Simberian
Electromagnetic Solutions

Minimization of Reflection from AC Coupling Capacitors

Simberian, Inc.
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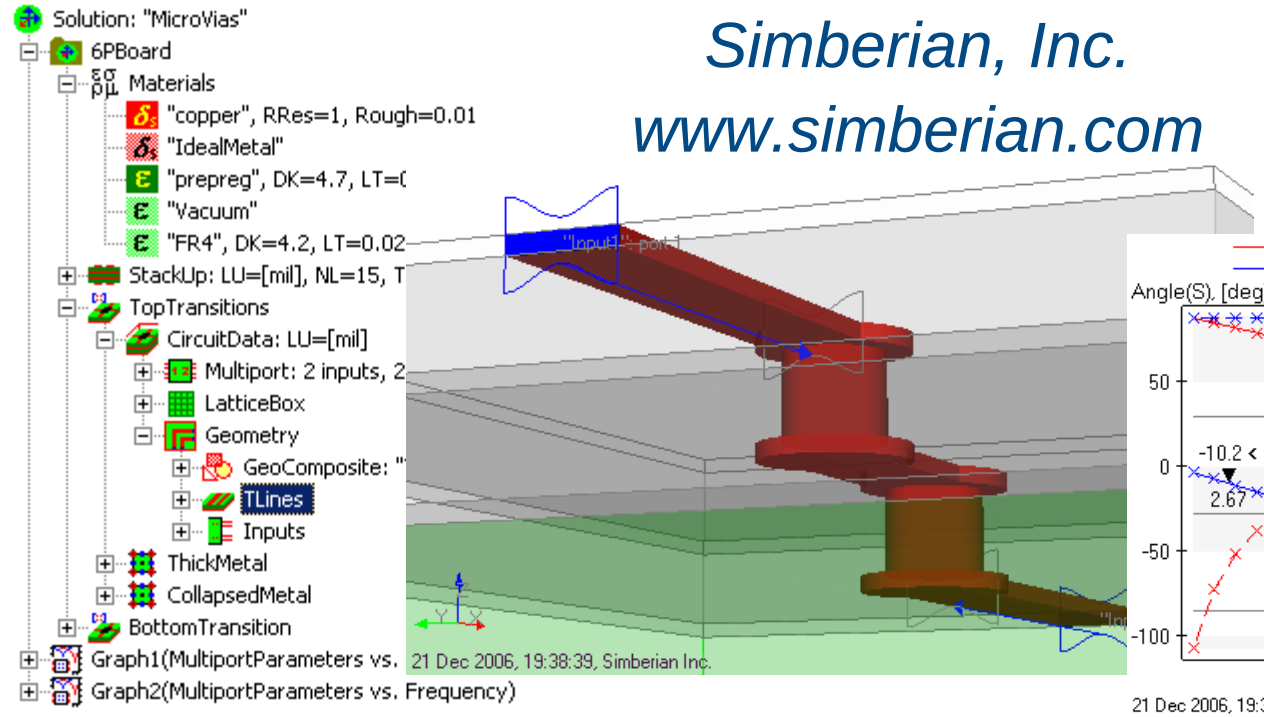

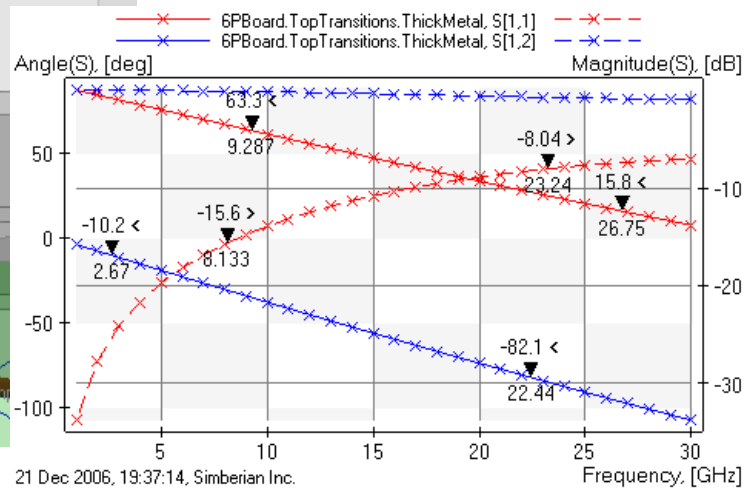

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Overview

- Introduction
- De-compositional analysis of a channel with AC decoupling capacitors
- Building models for AC capacitor mounting structures for a single-ended channel
- Minimization of reflection from the mounting structures with cut-outs in the reference plane
- Analysis of simple channels with AC coupling capacitors
- Conclusion

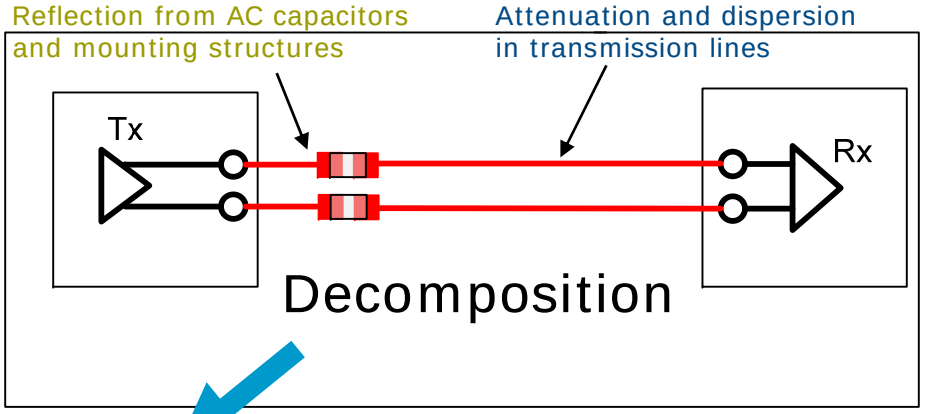
Introduction

- Serial multi-gigabit data channels usually have capacitors connected in series in micro-strip lines (AC coupling capacitors) to pass through the high-frequency signals content and to allow different DC supply for a driver and receiver at the same time
  - Mounting structures of such capacitor and capacitors themselves are discontinuities and reflection from them have to be minimized to improve signal quality
  - 3D electromagnetic analysis is required to estimate and to minimize the reflection from the AC coupling capacitors and mounting structures
- This example is follow-up to App Note #2008_02
  - Demonstrates how to minimize reflection from the AC coupling capacitors using cut-outs in the reference plane
  - Demonstrates how to build a system-level model of a simple channel with AC coupling capacitors within Simbeor environment
- Simbeor 2008 built on August 25th 2008 is used to generate the results

