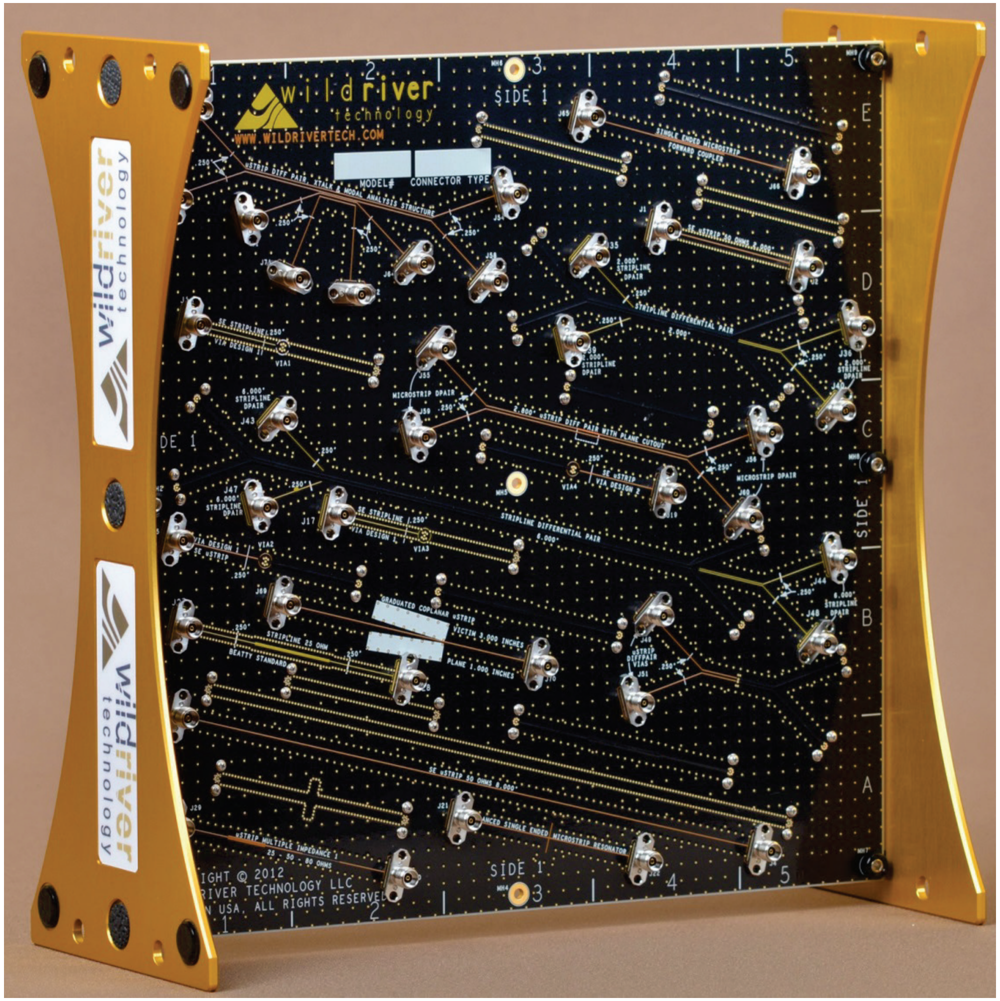


Guide to CMP-28/32 Simbeor Kit

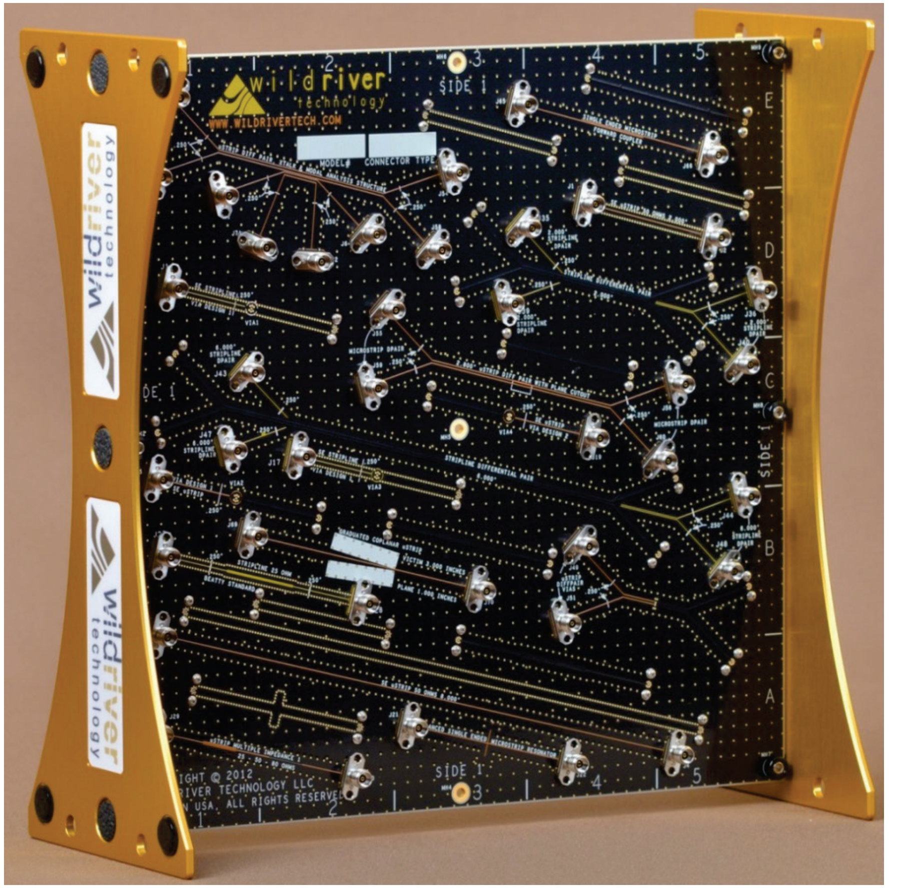
CMP-28 Rev. 4, Sept. 2014
Simbeor 2013.03, Aug. 10, 2014

Introduction

- Design of PCB and packaging interconnects for data links running at bitrates 28-32 Gbps and beyond is a challenging problem:
  - It requires electromagnetic analysis over extremely broad frequency bandwidth from DC to 40-50 GHz
  - No frequency-continuous dielectric models available from manufactures
  - No conductor roughness models available from manufacturers
  - Boards are not manufactured as designed – large variations and manipulations by manufacturers
  - Making accurate measurements over this bandwidth is difficult
- How to design interconnects and have acceptable analysis to measurement correlation from DC up to 40-50 GHz systematically?
  - Systematic validation or benchmarking process is the key:
    Making sure that interconnect analysis software is accurate, measurements done properly and board is manufactured as designed
  - CMP-28/32 channel modeling platforms is designed to illustrate and facilitate systematic analysis to measurement validation process…

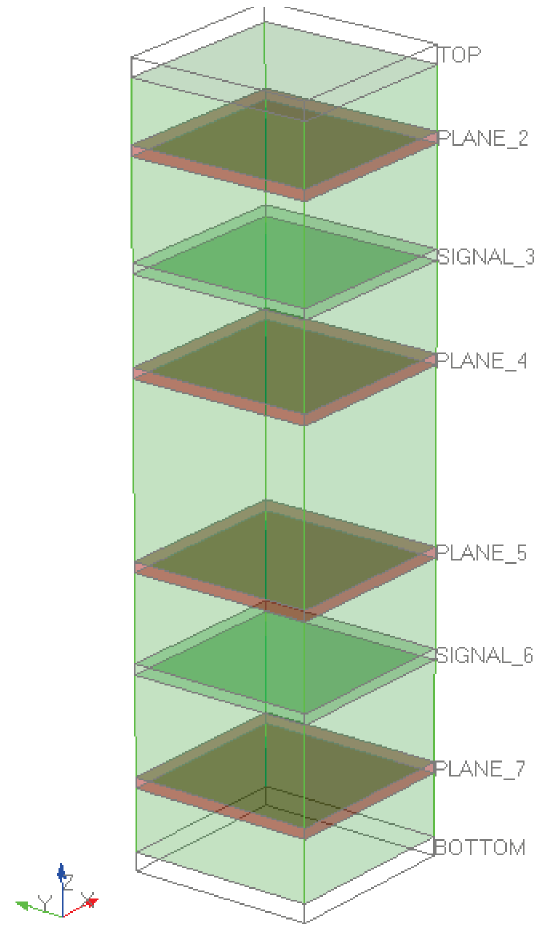
Simbeor Kit for CMP-28/32

- CMP-28/32 Channel Modeling Platform was developed by Wild River Technology to promote systematic approach to interconnect analysis to measurement validation up to 40/50 GHz or up to 28/32 Gbps
- It contains 27 micro-strip and strip-line interconnect structures equipped with 2.92 mm (CMP-28) and 2.4 mm (CMP-32) connectors and can be used to validate signal integrity simulators or measurement technique
- Simbeor electromagnetic signal integrity software from Simberian Inc. was used to design the platform and is used here to illustrate all elements of the analysis to measurement validation



Materials and stackup

- Materials: T=20[°C],...
  - "1OZ_COPPER", RR=1, SR=0.4, RF=2, RM=MHCC
  - "PLATED_1OZ_COPPER", RR=1, SR=0.4, RF=3.5, RM=MHCC
  - "Air"
  - "Solder_Mask", Dk=3.85, LT=0.02, PLM=WD, Dk(0)=4.64, Dk(inf)=3.4
  - "FR408HR_SL", Dk=3.815, LT=0.0117, PLM=WD, Dk(0)=4.27, Dk(inf)=3.55
  - "FR408HR_MS", Dk=3.815, LT=0.0117, PLM=WD, Dk(0)=4.27, Dk(inf)=3.55
- StackUp: LU=[mil], NL=8, T=93.6[mil], CSM=("Solder_Mask", 2.5[mil])
  - 1| Signal: "TOP", T=2.25, Ins="Air", Cond="PLATED_1OZ_COPPER"
  - 2| Medium: T=7.55, Ins="FR408HR_MS", DIE_003
  - 3| Plane: "PLANE_2", Cond="1OZ_COPPER", T=1.3, Ins="FR408HR_SL", Rough
  - 4| Medium: T=12, Ins="FR408HR_SL", DIE_005
  - 5| Signal: "SIGNAL_3", T=1.3, Ins="FR408HR_SL", Cond="1OZ_COPPER"
  - 6| Medium: T=10.6, Ins="FR408HR_SL", DIE_007
  - 7| Plane: "PLANE_4", Cond="1OZ_COPPER", T=1.3, Ins="FR408HR_SL"
  - 8| Medium: T=21, Ins="FR408HR_SL", DIE_009
  - 9| Plane: "PLANE_5", Cond="1OZ_COPPER", T=1.3, Ins="FR408HR_SL"
  - 10| Medium: T=10.6, Ins="FR408HR_SL", DIE_011
  - 11| Signal: "SIGNAL_6", T=1.3, Ins="FR408HR_SL", Cond="1OZ_COPPER"
  - 12| Medium: T=12, Ins="FR408HR_SL", DIE_013
  - 13| Plane: "PLANE_7", Cond="1OZ_COPPER", T=1.3, Ins="FR408HR_SL", Rough
  - 14| Medium: T=7.55, Ins="FR408HR_MS", DIE_015
  - 15| Signal: "BOTTOM", T=2.25, Ins="Air", Cond="PLATED_1OZ_COPPER"



16 Sep 2014, 06:49:42, Simberian Inc. 3D View Mode (press <E> to Edit).

Stackup confirmed by board manufacturer
Material models confirmed and identified in Simbeor (see the material identification section)

CMP-28 Simbeor Kit folders

- 1_MaterialIdentification
- 2_MaterialValidationDifferential
- 3_MicrostripSingle(1)
- 4_MicrostripSingle(2)
- 5_MicrostripDifferential(1)
- 6_MicrostripDifferential(2)
- 7_MicrostripDifferentialXTalk(3)
- 8_StripSingle(1)
- 9_StripSingle(2)
- 10_StripDifferential(1)
- CMP-28_Rev4
- ConnectorModel
- docs
- MicrostripDifferentiaCutOut
- ModelsToReUse
- CMP-28_Simbeor_Kit_Guide.pptx

Identification and validation of material models with single-ended and differential line segments

Validation for microstrip single-ended structures

Validation for microstrip differential structures

Validation for strip single-ended and differential structures

Measured data in Touchstone format and optionally board design (brd or ODB++ files available with CMP platform only)

Synthesis of connector model from measured data

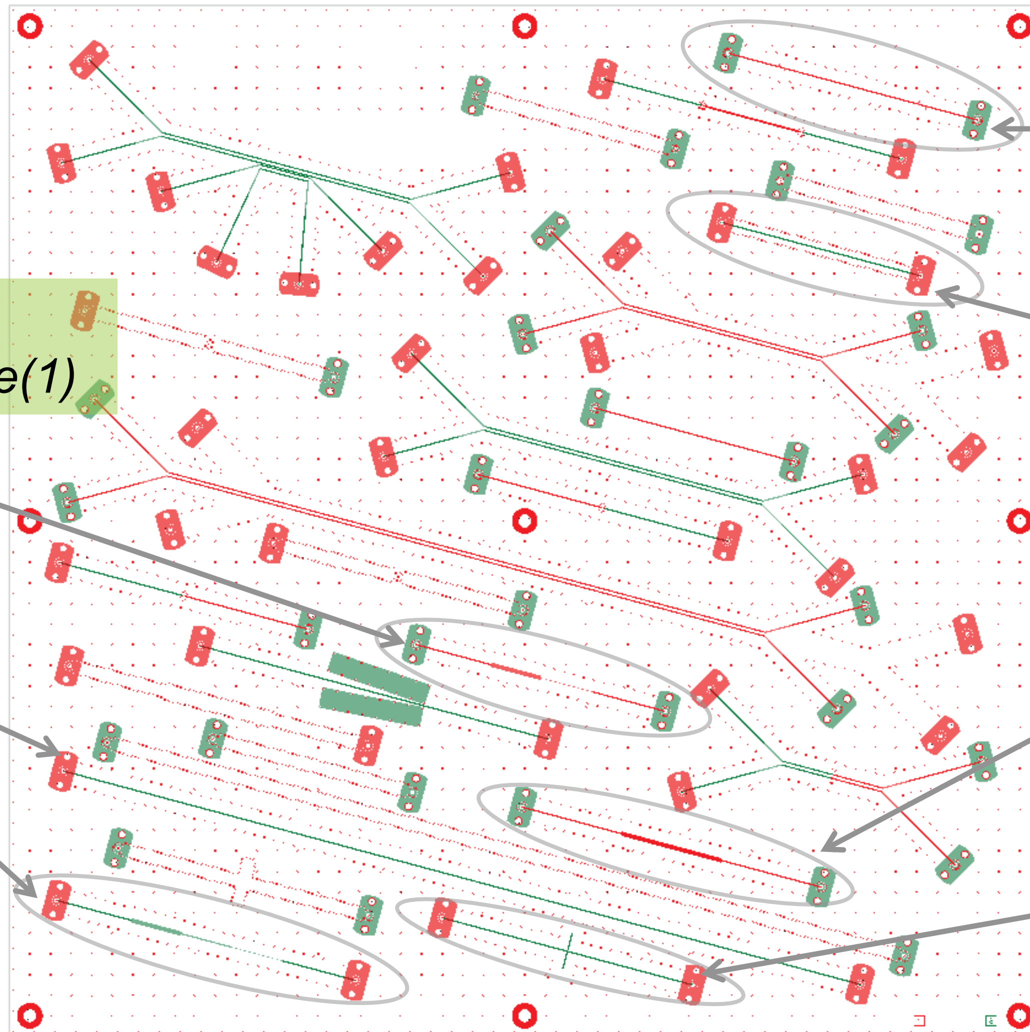
Supplemental docs from board manufacturer (available with CMP platform only)

Touchstone models created in Simbeor solutions for re-use

Microstrip (MS) single-ended (SE) planar structures

TOP – red
BOTTOM – green
Just 2 layers are visible in Simbeor Board Analyzer

Solution: 3_MicrostripSingle(1)



5) MS SE whiskers (J67-J68)

1) MS SE 2-inch segment (J1-J2)

7) MS SE Multi-Z (J31-J32)

2) MS SE 8-inch segment (J3-J4)

3) MS SE Beatty 25 Ohm resonator (J25-J26)

6) MS SE Multi-Z (J29-J30)

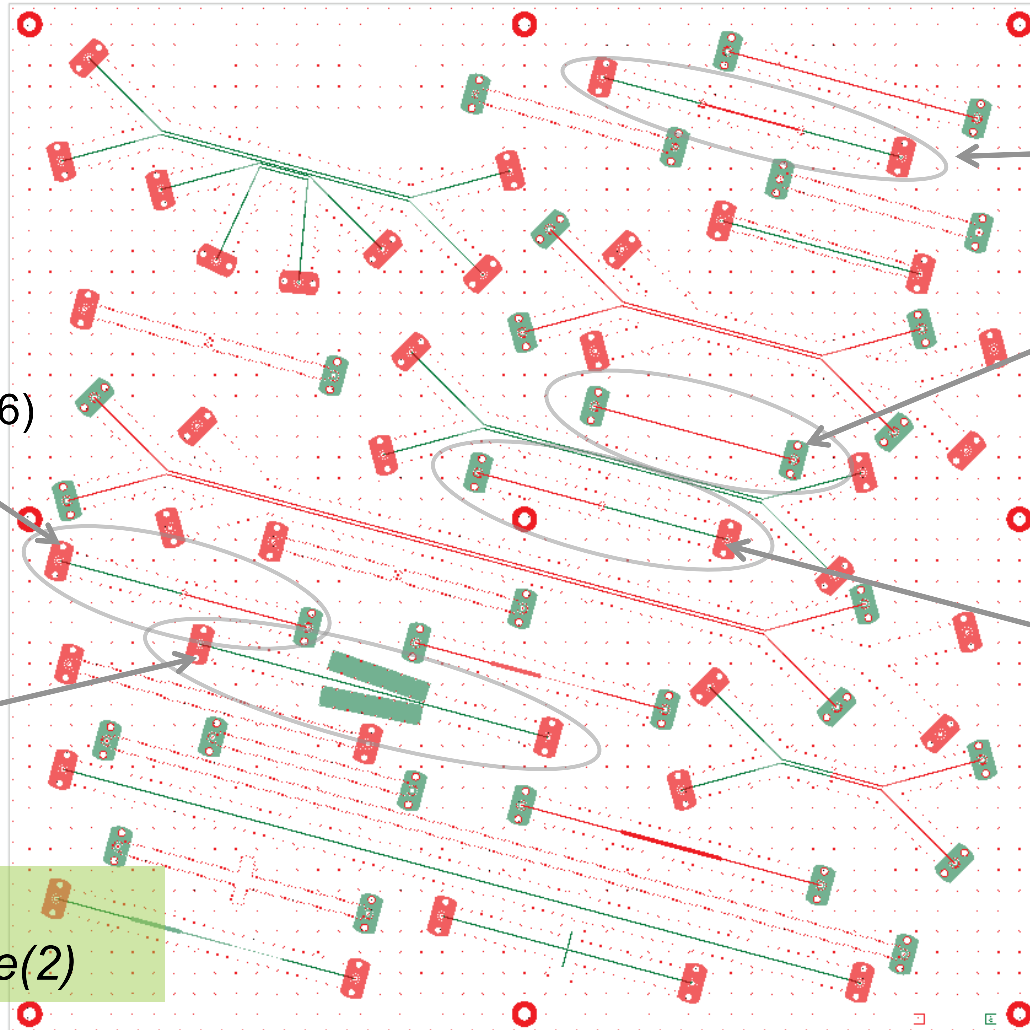
4) MS SE stub resonator (J21-J22)

Microstrip (MS) single-ended (SE) structures with discontinuities in reference conductor

TOP – red
BOTTOM – green
Just 2 layers are shown in Simbeor Board Analyzer

10) MS SE with inductive via (J15-J16)

9) MS SE with graduate coplanar section (J69-J70)



12) MS SE with 2 capacitive vias (J65-J66)

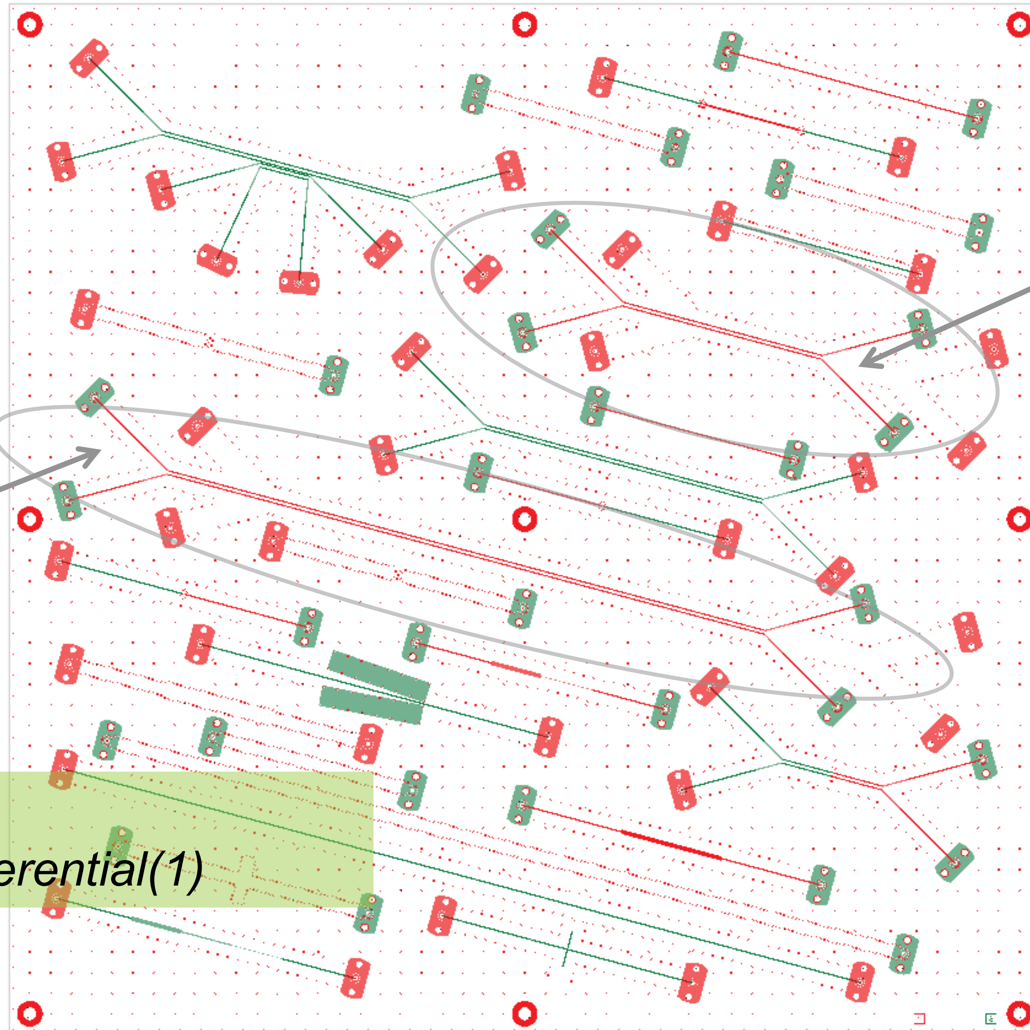
8) MS SE with voids in GND plane (J74-J75)

