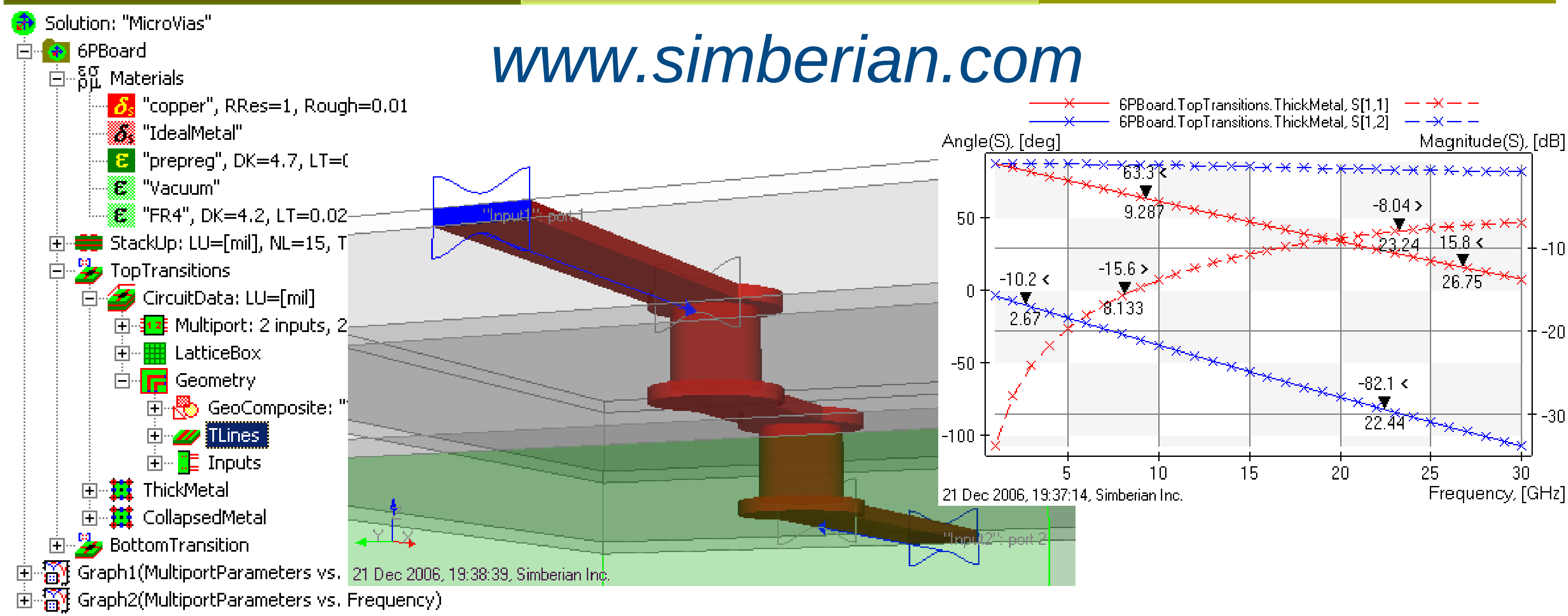
Simberian Electromagnetic Solutions

Examples of broadband extraction of transmission line parameters with Simbeor

www.simberian.com



Simbeor: Easy-to-Use, Efficient and Cost-Effective…

Introduction

- Goal is to illustrate how Simbeor 2007 can be used to build 3D full-wave broad-band transmission line models for different planar circuit manufacturing technologies

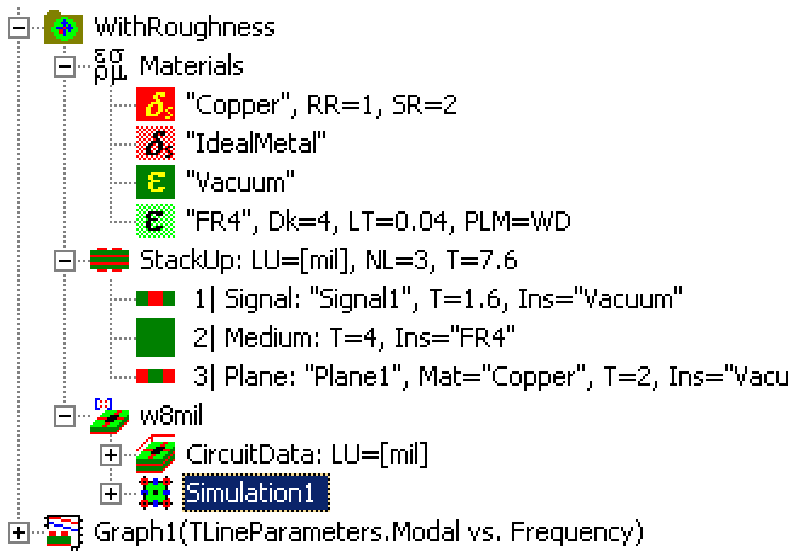
Simbeor technology at a glance

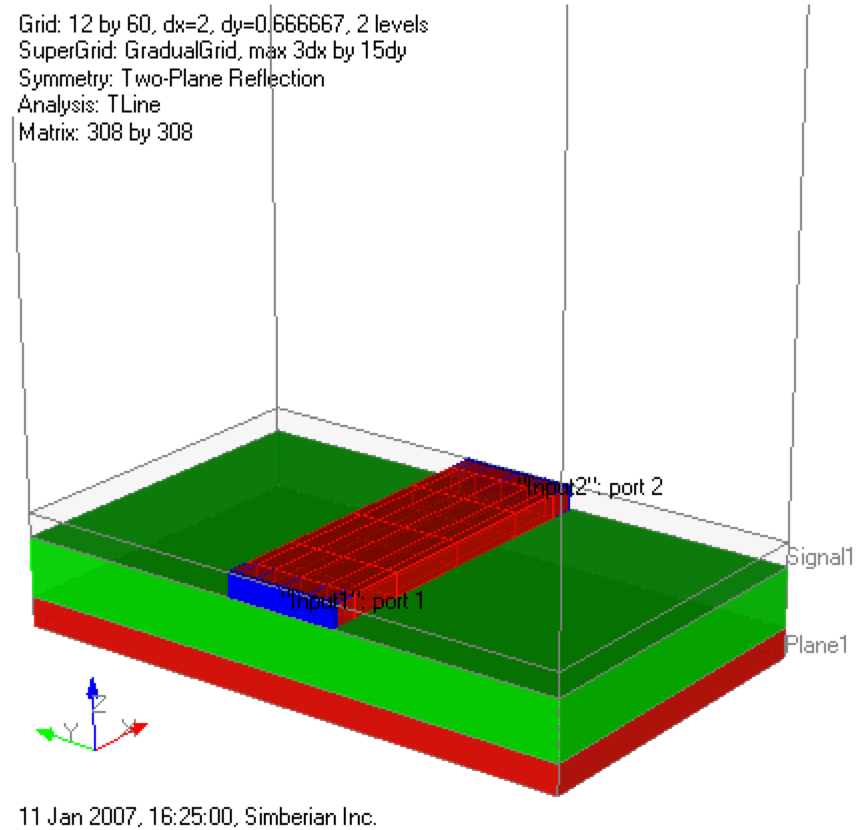
- Performs 3D full-wave analysis of transmission line segment and automatically extract frequency-dependent modal and RLGC matrix parameters per unit length for W-element models of multiconductor lines
- Uses broadband and causal dielectric models
- Simulates transition to skin-effect, shape and proximity effects at medium frequencies
- Accounts for skin-effect, dispersion and edge effect at high frequencies
- Has conductor models valid and causal over 5-6 frequency decades in general
- Accounts for conductor surface roughness and finish

PCB micro-strip line example

Example TLines\ Comparisons\ PCB\ PCB.esx

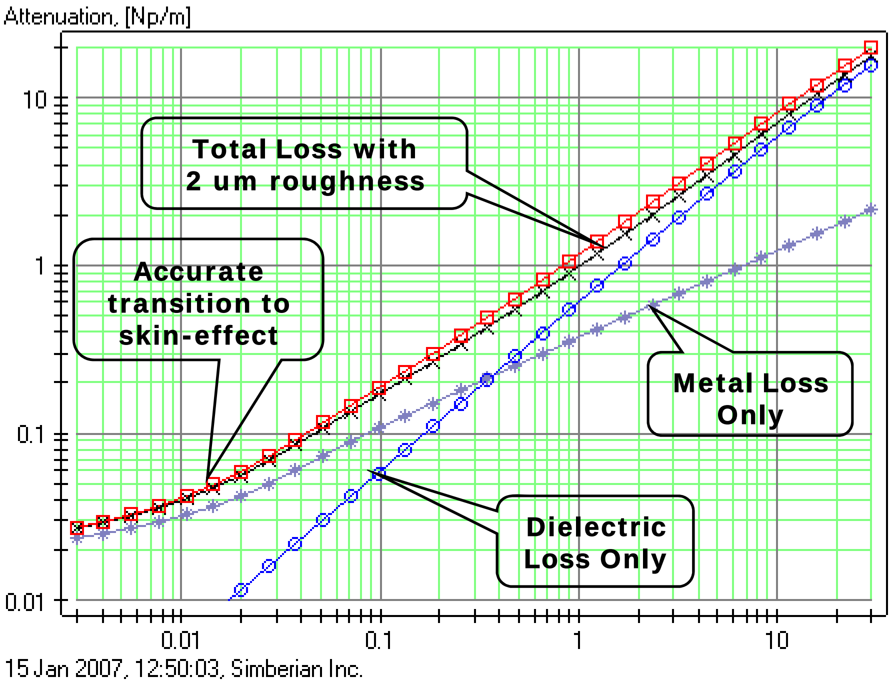
8 mil wide 1.6 mil thick strip on dielectric substrate with Dk=4.0 and LT=0.04 at 1 GHz. Substrate thickness 4 mil, plane thickness 2 mil.