De-compositional analysis of a serial multi-gigabit channel with AC coupling capacitors

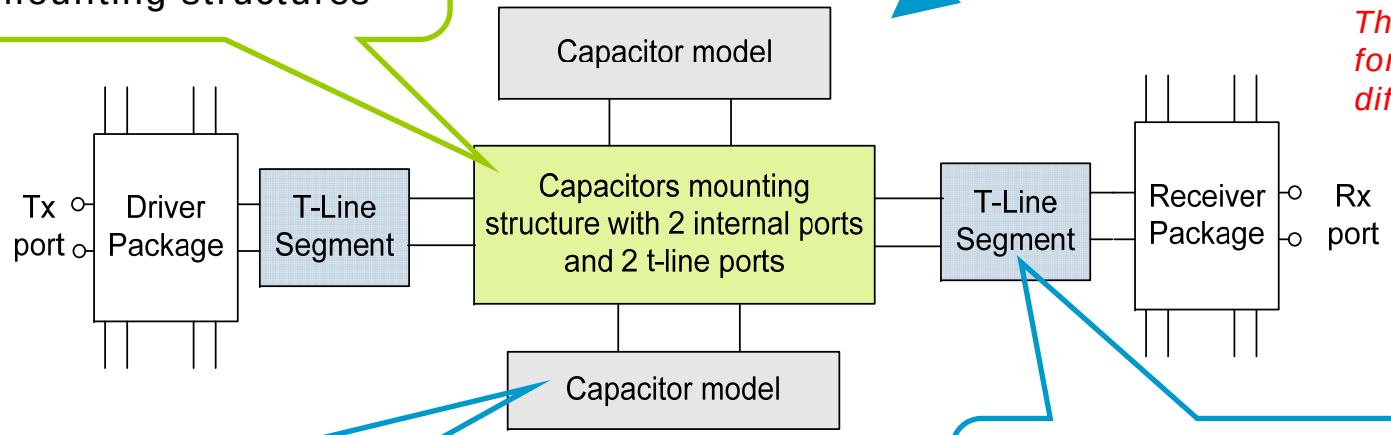
3-D full-wave electromagnetic analysis is required to generate models both for the mounting structure and transmission lines!

We will use Simbeor to do it.



Multiport S-parameter model for the capacitors mounting structures

The same approach for single and differential channels

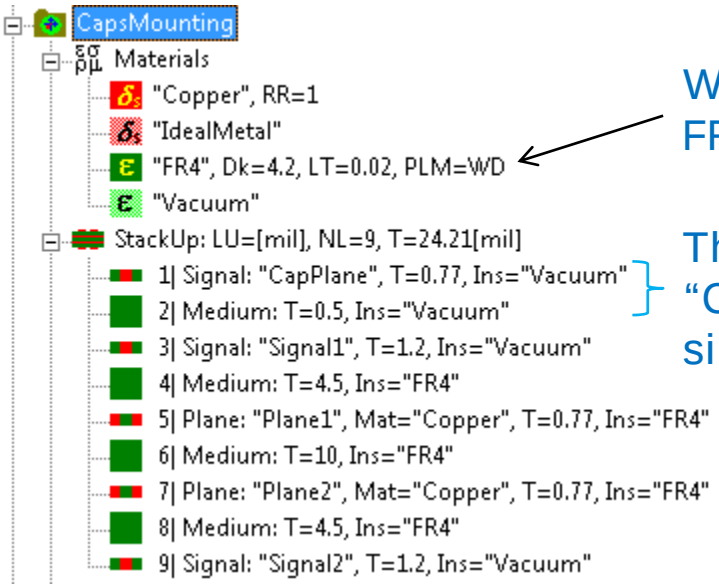


Capacitor model from a manufacturer (circuits or S-parameters)

W-element models for t-line segments defined with RLGC(f) p.u.l. tables

Materials and stack-up for analysis of the capacitors mounting structures

- Solution Simbeor Solutions/ PCB_MCM/ AC_CouplingCaps/ AC_CouplingCaps.esx created for this investigation
- Simple 4-layer stackup with two signal layers and two plane layers
- Stackup is extended to simulate connection of the capacitor slightly above the board surface



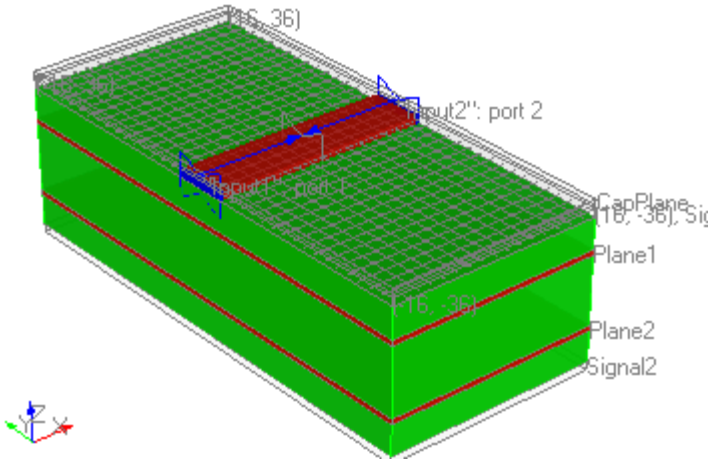
Wideband Debye model for FR-4 type dielectric

