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Simberian
Electromagnetic Solutions

Minimal-reflection bends in micro-strip lines

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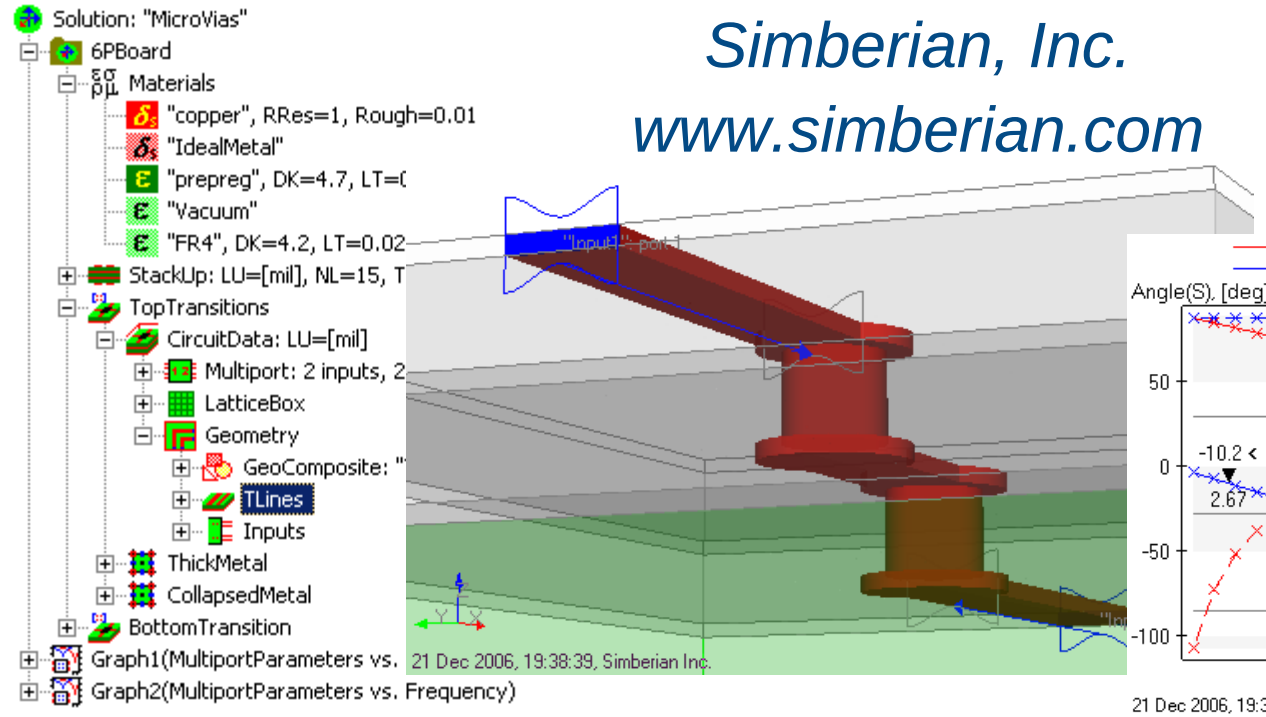

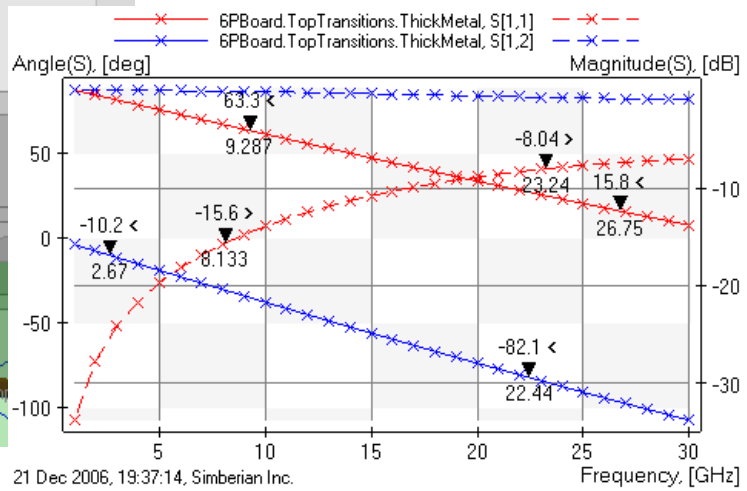

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Overview

- Introduction
- De-embedding and elimination of reflection cased by 50-Ohm normalization
- Minimization of reflection from bend with chamfer
- Minimization of reflection from bend with rectangular cut-out
- Analysis of a simple channel with 10 regular and optimal bends
- Conclusion

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Introduction

- Bends in micro-strip and strip lines are often discussed as a source of reflection in PCB interconnects (see SI list reflector http://www.freelists.org/archives/si-list/ - search for “bends”)
- It is practically impossible to detect the effect with TDR due to smallness of effect and not sufficient bandwidth and dynamic range of such measurements
- Precise frequency-domain measurements are required to detect the effect
  - The effect of bend may be hidden by the mismatch at the connectors or probes
  - Precise de-embedding is required that is hard to do on PCBs due to variations in dielectric properties
- Alternatively electromagnetic analysis with precise de-embedding can be used to reveal the effect and to minimize the reflection
- This example demonstrates how to do quick “what-if” experiments with Simbeor and provide design rules for PCB/packaging layout
- Simbeor 2008 built on September 9, 2008 has been used for all computations