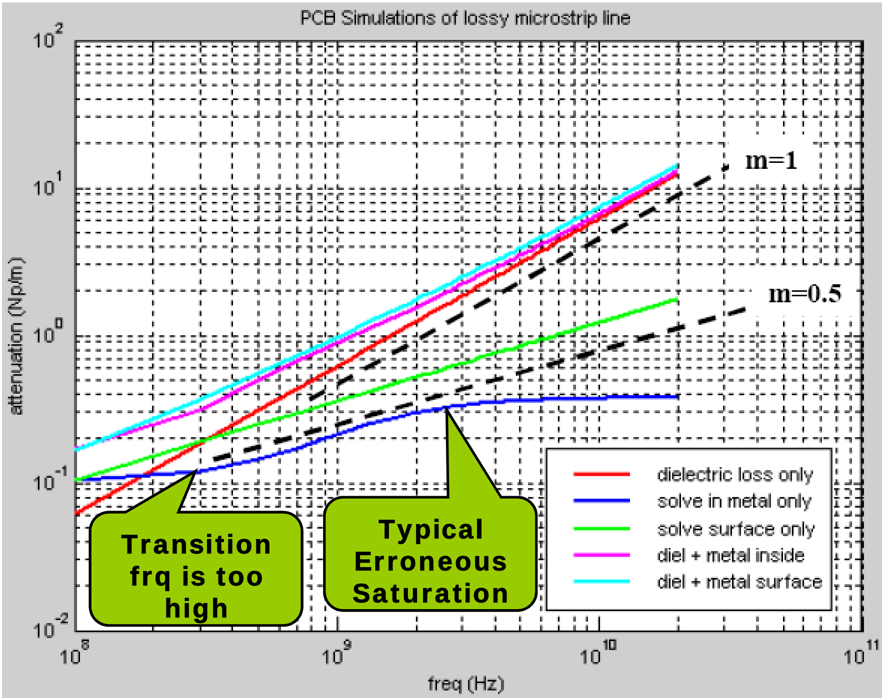




PCB micro-strip example: Attenuation

8 mil wide 1.6 mil thick strip on dielectric substrate with Dk=4.0 and LT=0.04 at 1 GHz modeled as wideband Debye. Substrate thickness 4 mil, plane thickness 2 mil.



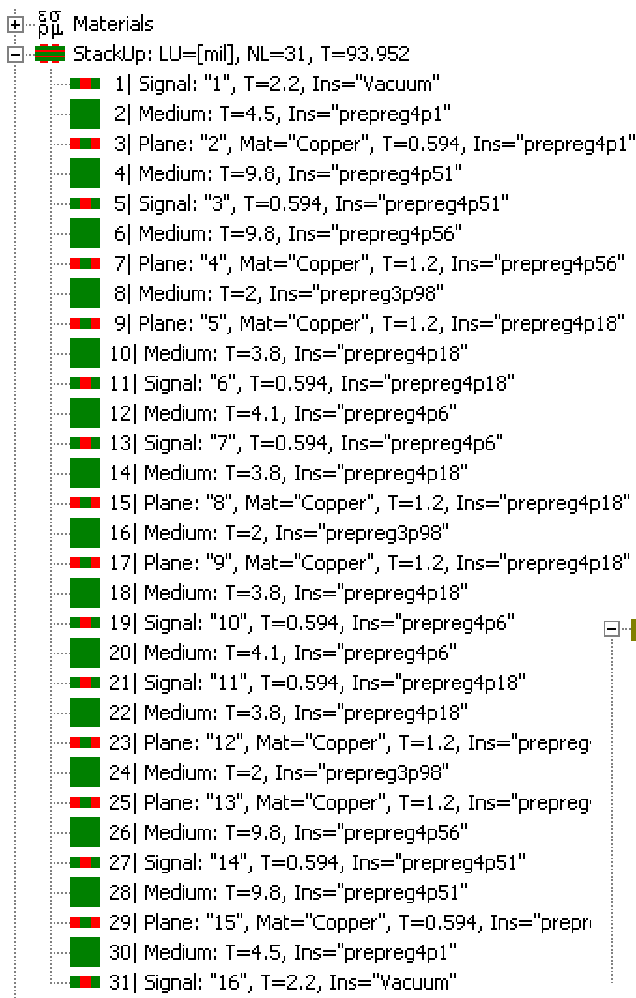


Simbeor results: red curve is complete losses with surface roughness 2 um

Skin-effect transition is around 3 MHz

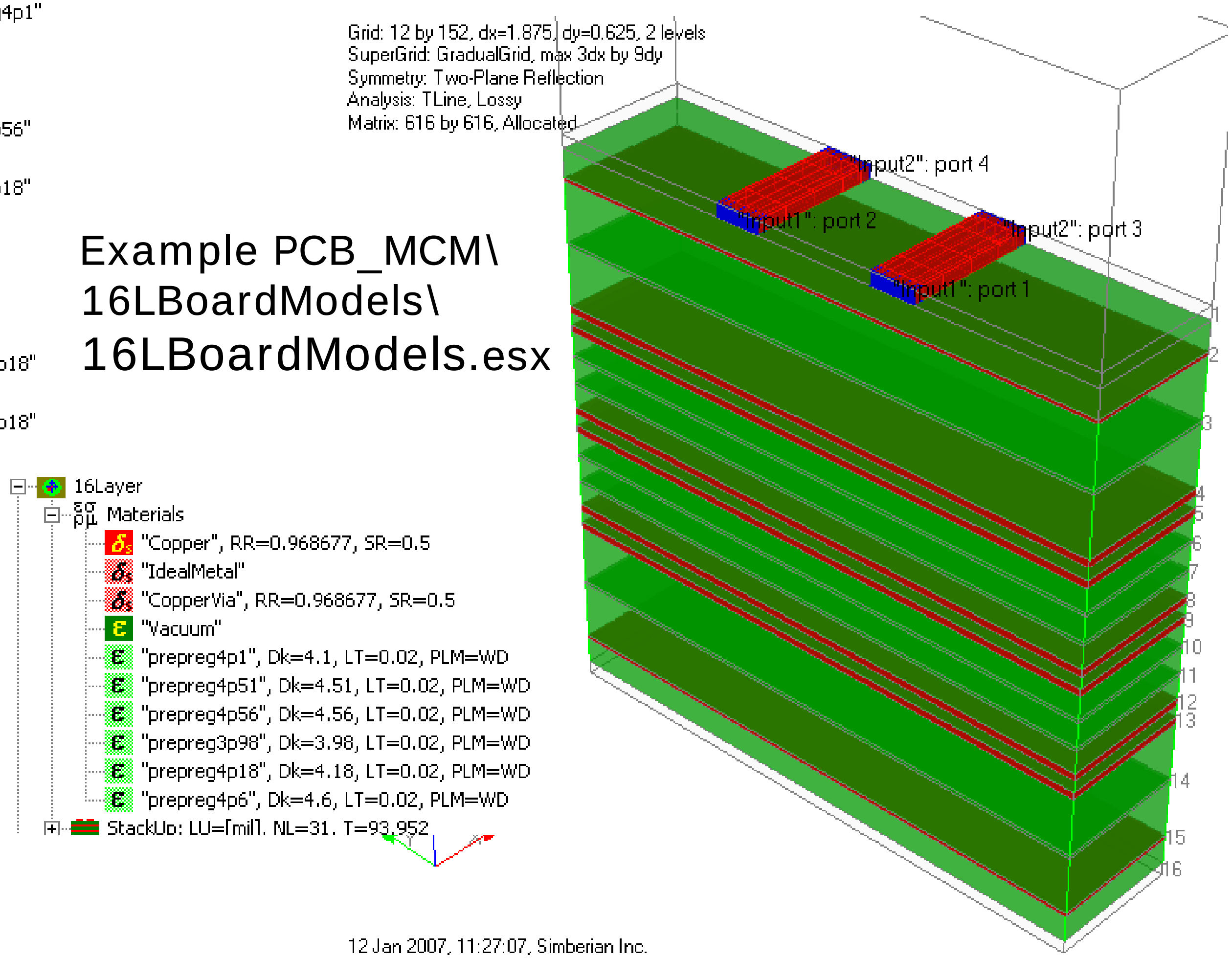
From “Accounting for High Frequency Transmission Line Loss Effects in HFSS”, Andrew Byers, Tektronix, 2003 HFSS Users Workshop, http://www.ansoft.com/workshops/hfworkshop03 Andy_Byers_Tektronix.pdf