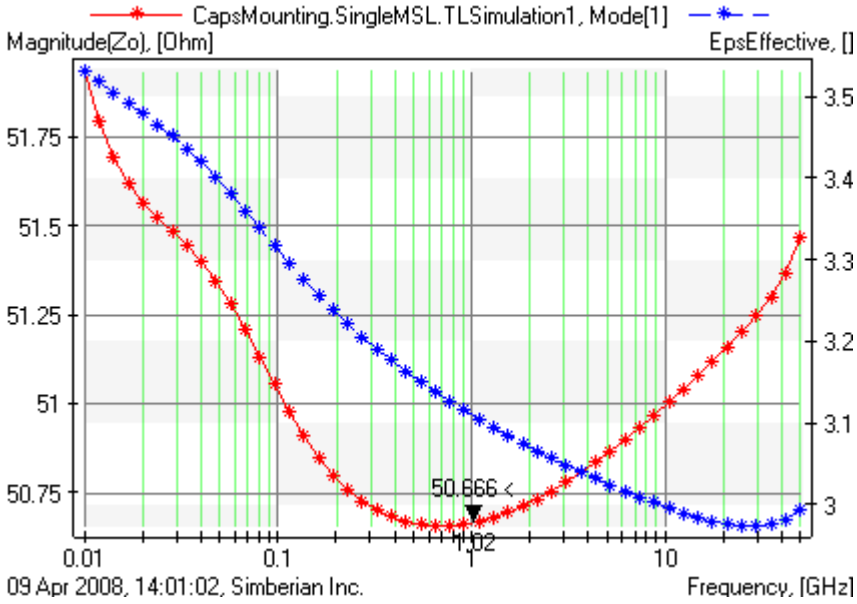
Thin layer of air and additional layer "CapPlane" of signal-type are added to simulate non-flat connection of the capacitors

Use Help > Tutorials > Tutorial 1 to learn how to build models for materials and stackup

Single-ended channel – transmission line (circuit SingleMSL)

- 8 mil wide strip on 4.5 mil substrate with Dk=4.2, LT=0.02 at 1 GHz and wideband Debye dielectric model

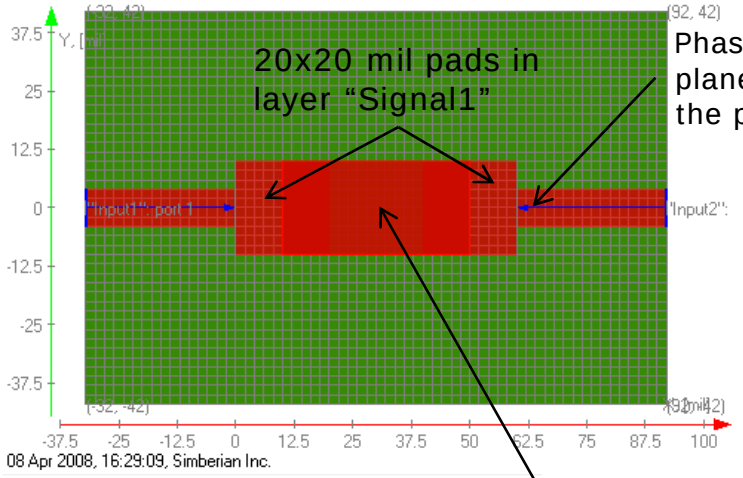


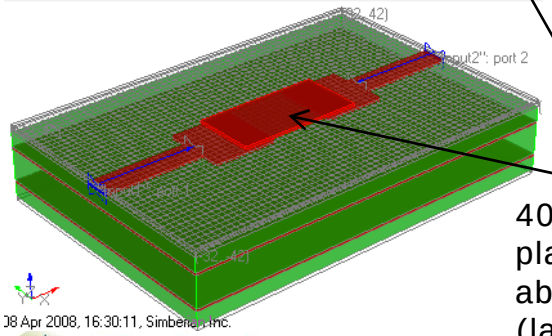


Use Help > Tutorials > Tutorial 2 to learn how to build broadband RLGC(f) models for transmission line

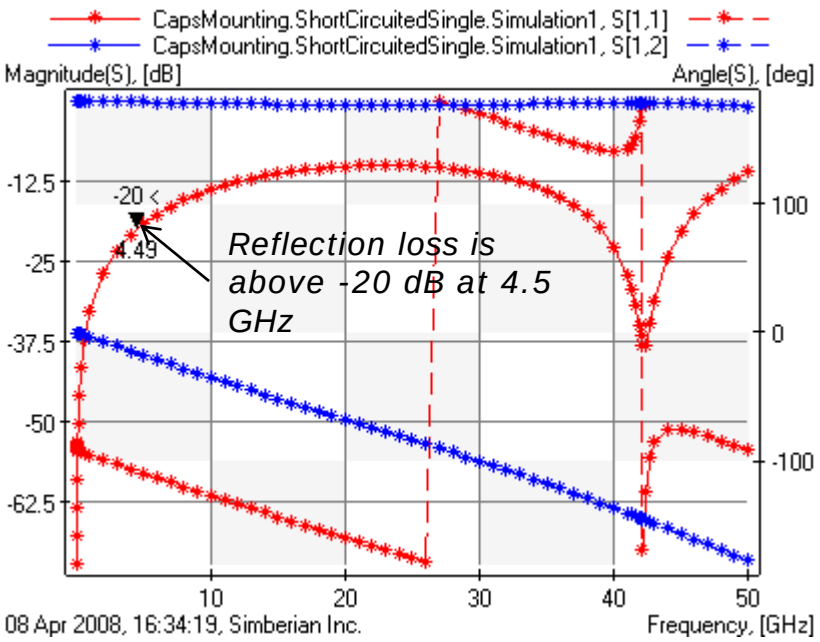
Short-circuit experiment with 0402 capacitor footprint (SCSingle)