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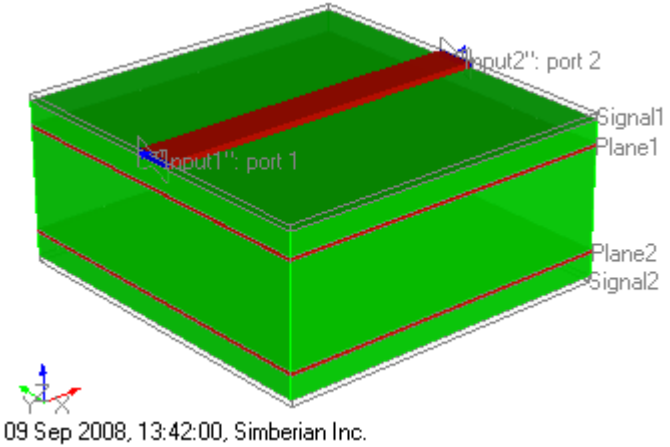
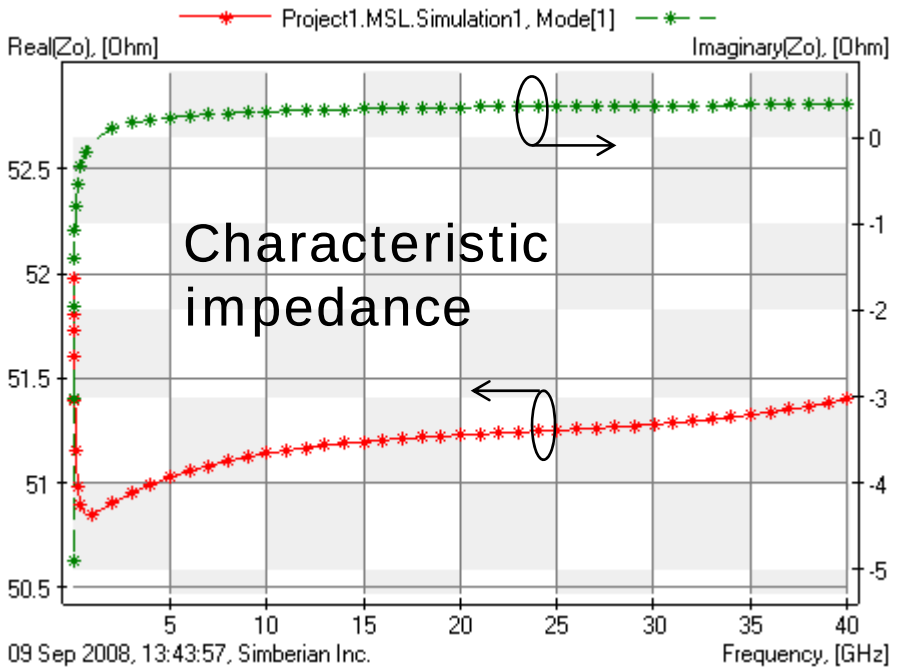
Micro-strip line

- Characteristic impedance of the micro-strip line is usually not exactly 50 Ohm: It is complex function and changing with the frequency as shown below

8-mil micro-strip line on 4.5 mil substrate (see materials and stackup on page 7)





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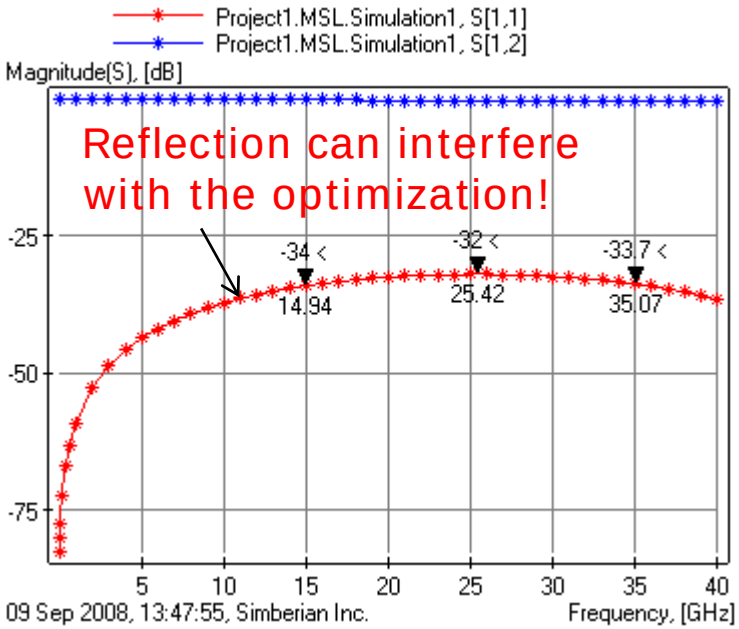
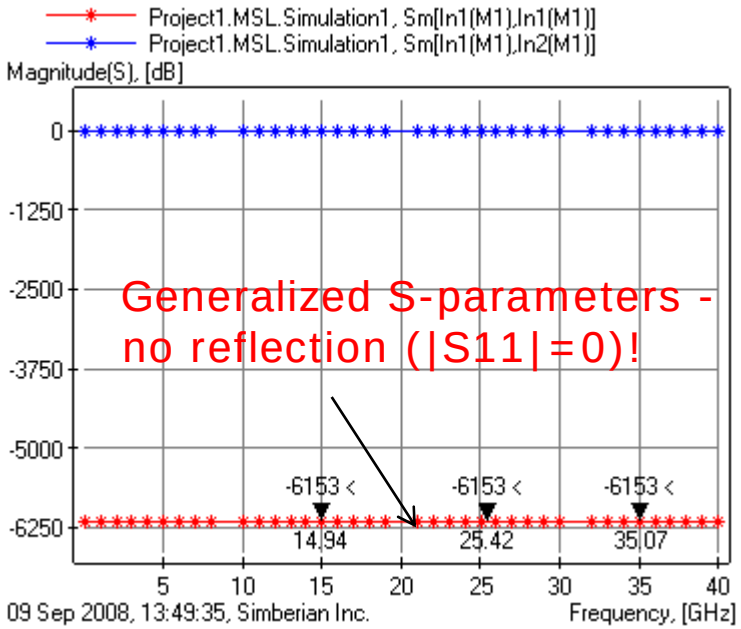
Removing normalization mismatch

