

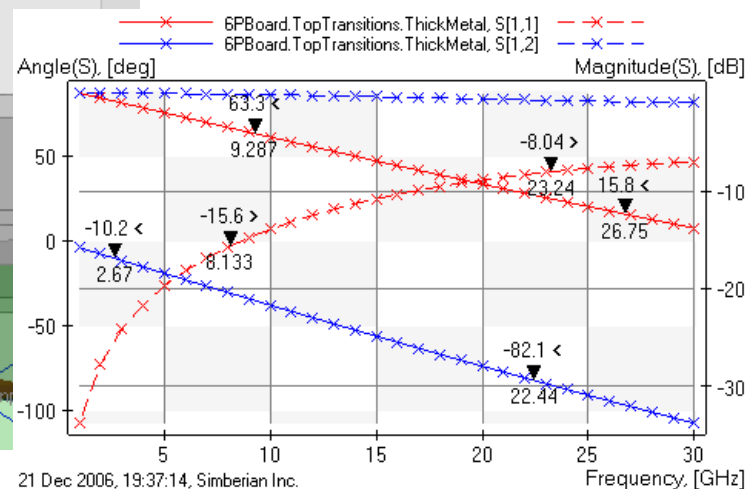
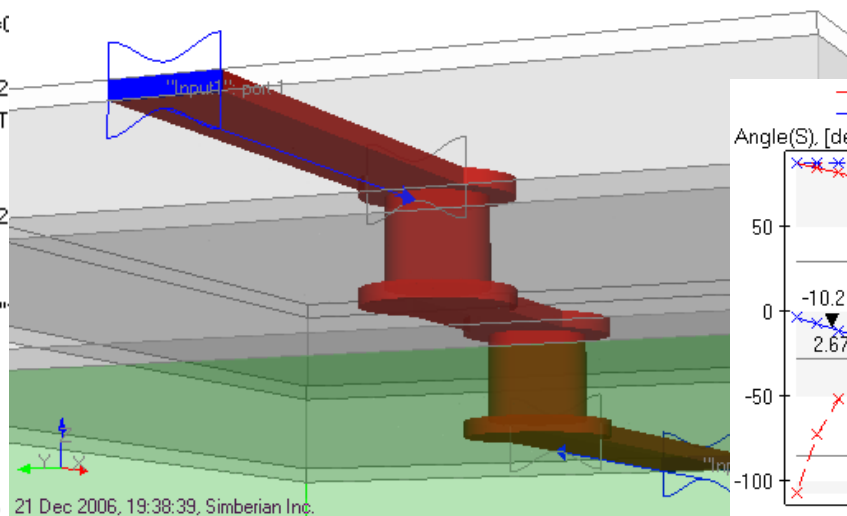
Modeling differential via-holes without stitching vias

Solution: "MicroVias"

- 6PBoard
 - Materials
 - "copper", RRes=1, Rough=0.01
 - "IdealMetal"
 - "prepreg", DK=4.7, LT=0.02
 - "Vacuum"
 - "FR4", DK=4.2, LT=0.02
 - StackUp: LU=[mil], NL=15, T
 - TopTransitions
 - CircuitData: LU=[mil]
 - Multiport: 2 inputs, 2
 - LatticeBox
 - Geometry
 - GeoComposite: "
 - TLines
 - Inputs
 - ThickMetal
 - CollapsedMetal
 - BottomTransition
- Graph1(MultiportParameters vs. Frequency) 21 Dec 2006, 19:38:39, Simberian Inc.
- Graph2(MultiportParameters vs. Frequency)

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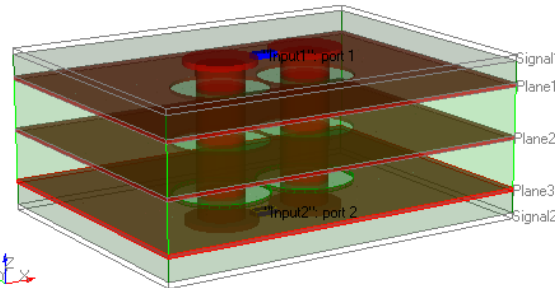


Introduction

- ❑ Electromagnetic simulation of differential vias without vias stitching the reference planes introduces uncertainty in the analysis of the multi-gigabit data channels
- ❑ The goal is to investigate possible ways to simulate differential multi-gigabit channels with localizable 3D full-wave S-parameter models extracted with Simbeor 2007
- ❑ Use HyperLynx 7.7 with Eldo from Mentor Graphics Corporation for system-level analysis

What is the differential via?

