications
- Filling a gap between existing electromagnetic and circuit simulators
  - Optimization of both antenna and circuit quantities
  - Design automation for eliminating repetitive design tasks
- Used by leading wireless companies worldwide
  - 7 out of the 10 largest technology companies in the world are our customers

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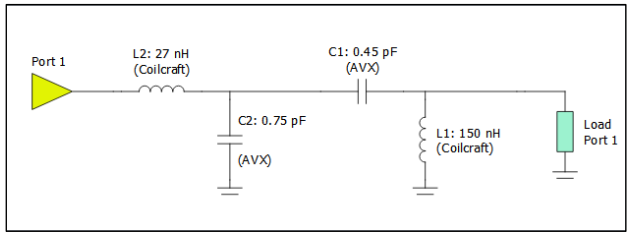
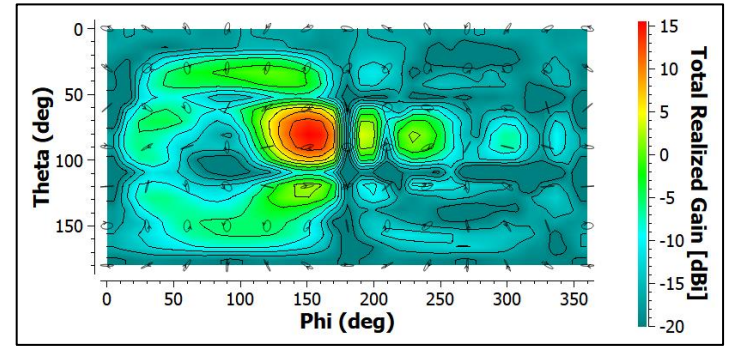
Optenni Lab Circuit Synthesis Software for Antenna Optimization

- Linear circuit simulator which understands antenna quantities and has built-in circuit synthesis capabilities
- Links to electromagnetic simulators and network analyzers
- Speeds up the antenna and RF design flow
- Improves the performance of wireless devices -> energy saving



Lumped matching synthesis

Microstrip matching synthesis



Array assessment and Optimization

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Ideal vs. realistic component models

Ideal

- No losses
- No parasitic reactances
- All mathematical values allowed
- Minimization of return loss maximizes power transfer

Realistic

- Losses included
- Parasitic reactances included
- Only a discrete set of values available
- Minimization of return loss does not necessarily maximize power transfer
- Limits for current and voltage