- To eliminate the normalization mismatch we use generalized modal S-parameters normalized to the complex characteristic impedance of the micro-strip line

S-parameters of 70 mil long 8-mil micro-strip line segment normalized to 50 Ohm



S-parameters of 70 mil long 8-mil micro-strip line segment normalized to the characteristic impedance of the line



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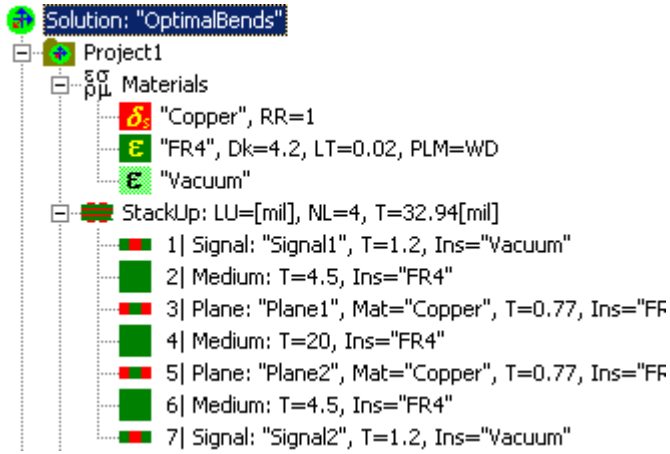
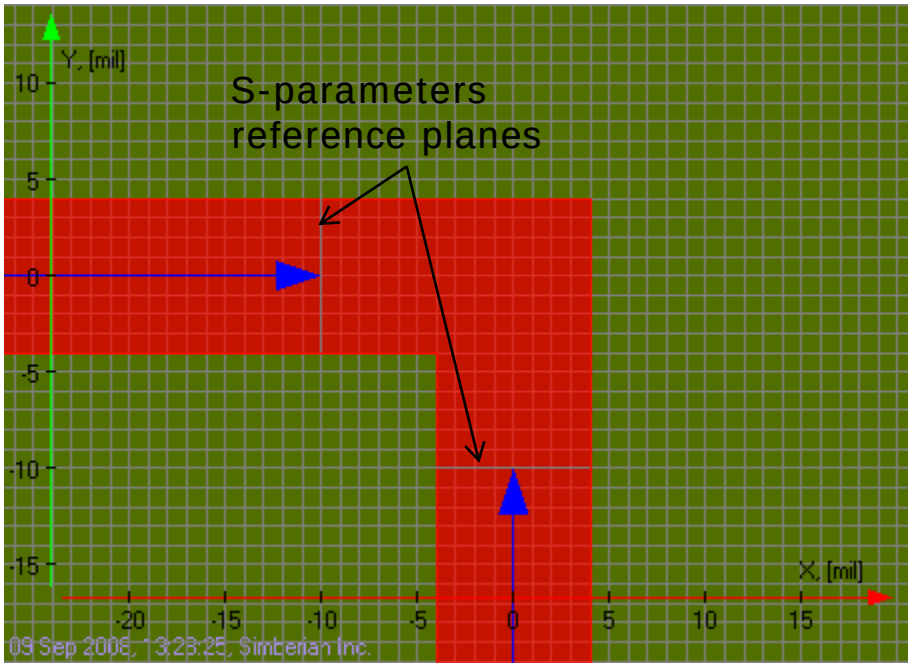
Original “reflective” bend

- Simple 4-layer stackup (only the first 2 layers are used in analysis of micro-strip structures)
- 8-mil micro-strip, reference planes are shifted 14 mil from the external corner of the bend