11) MS SE with capacitive via (J19-J20)

Solution: 4_MicrostripSingle(2)

Microstrip (MS) differential (DF) structures

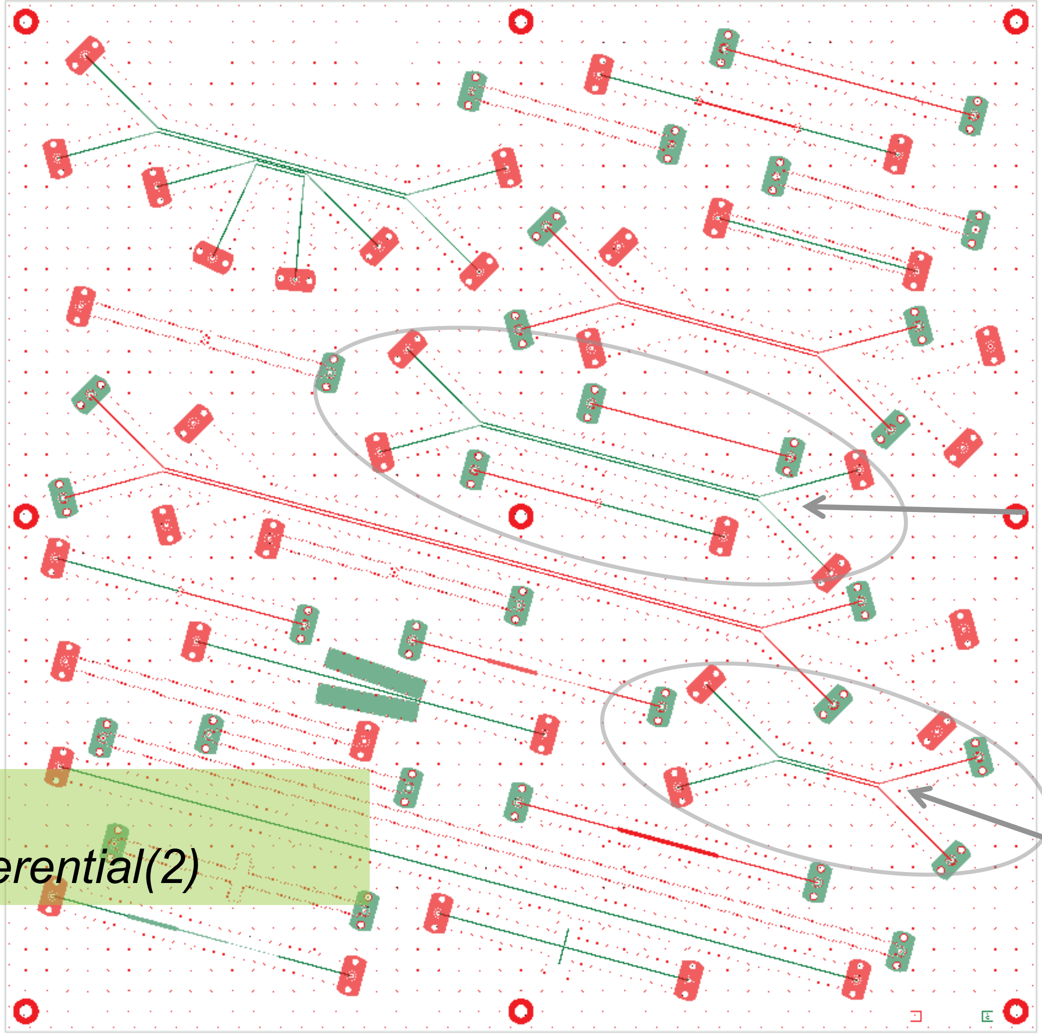
TOP – red
BOTTOM – green
Just 2 layers are shown in Simbeor Board Analyzer



Solution: 5_MicrostripDifferential(1)

Microstrip (MS) differential (DF) structures

TOP – red
BOTTOM – green
Just 2 layers are shown in Simbeor Board Analyzer



15) MS DF segment with void in GND plane (J55-J56-J59-J60)

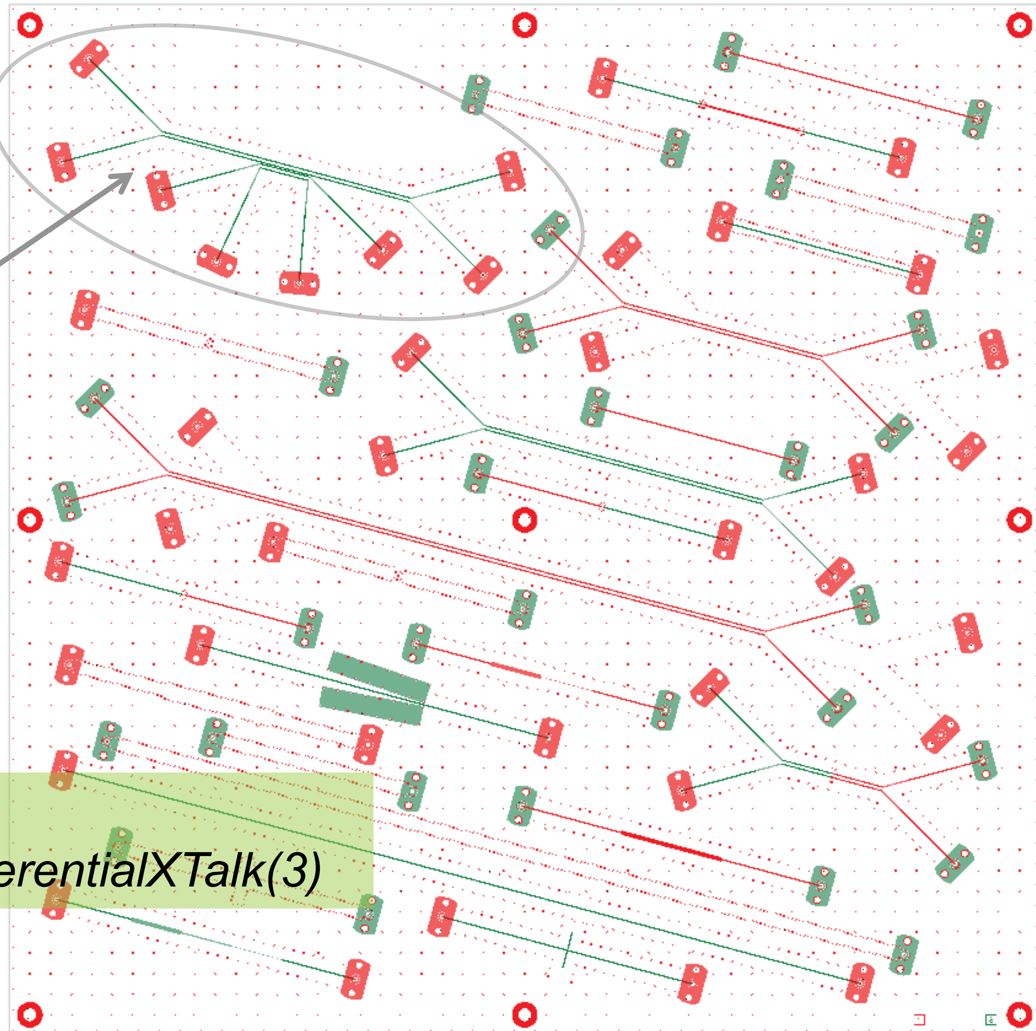
16) MS DF segment with vias (J49-J50-J51-J52)

Solution: 6_MicrostripDifferential(2)

Microstrip (MS) differential (DF) structures

TOP – red
BOTTOM – green
Just 2 layers are shown in Simbeor Board Analyzer

17) MS DF X-talk (J53-J54-J57-J58-J61-J64-J71-J72)

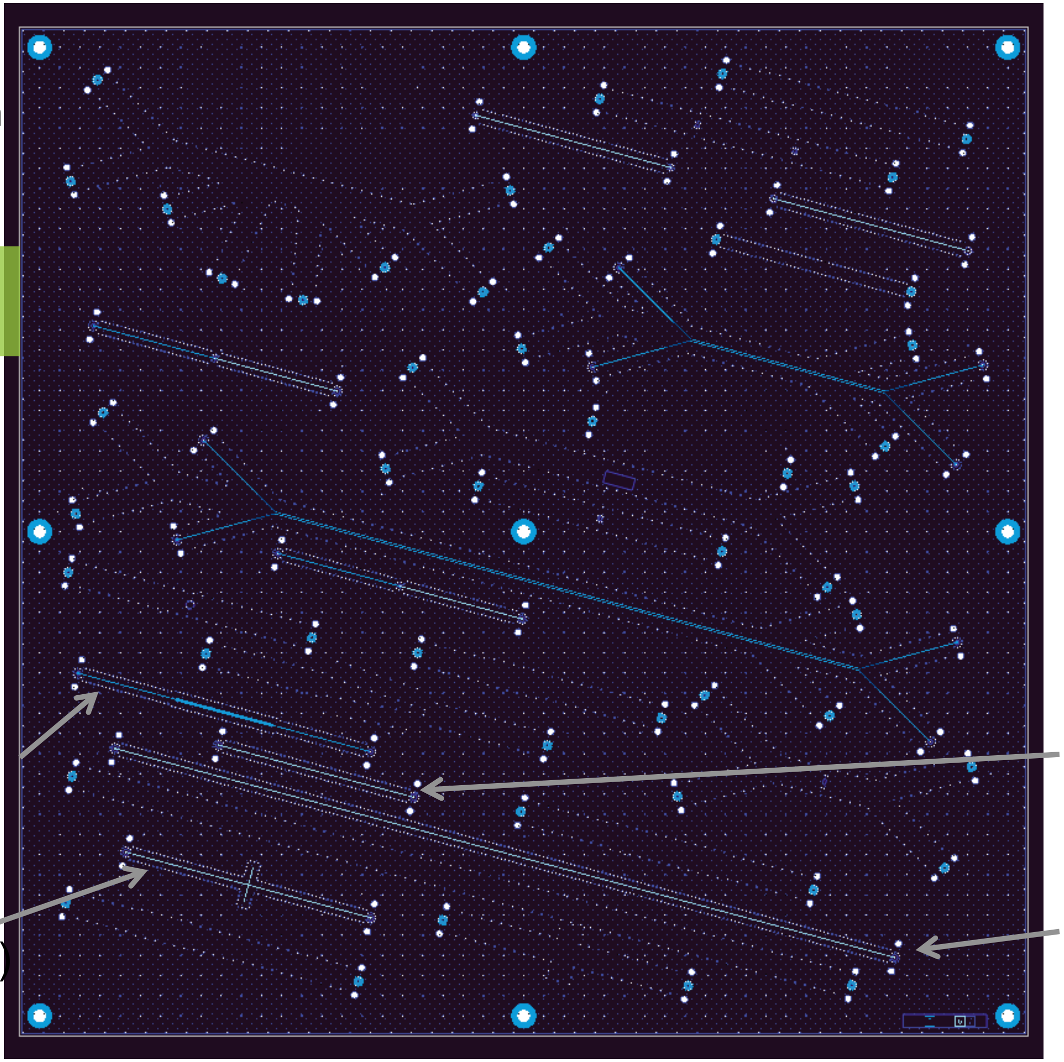


Solution: 7_MicrostripDifferentialXTalk(3)

Strip line (SL) single-ended (SE) and differential (DF) structures

SIGNAL_3 – blue
SIGNAL_6 – light blue
Just 2 layers are shown in Simbeor Board Analyzer

Solutions 8_StripSingle(1)



20) SL SE Beatty 25 Ohm (J27-J28)

21) SL SE stub resonator (J23-J24)

18) SL SE 2-inch segment (J15-J16)

19) SL SE 8-inch segment (J17-J18)

Strip line (SL) single-ended (SE) and differential (DF) structures

SIGNAL_3 – blue
SIGNAL_6 – light blue
Just 2 layers are shown in Simbeor Board Analyzer

Solution: 9_StripSingle(2)

25) SL SE 2-inch segment inductive launch (J9-J10)

24) SL SE 2-inch segment capacitive launch (J11-J12)

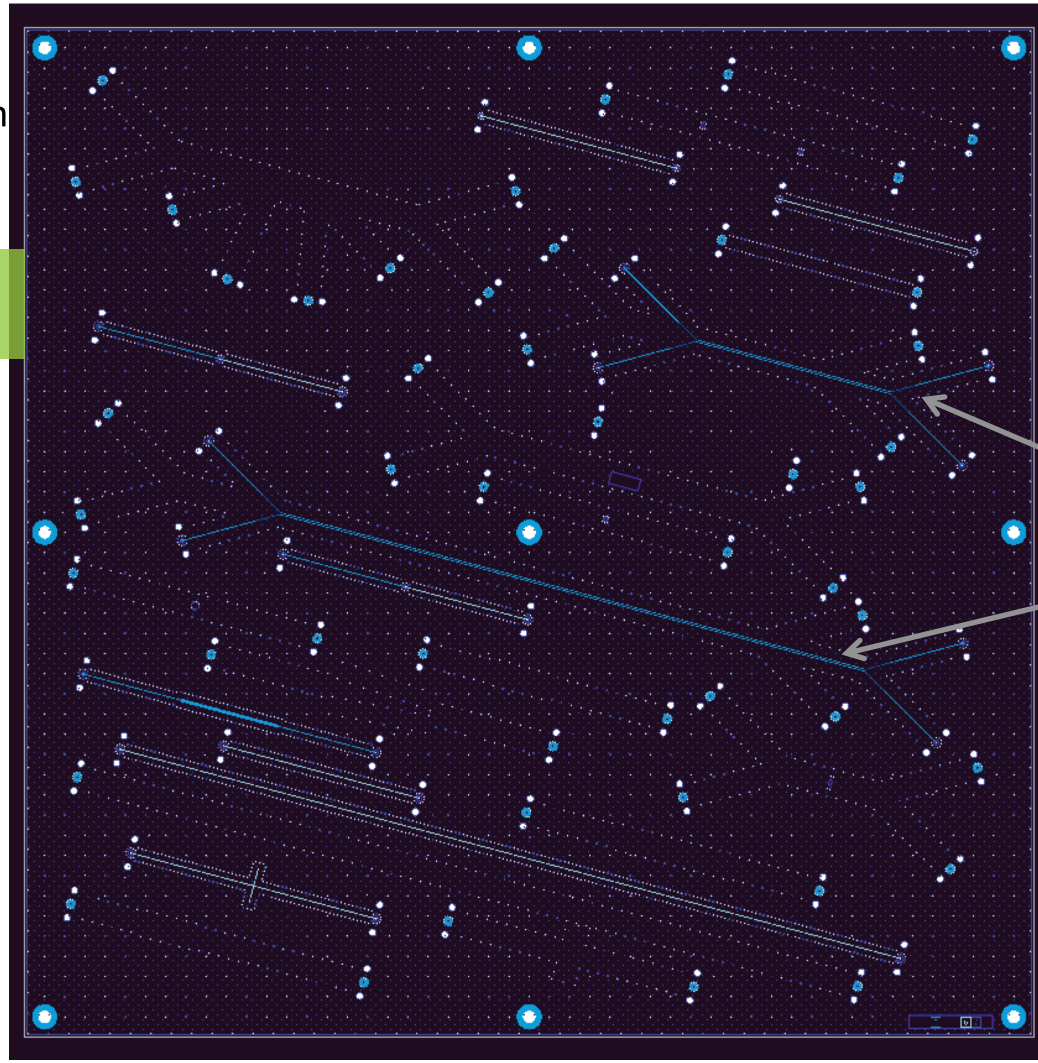
23) SL SE with back-drilled via (J13-J14)

22) SL SE with capacitive via (J17-J18)

Strip line (SL) single-ended (SE) and differential (DF) structures

SIGNAL_3 – blue
SIGNAL_6 – light blue
Just 2 layers are shown in Simbeor Board Analyzer

Solution: 10_StripDifferential(1)



26) SL DF 2-inch segment (J15-J16)

27) SL DF 6-inch segment (J15-J16)

Analysis to measurement validation steps

1. Use VNA to measure S-parameters and validate quality of the measurements
2. Get board geometry adjustments (stackup and trace widths) from manufacturer (if any) and use consistently in the material identification and the analysis (use cross-sectioning if no data provided)
3. Identify broad-band dielectric and conductor roughness models with GMS-parameters
4. Simulate all structures with the identified or validated material models and confirmed adjustments consistently and compare with the measurements (no further manipulations with data)

Step 1: Preliminary measurement quality estimation for single-ended structures

Folder: ..\CMP-28_Simbeor_Kit_Rev4\CMP-28_Rev4\Touchstone_Files\1stcal_single_ended

Touchstone Analyzer

File name	Quality	Passivity	Reciprocity	Causality
C:\Repository\Simbeor\CMP-28_Simbeor_Kit_Rev4\CMP-28_Rev4\Touchstone_Files\1stcal_sin...				
cmp28_gnd_voids_p1J74_p2J75.s2p	-	100	99.4	93.1
cmp28_graduated_coplanar_p1J70_p2J69.s2p	-	100	99.5	84.4
cmp28_mstrp_2in_p1J1_p2J2.s2p	-	100	99.7	82.3
cmp28_mstrp_8inch_p1J4_p2J3.s2p	-	100	99.8	82.5
cmp28_mstrp_Beatty_25ohm_p1J25_p2J26.s2p	-	100	99.4	98.3
cmp28_mstrp_multiZ_p1J31_p2J32.s2p	-	100	99.3	98.5
cmp28_mstrp_p1J30_p2J29.s2p	-	100	99.8	98.6
cmp28_mstrp_resonator_p1J22_p2J22.s2p	-	100	99.7	99.4
cmp28_mstrp_whiskers_p1J68_p2J67.s2p	-	100	99.8	94
cmp28_strpl_2in_50ohm_p1J6_p2J5.s2p	-	100	99.1	82.3
cmp28_strpl_2in_Capacitive_p1J10_p2J09.s2p	-	100	99.5	93.8
cmp28_strpl_2in_Inductive_p1J12_p2J11.s2p	-	100	99.4	84.6
cmp28_strpl_8inch_p1J7_p2J8.s2p	-	100	99.7	74.7
cmp28_strpl_Beatty_25ohm_p1J28_p2J27.s2p	-	100	99.4	95.5
cmp28_strpl_resonator_p1J23_p2J24.s2p	-	100	99.4	98
cmp28_via_pathology_p1J65_p2J66.s2p	-	100	99.8	97.5

PASSED!

Step 1: Preliminary measurement quality estimation for differential and via structures

Touchstone Analyzer

File name	Quality	Passivity	Reciprocity	Causality
C:\Repository\Simbeor\CMP-28_Simbeor_Kit_Rev4\CMP-28_Rev4\Touchstone_Files\2ndcal_d...				
Cal_Thru_3p74ns_p1_p2.s2p	-	100	99.8	99.9
Cal_Thru_3p74ns_p3_p4.s2p	-	100	99.6	99.9
cmp28_mstrp_diff_2inch_J38J37J34J33.s4p	-	100	99.8	71.4
cmp28_mstrp_diff_6inch_J46J45J42J41.s4p	-	100	99.8	73.1
cmp28_mstrp_diff_gnd_cutout_J59J60J55J56.s4p	-	100	99.8	89.7
cmp28_mstrp_diff_xtalk_J57J58J53J54.s4p	-	100	99.8	55.6
cmp28_mstrp_diff_xtalk_J57J64J53J72.s4p	-	100	99.9	77.2
cmp28_mstrp_diff_xtalk_J57J71J53J61.s4p	-	100	99.9	66.2
cmp28_mstrp_diff_xtalk_J57J72J53J64.s4p	-	100	99.9	67.8
cmp28_mstrp_diff_xtalk_J64J72J58J54.s4p	-	100	99.9	67.9
cmp28_mstrp_diff_xtalk_J71J58J61J54.s4p	-	100	99.9	66.9
cmp28_mstrp_diff_xtalk_J71J72J61J64.s4p	-	100	99.7	50
cmp28_mstrp_diff_xtalk_J72J58J64J54.s4p	-	100	99.9	63.6
cmp28_strpl_diff_2inch_J39J40J35J36.s4p	-	100	99.8	77.3
cmp28_strpl_diff_6inch_J47J48J43J44.s4p	-	100	99.9	78.3
C:\Repository\Simbeor\CMP-28_Simbeor_Kit_Rev4\CMP-28_Rev4\Touchstone_Files\3rdcal_vi...				
Cal_Thru_3p74ns_p1_p2_vias.s2p	-	100	99.4	99.9
Cal_Thru_3p74ns_p1_p2_vias_rpt.s2p	-	100	99.2	99.9
Cal_Thru_3p74ns_p3_p4_vias.s2p	-	100	99.5	100
cmp28_mstrp_diff_vias_J49J50J51J52.s4p	-	100	99.8	87.8
cmp28_mstrp_via_capacitive_p1J19_p2J20.s2p	-	100	99.2	94.8
cmp28_mstrp_via_inductive_p1J15_p2J16.s2p	-	100	99.6	96.6
cmp28_strpl_via_backdrilled_p1J14_p2J13.s2p	-	100	99.4	88
cmp28_strpl_via_capacitive_p1J18_p2J17.s2p	-	100	99.7	95.8

Folders: ..\CMP-28_Simbeor_Kit_Rev4\ CMP-28_Rev4\ Touchstone_Files\ 2ndcal_differential and 3rdcal_vias_2sided

PASSED!

Step 1: Final quality estimation with rational compact model (RCM)

Select all files in TA and push Build RCM button on the "Model Conversion and Quality Estimation Tools" panel (RCM options "Extrapolate to infinity" and "Extract Delay" and "Auto-adjust" are OFF)

Touchstone Analyzer

File name	Quality	Passivity	Reciprocity	Causality
C:\Repository\Simbeor\CMP-28_Simbeor_Kit_Rev4\CMP-28_Rev4\Touchstone_Files\1stc...				
cmp28_gnd_voids_p1J74_p2J75.s2p	99.5	100	99.4	-
cmp28_graduated_coplanar_p1J70_p2J69.s2p	99.7	100	99.5	-
cmp28_mstrp_2in_p1J1_p2J2.s2p	99.5	100	99.7	-
cmp28_mstrp_8inch_p1J4_p2J3.s2p	99.7	100	99.8	-
cmp28_mstrp_Beatty_25ohm_p1J25_p2J26.s2p	99.6	100	99.4	-
cmp28_mstrp_multiZ_p1J31_p2J32.s2p	99.6	100	99.3	-
cmp28_mstrp_p1J30_p2J29.s2p	99.6	100	99.8	-
cmp28_mstrp_resonator_p1J22_p2J22.s2p	99.7	100	99.7	-
cmp28_mstrp_whiskers_p1J68_p2J67.s2p	99.5	100	99.8	-
cmp28_strpl_2in_50ohm_p1J6_p2J5.s2p	99.6	100	99.1	-
cmp28_strpl_2in_Capacitive_p1J10_p2J09.s2p	99.5	100	99.5	-
cmp28_strpl_2in_Inductive_p1J12_p2J11.s2p	99.5	100	99.4	-
cmp28_strpl_8inch_p1J7_p2J8.s2p	99.6	100	99.7	-
cmp28_strpl_Beatty_25ohm_p1J28_p2J27.s2p	99.7	100	99.4	-
cmp28_strpl_resonator_p1J23_p2J24.s2p	99.6	100	99.4	-
cmp28_via_pathology_p1J65_p2J66.s2p	99.6	100	99.8	-

PASSED!