- Differential vias are two-viahole transitions through multiple parallel planes

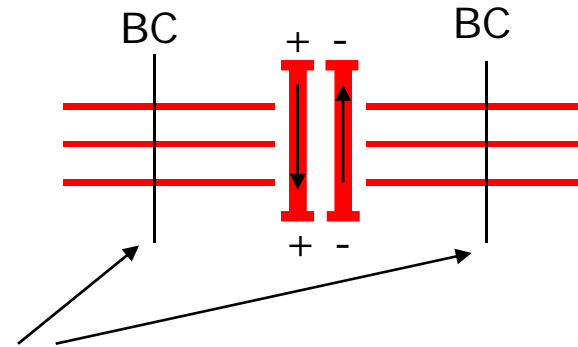


25 Apr 2007, 06:42:50, Simberian Inc.

- Two modes propagate independently through a **symmetrical** via pair
 - Differential (+-) – two vias are two conductors
 - Common (++) – two vias one conductor and parallel planes with everything attached to them is another conductor
- Signal in differential pair always contain differential mode (useful) and may contain common mode induced by asymmetries in driver and discontinuities

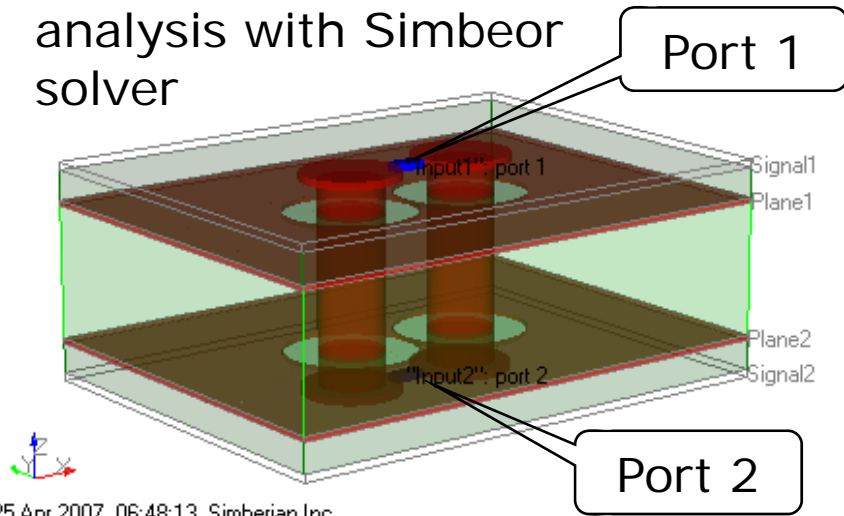
S-parameter models for differential vias

- Differential mode has two identical currents on the via barrels
- The vias can be isolated from the rest of the board for the electromagnetic analysis with any boundary conditions (BC)
 - Distance from the vias to the simulation area boundaries should be larger than the largest distance between the planes to reduce the effect
 - In that case, the differential mode S-parameters are practically independent of the boundary conditions