Cell size is 1 mil





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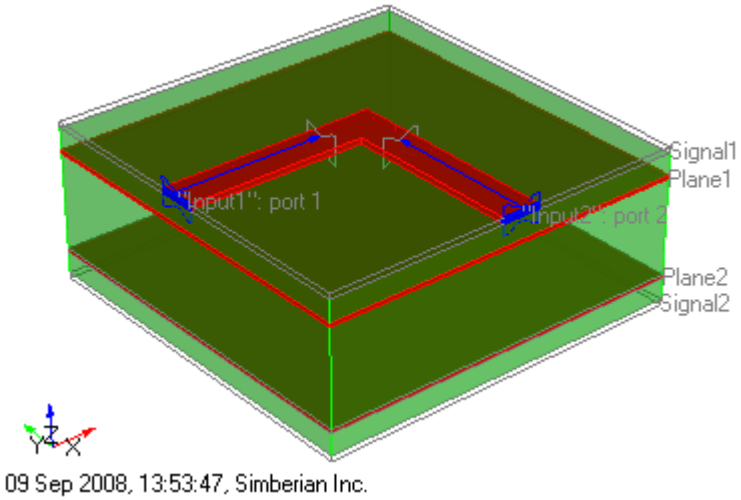
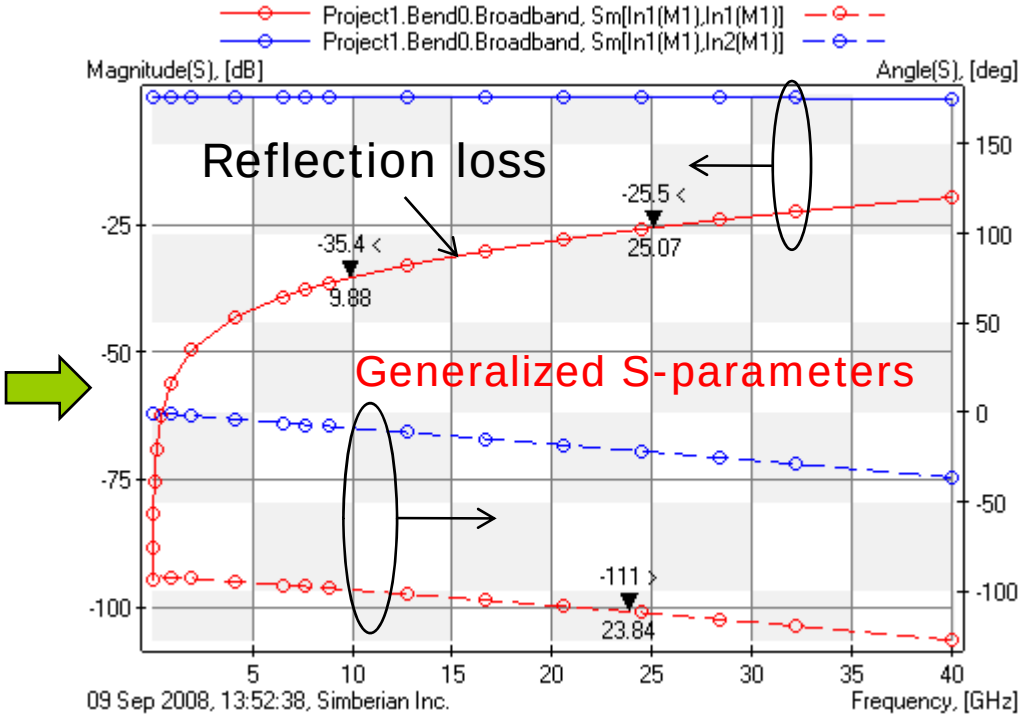
Original bend

- The reflection is very small up to 25 GHz
- Generalized S-parameters are necessary to detect the effect and to do the optimization





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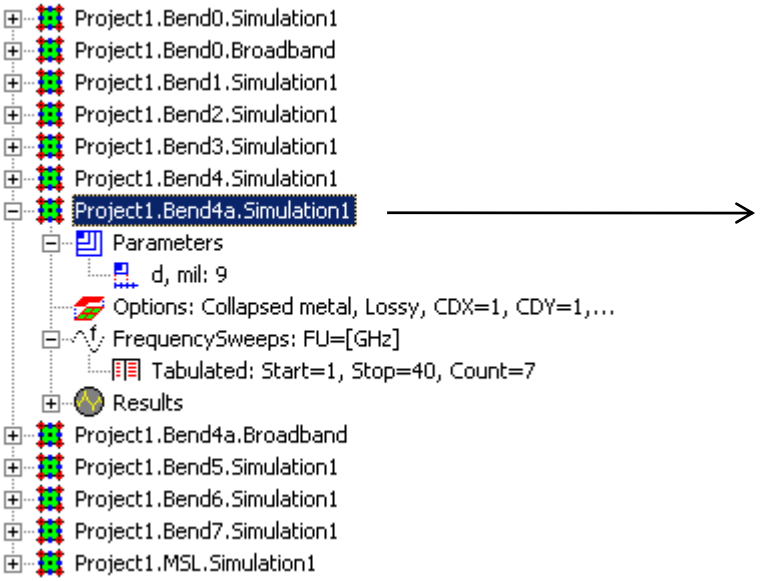
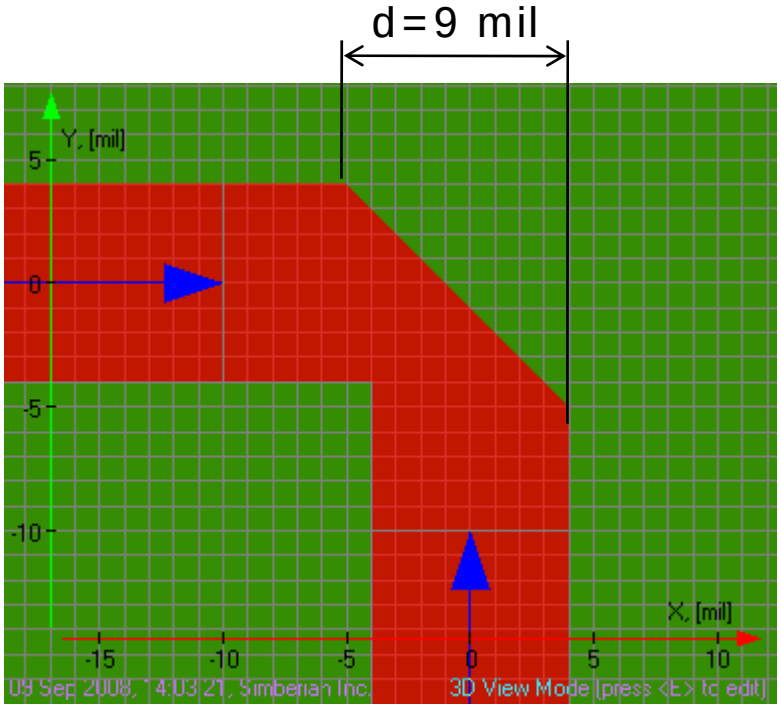
Parameterized solution with chamfer

- 9 circuits with changing parameter d, mil attached to each circuit to plot the results as function of parameter
- Each parameterized circuit is simulated at 7 frequency points: 1, 5, 10, 20, 30 and 40 GHz

Simulations in Simbeor:



Bend4a geometry (nearly optimal)