Quality estimation is just an example – all Touchstone models in Simbeor Solutions have pre-built RCM models used for TD analysis and validation!

See how to do it in demo-videos #2011_01 and 2011_02 at http://www.simberian.com/ScreenCasts.php…

Step 1: Final quality estimation with rational compact model (RCM)

Select all files in TA and push Build RCM button on the “Model Conversion and Quality Estimation Tools” panel (RCM options “Extrapolate to infinity” and “Extract Delay” and “Auto-adjust” are OFF)

Touchstone Analyzer

File name	Quality	Passivity	Reciprocity	Causality
C:\Repository\Simbeor\CMP-28_Simbeor_Kit_Rev4\CMP-28_Rev4\Touchstone_Files\2nd...				
cmp28_mstrp_diff_2inch_J38J37J34J33.s4p	99.5	100	99.8	-
cmp28_mstrp_diff_6inch_J46J45J42J41.s4p	99.6	100	99.8	-
cmp28_mstrp_diff_gnd_cutout_J59J60J55J56.s4p	99.5	100	99.8	-
cmp28_mstrp_diff_xtalk_J57J58J53J54.s4p	99.5	100	99.8	-
cmp28_mstrp_diff_xtalk_J57J64J53J72.s4p	99.6	100	99.9	-
cmp28_mstrp_diff_xtalk_J57J71J53J61.s4p	99.6	100	99.9	-
cmp28_mstrp_diff_xtalk_J57J72J53J64.s4p	99.6	100	99.9	-
cmp28_mstrp_diff_xtalk_J64J72J58J54.s4p	99.5	100	99.9	-
cmp28_mstrp_diff_xtalk_J71J58J61J54.s4p	99.5	100	99.9	-
cmp28_mstrp_diff_xtalk_J71J72J61J64.s4p	99.5	100	99.7	-
cmp28_mstrp_diff_xtalk_J72J58J64J54.s4p	99.6	100	99.9	-
cmp28_strpl_diff_2inch_J39J40J35J36.s4p	99.5	100	99.8	-
cmp28_strpl_diff_6inch_J47J48J43J44.s4p	99.3	100	99.9	-
C:\Repository\Simbeor\CMP-28_Simbeor_Kit_Rev4\CMP-28_Rev4\Touchstone_Files\3rd...				
Cal_Thru_3p74ns_p1_p2_vias.s2p	96.5	100	99.4	-
Cal_Thru_3p74ns_p1_p2_vias_rpt.s2p	96.8	100	99.2	-
Cal_Thru_3p74ns_p3_p4_vias.s2p	97	100	99.5	-
cmp28_mstrp_diff_vias_J49J50J51J52.s4p	98.9	100	99.8	-
cmp28_mstrp_via_capacitive_p1J19_p2J20.s2p	99.6	100	99.2	-
cmp28_mstrp_via_inductive_p1J15_p2J16.s2p	98.3	100	99.6	-
cmp28_strpl_via_backdrilled_p1J14_p2J13.s2p	97.7	100	99.4	-
cmp28_strpl_via_capacitive_p1J18_p2J17.s2p	93.4	100	99.7	-

PASSED!

Quality estimation is just an example – all Touchstone models in Simbeor Solutions have pre-built RCM models used for TD analysis and validation!

See how to do it in demo-videos #2011_01 and 2011_02 at http://www.simberian.com/ScreenCasts.php …

Step 2: Board geometry adjustments

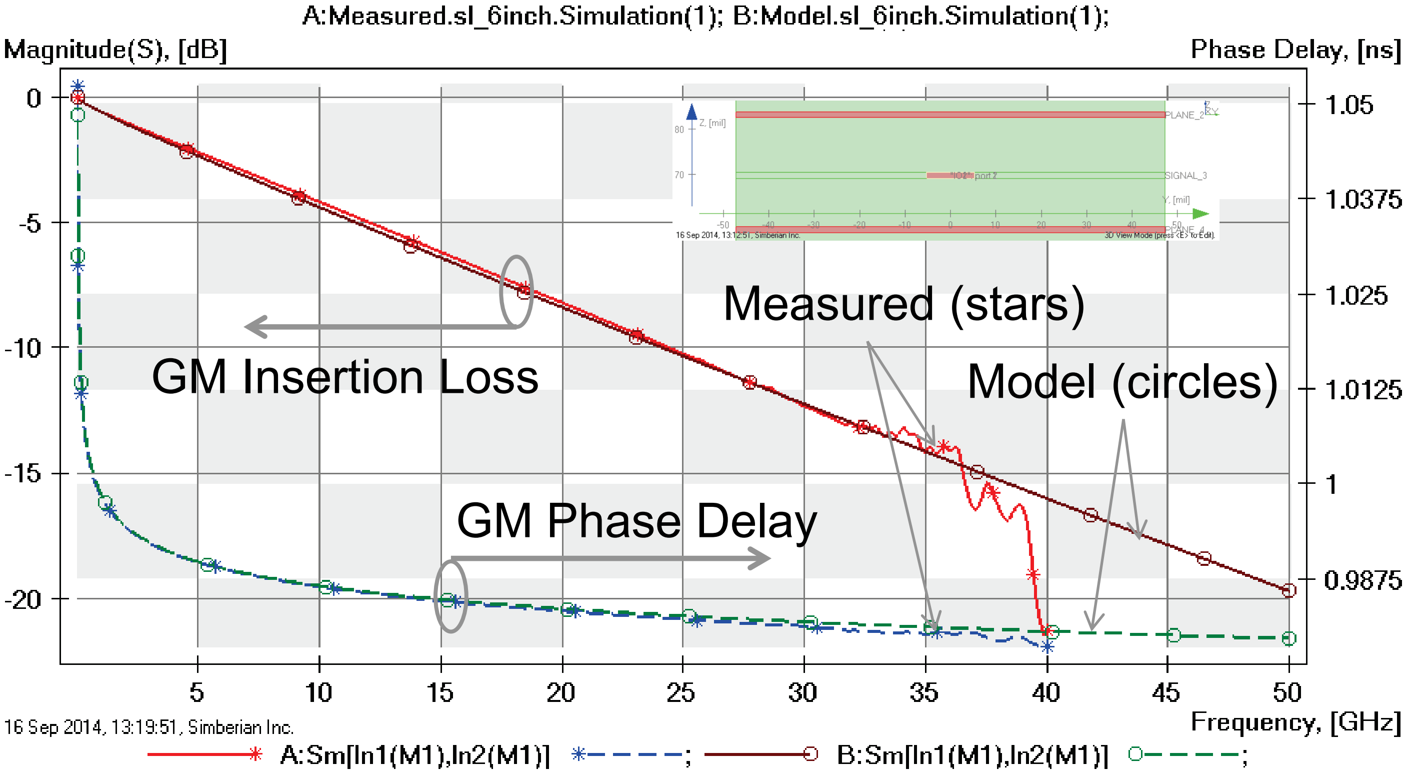
- Stackup is adjusted from data provided by manufacturer
- Single-ended width adjustments before analysis in Simbeor Board Analyzer (to match the impedance observed on TDR):
  - Micro-strip single-ended line widths are adjusted from 14.5 to 13.5 mil
  - Strip line single-ended widths are adjusted from 11.0 to 10.5 mil
- All other widths and dimensions are exactly as in the board design (may need consistent adjustments as follows from the validation)

Step 3: Identify material models

- Generalized Modal S-parameters (GMS-parameters) is the best way to identify broadband material models (patented by Simberian)
  - Use TDR to verify identities of the launches and t-lines
  - Use Phase Delay of GM transmission to identify/confirm dielectric constant
  - Use GM Insertion Loss to identify/confirm loss tangent and roughness
- Use data from manufactured (Isola FR408HR and Taiyo solder mask) as the starting point to identify dielectric models
- Use 2 and 8 inch strip line segments to validate FR408HR model and identify Modified Hammerstad conductor roughness model (Solution 1_MaterialIdentification)
- Use 2 and 8 inch micro-strip line segments to confirm FR408HR model and validate and identify Modified Hammerstad conductor roughness model for TOP/BOTTOM layers (1_MaterialIdentification)
- Use 2 and 6 inch differential strip and microstrip line segments to confirm/correct material models (2_MaterialValidationDifferential)

See App Notes #2014_02 and 2014_03 for details on identification with GMS-parameters at http://www.simberian.com/AppNotes.php

Step 3: Dielectric and conductor roughness model identification with strip line



Solution: 1_MaterialIdentification; Simbeor SFS solver;

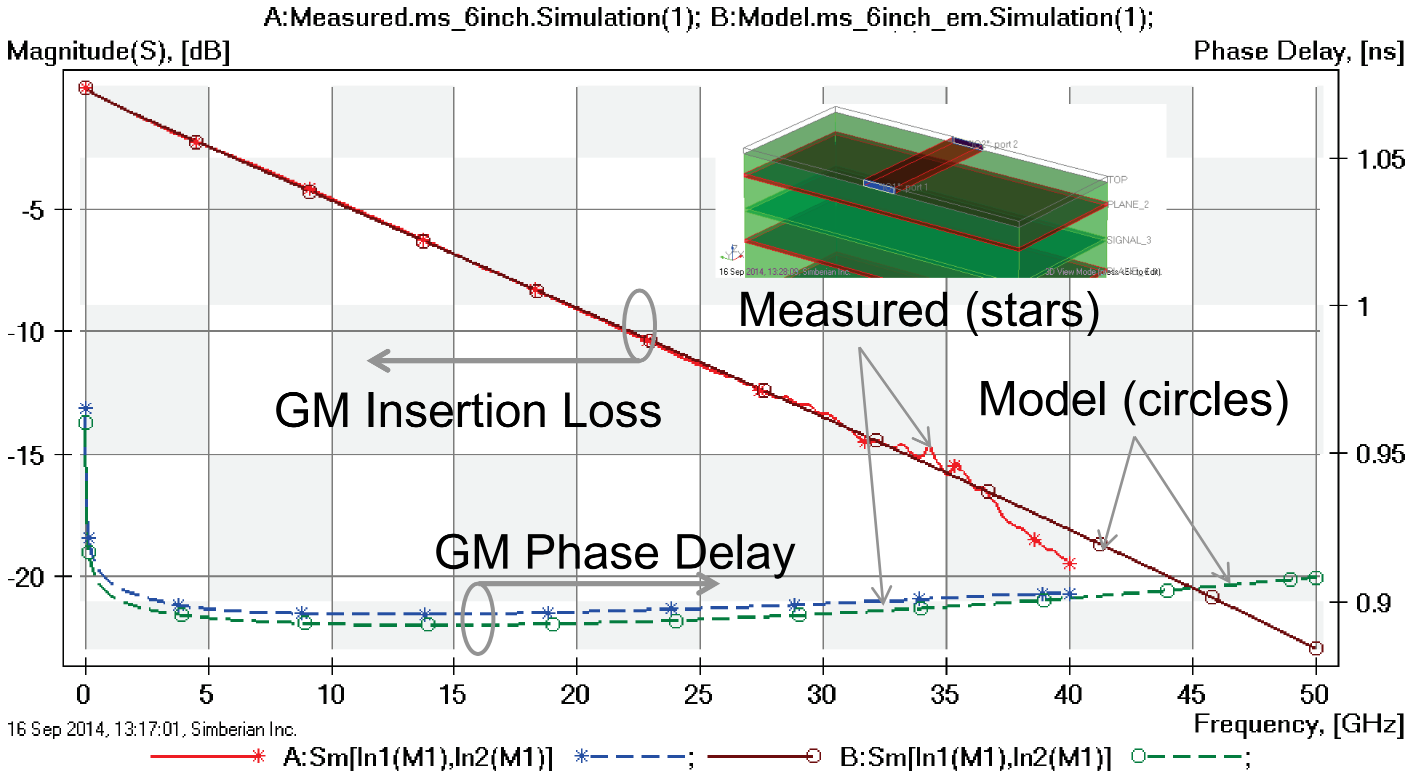
GM - Generalized Modal (reflection-less);

About 35 GHz useful bandwidth from the measured data due to mechanical differences;

Models are usable up to 50 GHz!

GMS parameters computed from S-parameters measured for 2 and 8 inch strip line segments (red and blue lines) and modeled for 6 inch strip line segment (brown and green lines):
FR408HR model: Wideband Debye, Dk=3.815 (3.66), LT=0.0117 @ 1 GHz;
Conductor roughness model: Modified Hammerstad, SR=0.4 um, RF=2;

Step 3: Dielectric and conductor roughness model identification with micro-strip line



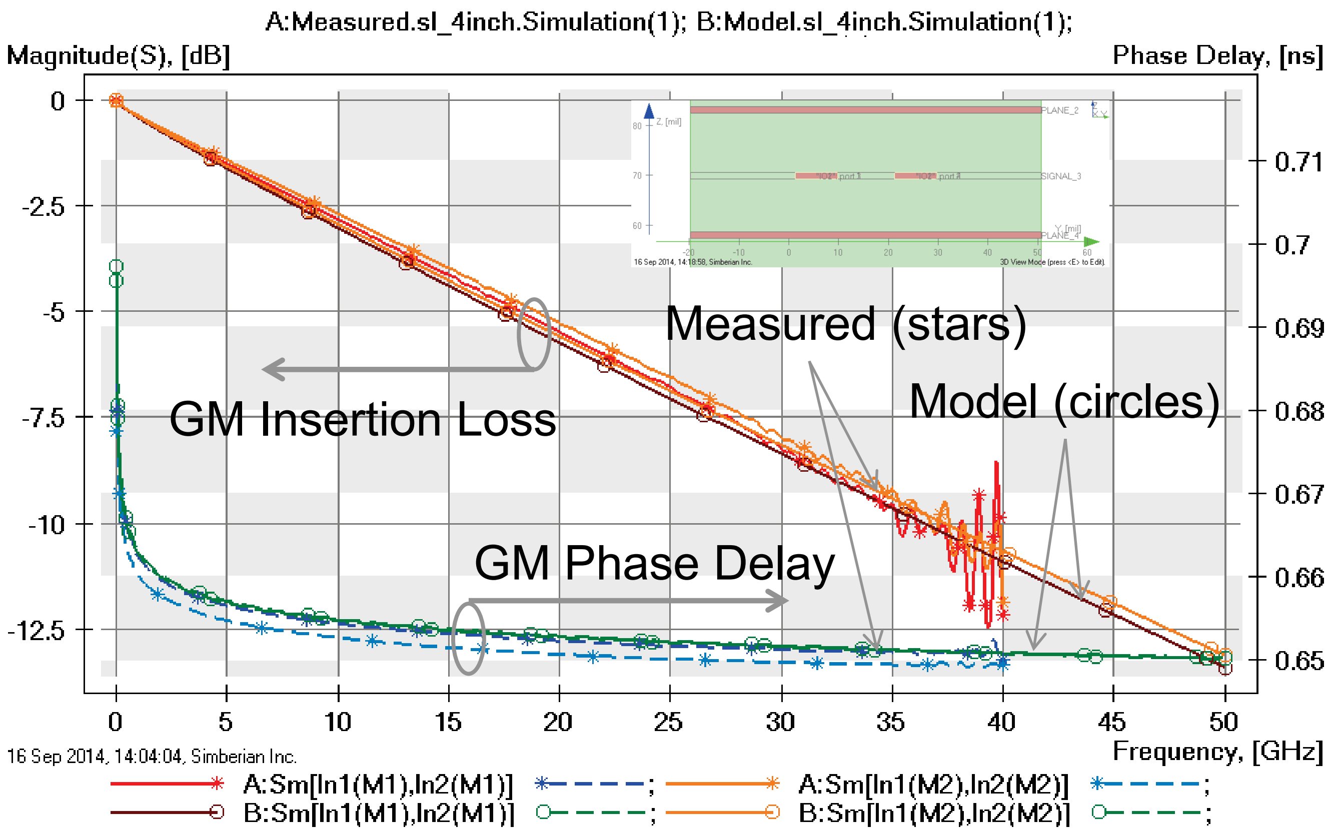
Solution:
1_MaterialIdentification;
Simbeor 3DML solver;

GM - Generalized Modal (reflection-less);

Models are usable up to 50 GHz!

GMS parameters computed from S-parameters measured for 2 and 8 inch micro-strip line segments (red and blue lines) and modeled for 6 inch micro-strip line segment (brown and green lines):
FR408HR model: Wideband Debye, Dk=3.815 (3.66), LT=0.0117 @ 1 GHz (same as for strip);
Taiyo solder mask model: Wideband Debye, Dk=3.85 (3.9), LT=0.02 @ 1 GHz;
Conductor roughness model: Modified Hammerstad, SR=0.4 um, RF=3.5;

Step 3: Dielectric and conductor roughness model identification with differential strip line



Solution: 2_MaterialIdentification Differential; Simbeor SFS solver;

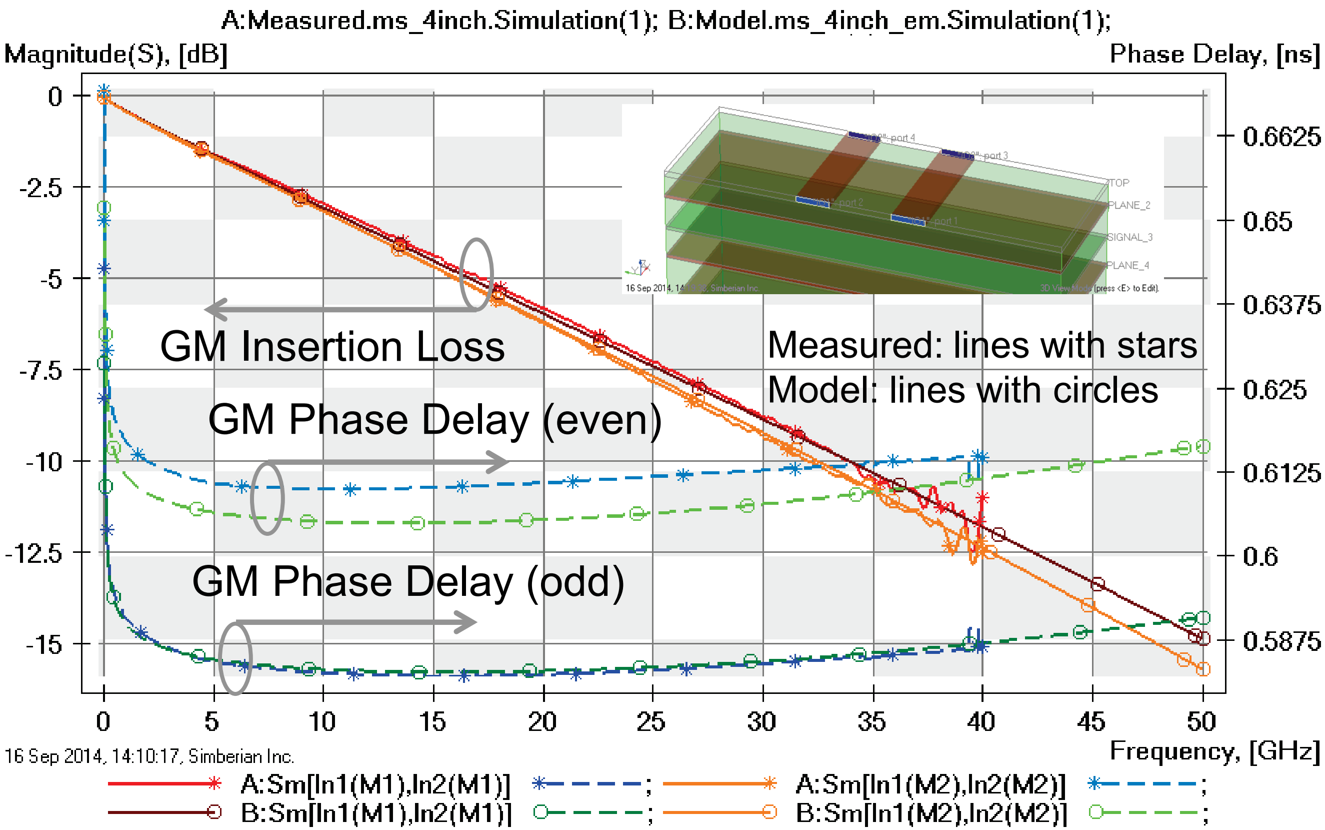
GM - Generalized Modal (reflection-less);

Odd modes: red, blue, brown and green lines; Even modes: orange, light blue and green lines;

Even modes – less then 1 ps/inch difference in phase delay;

GMS parameters computed from S-parameters measured for 2 and 6 inch differential strip line segments (lines with stars) and modeled for 4 inch diff. strip line segment (lines with circles):
FR408HR model: Wideband Debye, Dk=3.78 (3.66), LT=0.0117 @ 1 GHz – optionally strip layer can be filled with resin with smaller Dk to have modes propagate with different speed;
Conductor roughness model: Modified Hammerstad, SR=0.4 um, RF=2;

Step 3: Dielectric and conductor roughness model identification with micro-strip line



Solution:
2_MaterialIdentification
Differential;
Simbeor 3DML solver;

GM - Generalized Modal (reflection-less);

Odd modes: red, brown, blue and green lines;
Even modes: orange, light blue and green lines;

Even mode - about 1 ps/inch difference in phase delay;

GMS parameters computed from S-parameters measured for 2 and 6 inch micro-strip line segments (red and blue lines) and modeled for 4 inch micro-strip line segment (brown and green lines):
FR408HR model: Wideband Debye, Dk=3.815 (3.66), LT=0.0117 @ 1 GHz (same as for strip);
Taiyo solder mask model: Wideband Debye, Dk=3.85 (3.9), LT=0.02 @ 1 GHz;
Conductor roughness model: Modified Hammerstad, SR=0.4 um, RF=3.5;

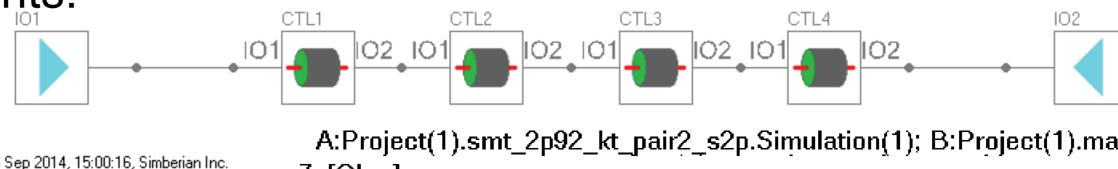
Step 4: Simulate all 27 structures and compare with the measurements

- Synthesize model for 2.92 mm connector with 2.4 mm adapter from measured S-parameters
- Compute and compare S-parameters for all structures (complete adapter-to-adapter links)
  - Compare simulated and measured magnitudes and phase/group delays in terminal and mixed-mode space up to 50 GHz
- Compute TDR from simulated and measured S-parameters and compare for all structures
  - Use rational compact models and Gaussian step with 20 ps 10-90% rise time
- Compute eye diagrams for 28 Gbps PRBS signals from simulated and measured S-parameters and compare for selected structures

See demo-videos #2013_01 and 2013_02 to see how to do post-layout analysis with geometry adjustments in Simbeor Board analyzer