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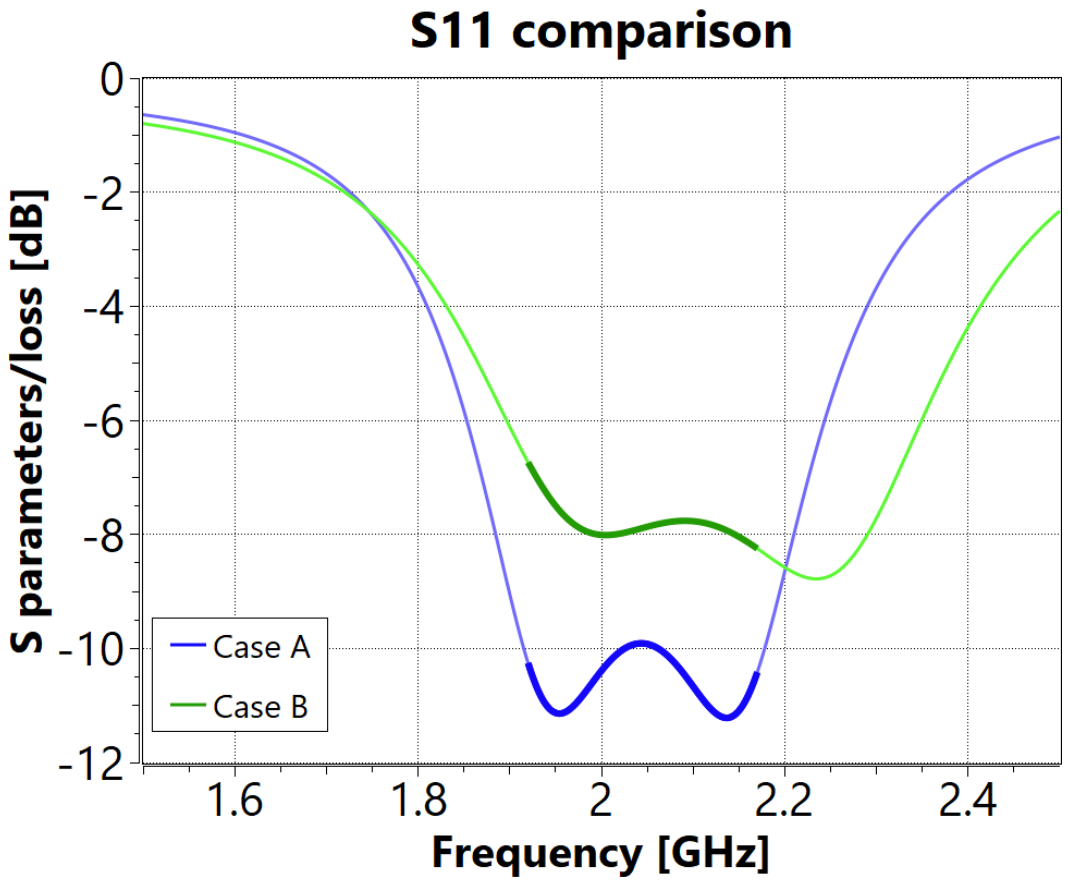
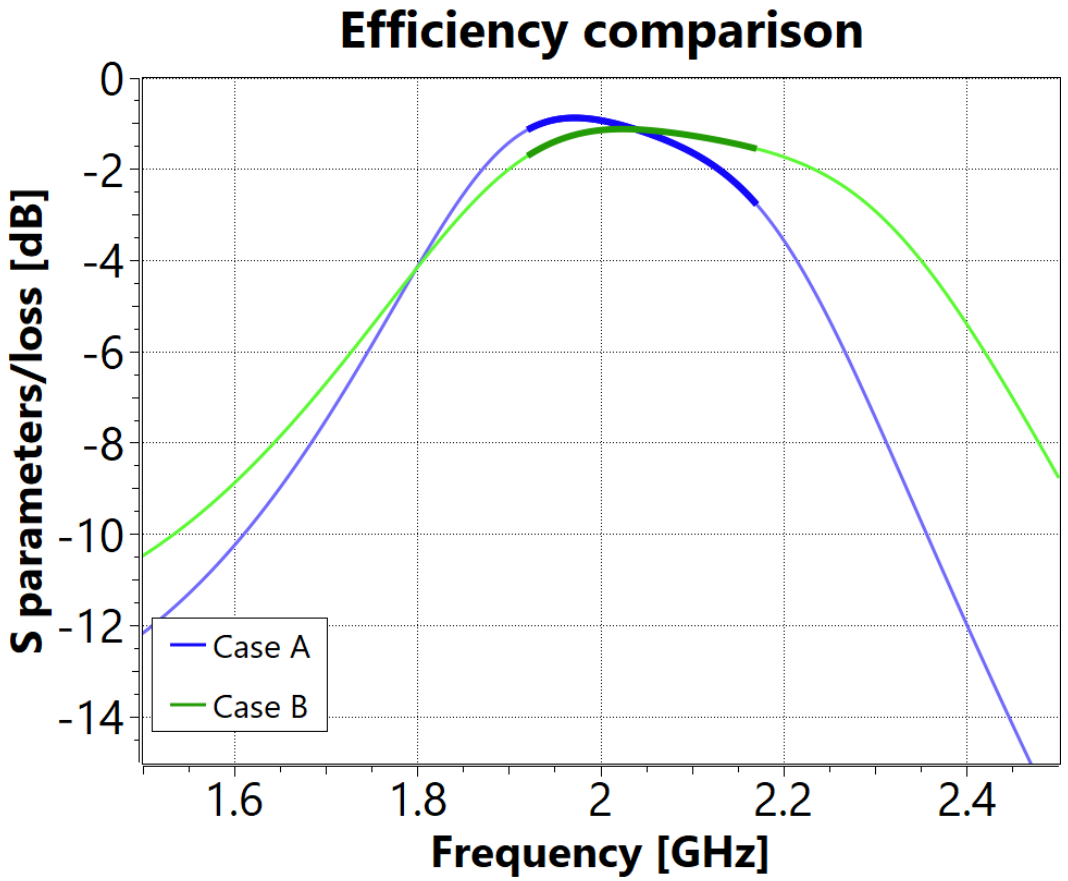
S11 vs. efficiency

Both cases use same Murata components for matching
Why is Case B better in efficiency but worse in matching?





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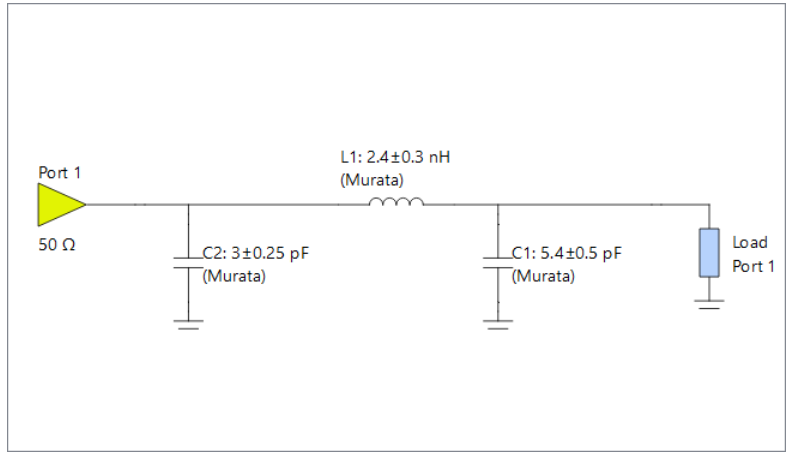
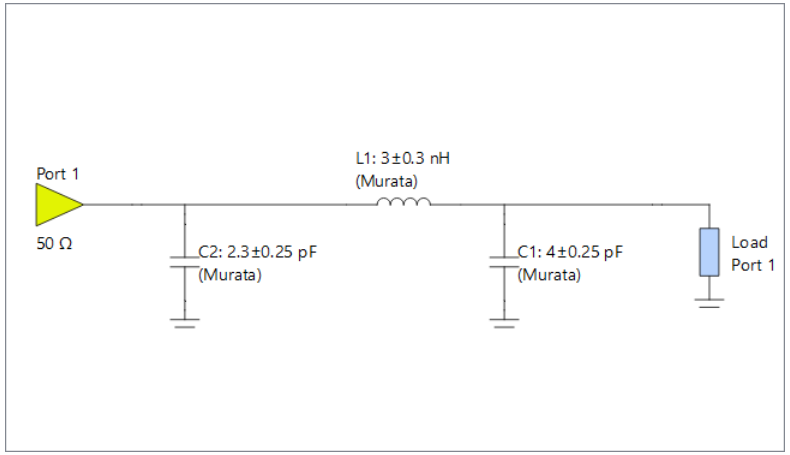
Power balance plot at 2.17 GHz