- Capacitor in micro-strip line with 8 mil wide trace
- Allows us to estimate the minimal possible reflection
- May be used to do the through calibration of the internal ports



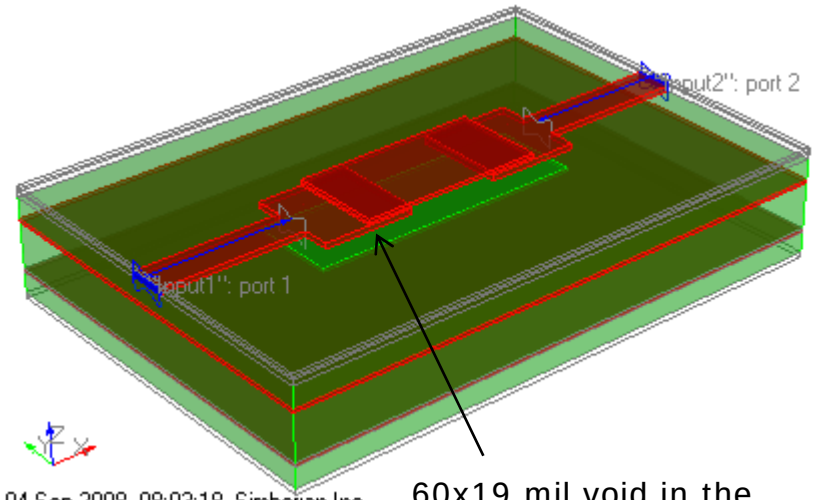


40x20 mil short-circuiting plate is slightly elevated above the board surface (layer “CapPlane”)

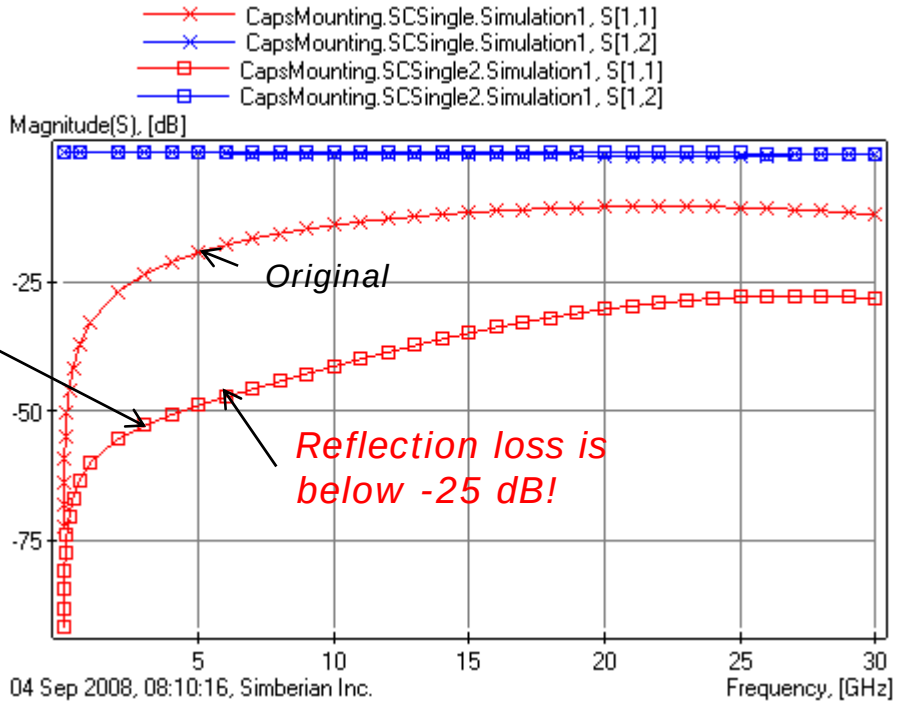


Short-circuit experiment with 0402 capacitor footprint with cut-out (SCSingle2)

- Cut-out 60 mil by 19 mil in the reference plane reduces the reflection loss

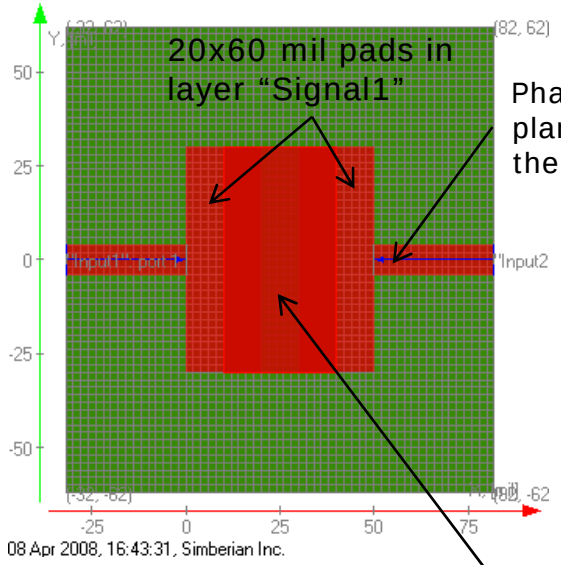


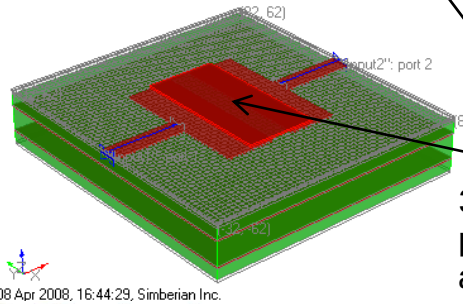
60x19 mil void in the reference plane below the capacitor mounting structure