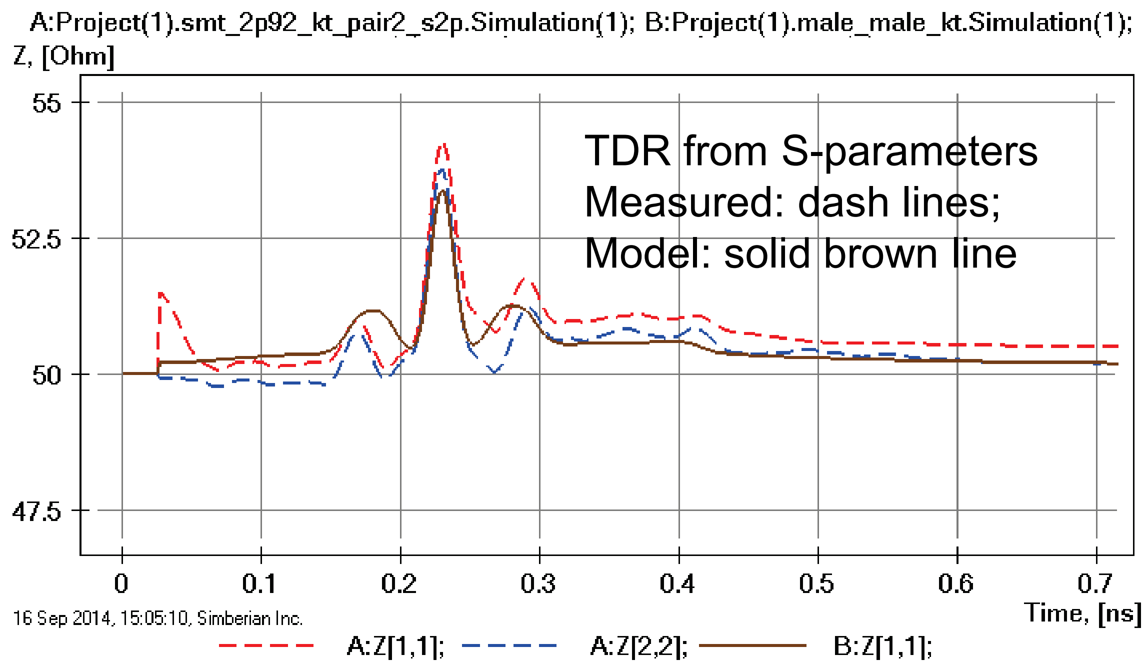
Synthesis of connector model

- Connector model is synthesized from S-parameters measured for two pairs of 2.4-2.92 mm adapter and 2.92 mm connectors connected back-to-back
- The model is constructed by matching measured magnitude and phase of transmission and reflection parameters to model composed with 4 coaxial line segments:

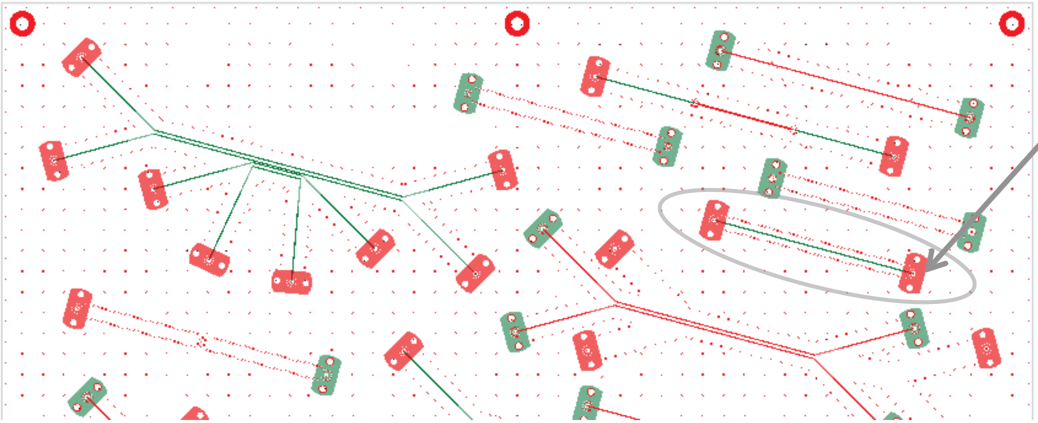


See details in Solution ConnectorModel;

Model S-parameters are saved to connector_2p92_kt.s2p file in ModelsToReUse for further use;

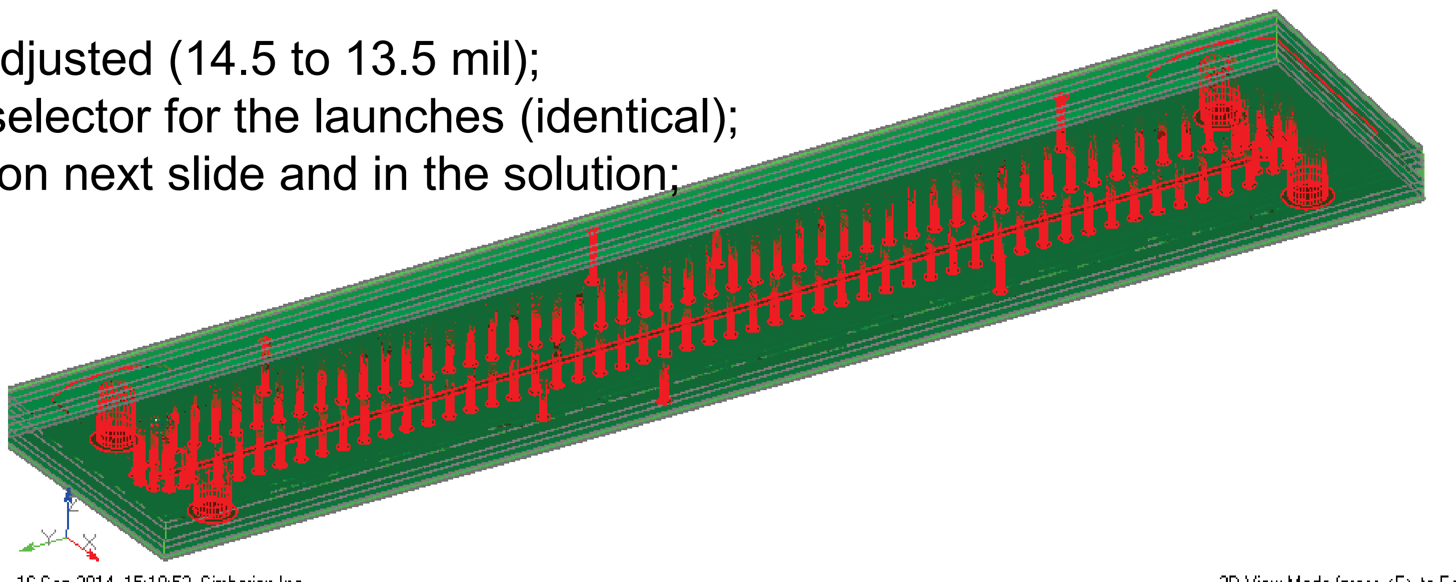


1) 2-inch microstrip line segment



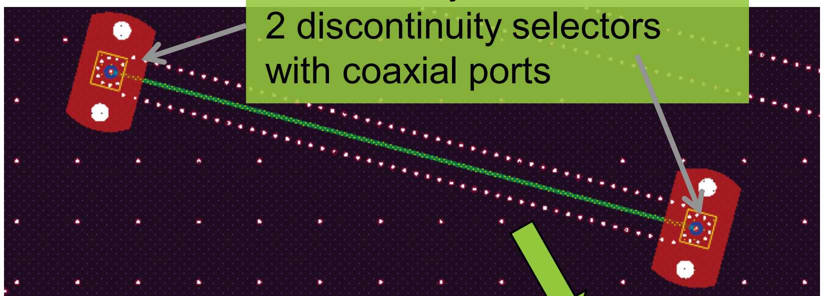
MS SE 2-inch segment (J1-J2)
Solution: 3_MicrostipSingle(1)
Measured:
cmp28_mstrp_2in_p1J1_p2J2.s2p
Selector/Project/Circuit:
MS_SE_2in_J1_J2

Board Analyzer:
Trace width is adjusted (14.5 to 13.5 mil);
2 discontinuity selector for the launches (identical);
See also notes on next slide and in the solution;



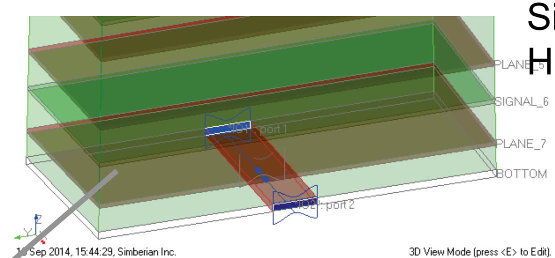
1) 2-inch microstrip line segment: De-compositional analysis

Board Analyzer:
2 discontinuity selectors
with coaxial ports

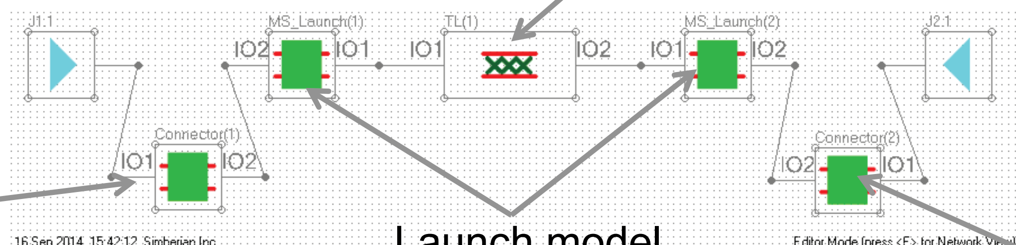


Auto-extraction

Trace width is adjusted in BA



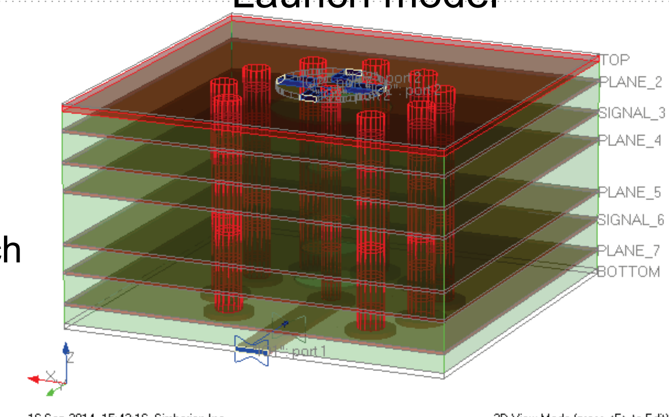
Simbeor 3DML (with HF dispersion)



Connector + adapter model (added)

Launch model

Connector + adapter model (added)

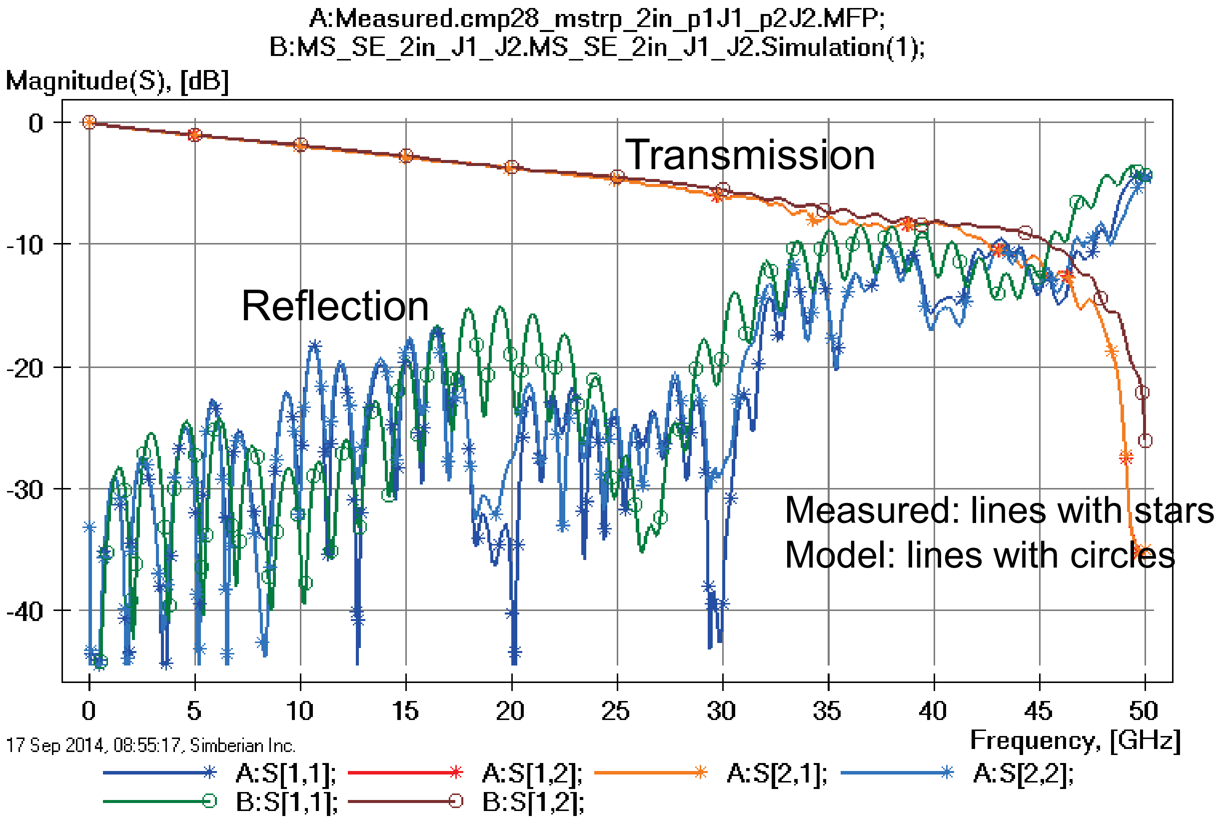


Simbeor 3DML

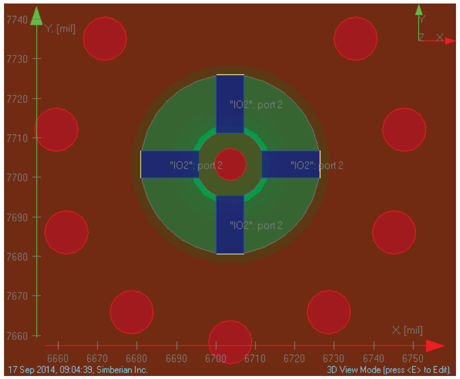
Connector + Launch are also simulated separately in PCB/MS_ConnectorAndLaunch for further reuse

See also solution notes for MS SE 2-inch segment

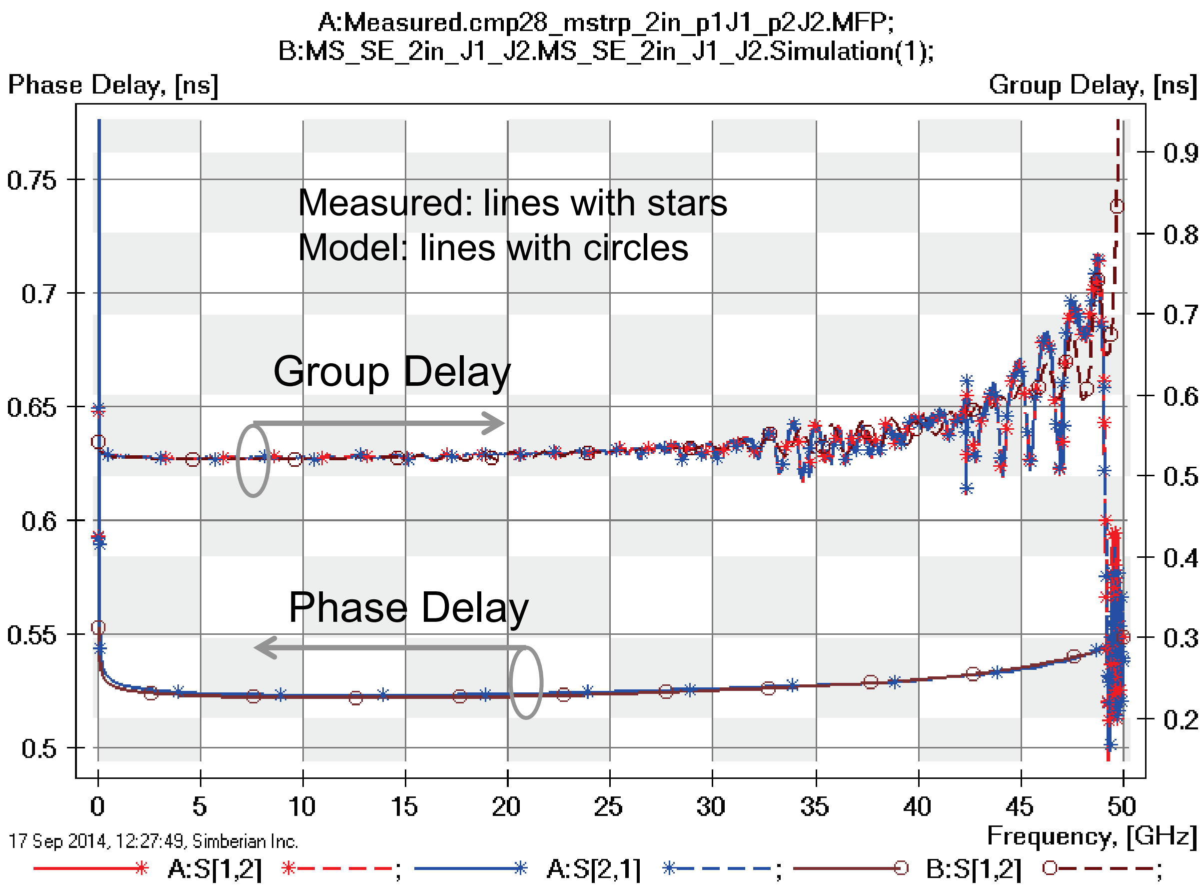
1) 2-inch microstrip line segment: Magnitude of S-parameters



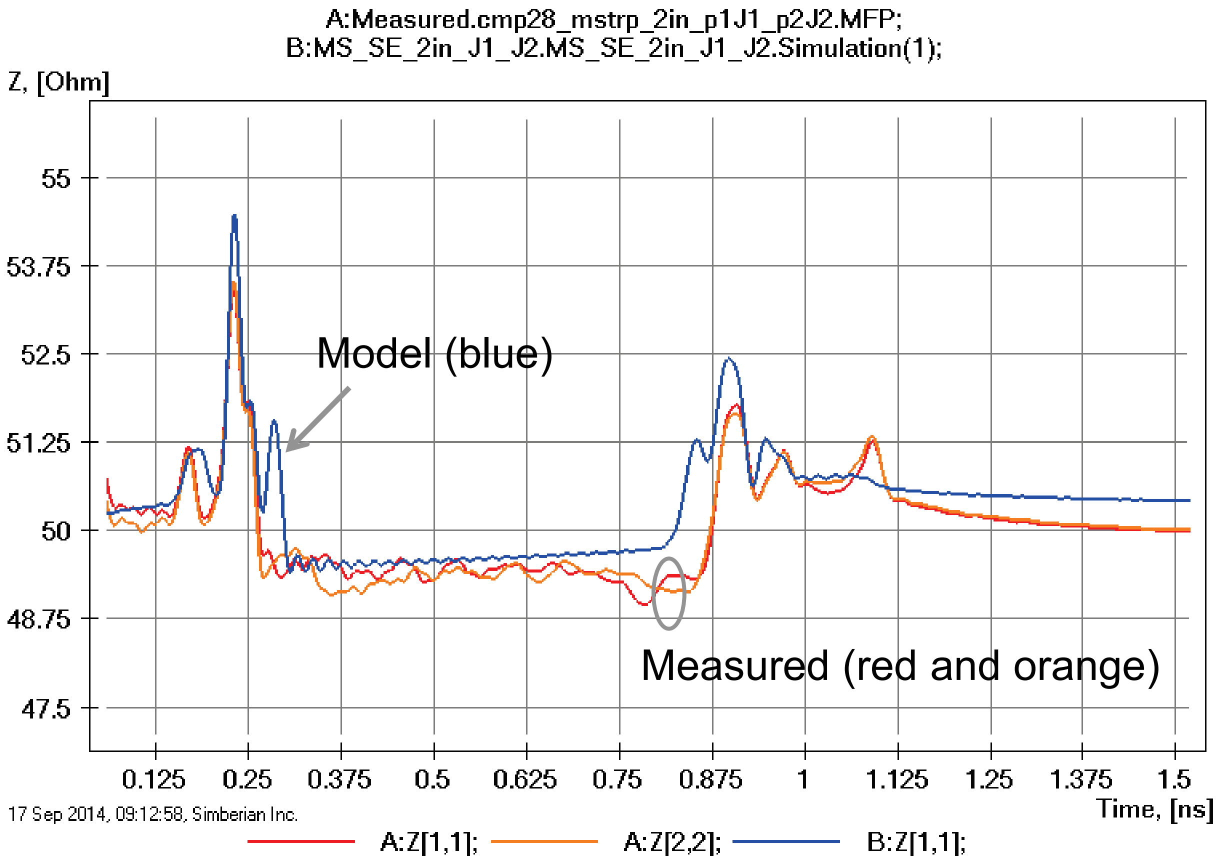
MS Launch looses the localization at about 30 GHz: Distance from signal via to stitching vias is about quarter of wavelength at 30 GHz – we cannot expect correlation above that frequency! Though, the impedance of the return path remains low due to plenty of stitching vias.