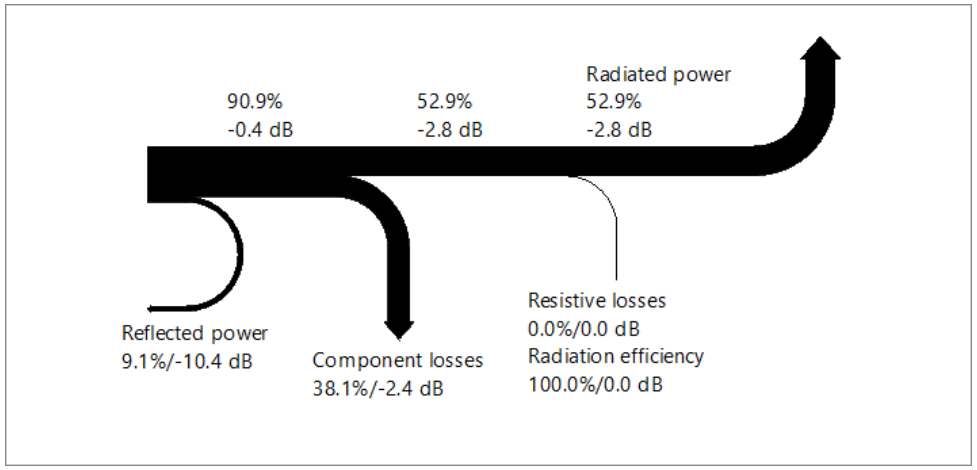
Case A

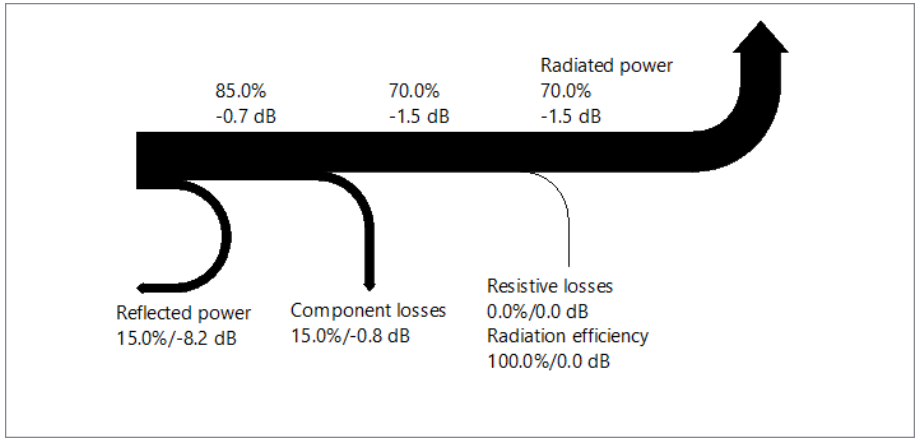
Case A has a lossy resonance which eats up a lot of power

Case B









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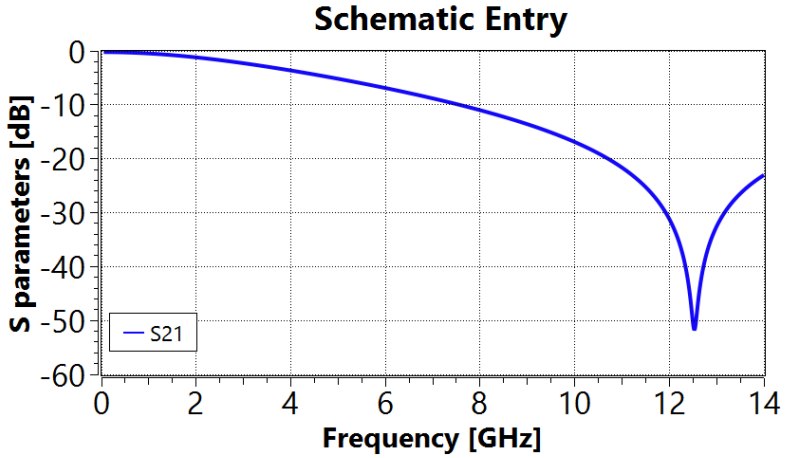
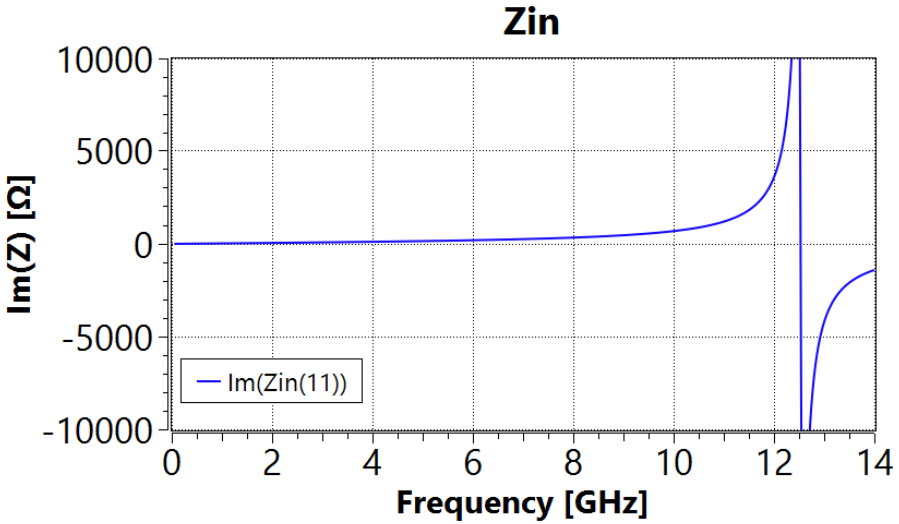
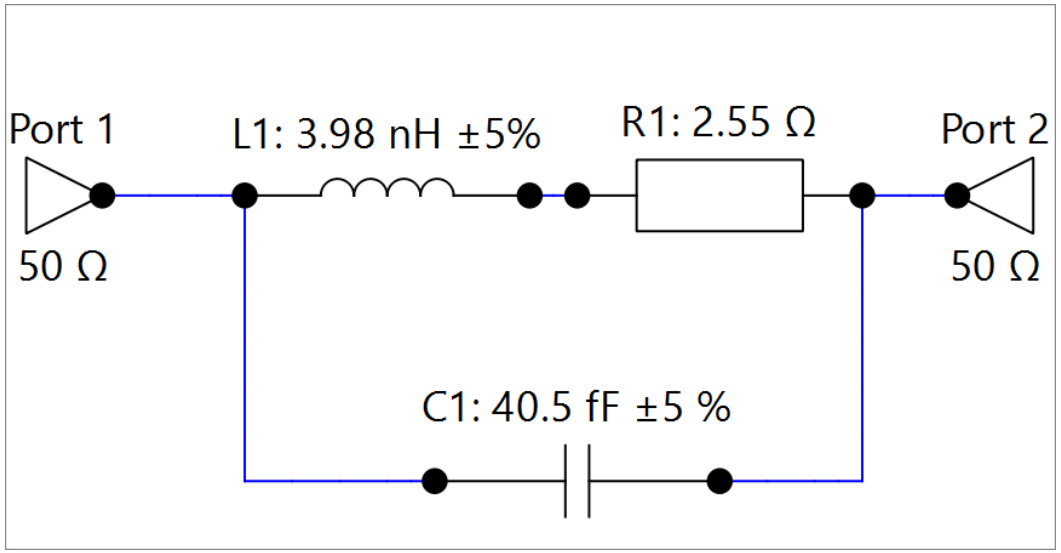
Equivalent circuits and self resonance frequency: inductors