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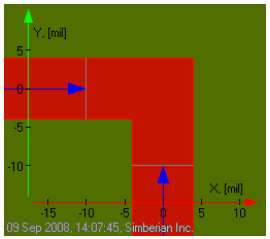
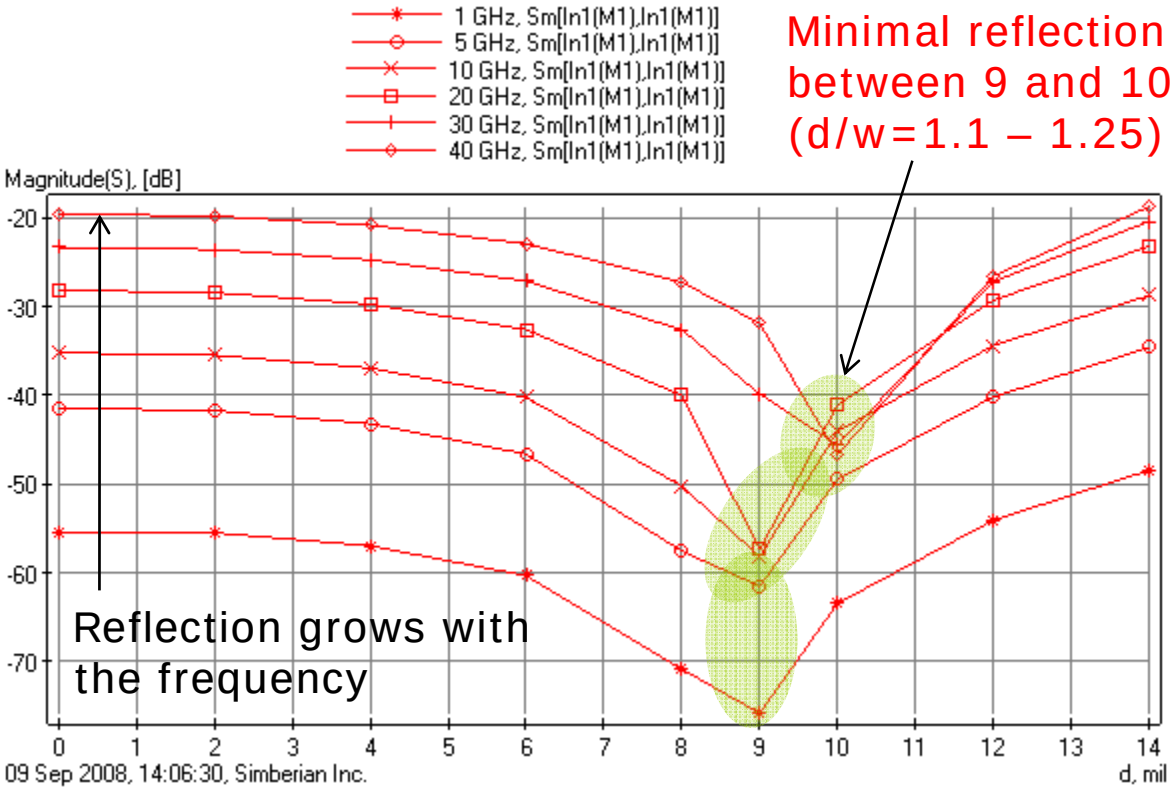
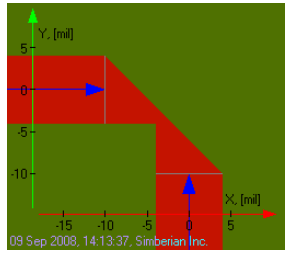
Finding optimal chamfer position

- Plotting the reflection as function of the chamfer position allows us to find the minimum







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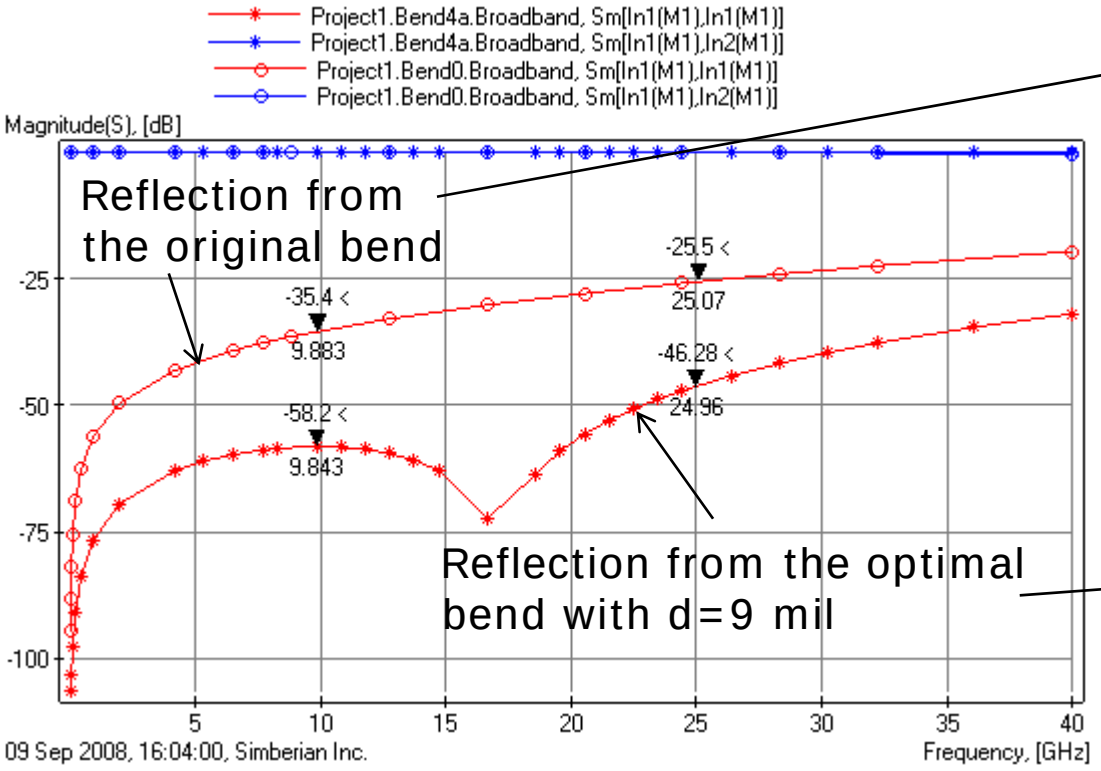
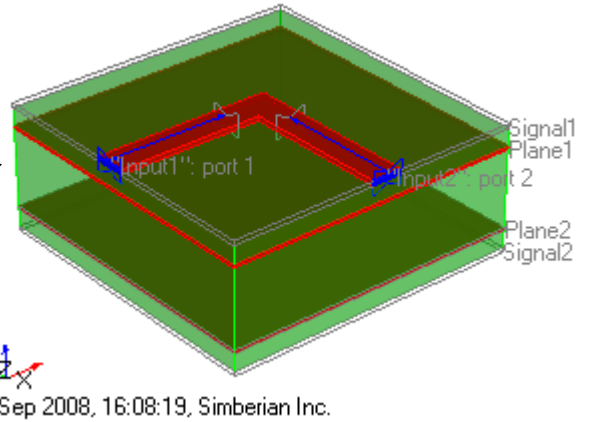
Chamfered optimal bend vs. the original