1) 2-inch microstrip line segment: Transmission phase and group delay

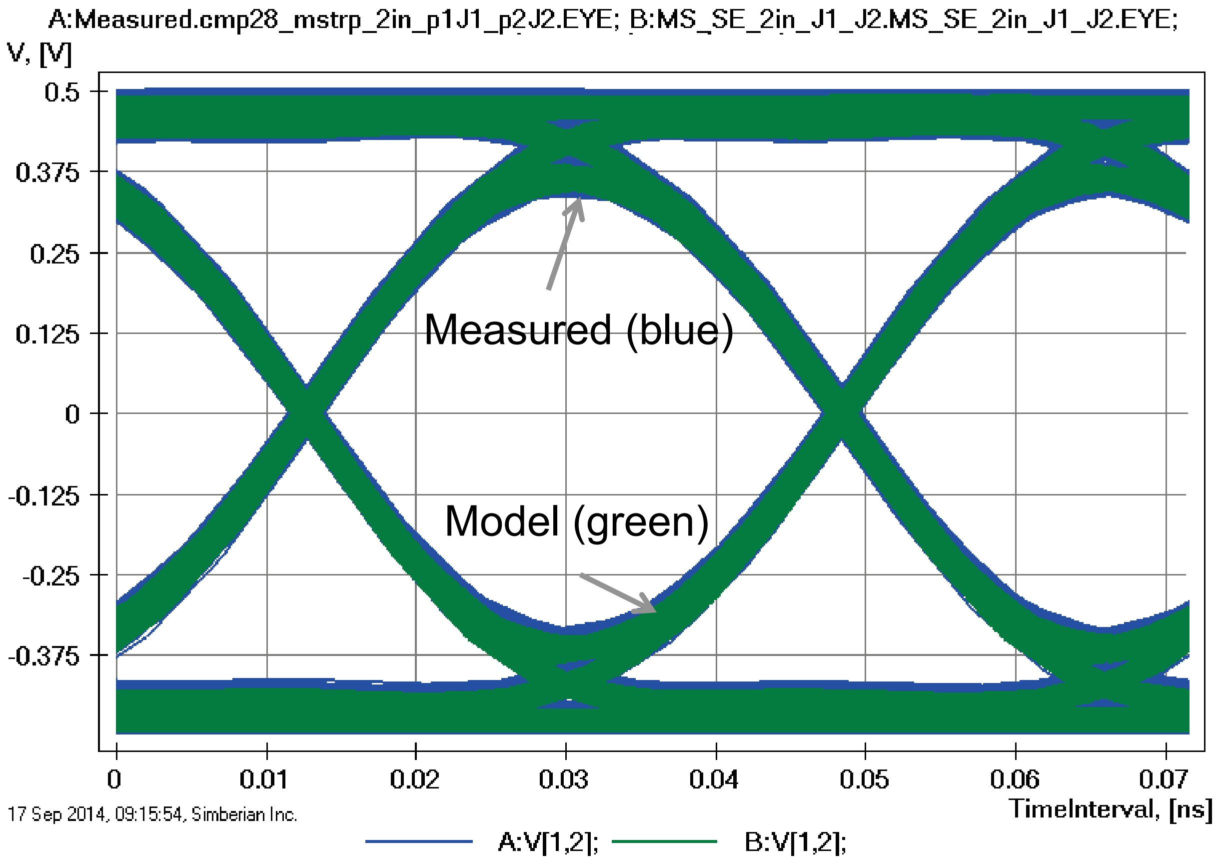


1) 2-inch microstrip line segment: TDR with 20 ps Gaussian step



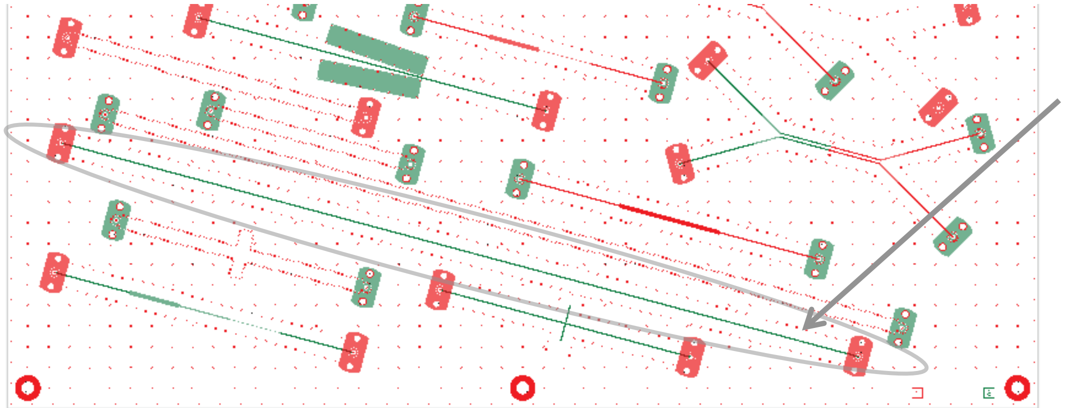
Variations of impedance along the traces visible here indicates that either trace width is varying or dielectric is inhomogeneous (or both); This is not accounted for in the model and explains differences in the reflection.

1) 2-inch microstrip line segment: 28 Gbps PRBS, 25 ps rise/fall time



Eyes are on top of each other!

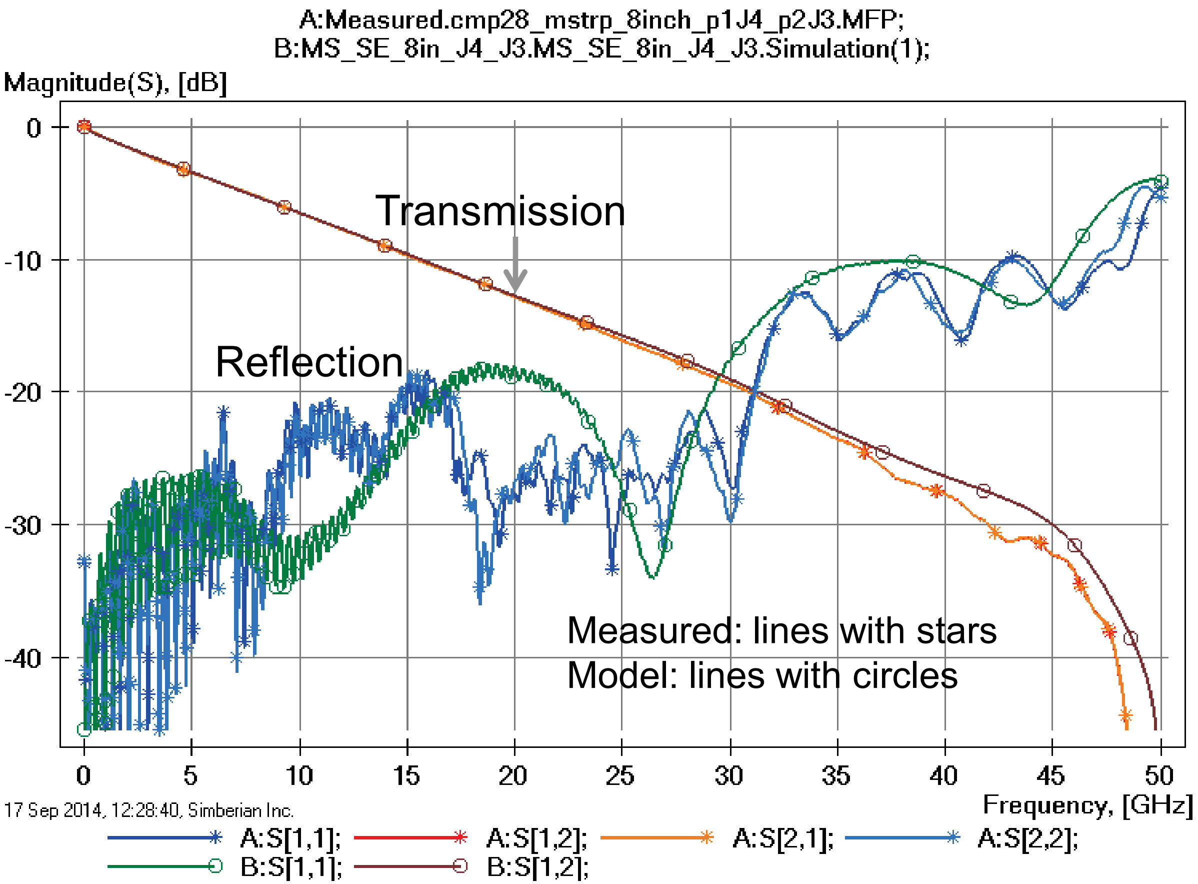
2) 8-inch microstrip line segment



MS SE 8-inch segment (J3-J4)
Solution: 3_MicrostipSingle(1)
Measured:
cmp28_mstrp_8in_p1J4_p2J3.s2p
Selector/Project/Circuit:
MS_SE_8in_J4_J3

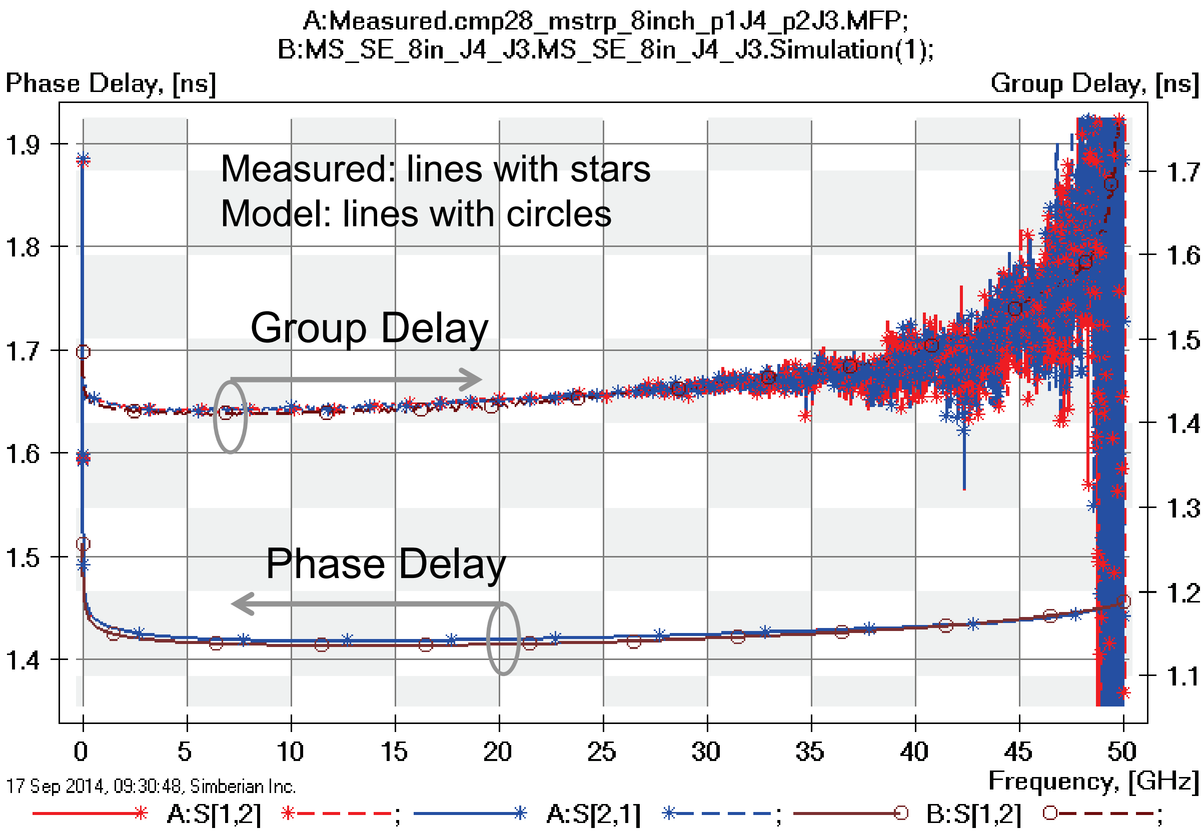
Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
See also notes in the solution;

2) 8-inch microstrip line segment: Magnitude of S-parameters

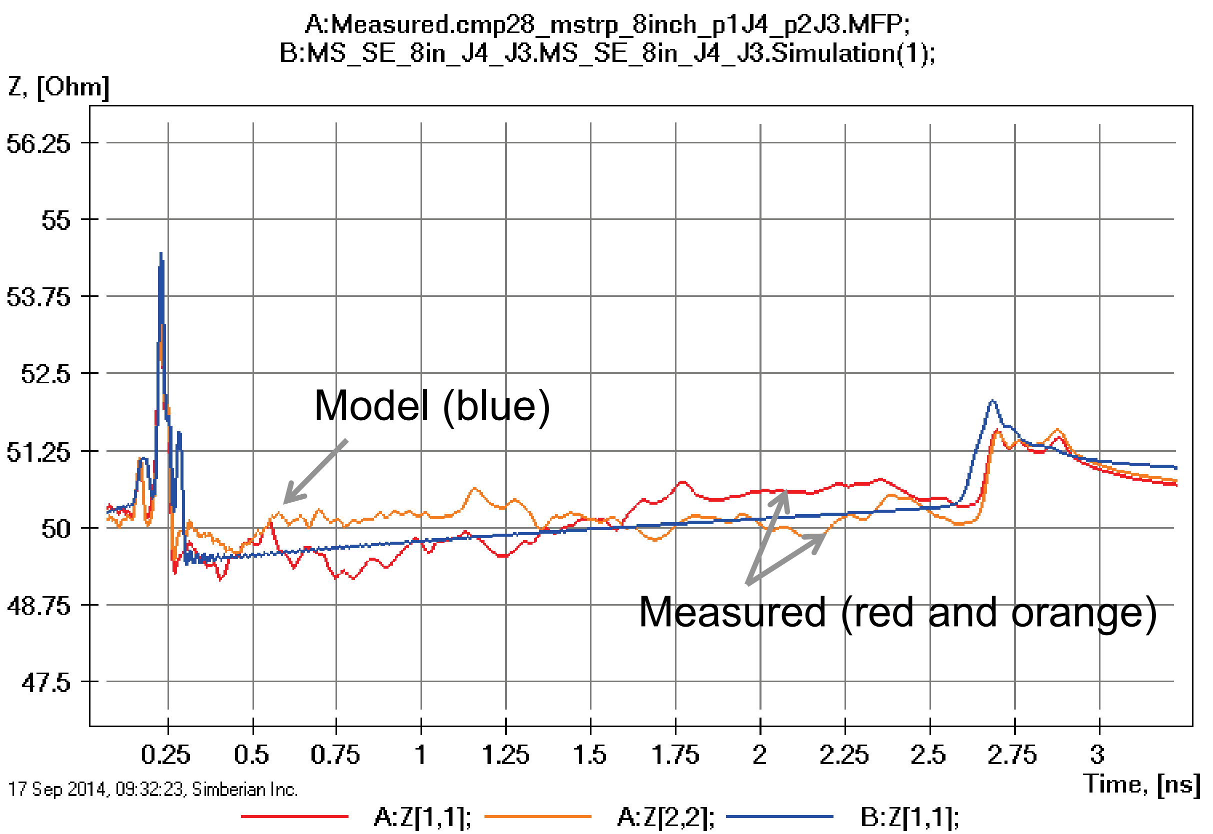


Loss of launch localization above 30 GHz explains additional insertion losses; Variation of trace width and dielectric properties explains differences in reflection losses;

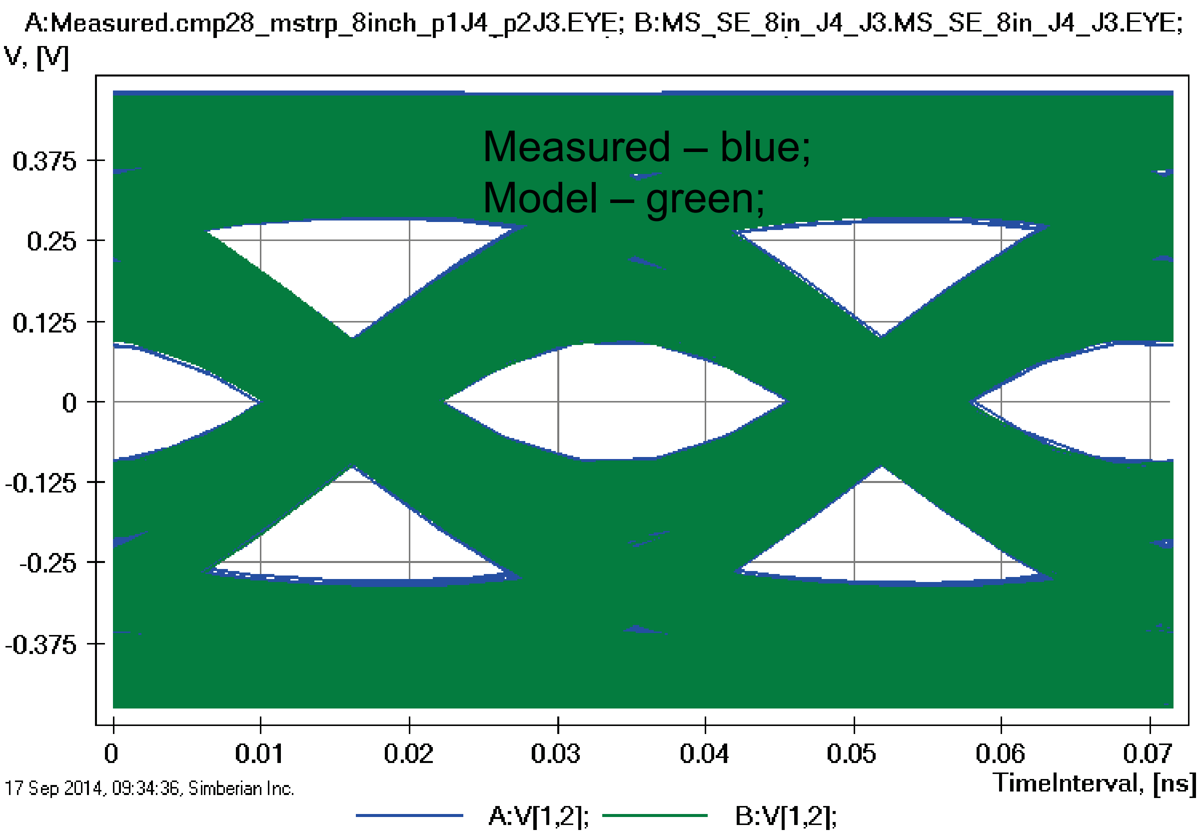
2) 8-inch microstrip line segment: Transmission phase and group delay



2) 8-inch microstrip line segment: TDR with 20 ps Gaussian step

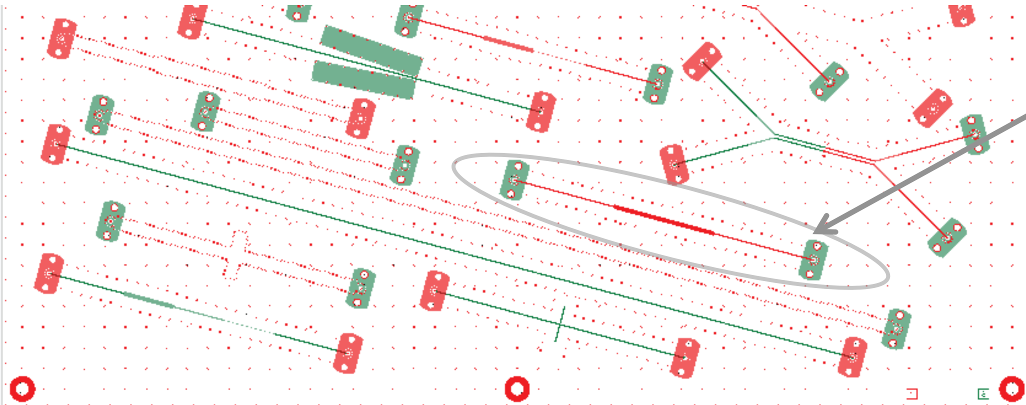


2) 8-inch microstrip line segment: 28 Gbps PRBS, 25 ps rise/fall time



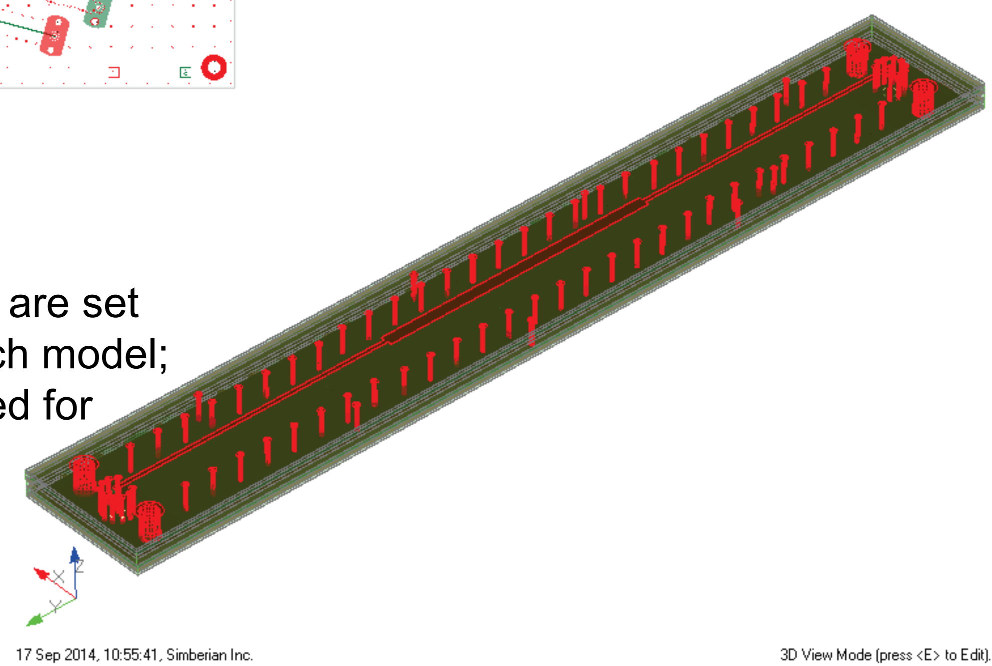
Eyes are on top of each other!