Equivalent circuit fitted to a 4 nH inductor from Coilcraft



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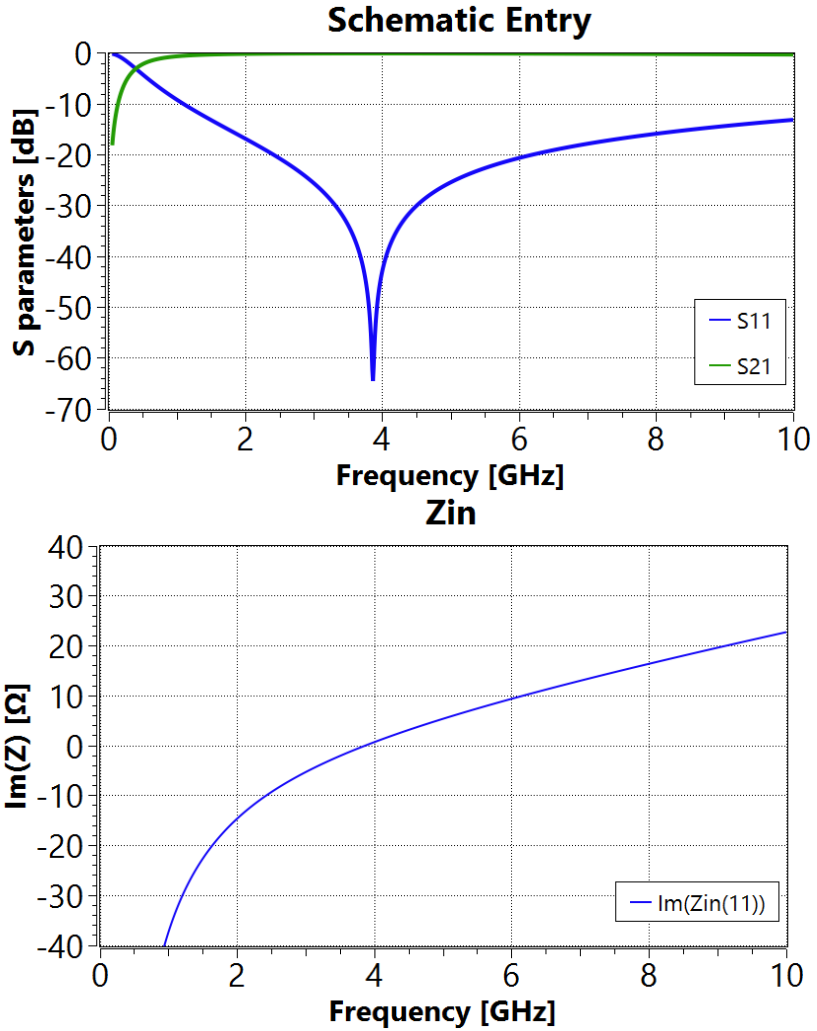
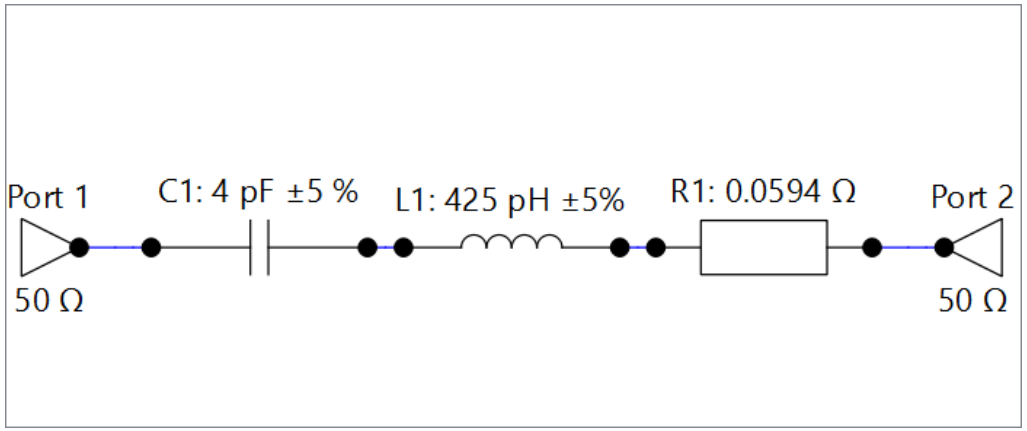
Equivalent circuits and self resonance frequency: capacitors