- Reflection from the optimal bend is reduced by about -20 dB





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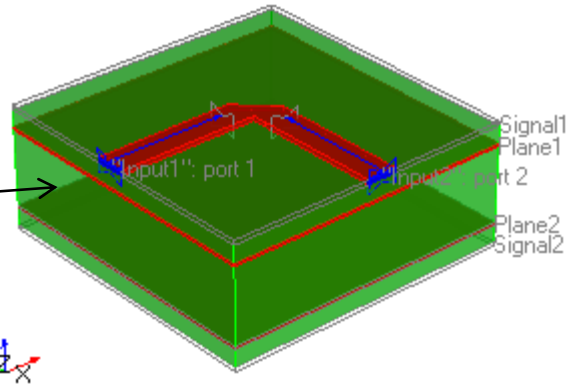

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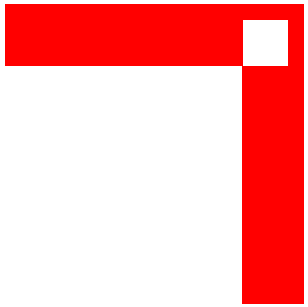
Are there other ways to reduce the reflection?

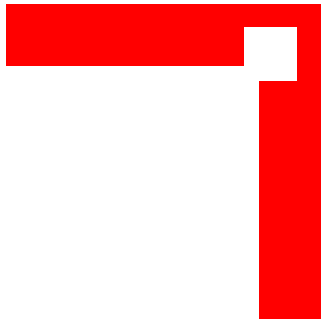
- Yes – anything that reduces the excessive capacitance and does not increase the inductance would work

External corner cut

Middle cut



Internal corner cut



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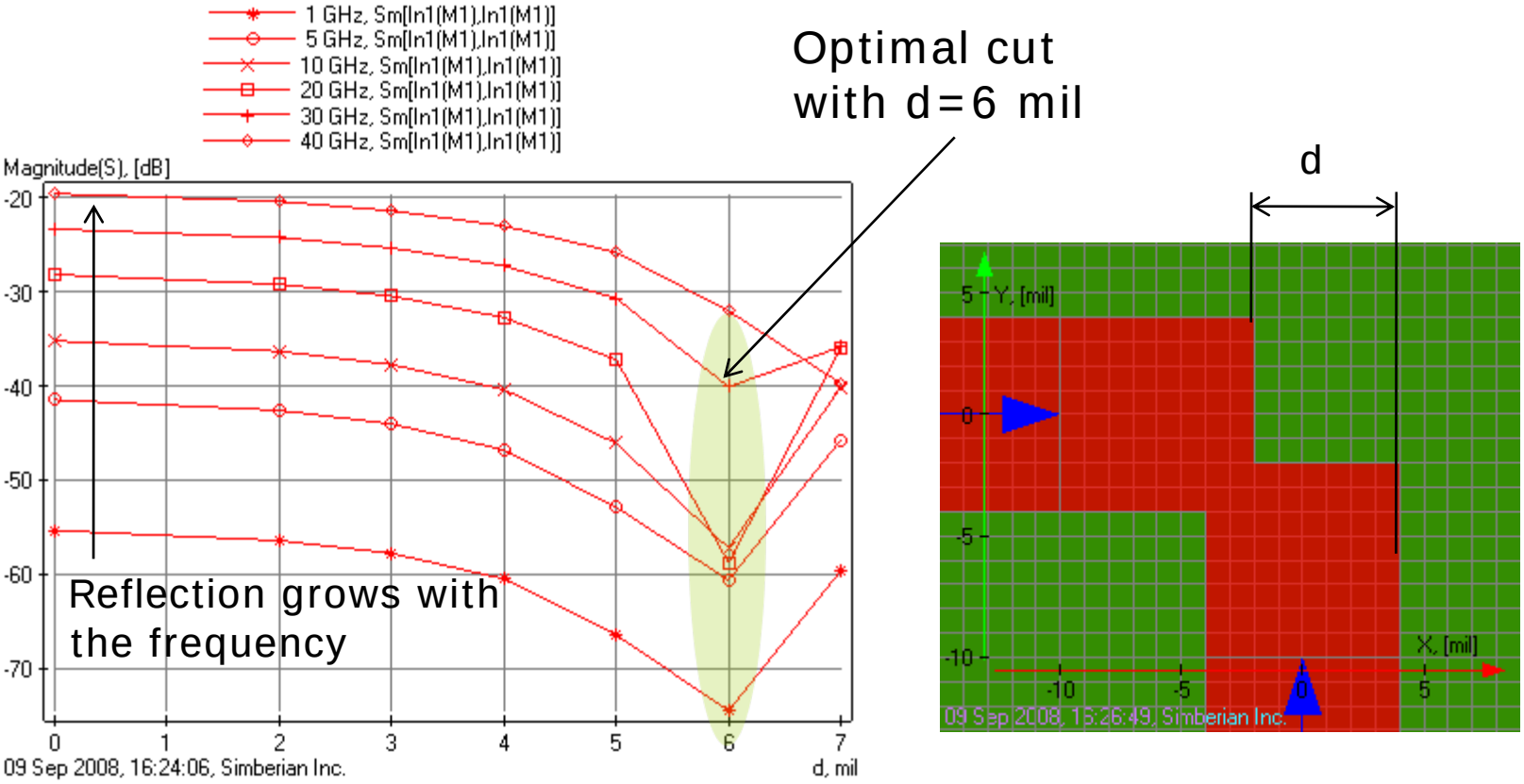
Optimization of bend with external corner cut