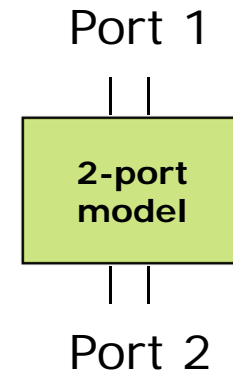


Any 3D full-wave solver can be used to generate a differential via model

Differential via-holes analysis with Simbeor solver



25 Apr 2007, 06:48:13, Simberian Inc.

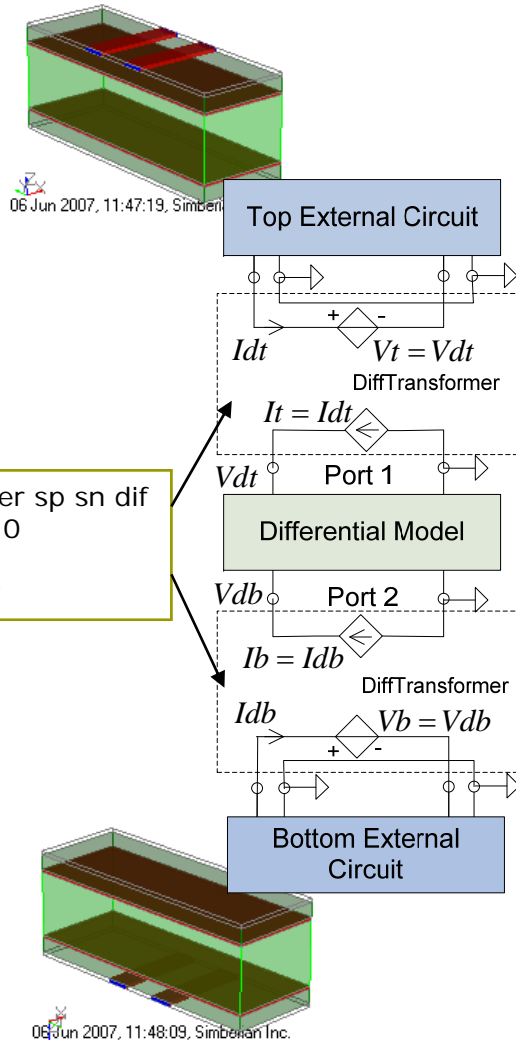


Solver generates Touchstone s2p file with tabulated scattering (S) parameters

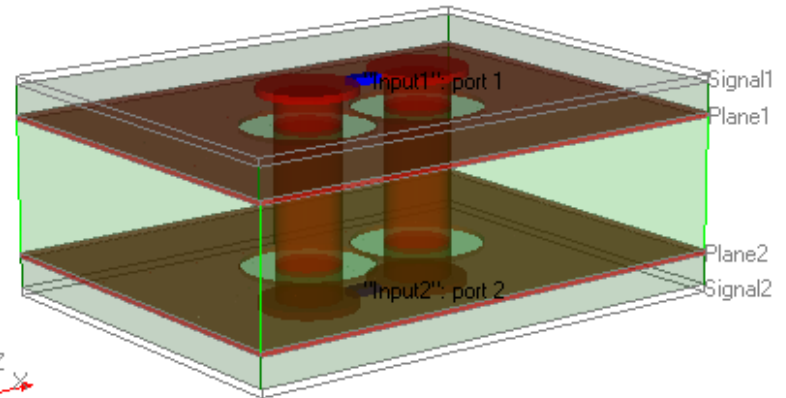
```
# Hz S MA R 50
!Touchstone multiport model file <Project1_DifVias_Simulation1.s2p>
!Created with Simbeor 2007.05

!Frequency Hz |S[1,1]| arg(S[1,1]) |S[1,2]| arg(S[1,2]) |S[2,1]| arg(S[2,1]) |S[2,2]| arg(S[2,2])
1e+007 0.00019967204037128 80.2602696805706 0.99996135358717 -0.0323490304593697 0.999961353587184 -0.0323490304593693 0.000199673211473872 80.2582768233478
1.6681e+007 0.000322468838468293 82.6000881350992 0.999950431873029 -0.0533202384129493 0.999950431873026 -0.0533202384194636 0.000322467239270051 82.6017028071304
...
1.9e+010 0.244570464339174 35.2840265413718 0.961777164971986 -55.3104068976763 0.961777164971987 -55.3104068976763 0.244498847955767 35.2671173277359
2e+010 0.248547099289332 32.5237839600036 0.960378206732979 -58.1318674656129 0.960378206732979 -58.1318674656129 0.248469713303658 32.5058580236588
```

Differential via-hole model in the system-level analysis



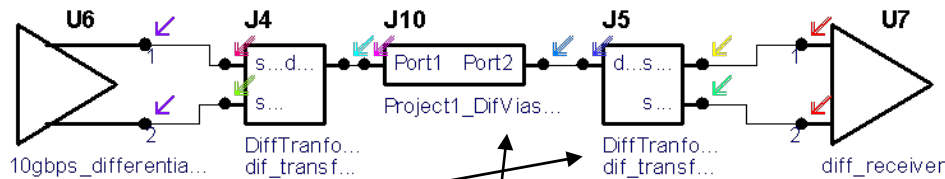
Common mode is open-circuited (reflected)



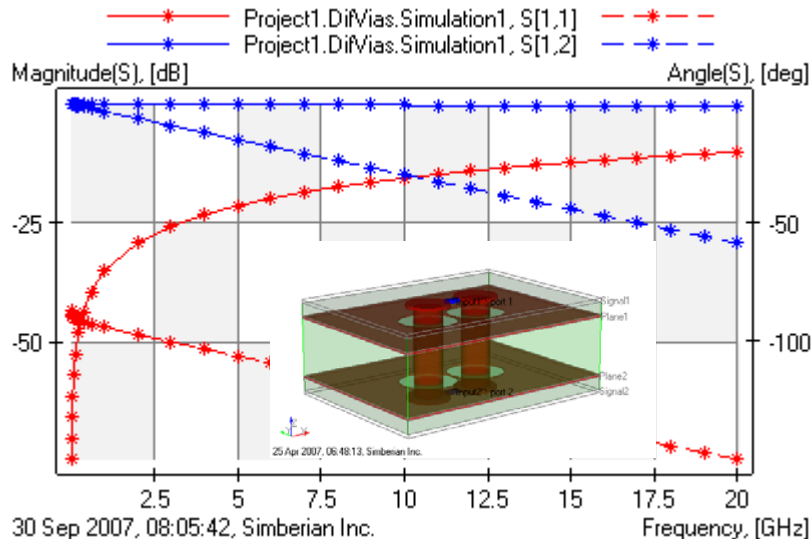
25 Apr 2007, 06:48:13, Simberian Inc.

Example of a differential channel analysis with just differential model of via-holes

Design File Tutorial Just Differential
HyperLynx V7.7



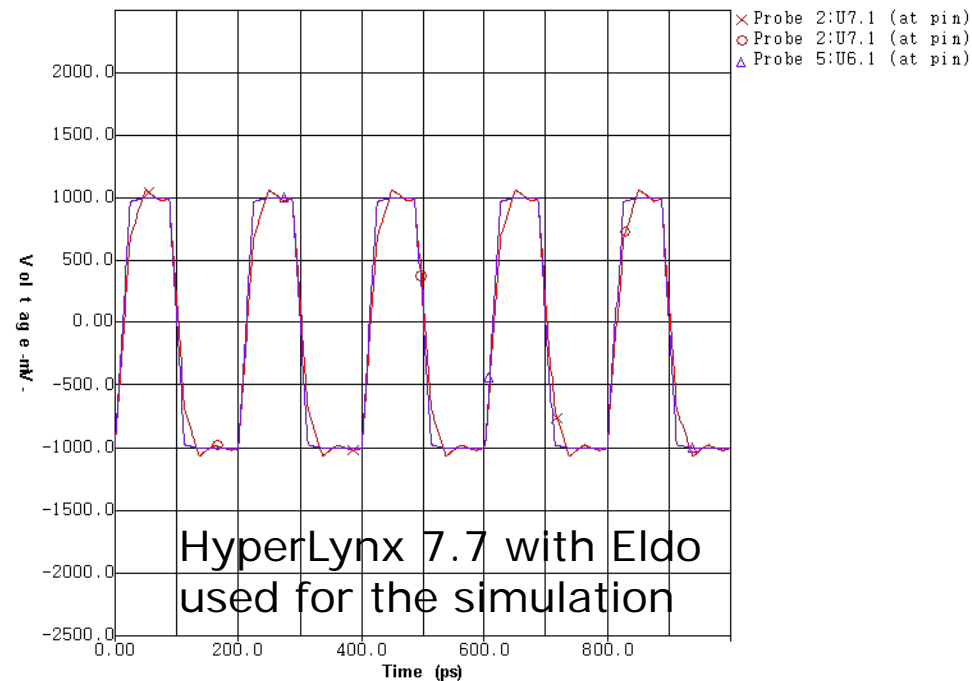
```
.subckt DiffTransformer sp sn dif
e1 sp sn trans dif 0 1.0
f1 0 dif e1 1.0
.ends DiffTransformer
```