PCB differential micro-strip line example

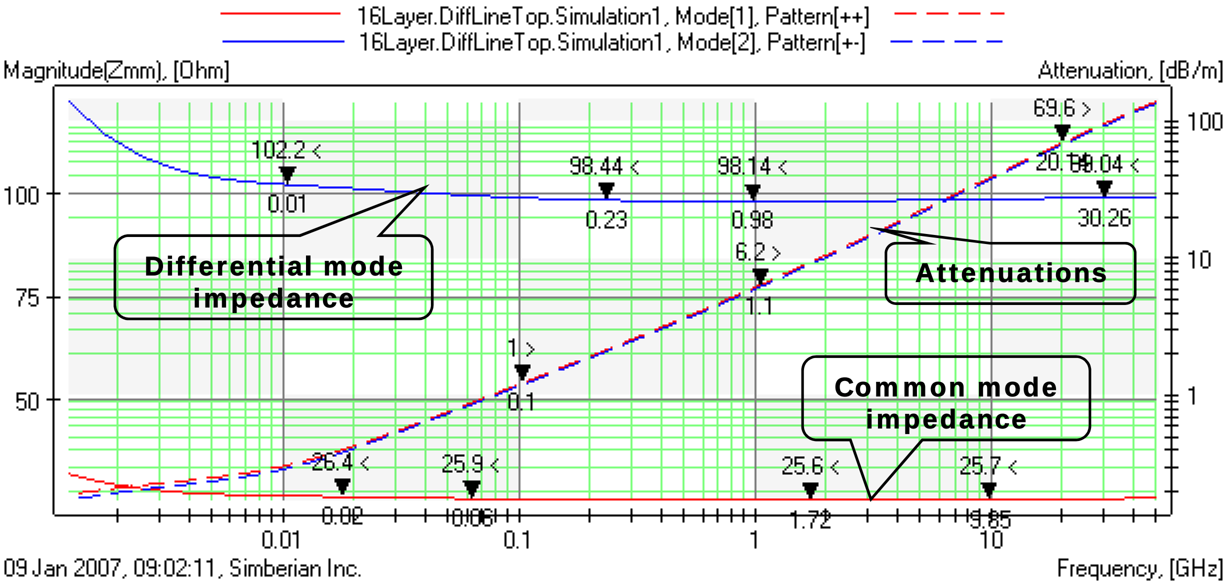


7.5 mil wide 2.2 mil thick strips 20 mil apart. Dielectric substrate with Dk=4.1 and LT=0.02 at 1 GHz. Substrate thickness 4.5 mil, plane thickness 0.594 mil.

Example PCB_MCM\
16LBoardModels\
16LBoardModels.esx

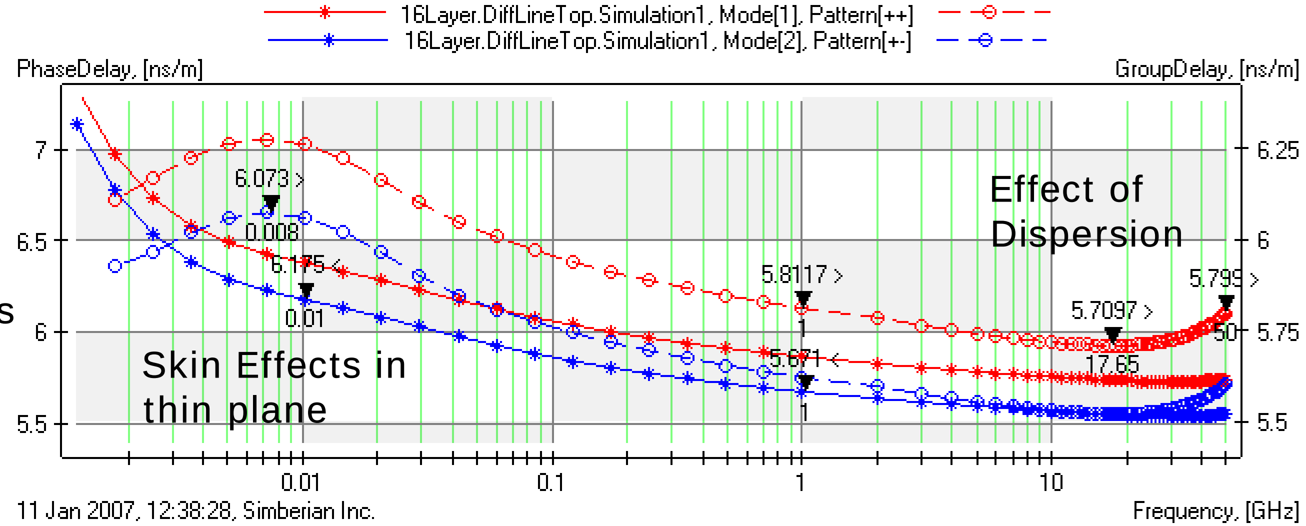


Modal parameters of the differential micro-strip line with metal surface roughness 0.5 um



Magnitude of characteristic impedance and attenuation of the differential and common modes

Phase and group delays p.u.l. of the differential and common modes – illustrates skin and dielectric dispersion effects



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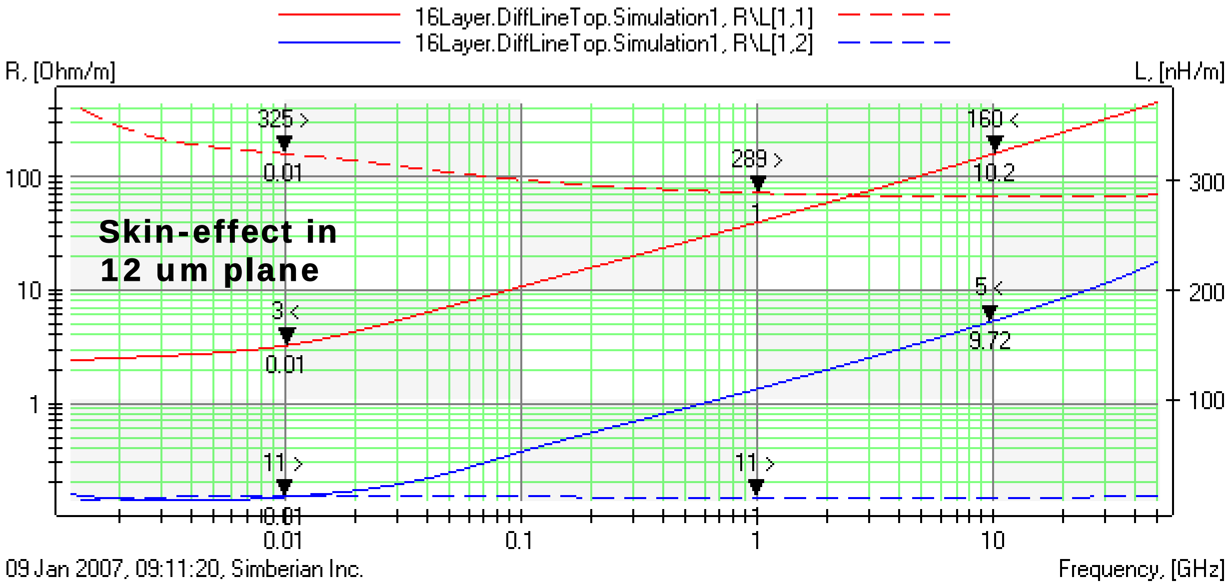
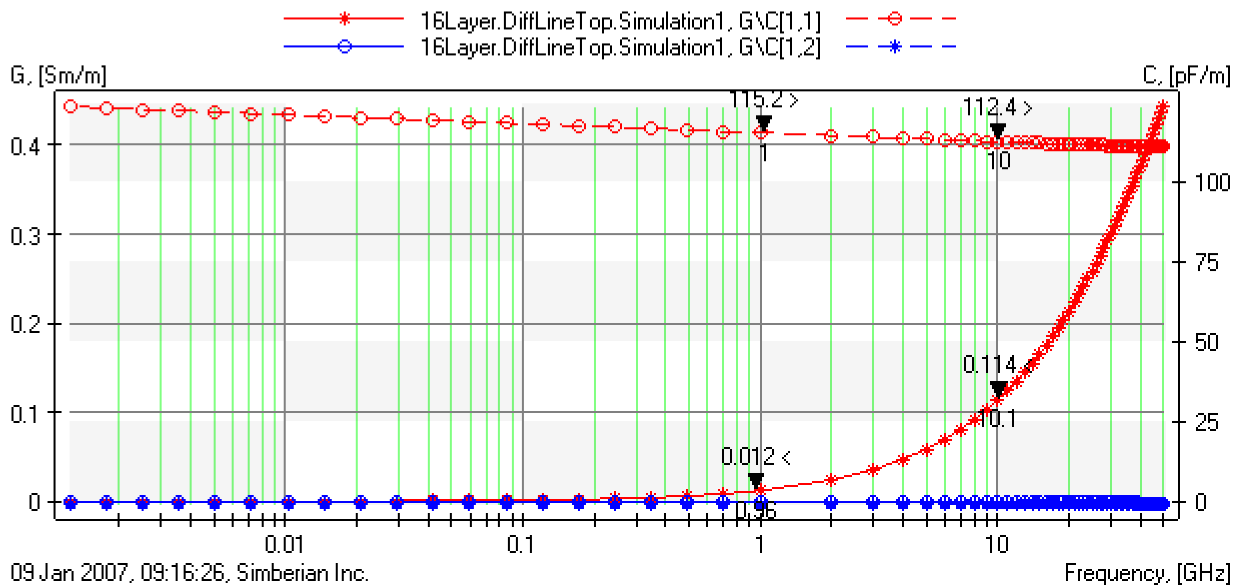
RLGC parameters of the differential micro-strip line with metal surface roughness 0.5 um