3) Microstrip 25-Ohm Beatty standard



MS SE Beatty 25-Ohm (J25-J26)
Solution: 3_MicrostipSingle(1)
Measured:
cmp28_Beatty_25ohm_p1J25_p2J26.s2p
Selector/Project/Circuit:
MS_SE_Beatty_25Ohm_J25_J26

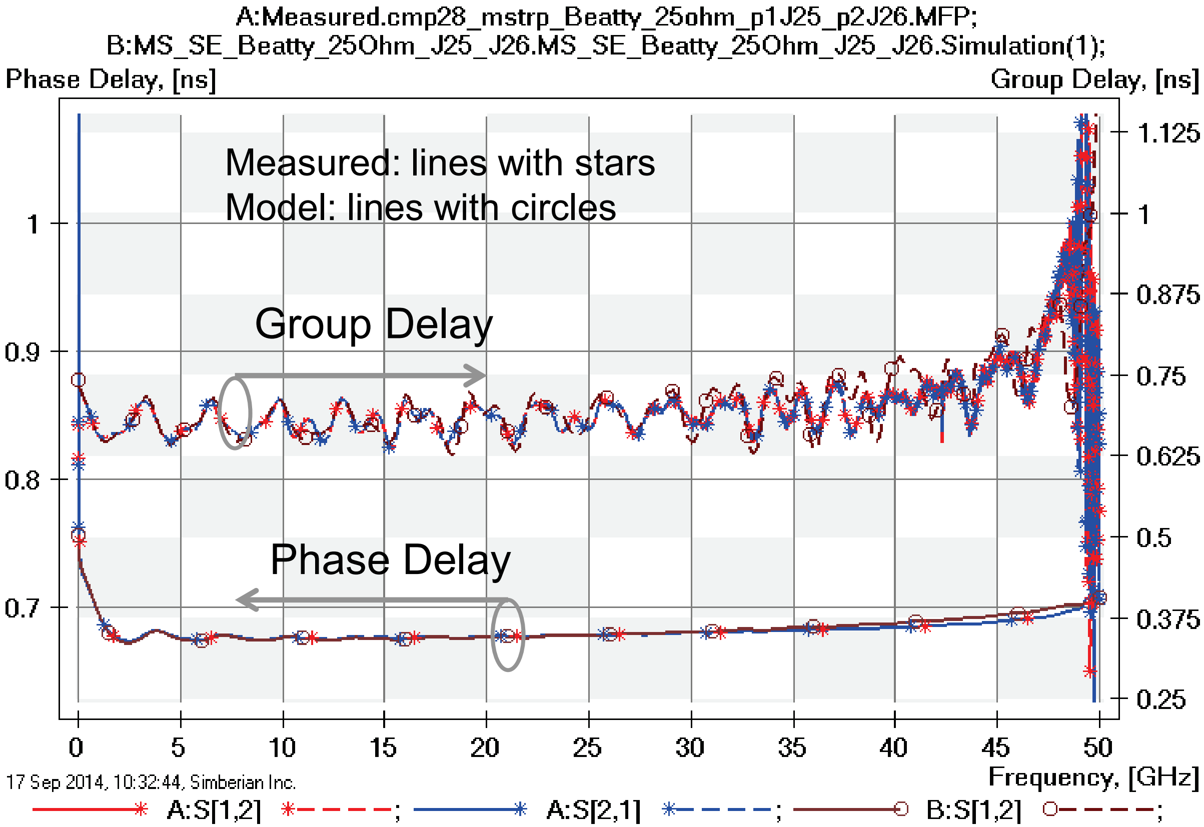
Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
Additional 2 discontinuity selectors added for steps (identical);
See also notes in the solution;



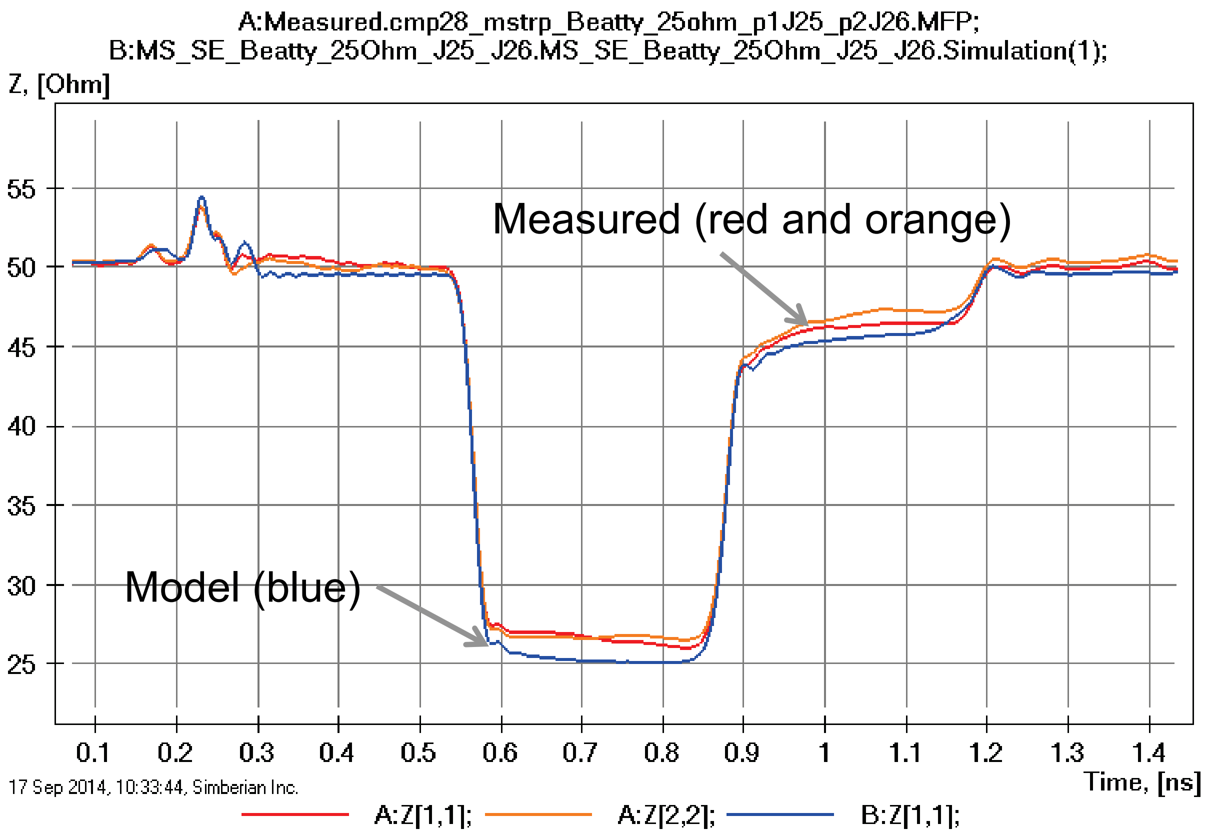
3) Microstrip 25-Ohm Beatty standard: Magnitude of S-parameters

Loss of launch localization above 30 GHz explains additional insertion losses; Variation of trace width and dielectric properties explains differences in reflection losses;

3) Microstrip 25-Ohm Beatty standard: Transmission phase and group delay

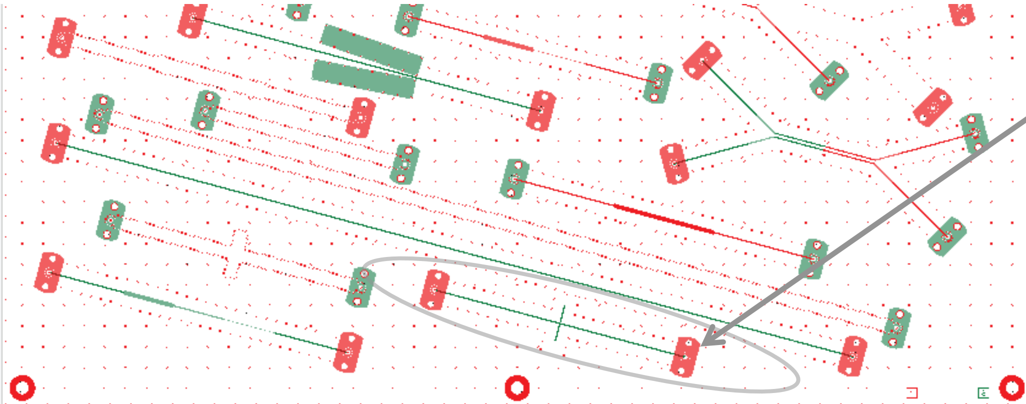


3) Microstrip 25-Ohm Beatty standard: TDR with 20 ps Gaussian step



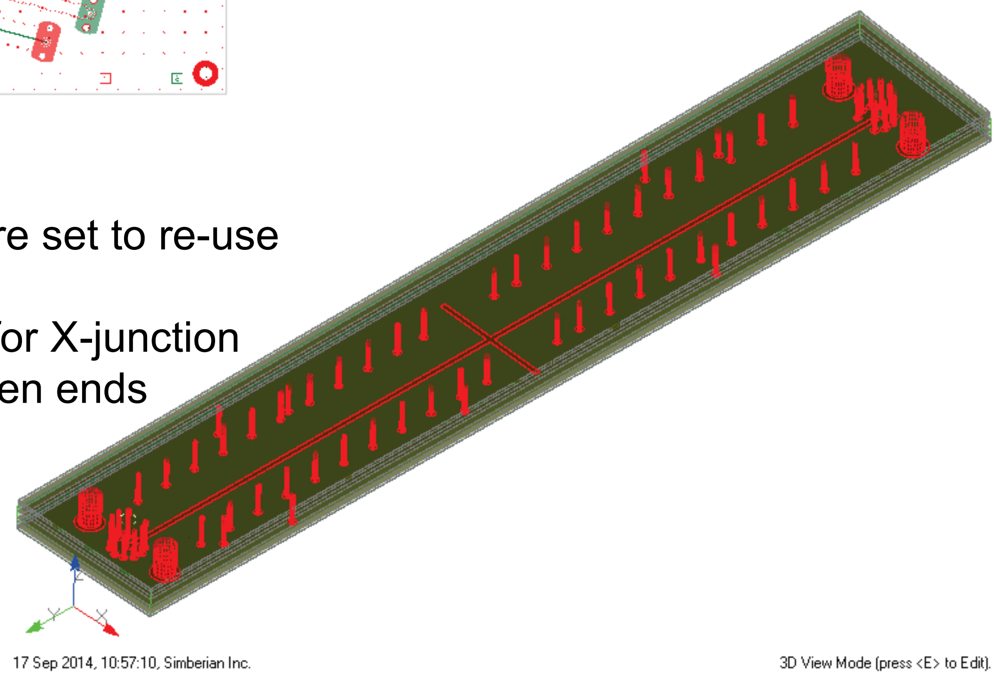
Impedance of the wider section is off (no adjustments);

4) Microstrip stub resonator

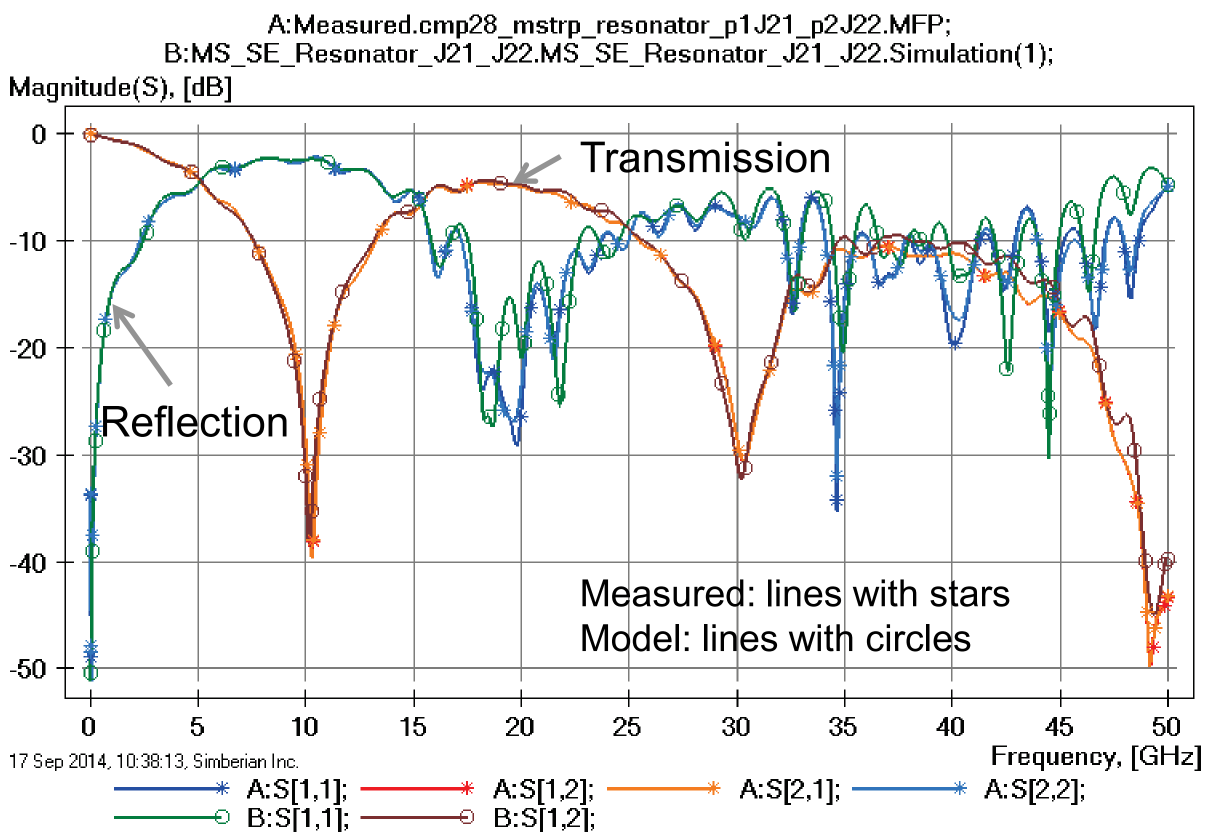


MS SE Resonator (J21-J22)
Solution: 3_MicrostipSingle(1)
Measured:
cmp28_resonator_p1J21_p2J22.s2p
Selector/Project/Circuit:
MS_SE_Resonator_J21_J22

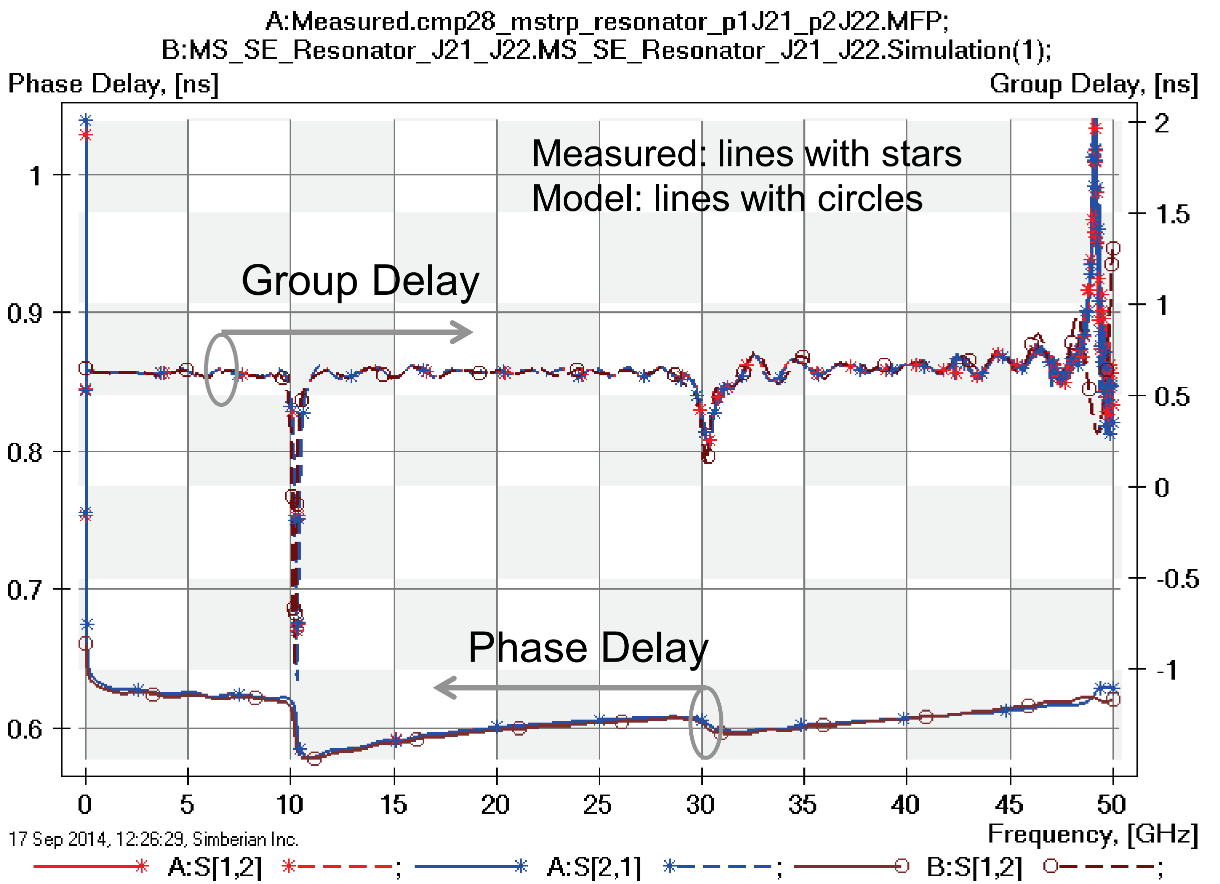
Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
Additional discontinuity selector is added for X-junction and 2 discontinuity selectors added for open ends (identical);
See also notes in the solution;



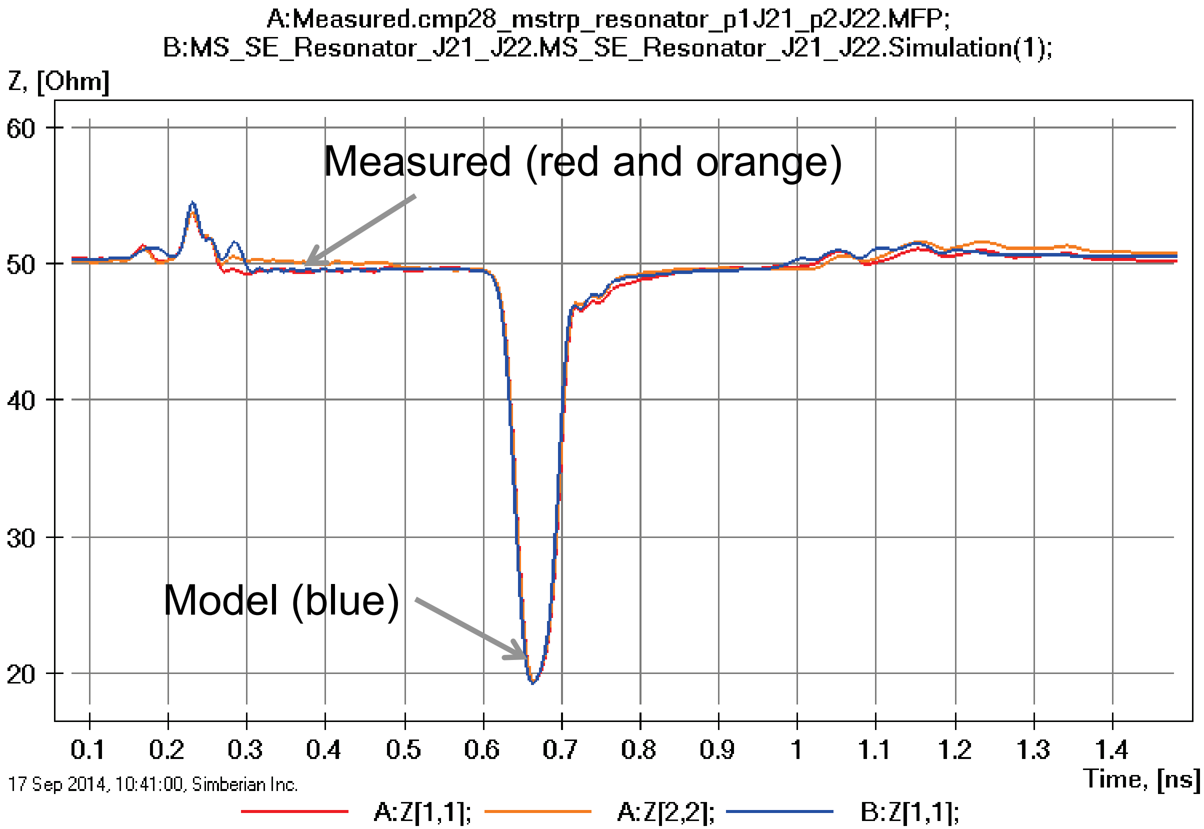
4) Microstrip stub resonator: Magnitude of S-parameters



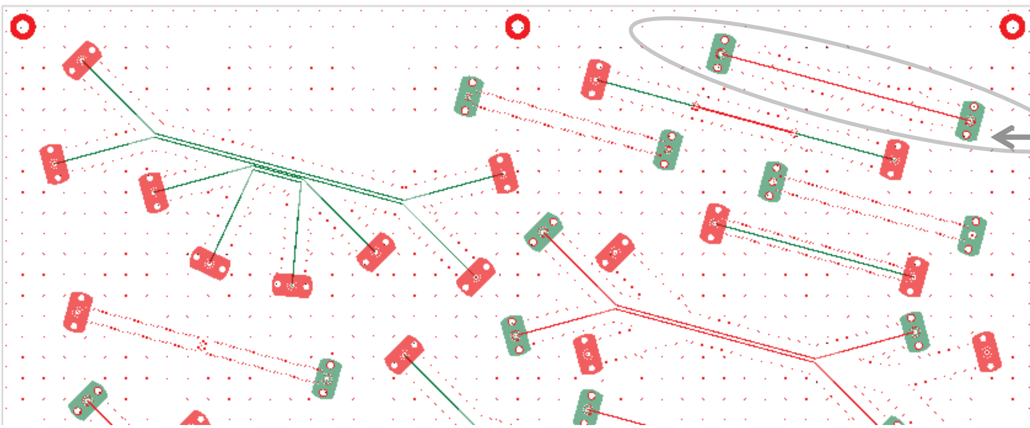
4) Microstrip stub resonator: Transmission phase and group delay



4) Microstrip stub resonator: TDR with 20 ps Gaussian step

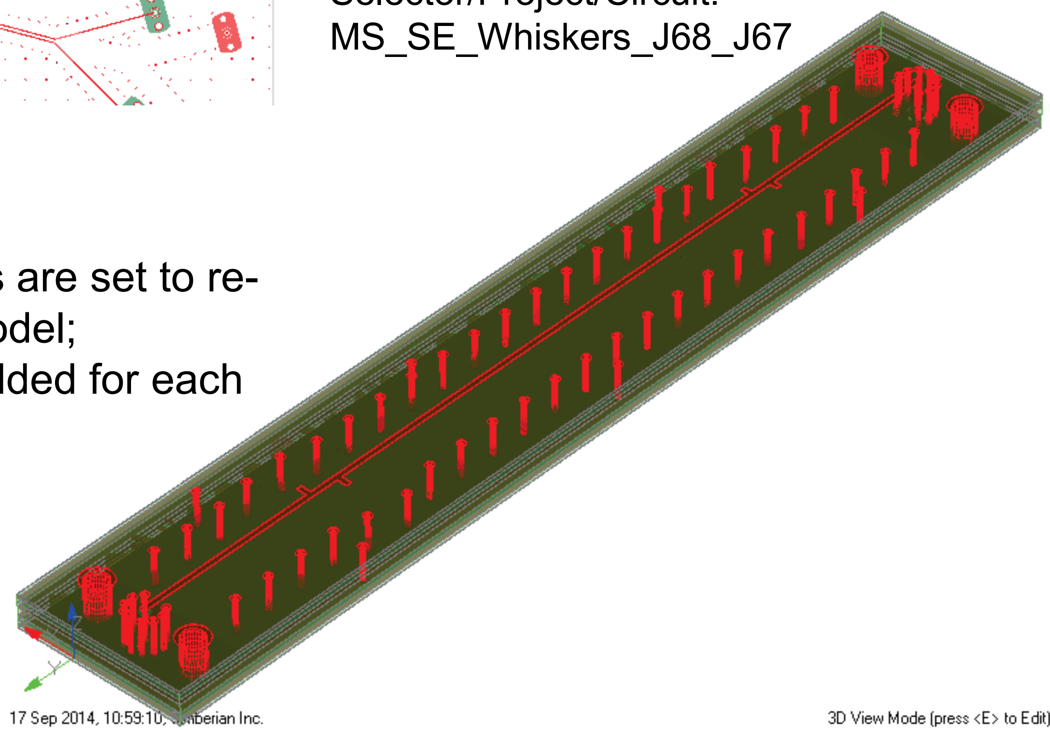


5) Microstrip whiskers (short stubs)