Propagation of 10 Gbps differential signal through pair of via-holes (not optimal vias are from Simbeor Tutorial 3)

OSCILLOSCOPE

Design file: TUTORIALJUSTDIFFERENTIAL.FFS Designer:
HyperLynx V7.7



HyperLynx 7.7 with Eldo
used for the simulation

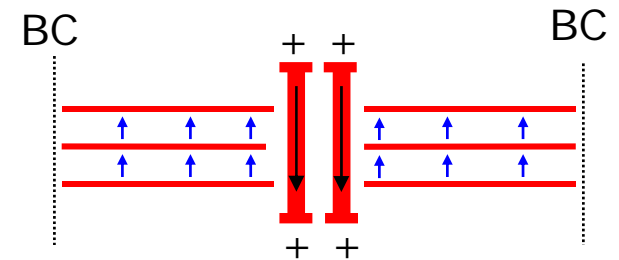
Date: Sunday Sep. 30, 2007 Time: 7:43:17

Show Latest Waveform = YES, Show Previous Waveform = YES

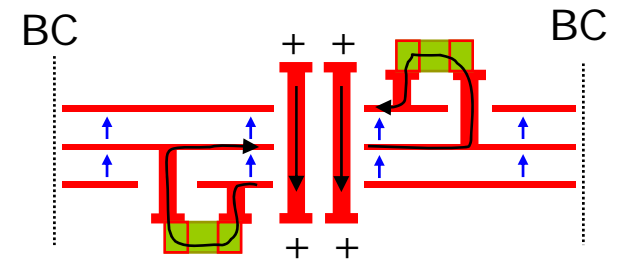
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What about modeling vias with the common mode?

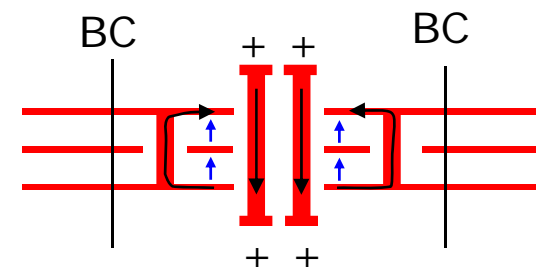
- Planes are not terminated and the return current for common mode is the “displacement” current between the planes
 - The problem is **non-localizable** – may require analysis of the whole board



- Planes are terminated with the decoupling capacitors and the return current is a combination of the “displacement” currents through capacitors and planes
 - Decaps have low impedance only in a narrow band – thus the problem again is **non-localizable** for broadband EM analysis



- Stitching vias are used to connect the reference planes for the connected layers and the return current is mostly conductive
 - Problem can be localized (**localizable**) and solved with any boundary conditions



Non-localizable cases without stitching vias

- In general, the common-mode part of S-parameter model becomes dependent on the simulation area and boundary conditions
 - Independence of the boundary conditions indicates that the problem is localizable
- Any type of locally enforced boundary conditions is not correct for the non-localizable problem
 - PEC (perfect electric conductor walls) are equivalent to short-circuiting the planes at a distance from vias – preferable
 - PMC (perfect magnetic conductor walls) are equivalent to open-circuiting the planes at a distance from vias – incorrect low frequency asymptotic of S-parameters
 - PML (perfectly matched layer) or ABC (absorbing boundary conditions) – absorbs energy at a distance from vias
 - Not equivalent to the infinite planes (infinite planes or radial waveguides reflect energy at any location because of changing impedance)
 - Common mode energy is completely lost for the system level analysis (it will appear somewhere)

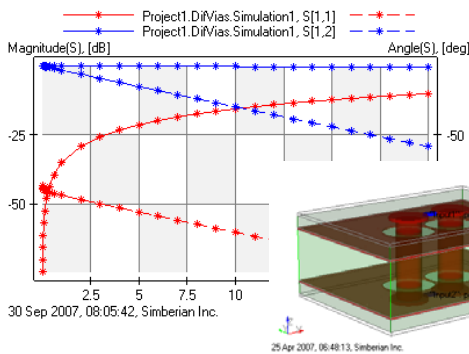
How to simulate differential vias with the common mode?