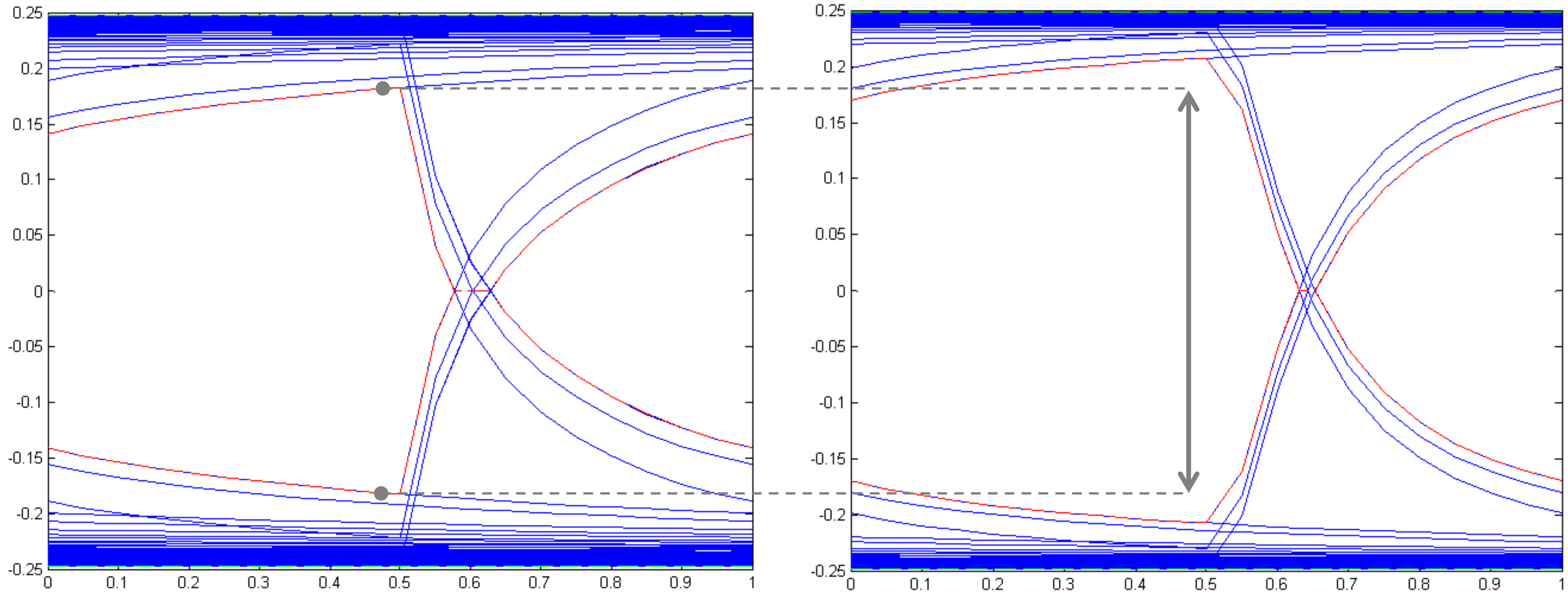
Elements of p.u.l. resistance and inductance matrices



Elements of p.u.l. conductance and capacitance matrices

Eye diagram comparison for 5-in differential micro-strip line segment with10 Gbs data rate

Two 7.5 mil traces 20 mil apart on 4.5 mil dielectric and 0.6 mil plane, 0.5 um roughness. Worst case eye diagram for 100 ps bit interval.



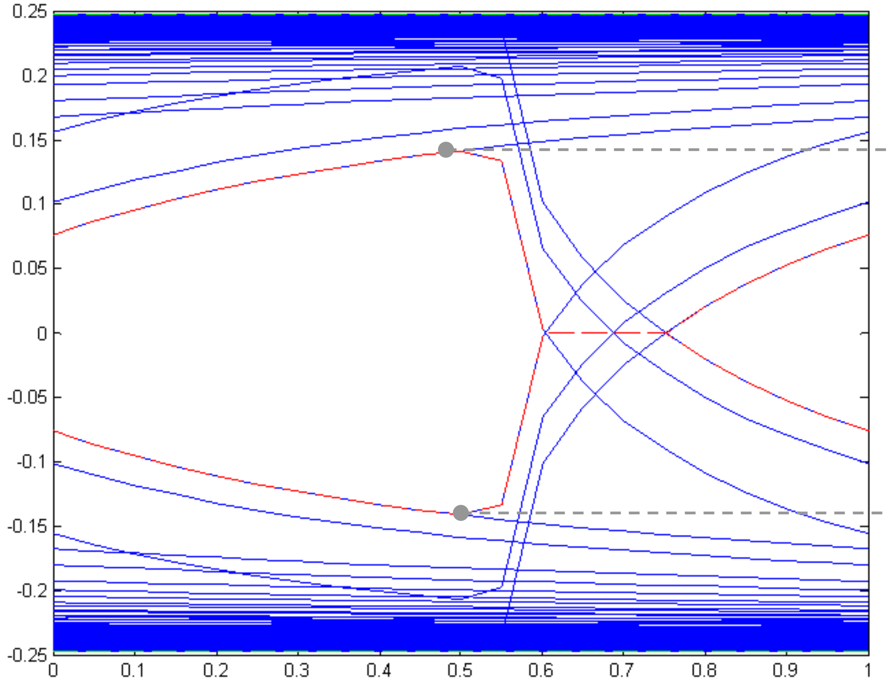
Worst case eye diagram computed with W-element defined with tabulated RLGC parameters extracted with Simbeor

Worst case eye diagram computed with W-element defined with t-line parameters extracted with a static solver

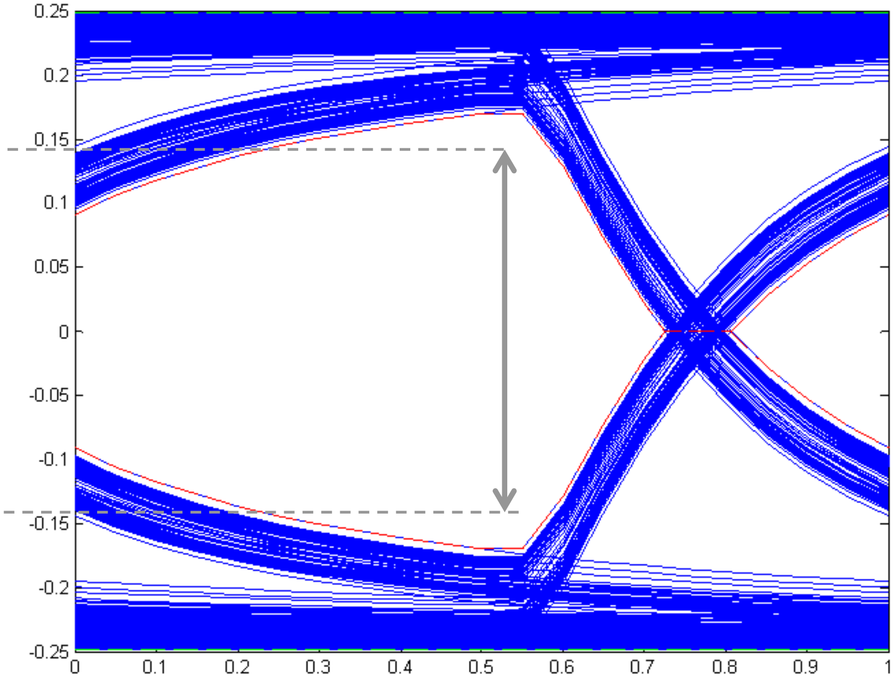
Computed by V. Dmitriev-Zdorov, Mentor Graphics

Eye diagram comparison for 5-in differential micro-strip line segment with 20 Gbs data rate

Two 7.5 mil traces 20 mil apart on 4.5 mil dielectric and 0.6 mil plane, 0.5 um roughness.
Worst case eye diagram for 50 ps bit interval – May affect channel budget!



Worst case eye diagram computed with W-element defined with tabulated RLGC parameters extracted with Simbeor

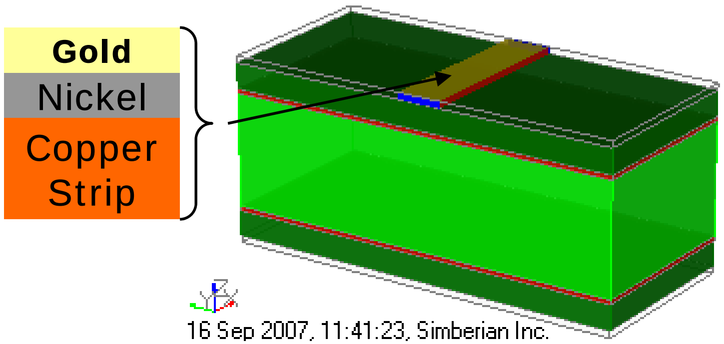


Worst case eye diagram computed with W-element defined with t-line parameters extracted with a static solver

Computed by V. Dmitriev-Zdorov, Mentor Graphics

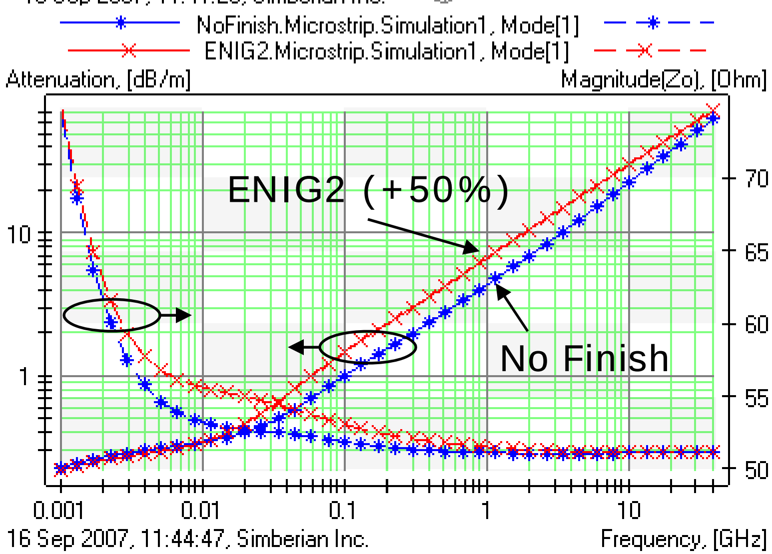
PCB microstrip line with plated conductor