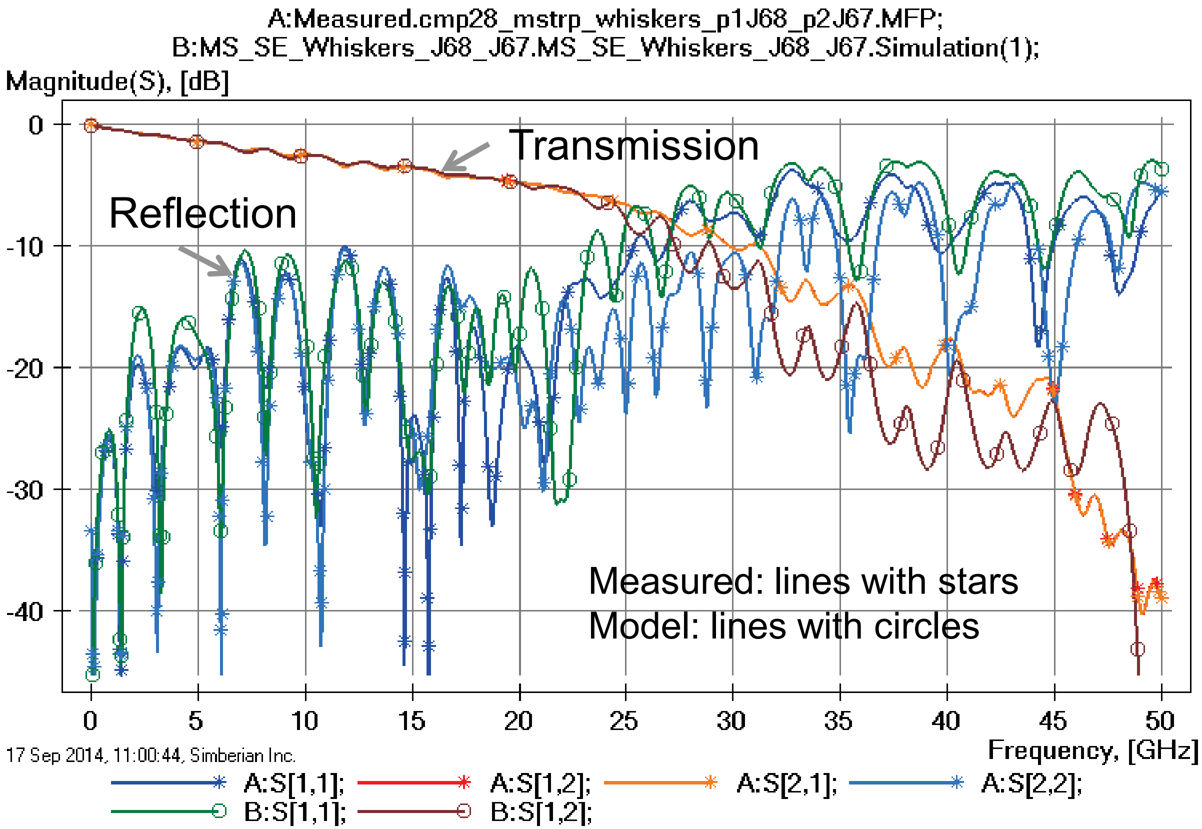


MS SE Whiskers (J67-J68)
Solution: 3_MicrostipSingle(1)
Measured:
cmp28_whiskers_p1J68_p2J67.s2p
Selector/Project/Circuit:
MS_SE_Whiskers_J68_J67

Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
Additional discontinuity selectors are added for each pair of whiskers (identical);
See also notes in the solution;



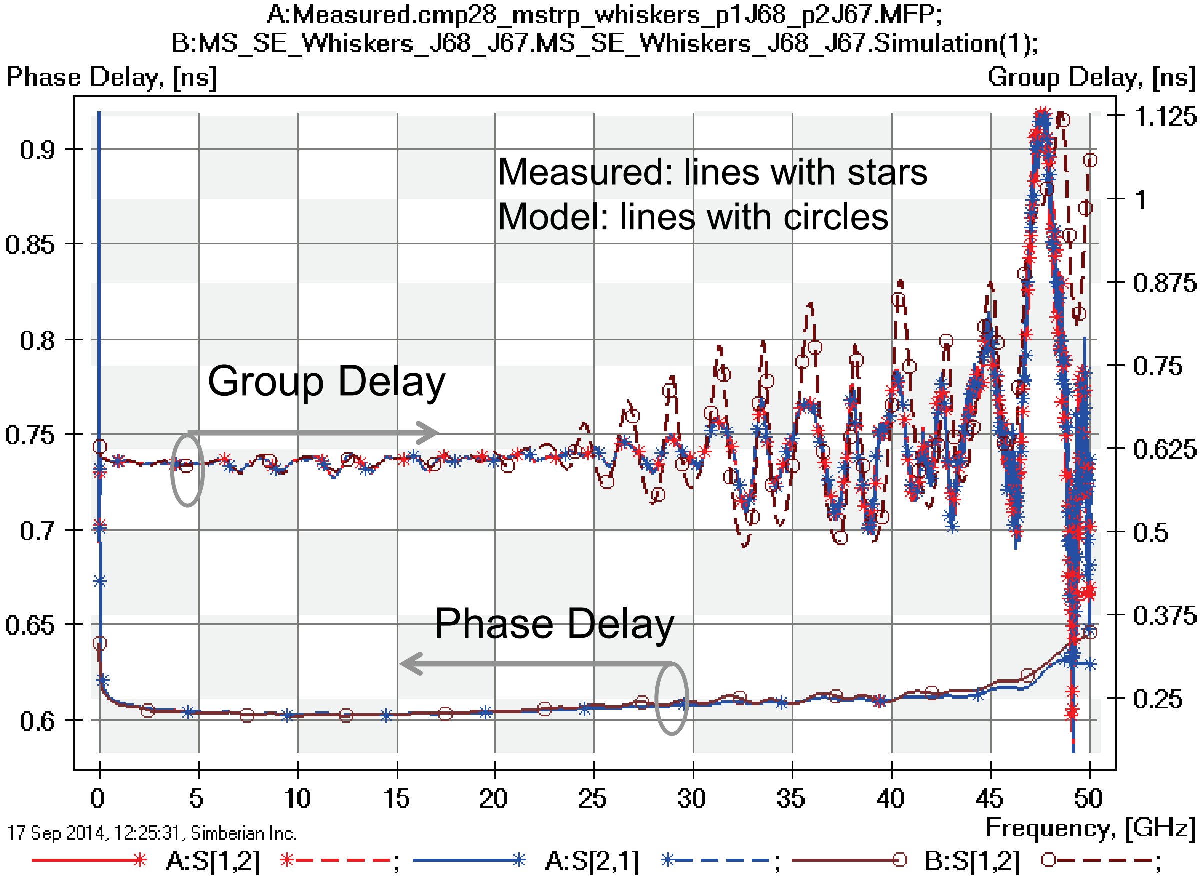
5) Microstrip whiskers: Magnitude of S-parameters



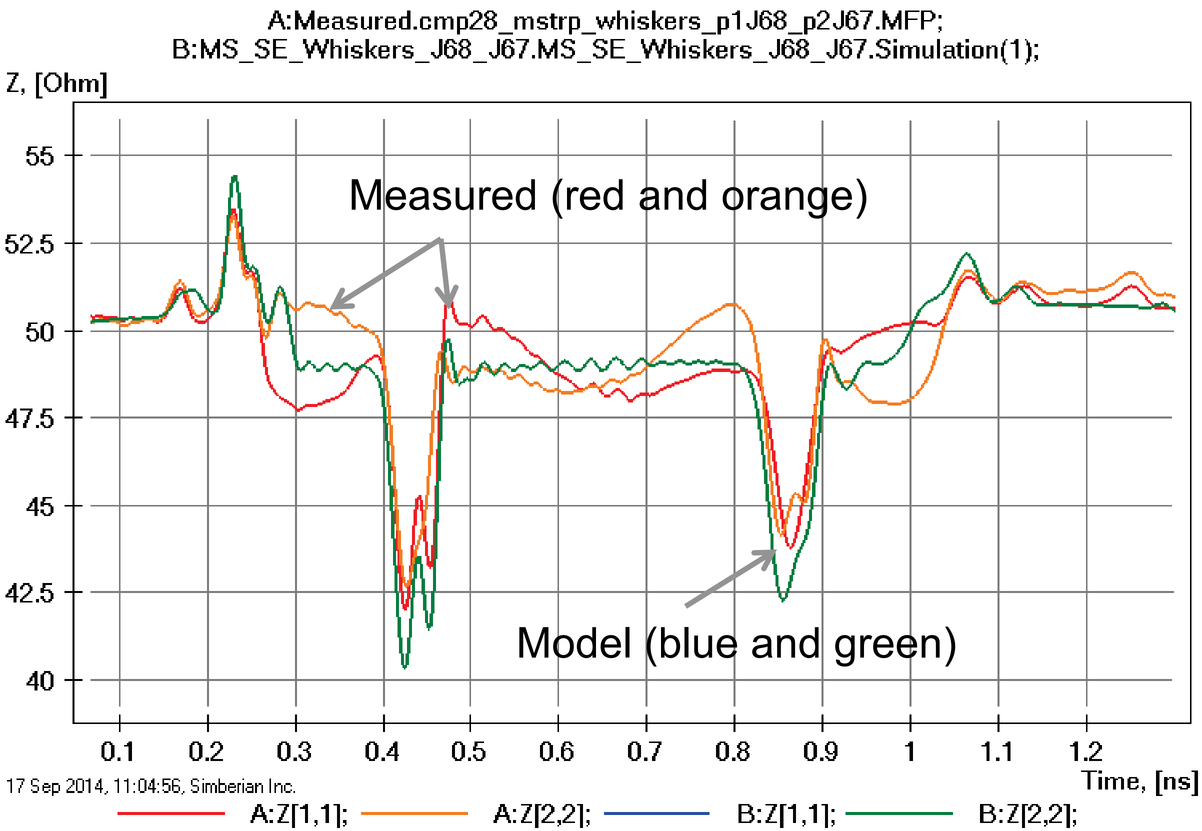
Discrepancies above 20-25 GHz

Substantial differences in insertion and reflection loss above 20-25 GHz;
See notes for TDR;

5) Microstrip whiskers: Transmission phase and group delay

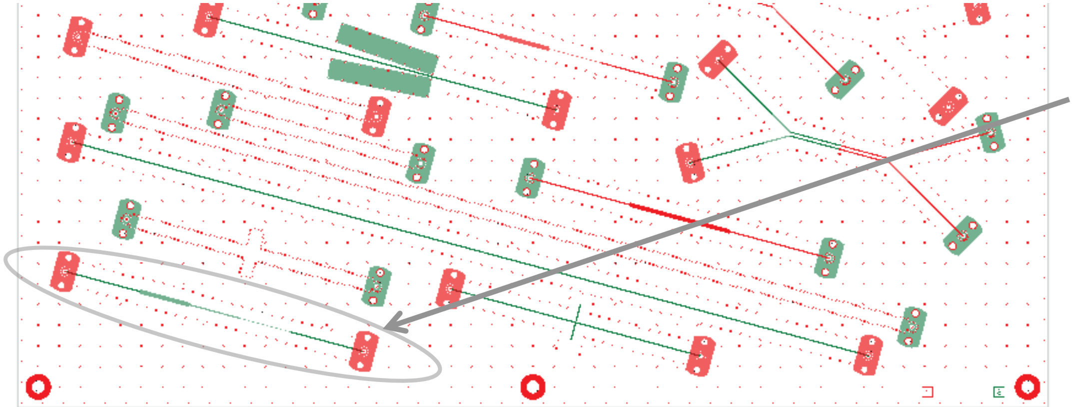


5) Microstrip whiskers : TDR with 20 ps Gaussian step



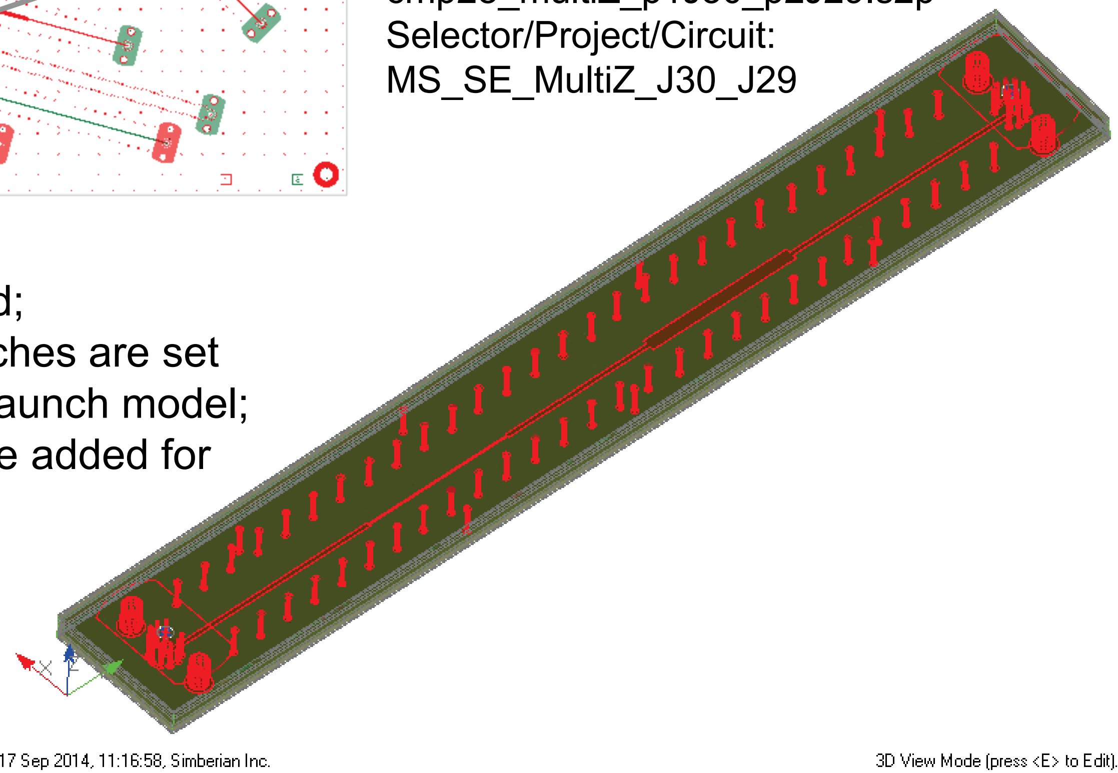
TRACES ON THE BOARD ARE NOT UNIFORM – it explains the differences above 20-25 GHz

6) Microstrip multi-Z link 1

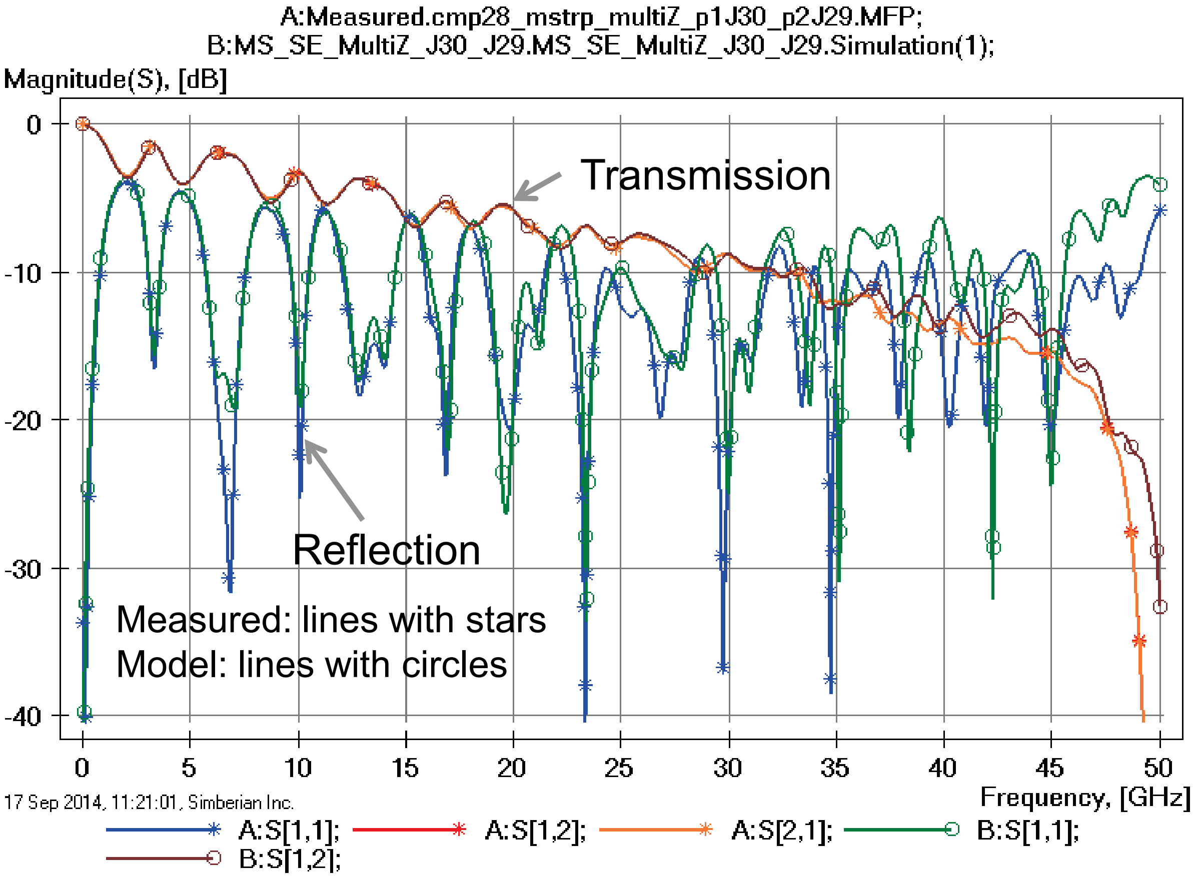


MS SE Multi-Z (J29-J30)
Solution: 3_MicrostipSingle(1)
Measured:
cmp28_multiZ_p1J30_p2J29.s2p
Selector/Project/Circuit:
MS_SE_MultiZ_J30_J29

Board Analyzer:
Only 14.5 mil trace width is adjusted;
2 discontinuity selector for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
Additional discontinuity selectors are added for all steps;
See also notes in the solution;

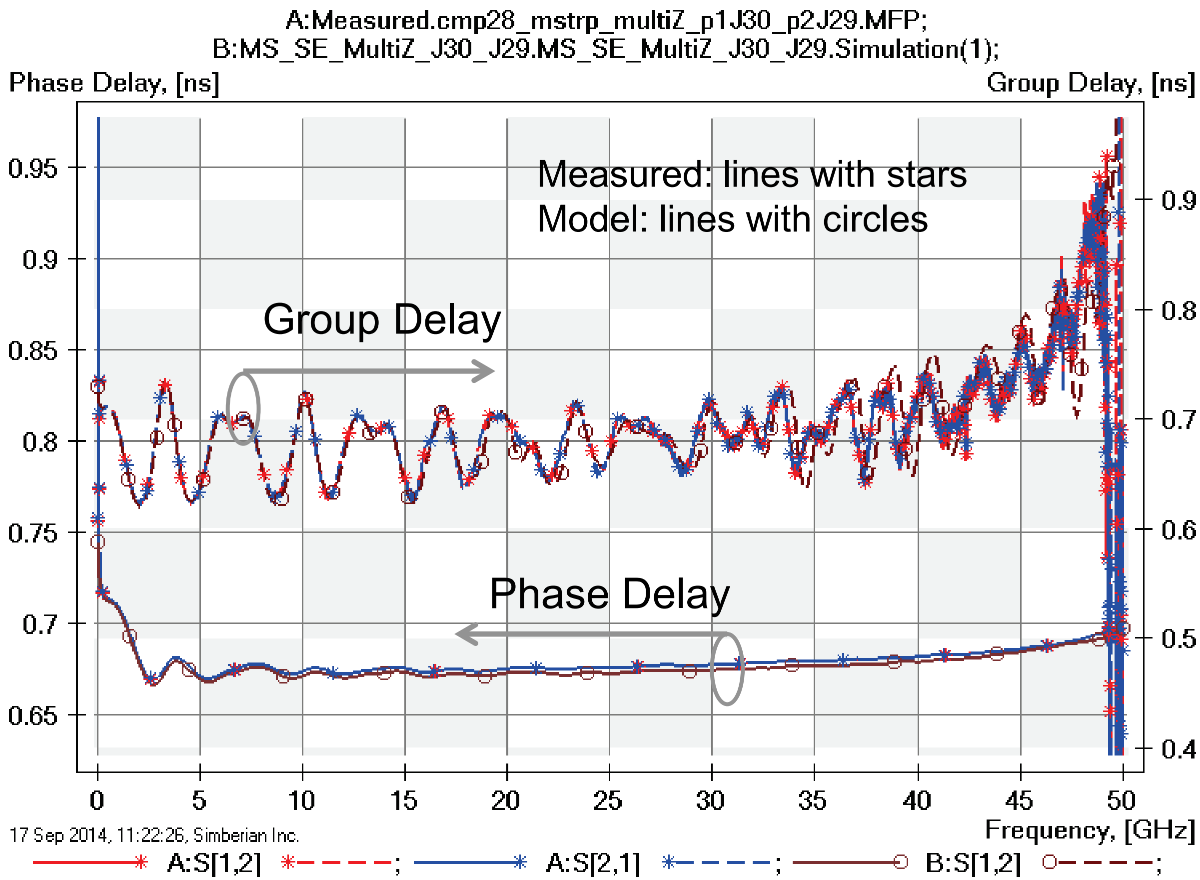


6) Microstrip multi-Z link 1: Magnitude of S-parameters

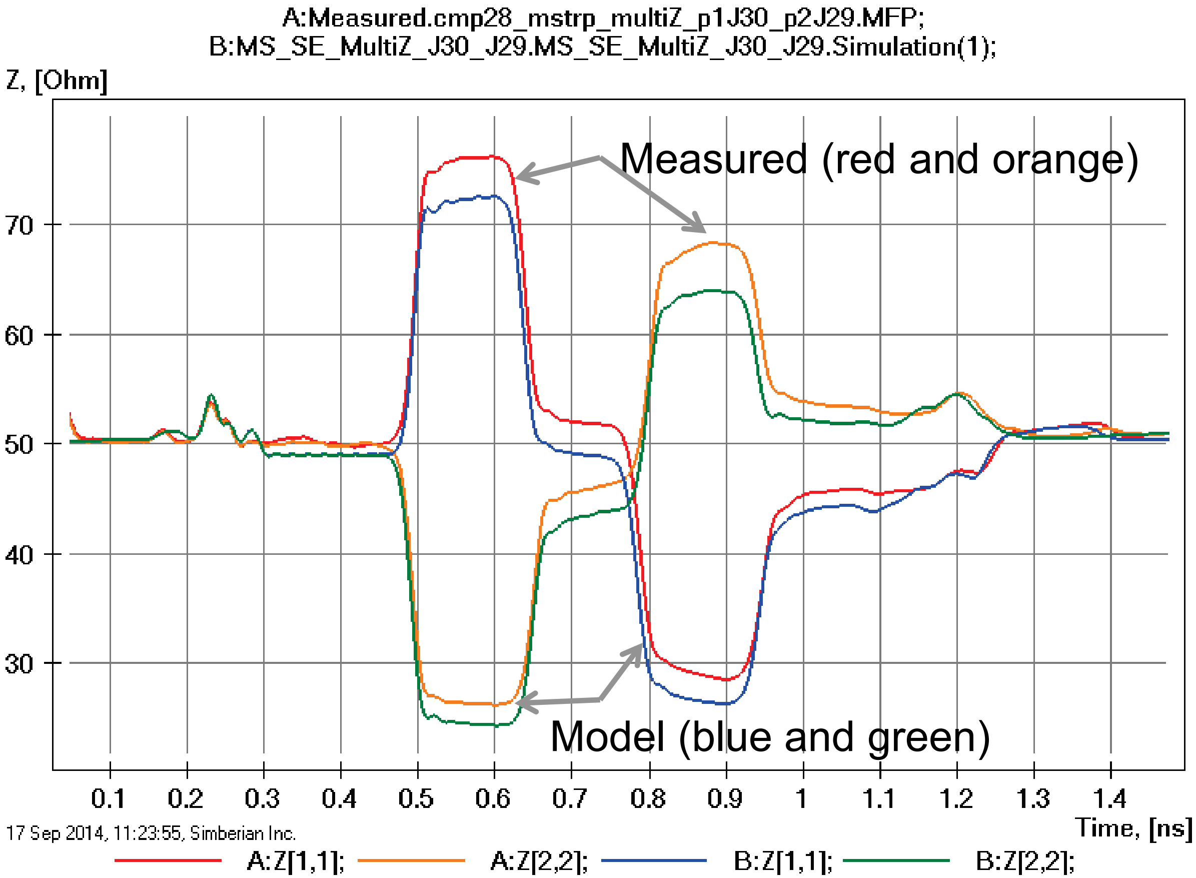


Variation of trace width and dielectric properties explains differences in reflection losses;