- Simulate the whole board in a 3D full-wave solver with all plane terminations
 - Hardly ever possible and not practical
- Use a hybrid solver with 2D parallel-plane models
 - Practical, but accurate only if such solvers include 3D full-wave models for differential mode (no such solvers available so far)
- Localize the problem with asymptotically correct PEC boundary conditions
 - Influence of the boundary conditions on the performance at the system level may be insignificant in many cases
 - May work if no common mode or it is very small at the connections to the vias

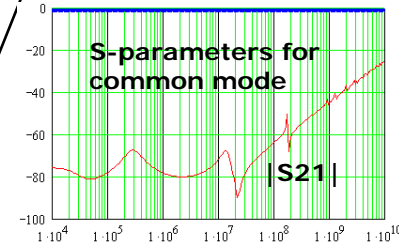
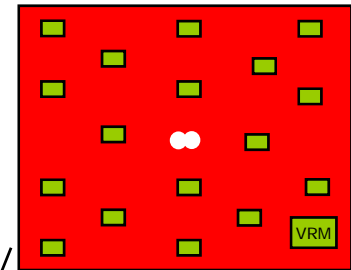
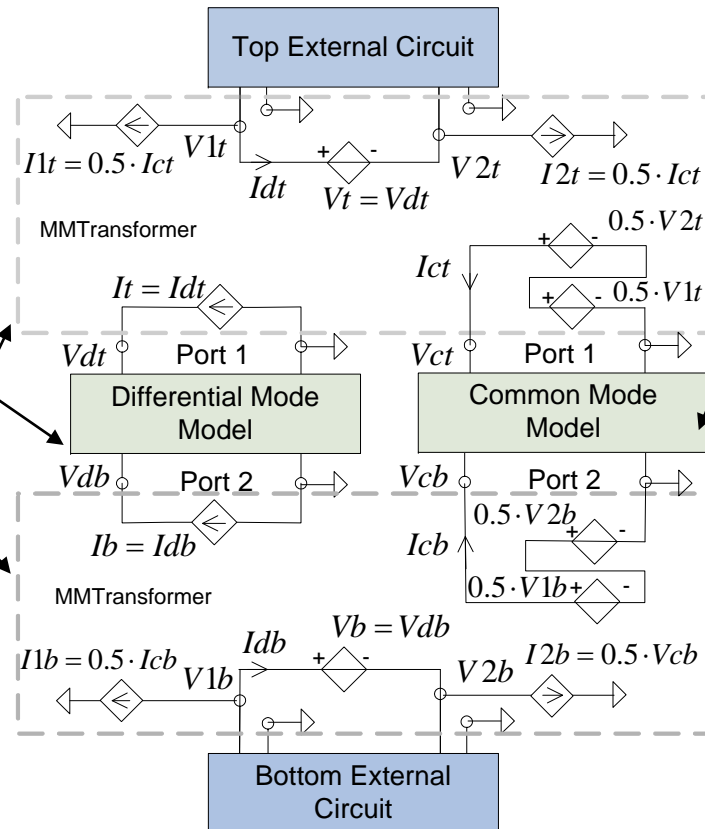
Separation of differential and common mode at a differential via-holes for hybrid analysis

Differential mode model can be created with any 3D full-wave solver

Common mode models can be created with a 2D transmission plane solver



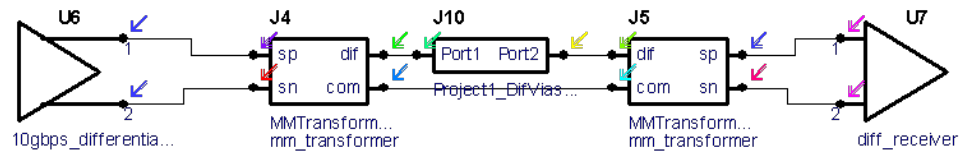
```
subckt MMTransformer sp sn dif com
*transformer to and from differential
e1 sp sn trans dif 0 1.0
f1 0 dif e1 1.0
*transformer to and from common
f2 sp 0 e2 0.5
f3 sn 0 e3 0.5
e2 0 n1 trans sp 0 0.5
e3 n1 com trans sn 0 0.5
.ends MMTransformer
```



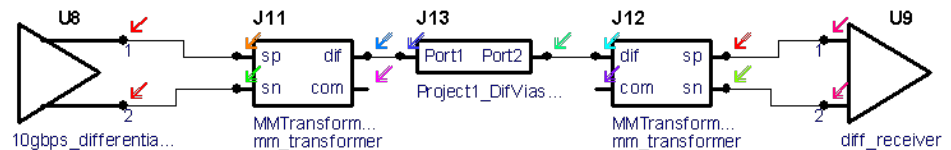
Comparison of different common-mode termination conditions without skew

Design File: TutorialDifAndCommon.tfs
HyperLynxLineSimV7.7

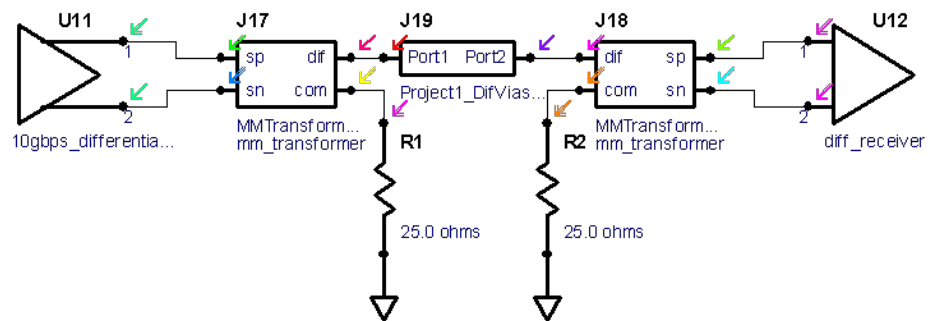
1. Common mode propagate through vias – PEC-like conditions