Short-circuit experiment with 0603 capacitor footprint (SCSingle0603)

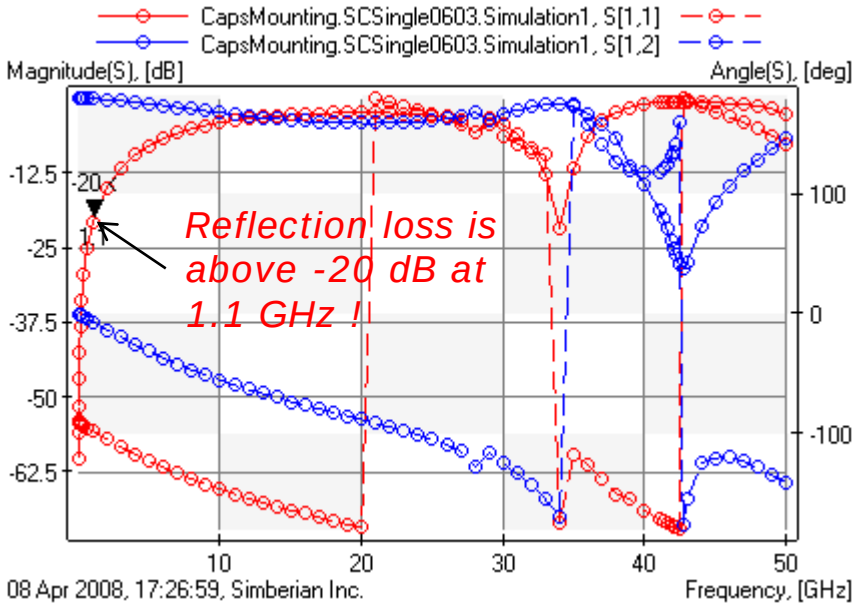
- The larger the footprint the larger the minimal possible reflection loss
- Impedance of the actual capacitor will make reflection worse





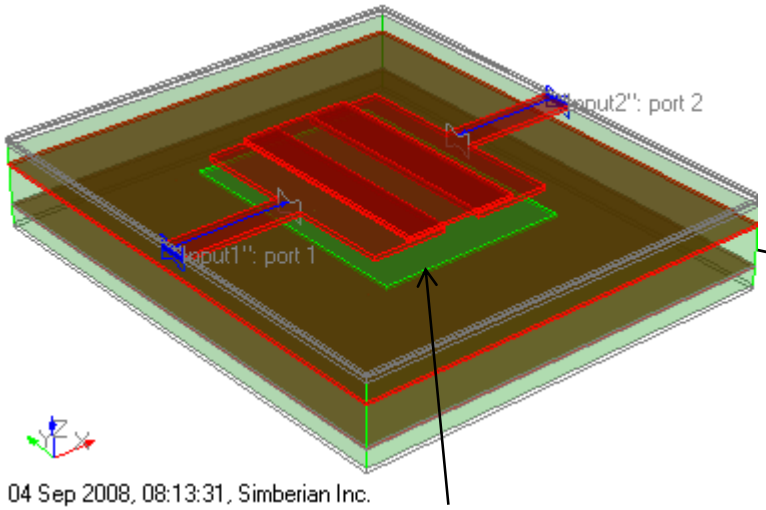
30x60 mil short-circuiting plate is slightly elevated above the board surface (layer “CapPlane”)

Simulation from 10 MHz to 50 GHz

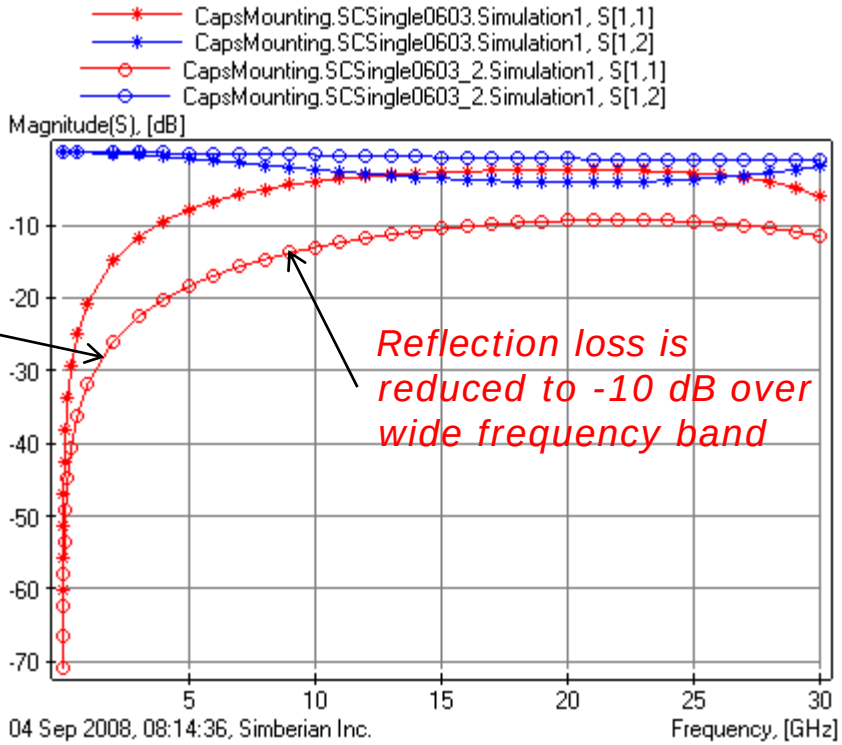


Short-circuit experiment with 0603 capacitor footprint with cut-out (SCSingle0603_2)

- Cut-out 50 mil by 68 mil in the reference plane considerably reduces the reflection loss