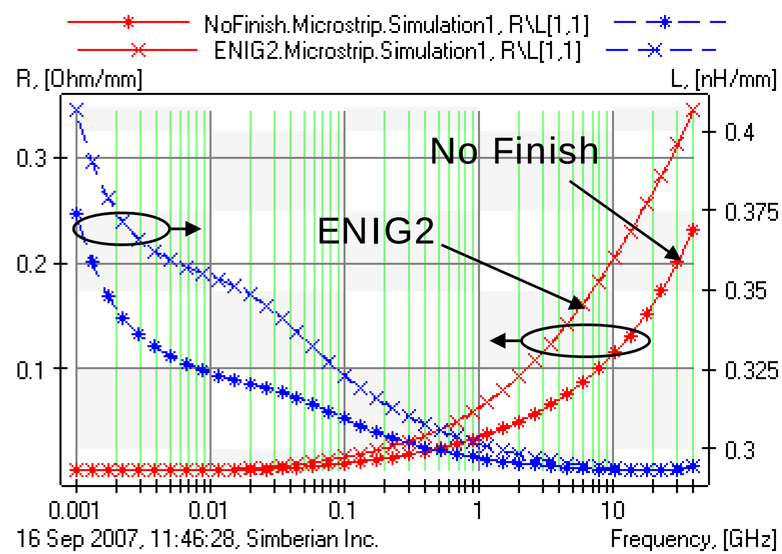
- Simbeor allows you to simulate conductor surface finish for RoHS technologies such as ENIG



Example TLines\ ENIGMetalFinishEffect\ ENIGMetalFinishEffect.esx

NoFinish – 8 mil microstrip on 4.5 mil dielectric with Dk=4.2, LT=0.02 at 1 GHz.
ENIG2 - microstrip surface is finished with 6 um layer of Nickel and 0.1 um layer of gold on top

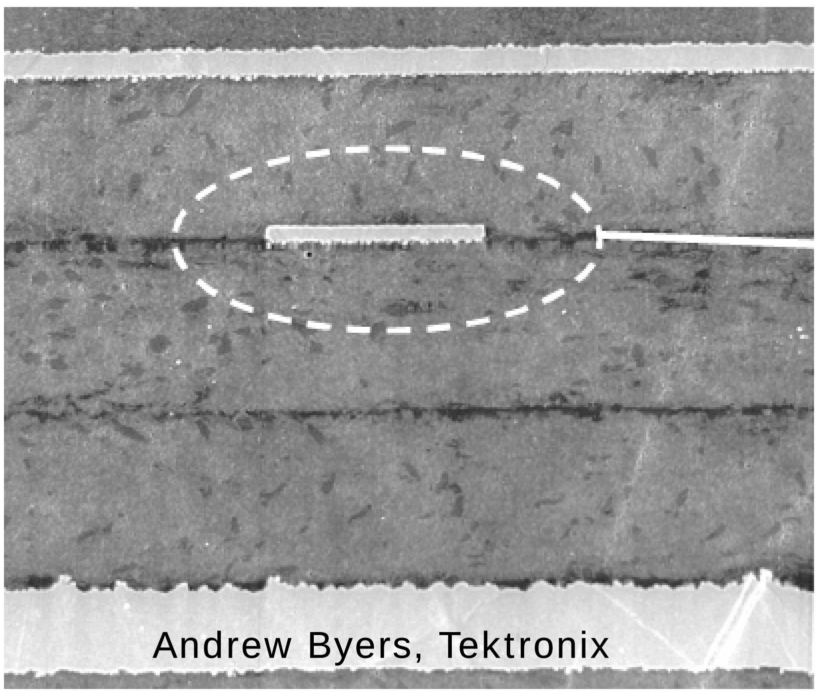


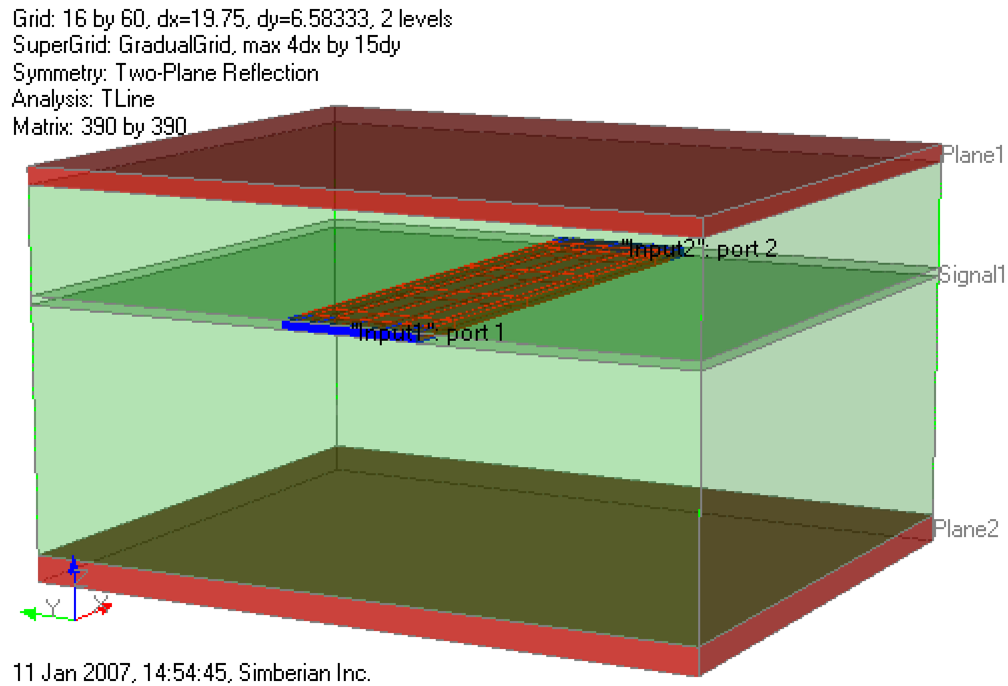


Package strip line example

Example TLines\ Comparisons\ Package\ Package.esx

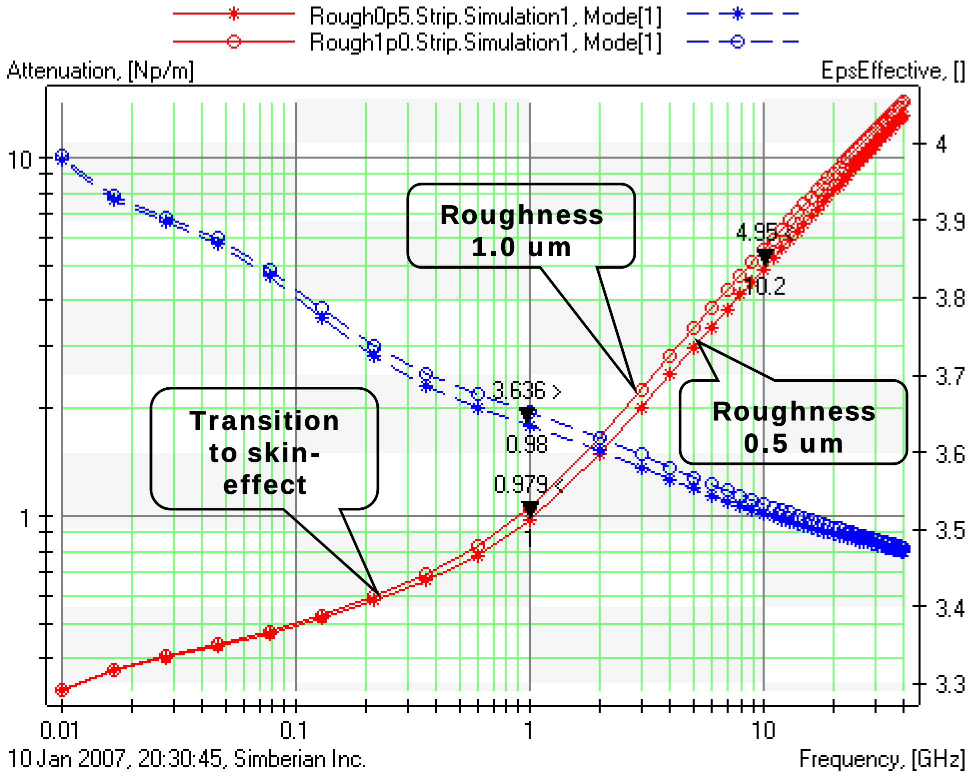
79 um wide and 5 um thick strip in dielectric with Dk=3.4 and LT=0.008 at 10 GHz.
Distance from strip to the top plane 60 um, to the bottom plane 138 um.
Top plane thickness is 10 um, bottom 15 um.
R.m.s. roughness is 1 um on bottom surface and almost flat on top surface of strip.