Equivalent circuit fitted to a 4 pF capacitor from AVX



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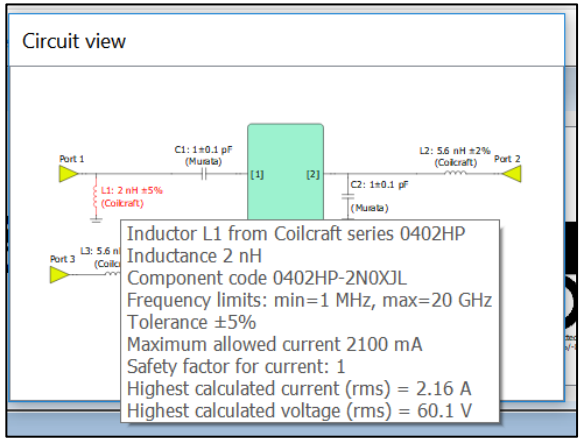
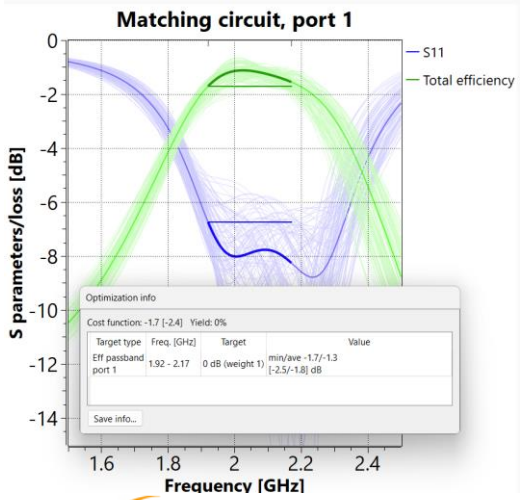
Optenni Lab component library

- Contains over 7000 inductor and over 15000 capacitor models from leading manufacturers (AVX, Coilcraft, Johanson, Murata, TDK, Taiyo Yuden) and some switch models from Infineon
- Information about product codes, tolerances and maximum current/voltage included





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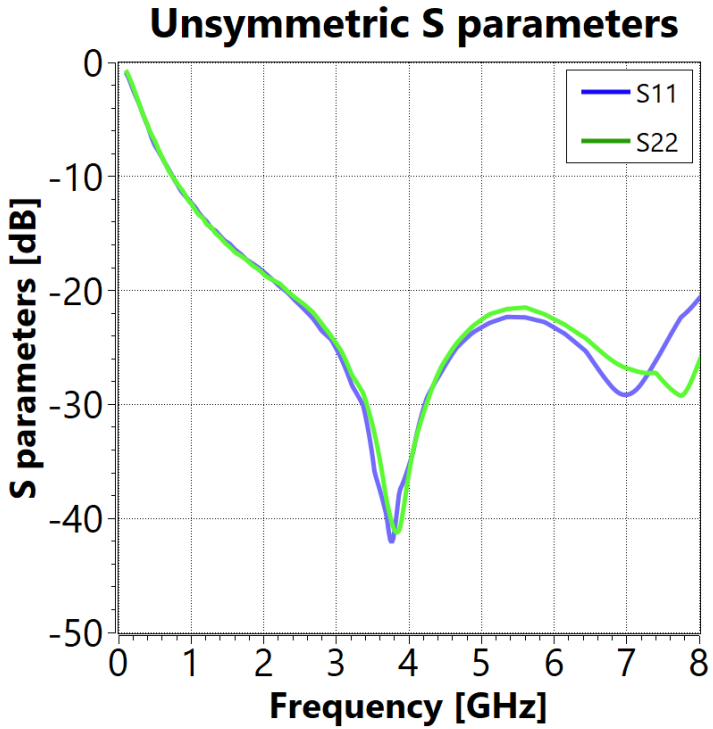
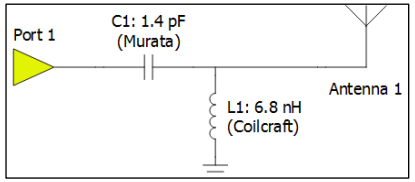
Observations about the component models