- Magnitude of the reflection coefficient |S11| as function of the cut size shows the minimum



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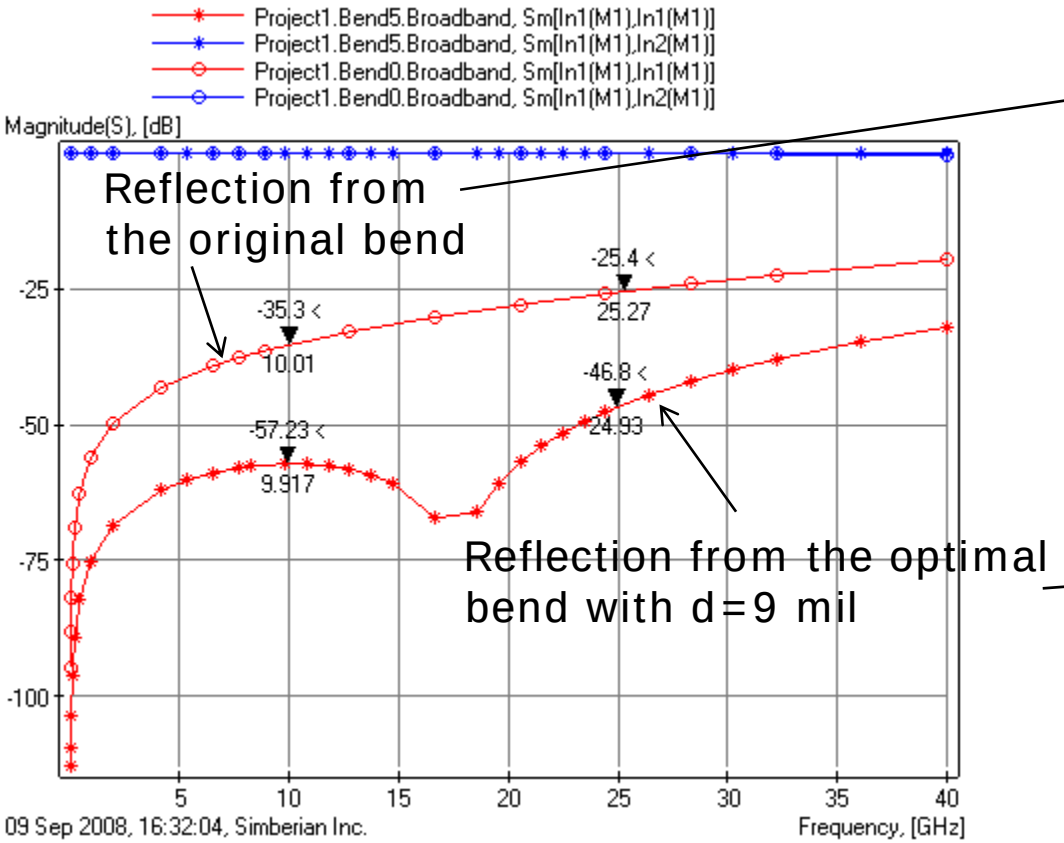
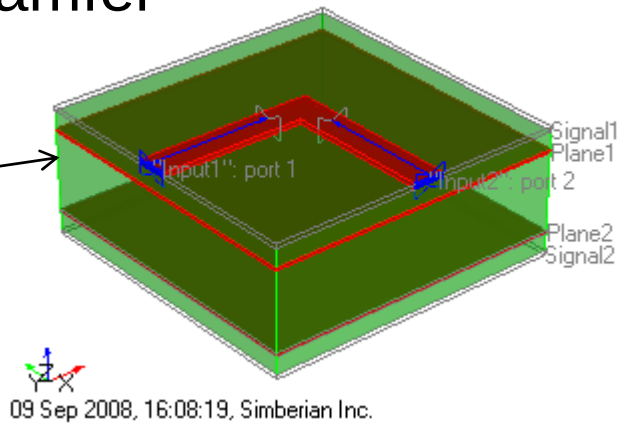
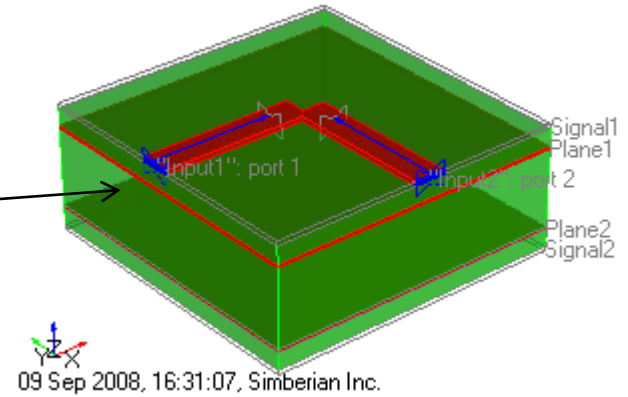
Optimal bend with external cut vs. the original or regular