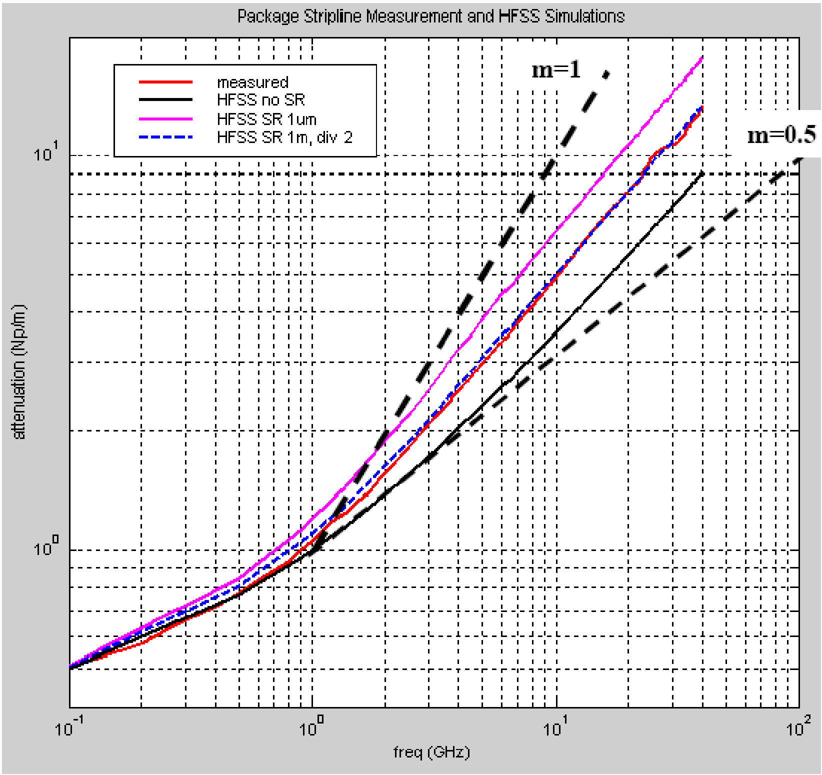


Package strip line – effect of roughness on attenuation and effective dielectric constant

79 um wide and 5 um thick strip in dielectric with Dk=3.4 and LT=0.008 at 10 GHz modeled as wideband Debye. Distance to top plane 60 um, to bottom plane 138 um. Top plane thickness is 10 um, bottom 15 um



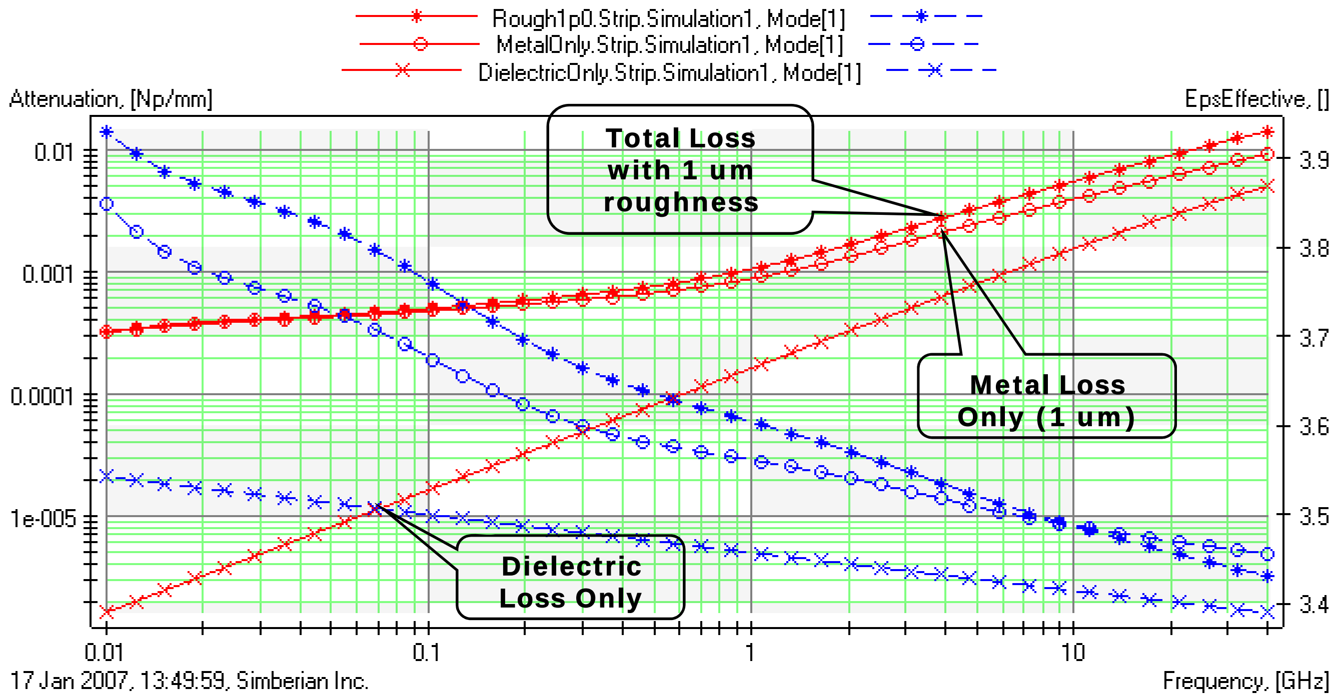
Simbeor results with r.m.s. roughness of all metal objects is 1 um (circles) and 0.5 um (stars)



From “Accounting for High Frequency Transmission Line Loss Effects in HFSS”, Andrew Byers, Tektronix, 2003 HFSS Users Workshop, http://www.ansoft.com/workshops/hfworkshop03 Andy_Byers_Tektronix.pdf

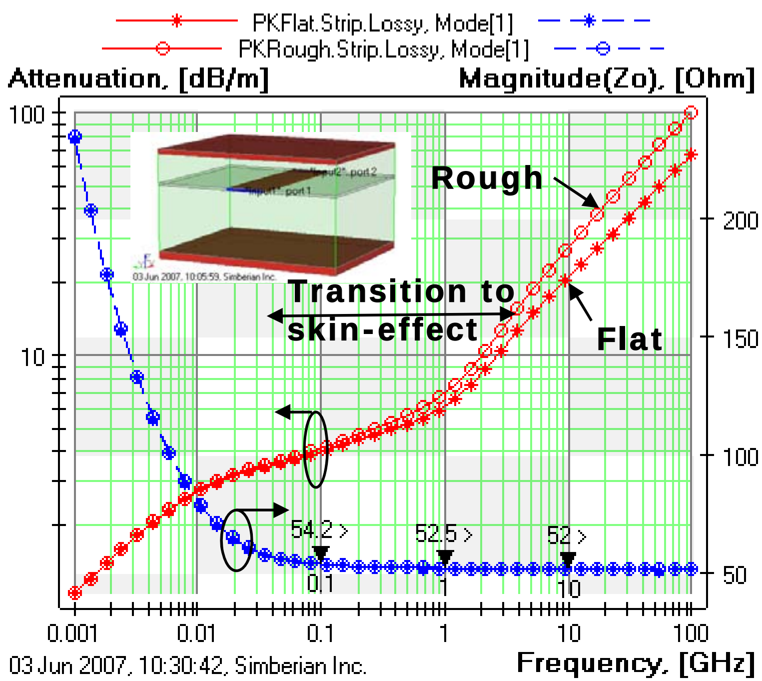
Package strip line – effect of dielectric and metal losses on attenuation and dispersion

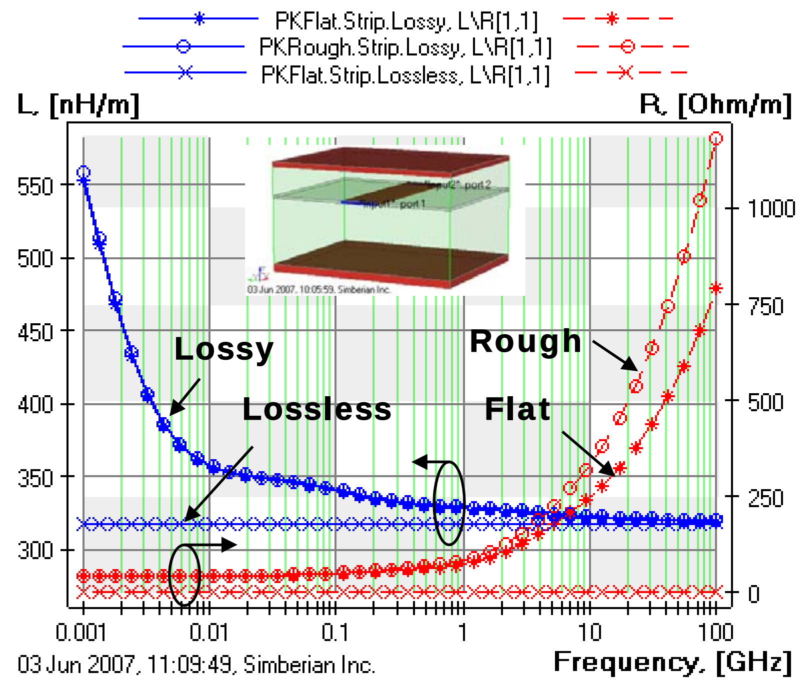
79 um wide and 5 um thick strip in dielectric with Dk=3.4 and LT=0.008 at 10 GHz modeled as wideband Debye. Distance to top plane 60 um, to bottom plane 138 um. Top plane thickness is 10 um, bottom 15 um



Package strip line with different roughness for top and bottom surfaces of strip

- Broadband analysis: transition to skin-effect, skin-effect with roughness, proximity and edge-effects…