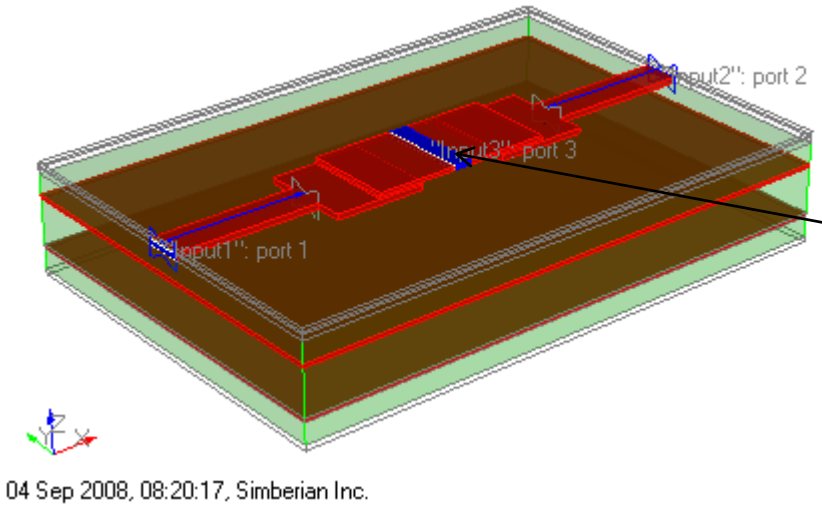


50x68 mil void in the reference plane below the capacitor mounting structure



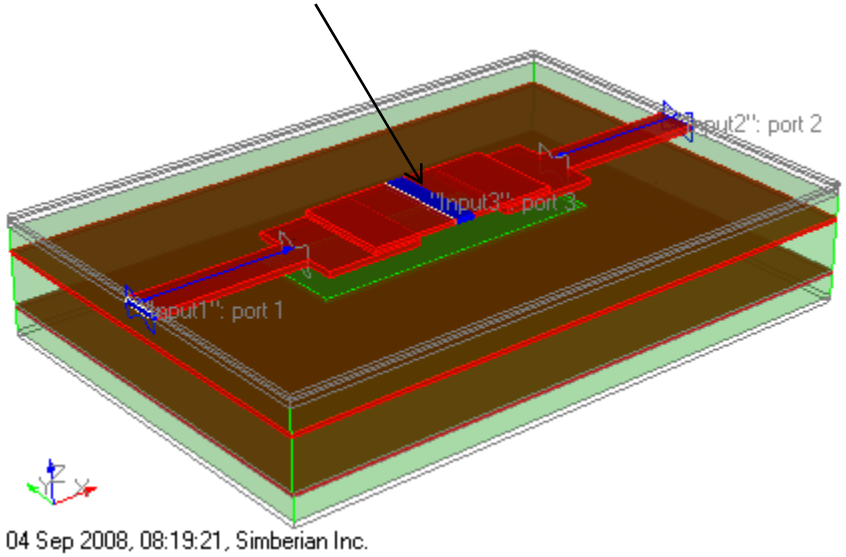
Series internal port to connect 0402 capacitor (SPSingle and SPSingle2)

- Series port is the only option in case of cut-out of the reference plane below the capacitor (no reference below the pads to construct parallel ports)



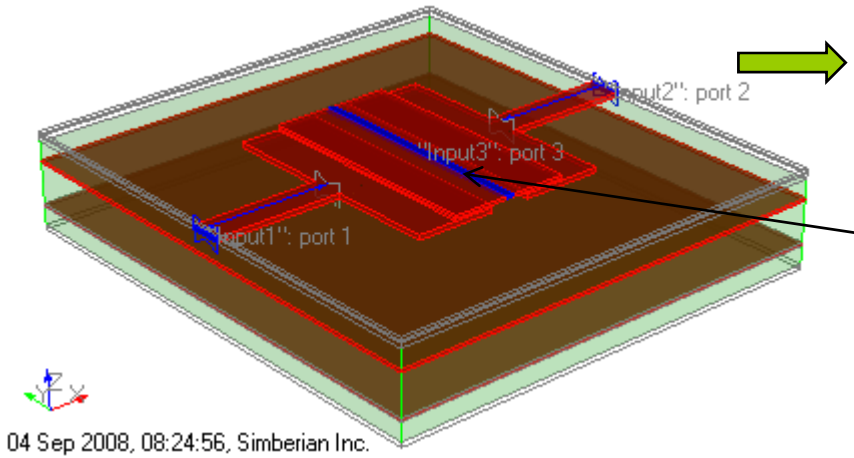
3-port broad-band S-parameter models of the mounting structures are extracted for both configurations

Series X-directed port #3 to connect the capacitor model



Series internal port to connect 0603 capacitor (SPSingle0603 and SPSingle0603_2)

- Series port is the only option in case of cut-out of the reference plane below the capacitor (no reference below the pads to construct parallel ports)