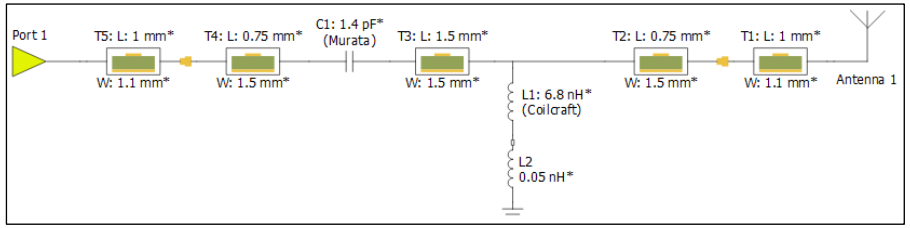
- Most component models are based on simulations, as the data is so smooth
- Some measurement based models have artefacts due to poor de-embedding (unsymmetric response, ripple, non-passivity)
- Most component models do not include the component pads, i.e. there is no ground coupling
- If there is a ground coupling, the layout needs to be modelled carefully

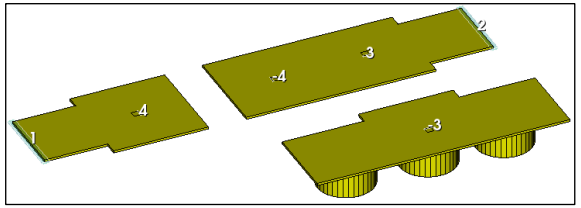


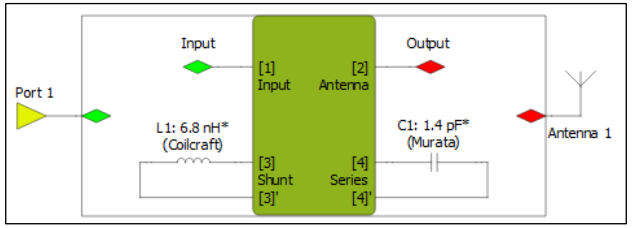
Layout modeling in Optenni Lab

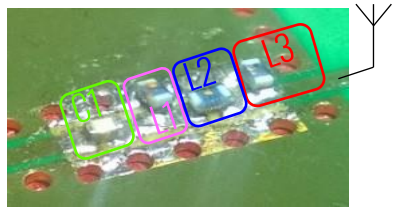
- When frequency increases, the parasitic effects arising from the PCB layout become more and more important
- Optenni Lab supports microstrip based simple layout models and full, multiport EM-models of PCB layout

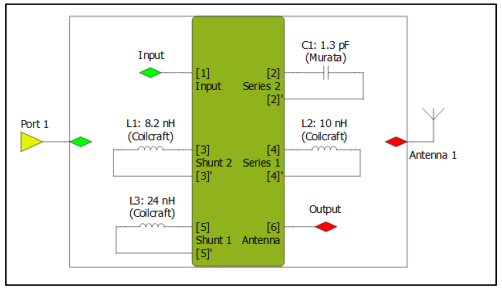












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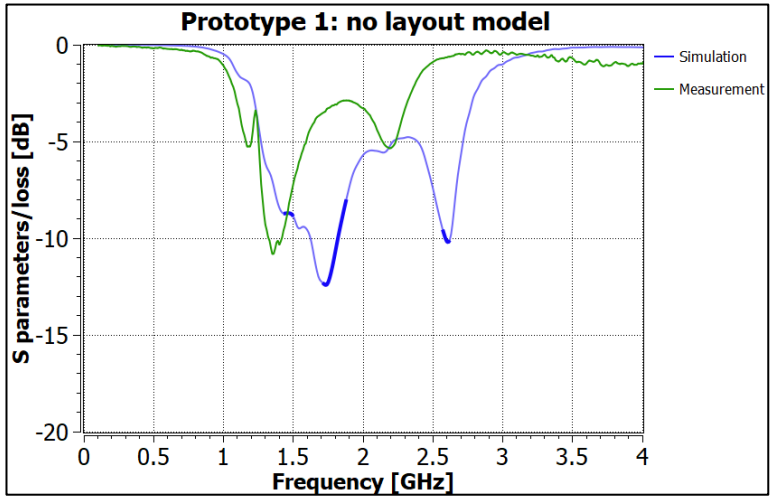
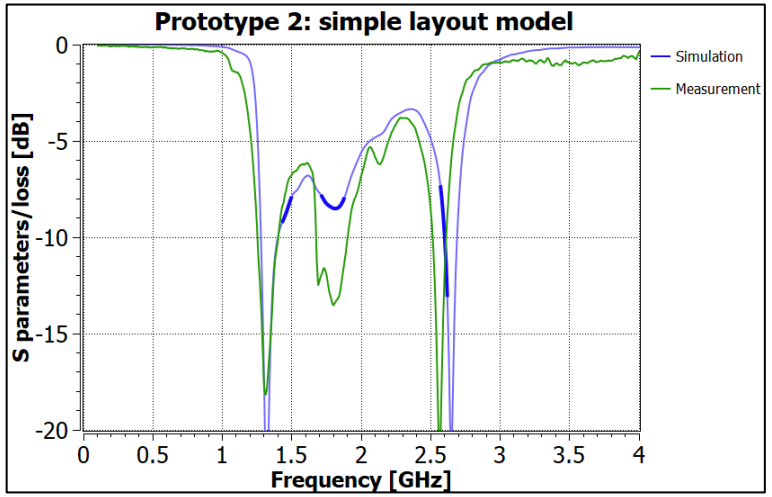
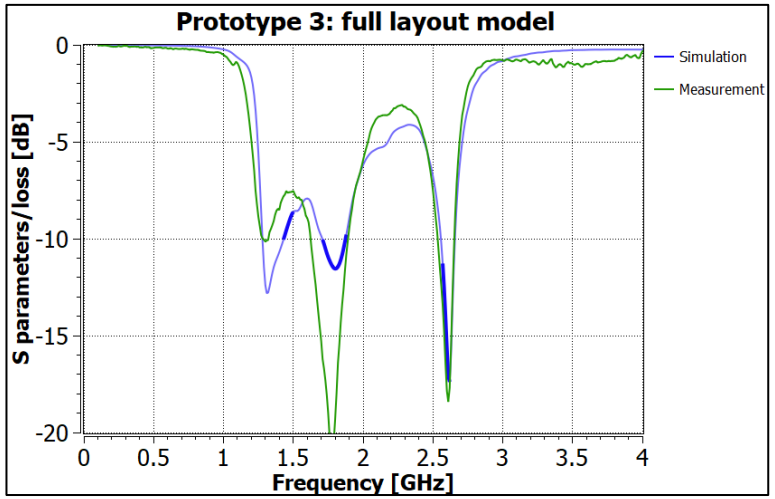
Test cases for layout modeling