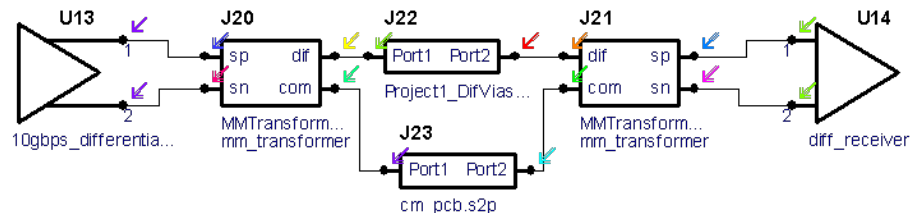
2. Common mode reflected – PMC-like conditions



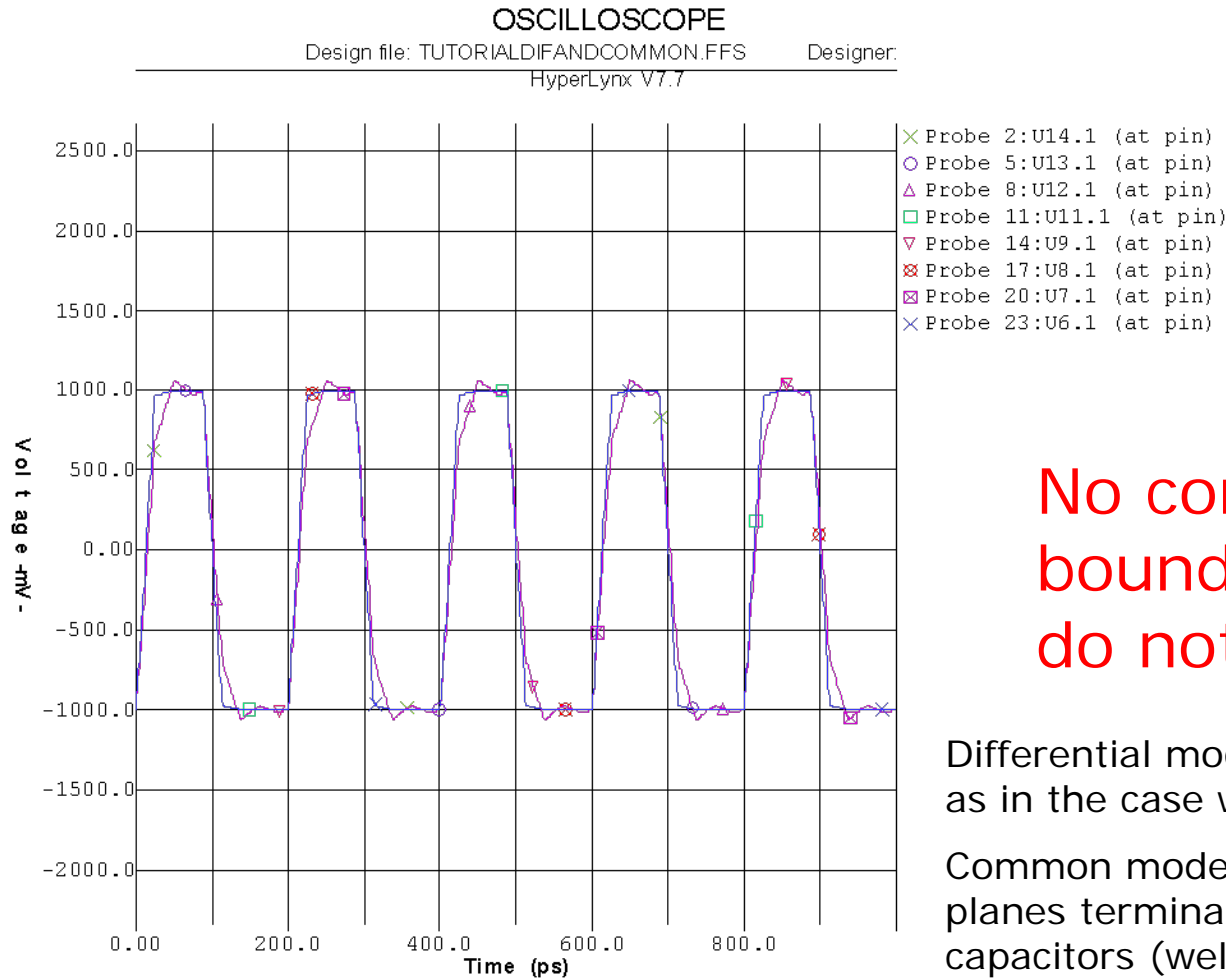
3. Common mode absorbed – ABC-like conditions



4. Common mode terminated with 2-port model of decoupled PDN



All terminations are identical because of no common mode in the channel



**No common mode –
boundary conditions
do not matter!**

Differential mode model of via is the same as in the case with differential only model

Common mode model is transmission planes terminated with multiple decoupling capacitors (well-decoupled planes)