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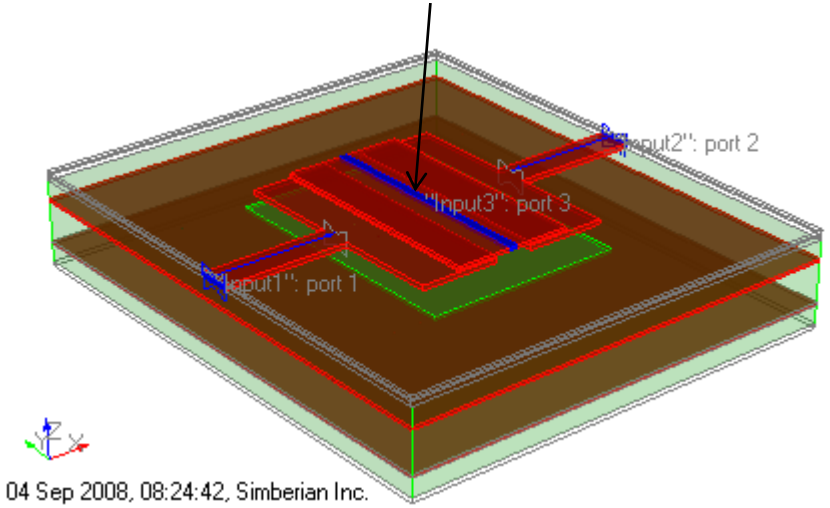
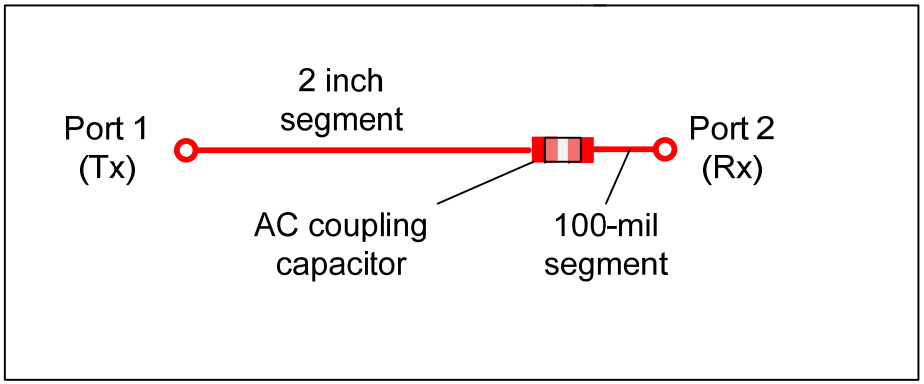


Analysis of a simple data channel with AC coupling capacitor (circuits in the project Channels)

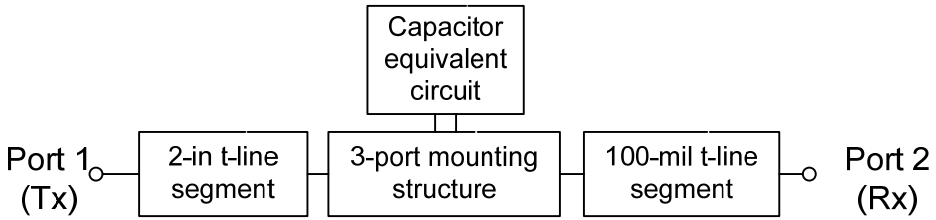
- Capacitor model: C=100 nF, ESR=1 mOhm, ESL= 100 nH
- Capacitor is placed closer to the receiver port 2



Sketch of the channel

We will use broadband RLGC(f) model of 50-Ohm micro-strip line and extracted S-parameters of the capacitor mounting structure

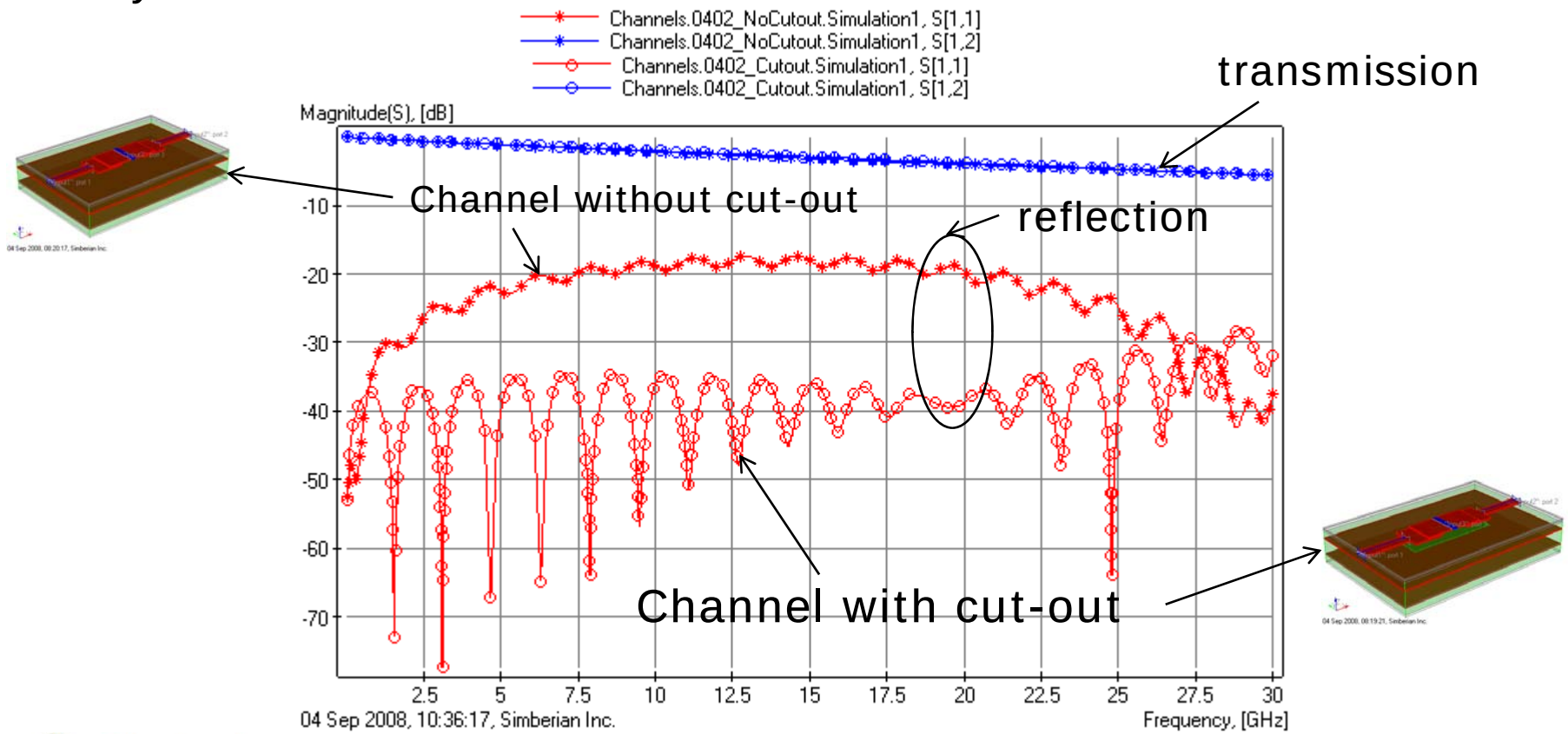
Simbeor de-compositional model of the channel