- Three prototypes were simulated and measured







Prototypes by Jaakko Juntunen, Optenni Ltd

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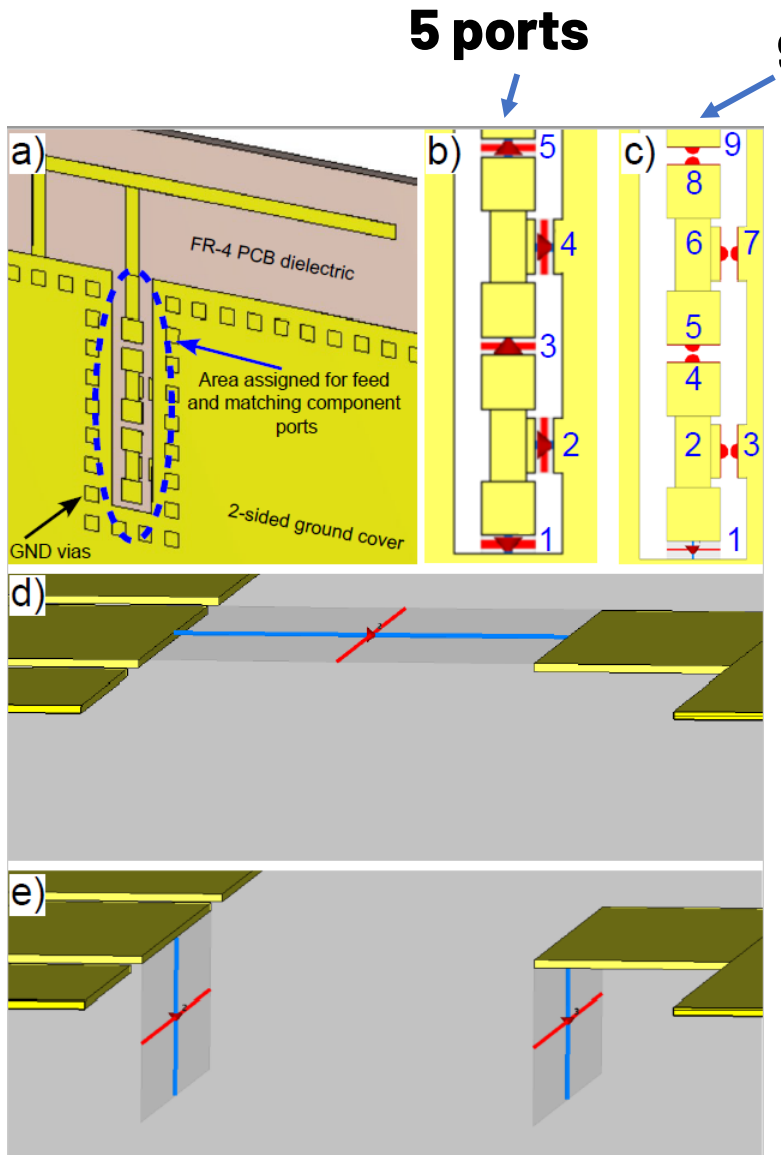
Layout modeling: ports

- Example: 4 matching components
  - 2 in series, 2 in shunt
- Layout is analyzed in an EM simulator, components placed in Optenni Lab
- Two modeling approaches:
  - No reference to ground (**5-port** model)
  - Pair of ports referring to ground (**9-port** model)