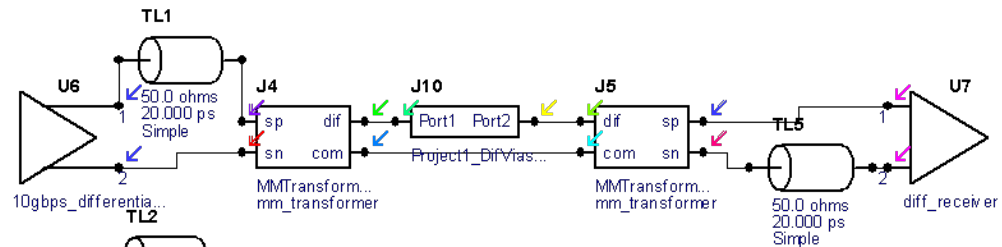
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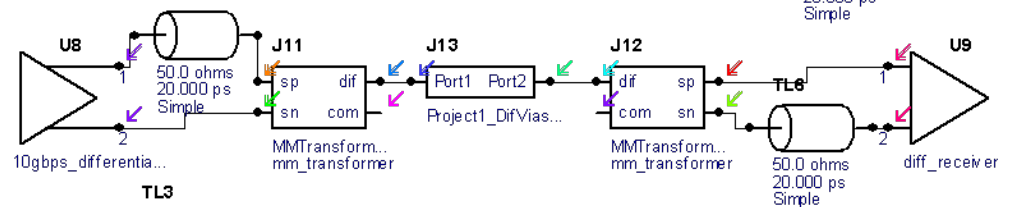
Comparison of different common-mode termination conditions with 20 ps skew

Design File: Tutorial DifAndCommonSkewed.tfs
HyperLynx LineSim V7.7

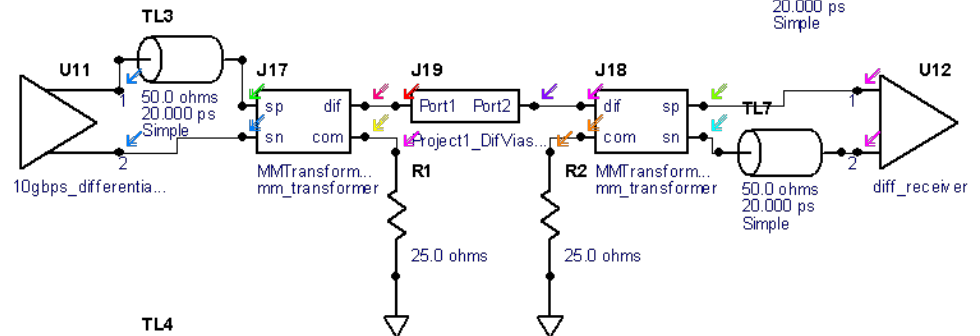
1. Common mode propagate through vias – PEC-like conditions



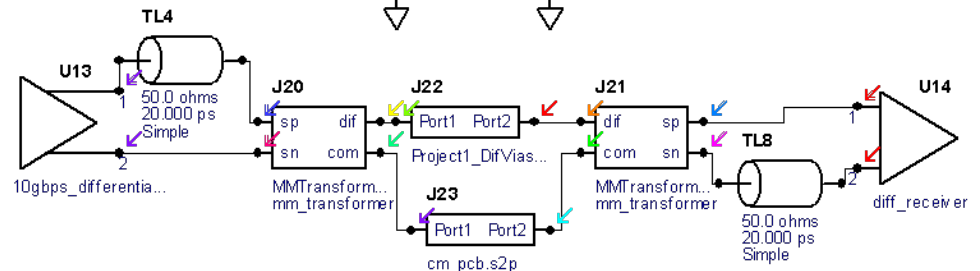
2. Common mode reflected – PMC-like conditions