The channel is simulated in frequency domain as connection of multiports

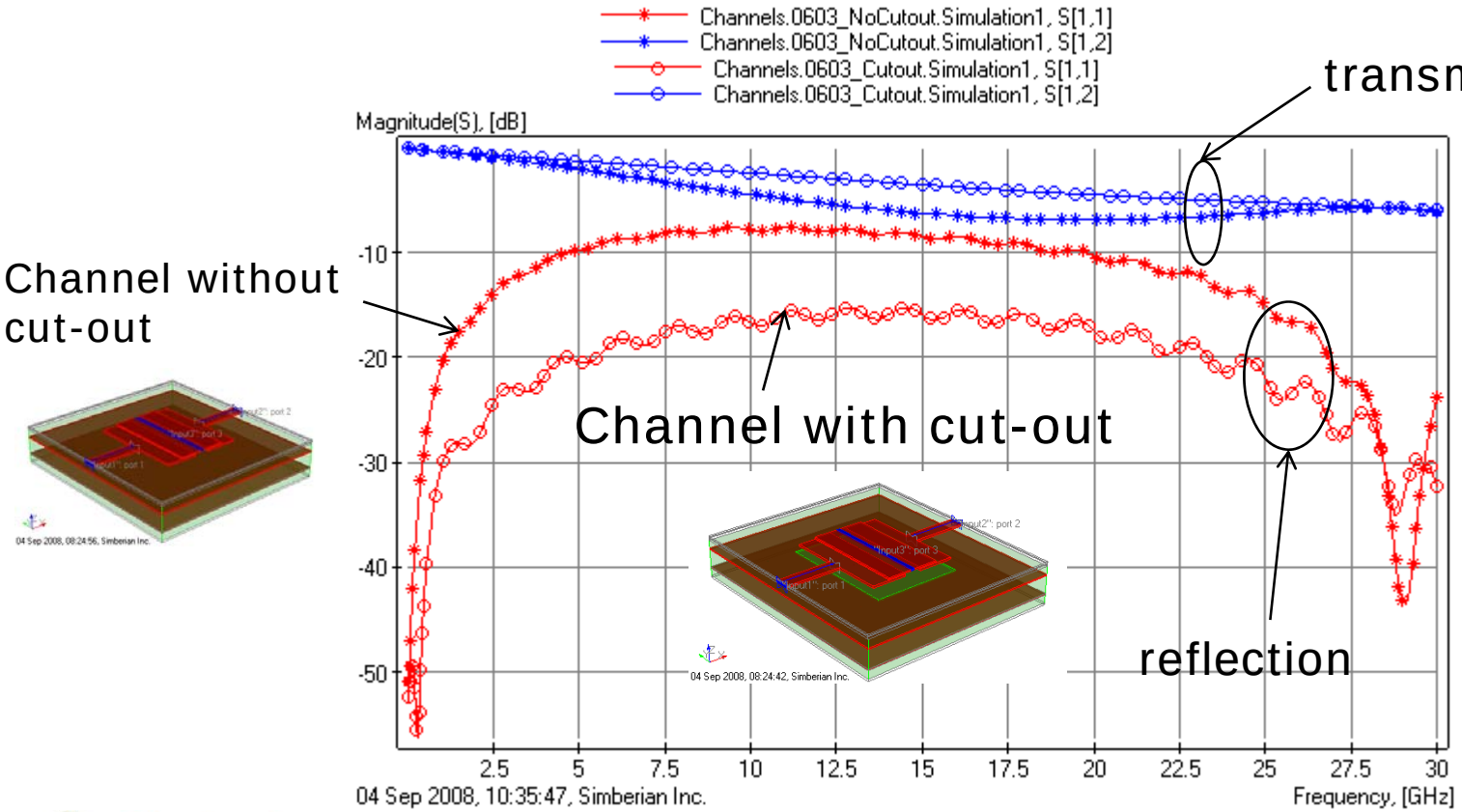
Simbeor models of the simple channel with 0402 capacitor

- We can see considerable reduction of the channel reflection loss
- S-parameter model of the complete channel can be used in a system-level simulator



Simbeor models of the simple channel with 0603 capacitor

- Considerable reduction of losses in the channel can be observed
- Without cut out a similar channel with additional via-hole discontinuities may fail because of resonances between the mounting structure and via-holes



Conclusion

- Simple examples of Simbeor application for extraction of electromagnetic models and for minimization of reflection losses from AC coupling capacitors are provided
- Optimal geometry of the mounting structure practically removes reflections from 0402 capacitors and considerably reduces the reflection loss from 0603 capacitors
- Electromagnetic models of the mounting structures can be used
  - For accurate modeling of multi-gigabit serial data channels
  - For identification of the models for the capacitors by comparison of simulation and measurement results
- Model of a complete channel in frequency domain is convenient to estimate insertion and reflection losses and can be used as a black-box model in a system-level simulator
- Analysis and loss minimization for differential channels is similar
- Setting up all simulations and model building with Simbeor took approximately 1 hour

Solutions and contact

- Simbeor solution file is in
  Simbeor Solutions/ PCB_MCM/ AC_CouplingCaps/ AC_CouplingCaps.esx
  - It contains all electromagnetic models and linear circuit analysis
- Send questions and comments to
  - General: info@simberian.com
  - Sales: sales@simberian.com
  - Support: support@simberian.com
- Web site www.simberian.com