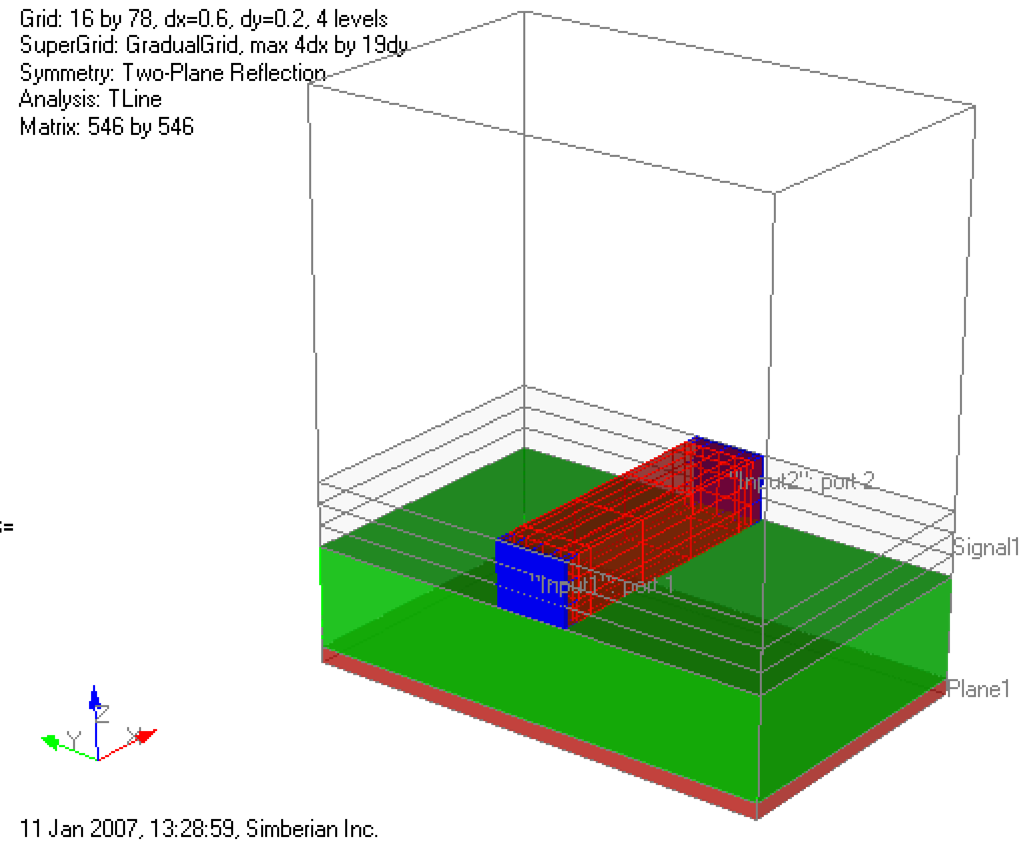
79 um wide and 5 um thick strip in dielectric with Dk=3.4 and LT=0.008 at 10 GHz modeled as wideband Debye. Distance to top plane 60 um, to bottom plane 138 um. Top plane thickness is 10 um, bottom 15 um. **RMS roughness is 1 um on all surfaces except top of the strip, that is flat.**

On-chip micro-strip line example

Example: TLines\ Comparisons\ OnChip\ OnChip.esx

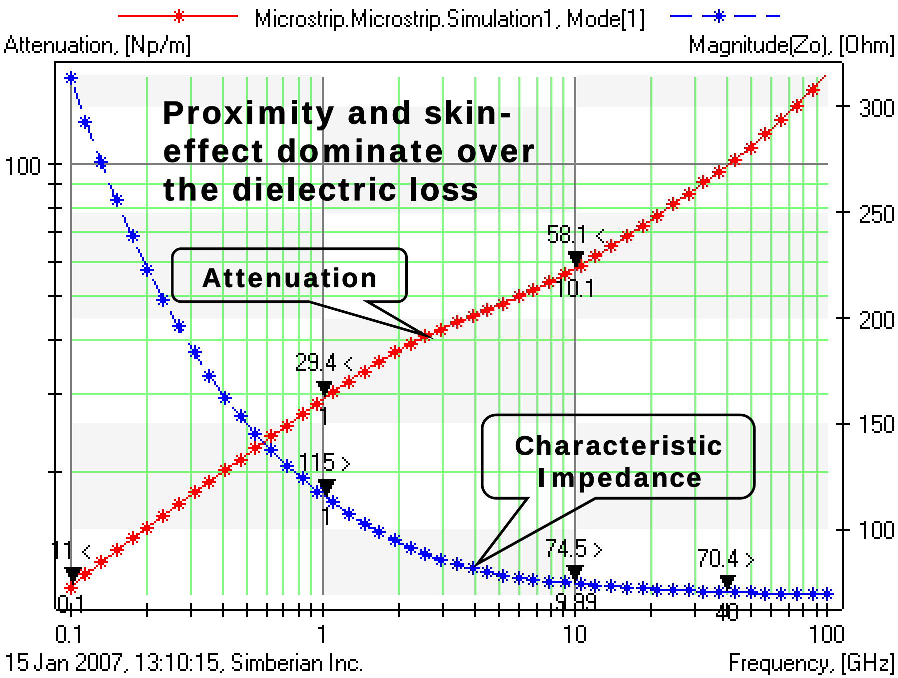
2.4 um wide and 2.07 um thick micro-strip on substrate with Dk=4.1 and LT=0.001 at 10 GHz modeled as one-pole Debye with relaxation frequency 1 THz.
Substrate thickness is 3.25 um.
Plane thickness is 0.5 um,
metal conductivity is 3.22e7.

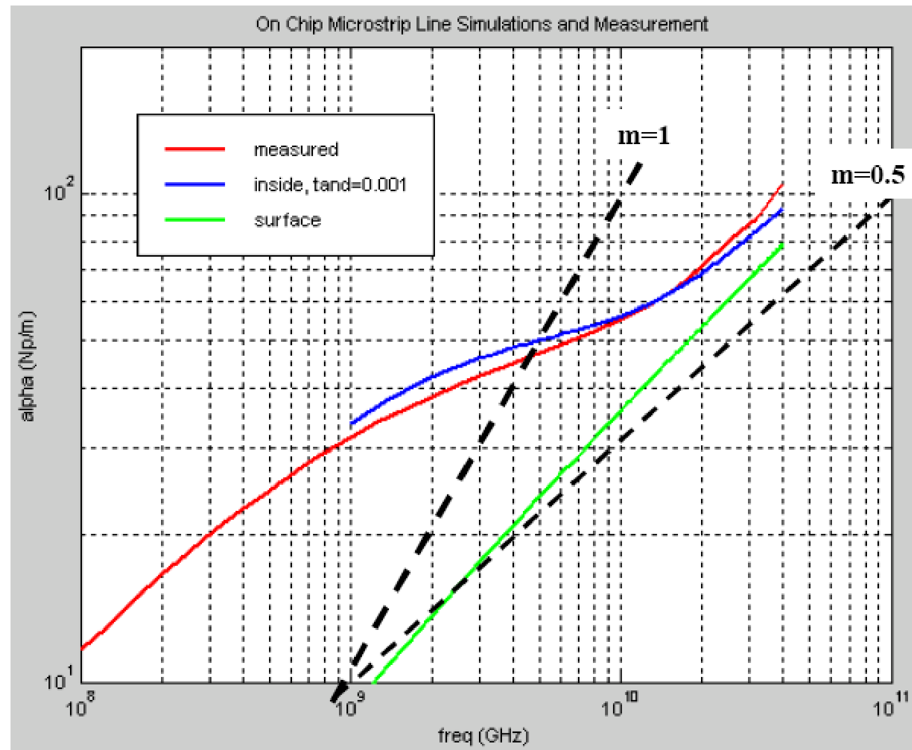
```
Solution: "OnChip"
  Microstrip
    Materials
      "Aluminum", RR=1.80162, SR=0.1
      "IdealMetal"
      "Vacuum"
      "SiO2", Dk=4.1, LT=0.001, PLM=1PD
    StackUp: LU=[um], NL=3, T=5.82
      1| Signal: "Signal1", T=2.07, Ins="Vacuum"
      2| Medium: T=3.25, Ins="SiO2"
      3| Plane: "Plane1", Mat="Aluminum", T=0.5, Ins=
    Microstrip
      CircuitData: LU=[um]
      Simulation1
  Graph1(TLineParameters.Modal vs. Frequency)
```



On-chip micro-strip line: skin-effect

2.4 um wide and 2.07 um thick micro-strip on substrate with Dk=4.1 and LT=0.001 at 10 GHz modeled as one-pole Debye with relaxation frequency 1 THz. Substrate thickness is 3.25 um. Plane thickness is 0.5 um, metal conductivity is 3.22e7.