Simulation by Sergei Kosulnikov, Optenni Ltd

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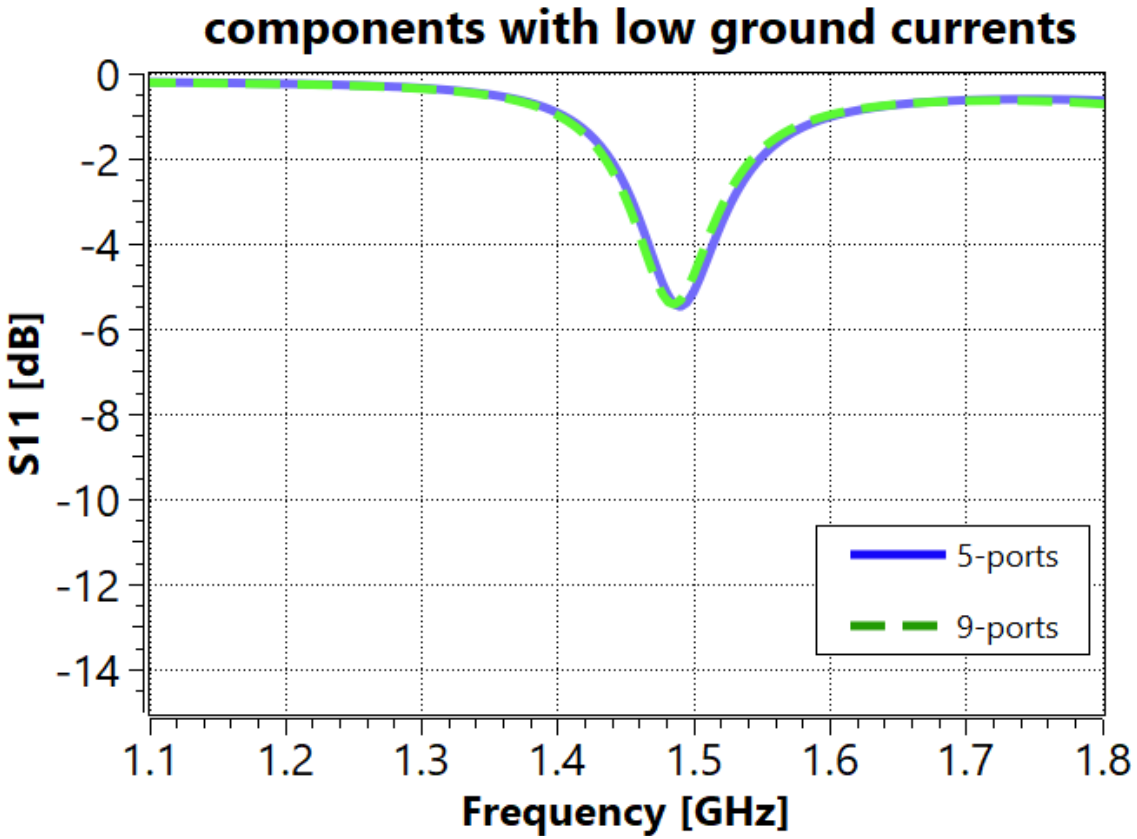
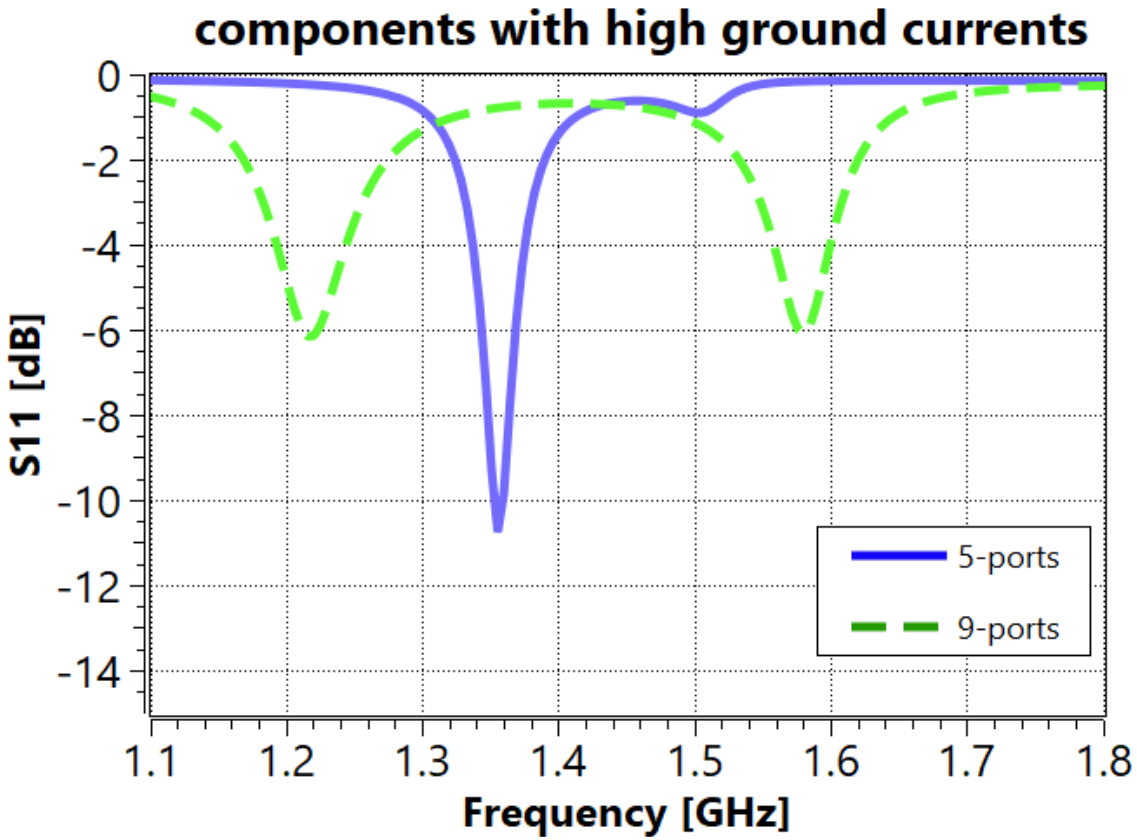
Numerical experiments: results





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Conclusions

- When designing matching circuits, it is important to use realistic component models so that losses and parasitic reactances are taken into account
- The quality of vendor-provided component models varies
- The PCB layout has a significant effect on the matching, especially at higher frequencies
- If there is significant ground coupling, the components should be placed between two ports referring to ground

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