- Reflection from the optimal bend is reduced by about -20 dB almost as in the case with the chamfer







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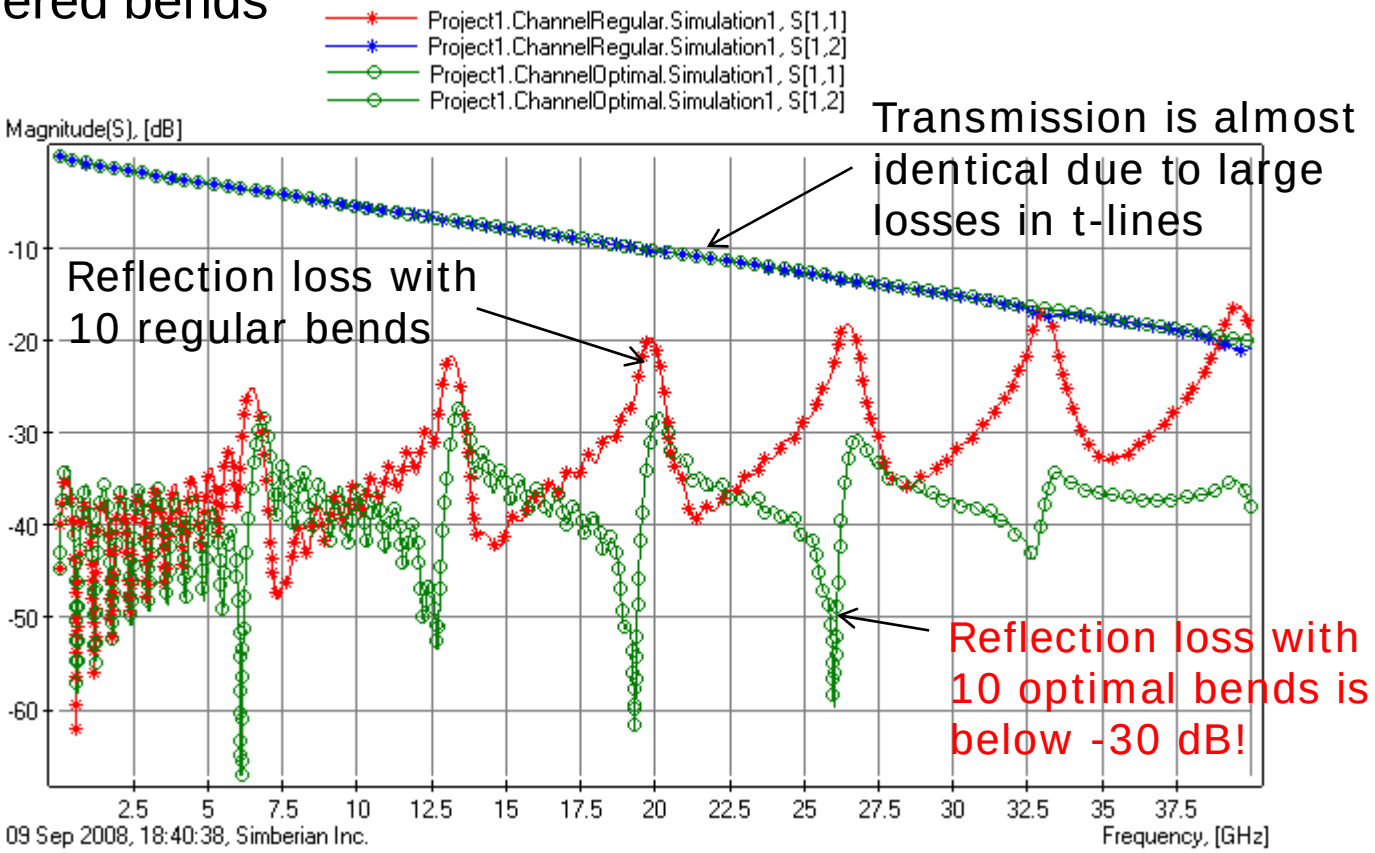
Analysis of a simple channel with bends

- Micro-strip channel with 10 bends separated by 0.5 inch segments of micro-strip line is investigated with the regular and optimal chamfered bends



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Conclusion

- The effect of the 90-degree bend is minor and only precise de-embedding and generalized S-parameters can be used to investigate and minimize the reflection
- Chamfered bend with d/w=1.1-1.25 minimizes the reflection from 90-degree bends
- Different shapes of cut-outs can be used to minimize the reflection
- Electromagnetic models of the bends created with Simbeor can be used for accurate modeling of multi-gigabit data channels
- Setting up all simulations and model building with Simbeor took approximately 1 hour

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Solutions and contact

- Simbeor solution files are available for download from the simberian web site
  - http://www.simberian.com/AppNotes/Solutions/BendsOptimization_2008_05.zip
- Send questions and comments to
  - General: info@simberian.com
  - Sales: sales@simberian.com
  - Support: support@simberian.com
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