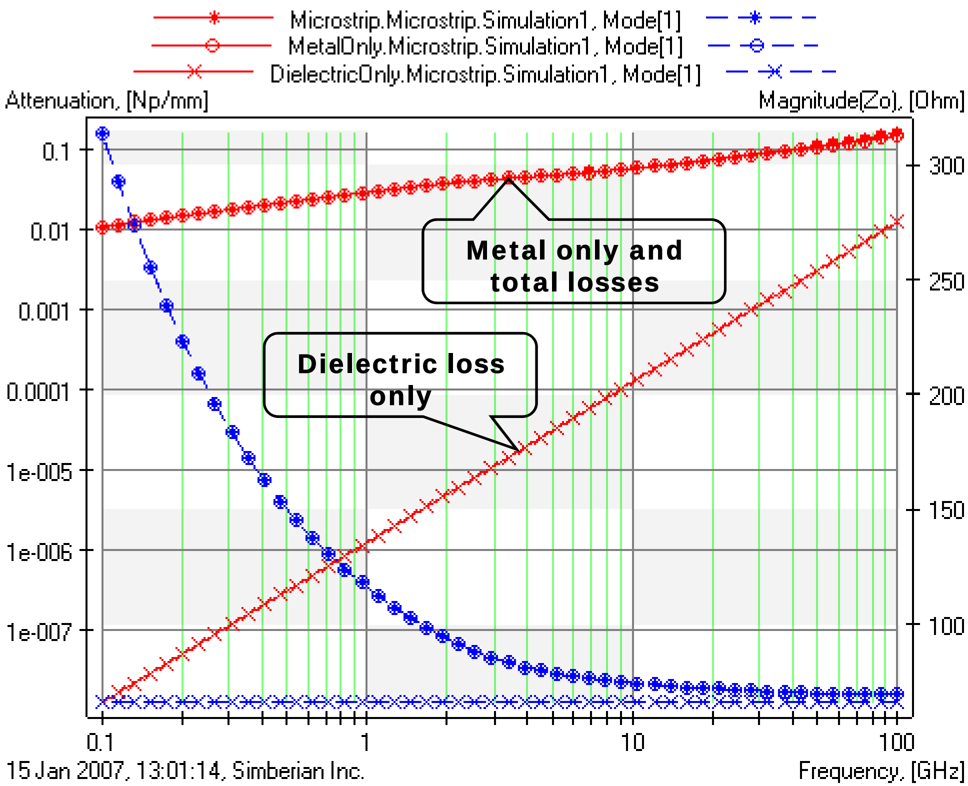


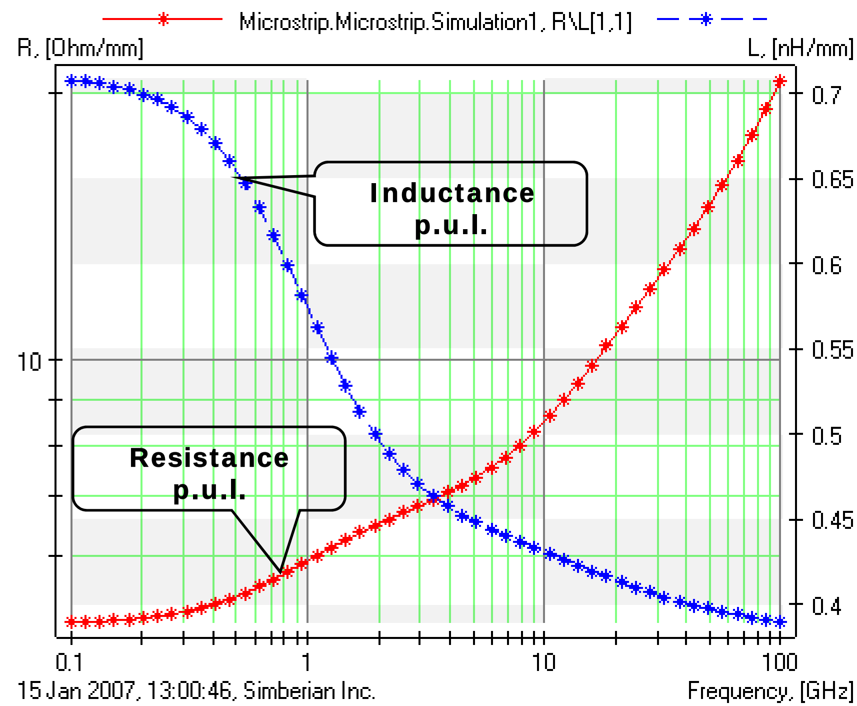
Simbeor results with r.m.s. roughness of all metal objects is 0.1 um

From "Accounting for High Frequency Transmission Line Loss Effects in HFSS", Andrew Byers, Tektronix, 2003 HFSS Users Workshop, http://www.ansoft.com/workshops/hfworkshop03 Andy_Byers_Tektronix.pdf

Domination of the skin-effect over dielectric loss for the on-chip micro-strip line

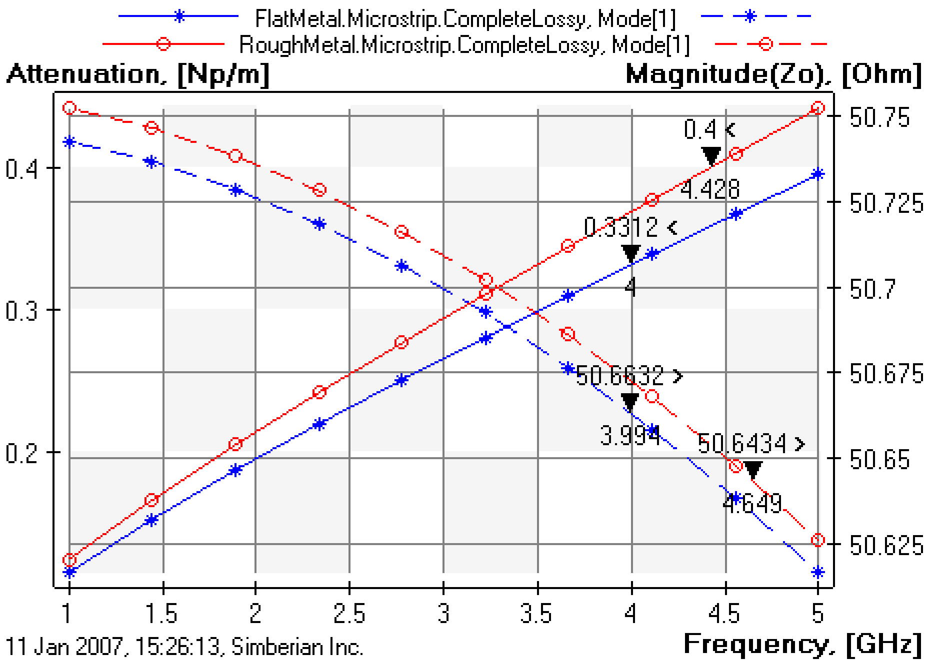
2.4 um wide and 2.07 um thick micro-strip on substrate with Dk=4.1 and LT=0.001 at 10 GHz modeled as one-pole Debye with relaxation frequency 1 THz. Substrate thickness is 3.25 um. Plane thickness is 0.5 um, metal conductivity is 3.22e7.





Microwave IC (MIC) micro-strip line example

Example: TLines\ AttenuationTest1\ AttenuationTest1.esx



Microstrip line: Blue curves – attenuation and impedance with flat metal surfaces, red curves with metal surface roughness 0.5 um.

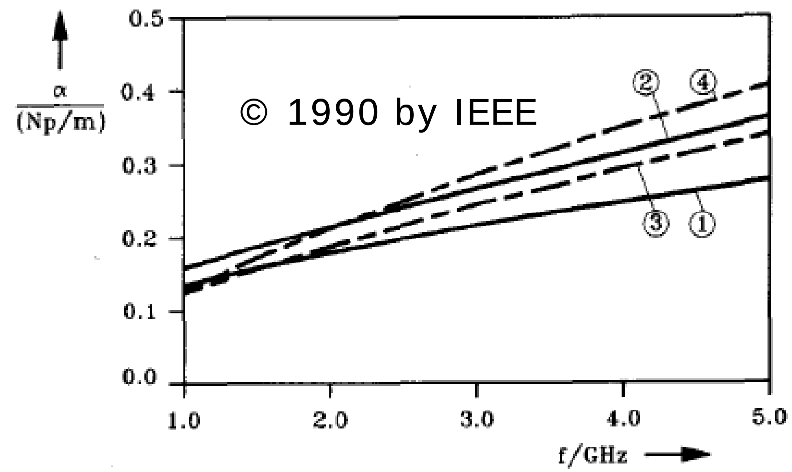


Fig. 4. Attenuation of a microstrip waveguide with an alumina substrate and copper metallizations. ($a = 3.0$ mm, $w = 0.508$ mm, $t_B = 10$ μm, $b = 1.27$ mm, $t_S = 7.87$ μm, $c = 4.0$ mm, $\epsilon_{r1} = 9.35 - j1.9635 \cdot 10^{-3}$). *1:* metallization surface without roughness ($\kappa = 5.78628 \cdot 10^7$ S/m, $\epsilon_{rB} = \epsilon_{rS} = -j1.04 \cdot 10^9$ at $f = 1$ GHz; *2:* considering the surface roughness; *3:* theoretical results from [3]; *4:* measured results from [3].

1) F.J. Schmuckle, R. Pregla, "The method of lines for the analysis of lossy planar waveguides", IEEE Trans. on MTT, v. 38, 1990, N 10, p. 1473-1479.
2) R.A. Pucel, D.J. Masse, C.P. Hartwig, "Losses in microstrip", IEEE Trans. on MTT, vol. 16, 1968, N 6, p. 342-350.

Conclusion

- Analysis of signal propagation in multilayered interconnects requires 3D full-wave models for transmission lines in case if
  - Models valid over 5-6 frequency decades are required (multi-gigabit serial data channels)
  - Polarization and high-frequency dispersion effects have to be taken into account
  - Roughness effects have to be taken into account
  - Conductor plating effects have to be taken into account
- Simplified electromagnetic and static models may be not correct and result in the design failure, project delays, increased cost …

Solutions and contacts

- All solution files for these notes are available in My Documents/Simbeor Solutions directory after installation of Simbeor 2007
- Send questions and comments to
  - General: info@simberian.com
  - Sales: sales@simberian.com
  - Support: support@simberian.com
- Web site www.simberian.com