3. Common mode absorbed – ABC-like conditions



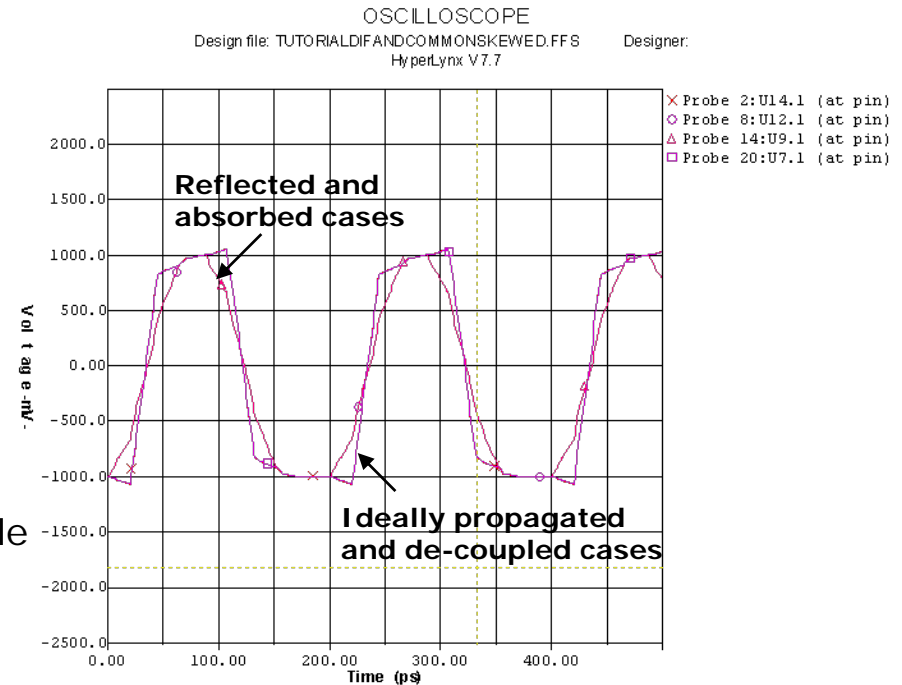
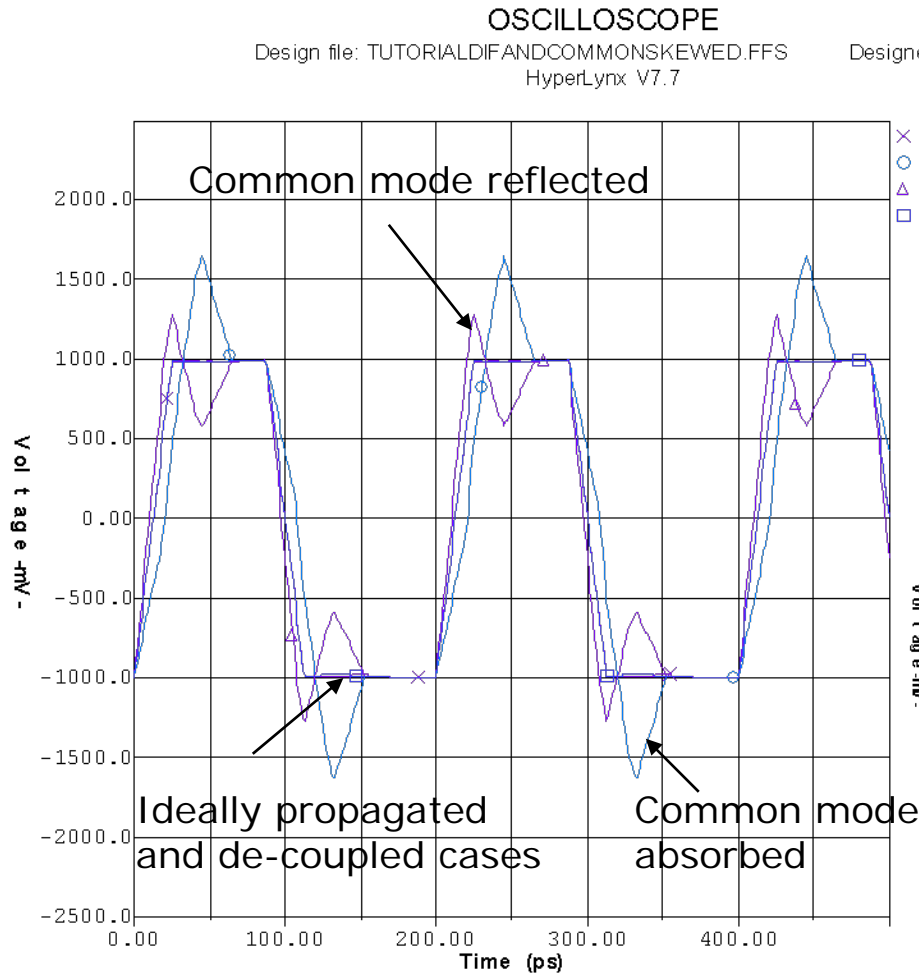
4. Common mode terminated with 2-port model of decoupled PDN



Differential signal reflection and transmission

Now termination matters!

Different boundary conditions produce different results!

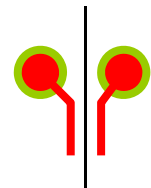
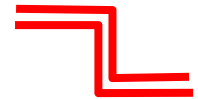
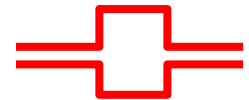
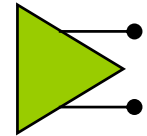


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Show Latest Waveform = YES, Show Previous Waveform = YES

Avoid conversion from differential to common mode by design!

- ❑ Use symmetrical drivers and receivers that do not generate common mode
- ❑ Keep traces at the same distance and bypass discontinuity symmetrically if absolutely necessary
- ❑ If a discontinuity converts differential mode into common – use mirror discontinuity to convert it back into differential mode
- ❑ Via-holes and transition to the traces have to be symmetrical
- ❑ **Common mode analysis is not necessary if no common mode generated**



Conclusion

- ❑ Localized 3D full-wave analysis of the common mode propagation through differential vias without stitching vias is not correct with any type of boundary conditions
 - Only hybrid model combining 3D full-wave differential mode model with a system-level 2D transmission plane model of PDN can reliably predict the transition of common mode through the via pair
- ❑ Stitching vias connecting reference planes of the input and output transmission lines allow to localize the problem and to avoid the hybrid system-level analysis
- ❑ Common mode can be reduced by design – any localized model for common mode can be used in this case

Solutions and contact

- Solution files and HyperLynx schematic files are available for download from the simberian web site

http://www.simberian.com/AppNotes/Solutions/DiffViasWithCommonMode_2007_07.zip

- Send questions and comments to

- General: info@simberian.com

- Sales: sales@simberian.com

- Support: support@simberian.com

- Web site www.simberian.com