6) Microstrip multi-Z link 1: Transmission phase and group delay

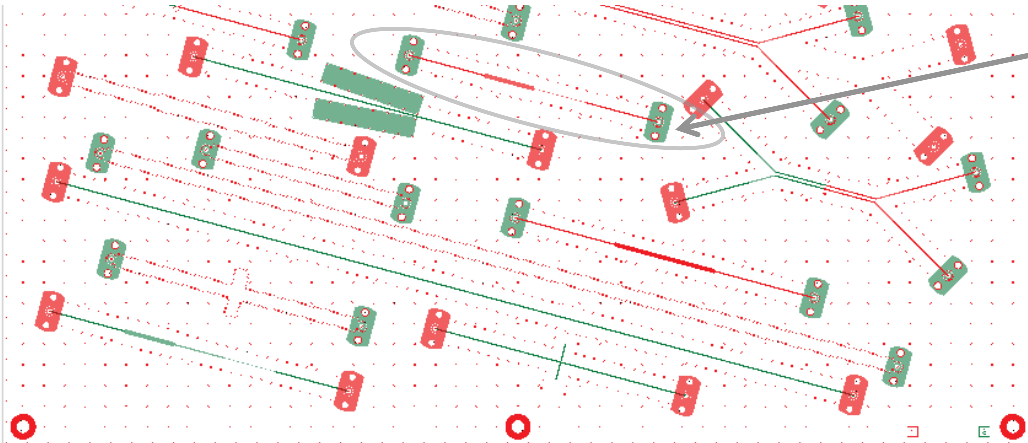


6) Microstrip multi-Z link 1: TDR with 20 ps Gaussian step



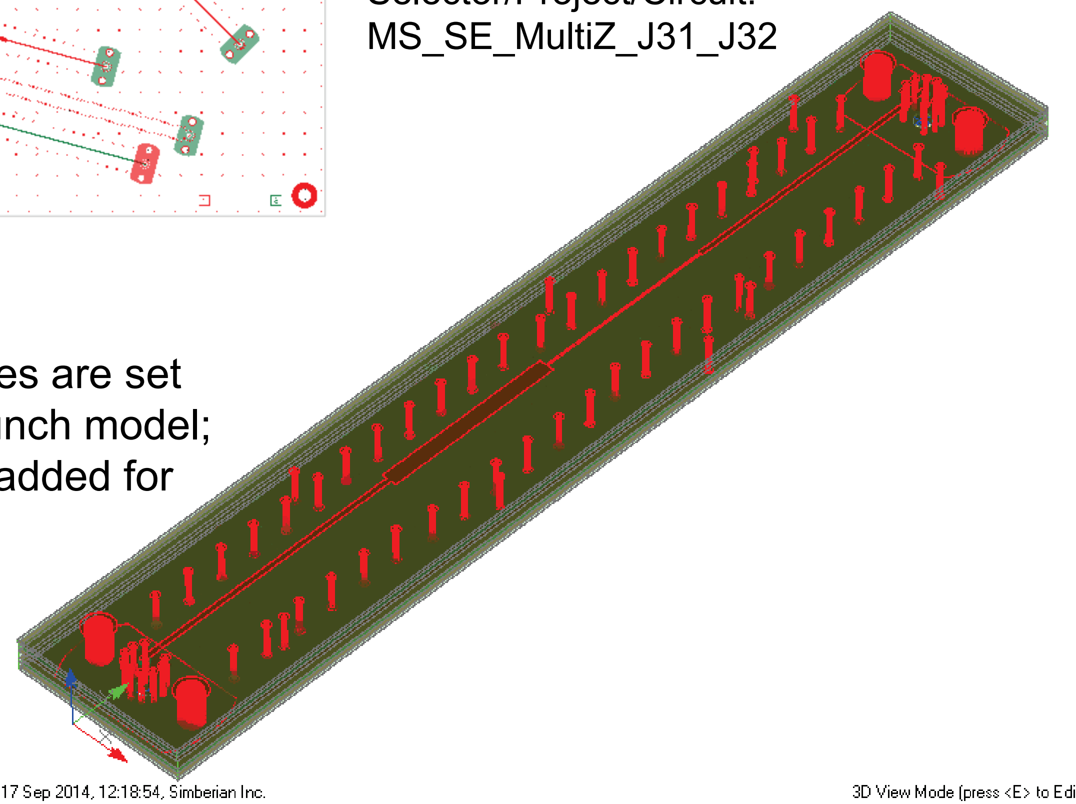
About 10% difference in wider lines;
About 5% in narrow lines;
No width adjustments in wider and narrower strips;

7) Microstrip multi-Z link 2

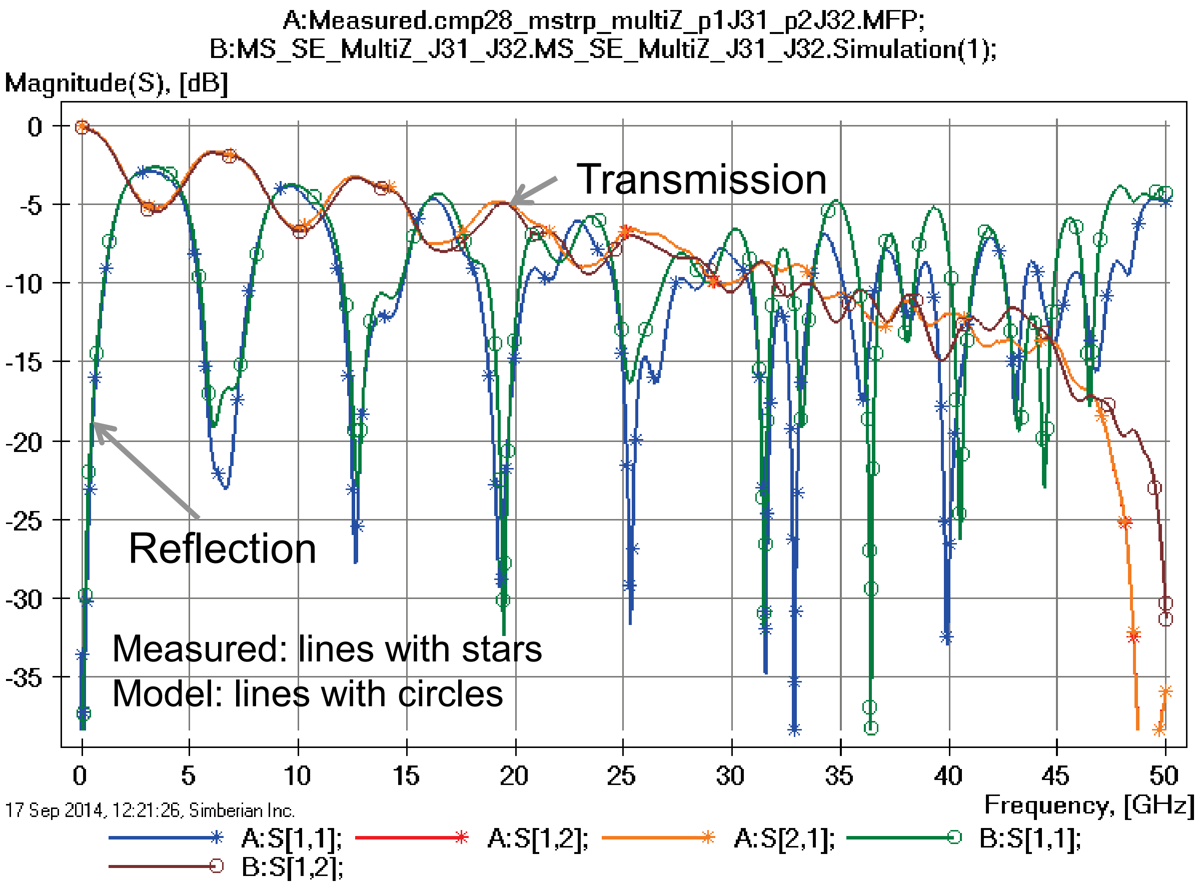


MS SE Multi-Z (J31-J32)
Solution: 3_MicrostipSingle(1)
Measured:
cmp28_multiZ_p1J31_p2J32.s2p
Selector/Project/Circuit:
MS_SE_MultiZ_J31_J32

Board Analyzer:
Only 14.5 mil trace width is adjusted;
2 discontinuity selector for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
Additional discontinuity selectors are added for all steps;
See also notes in the solution;

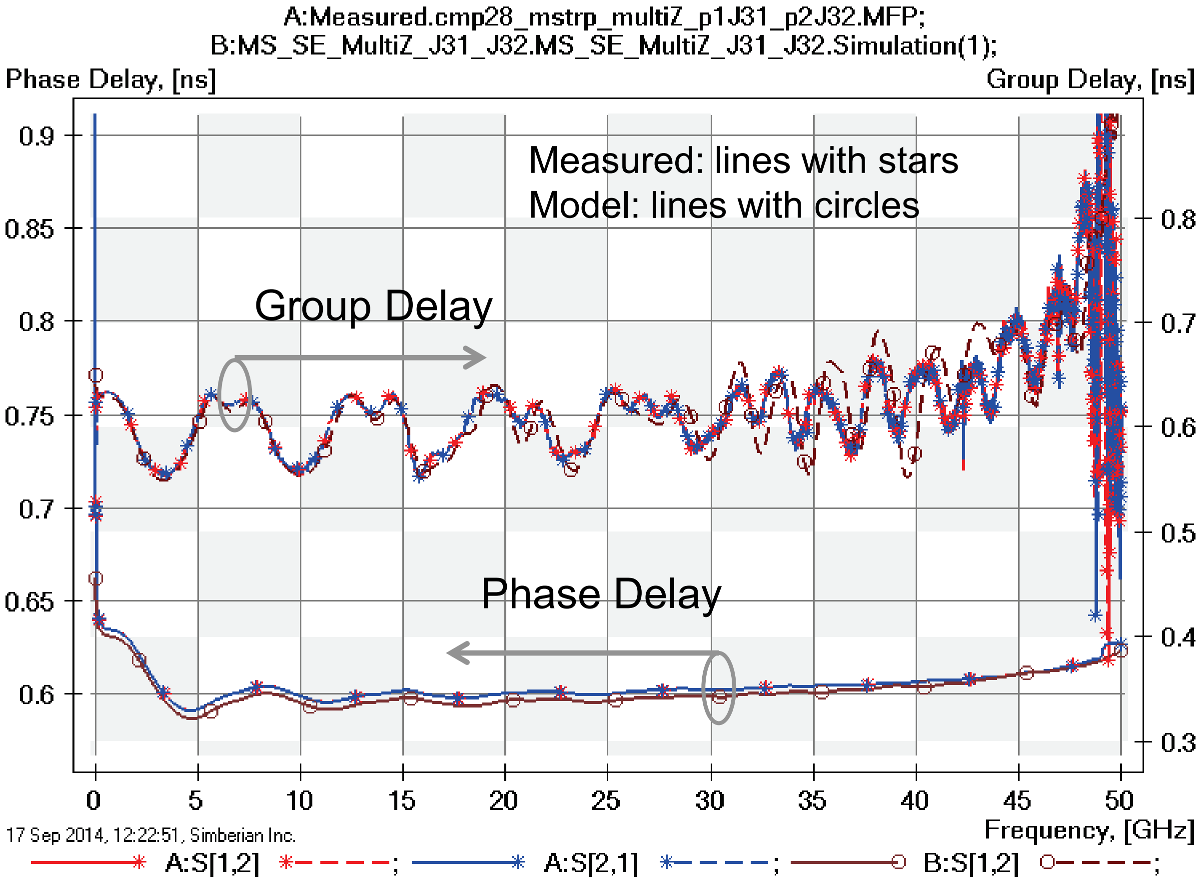


7) Microstrip multi-Z link 2: Magnitude of S-parameters

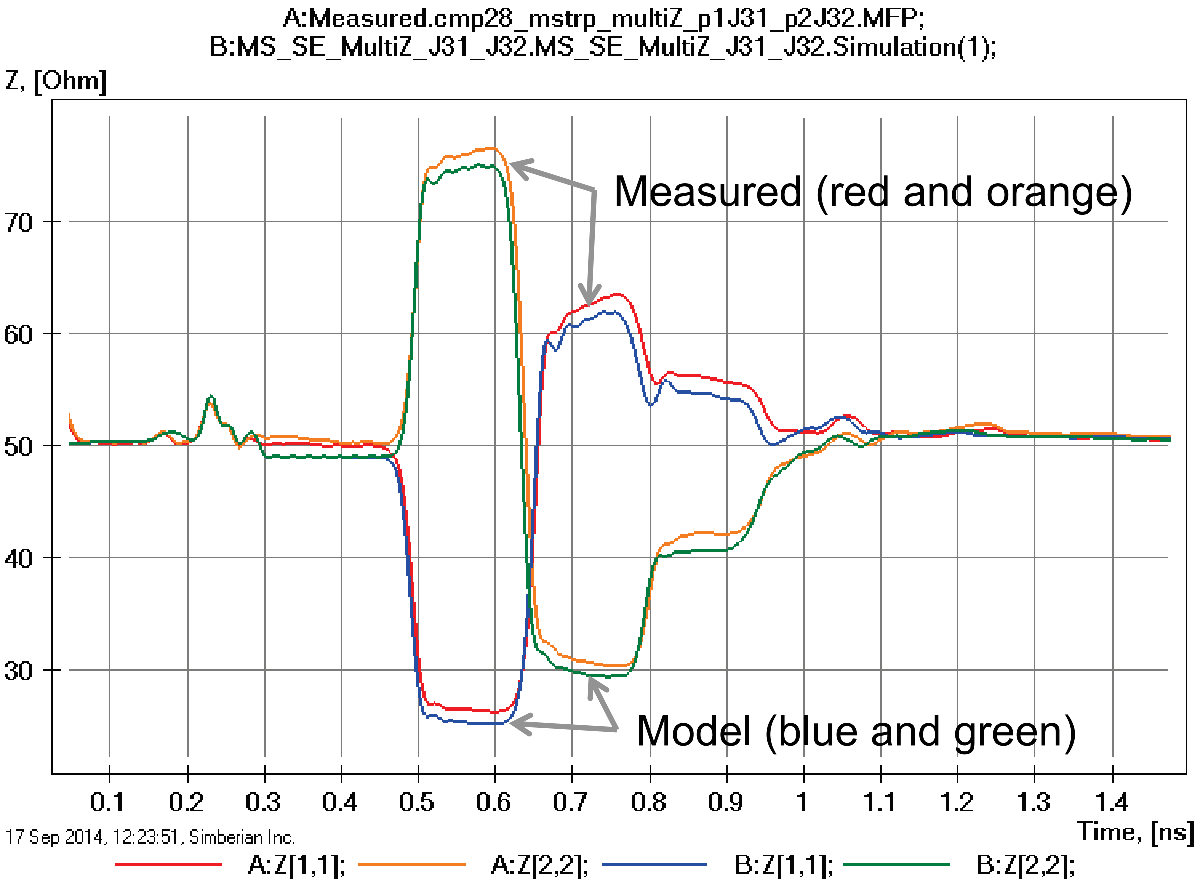


Variation of trace width and dielectric properties explains differences in reflection losses;

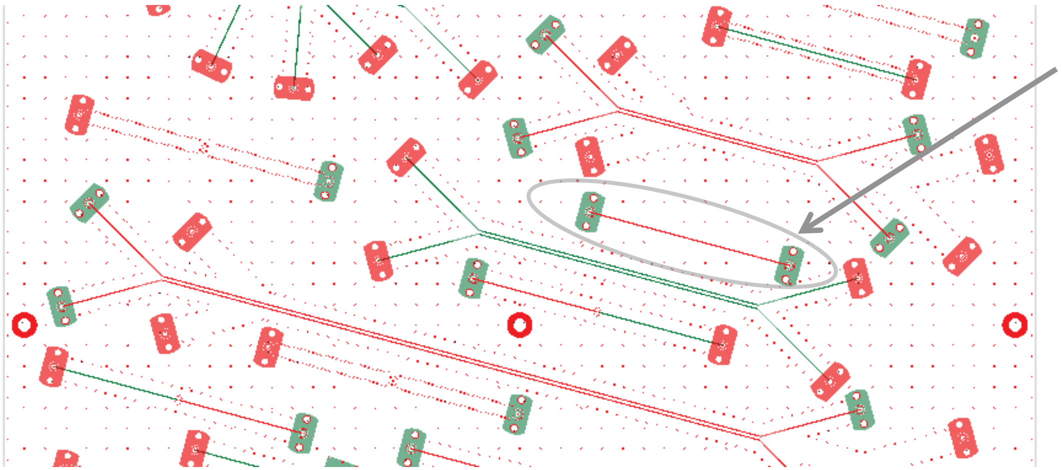
7) Microstrip multi-Z link 2: Transmission phase and group delay



7) Microstrip multi-Z link 2: TDR with 20 ps Gaussian step

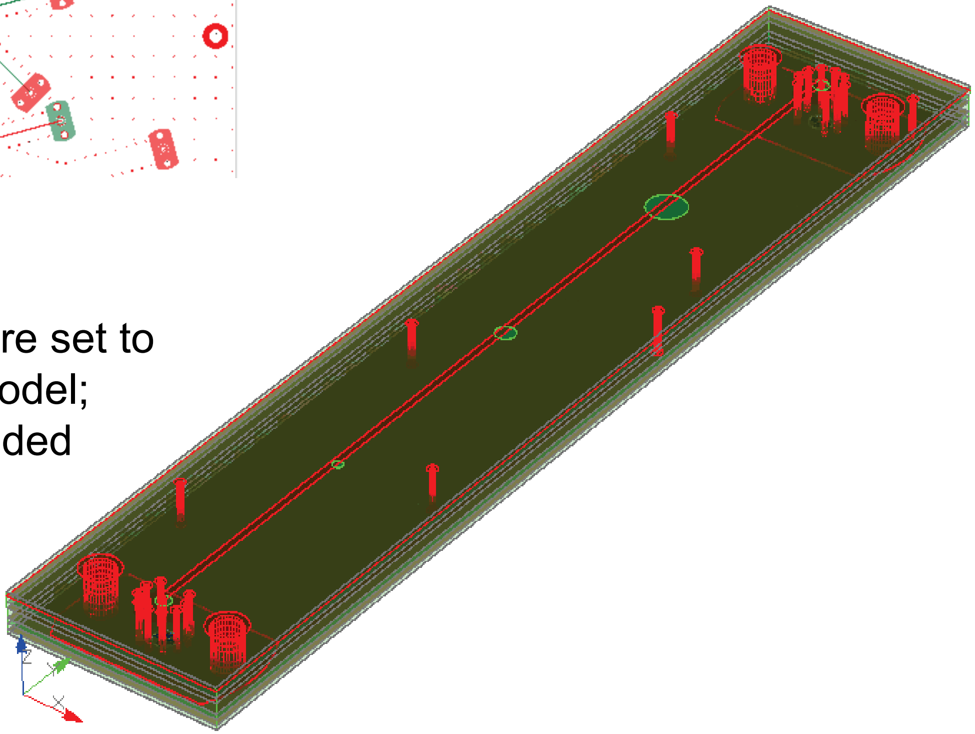


8) Microstrip line with voids in GND plane

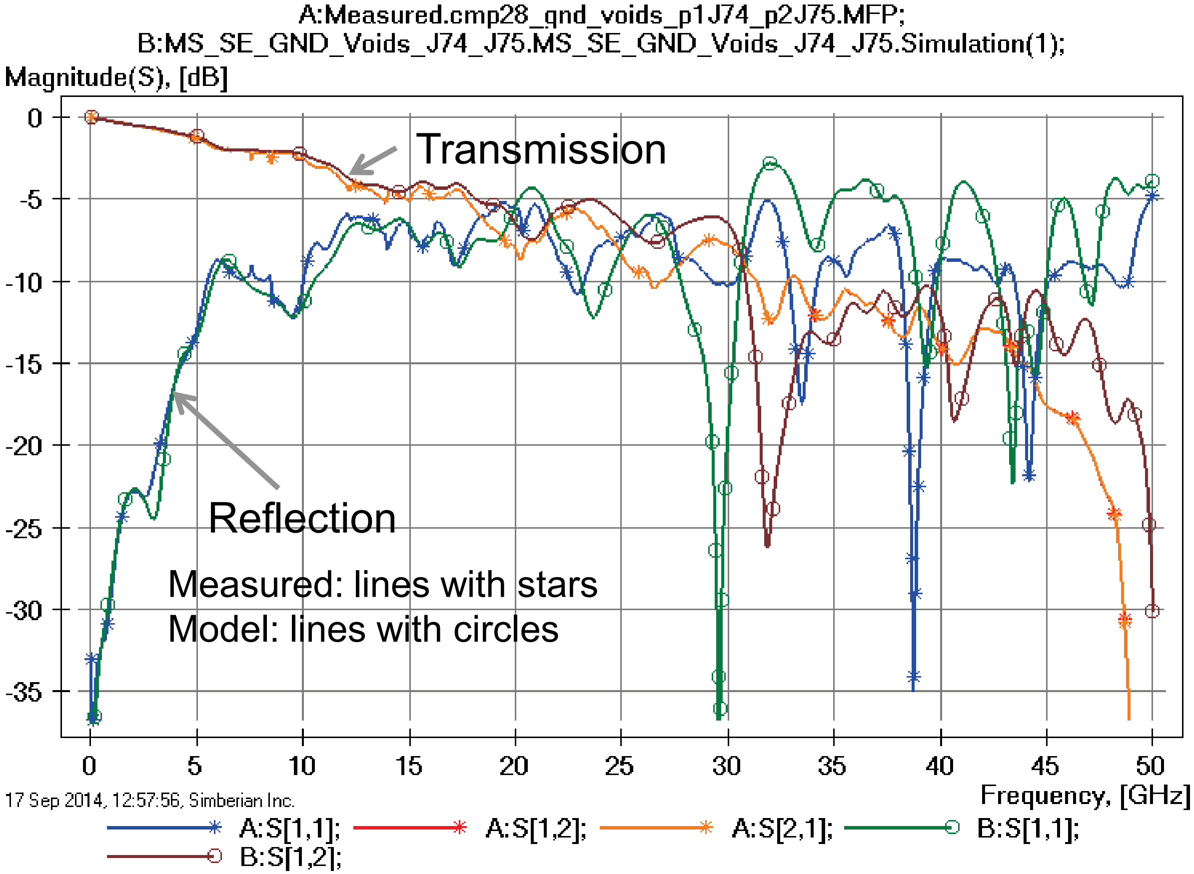


MS SE GND voids (J74-J75)
Solution: 4_MicrostipSingle(2)
Measured:
cmp28_gnd_voids_p1J74_p2J75.s2p
Selector/Project/Circuit:
MS_SE_GND_Voids_J74_J75

Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
Additional 3 discontinuity selectors are added around all voids in the reference plane;
See also notes in the solution;



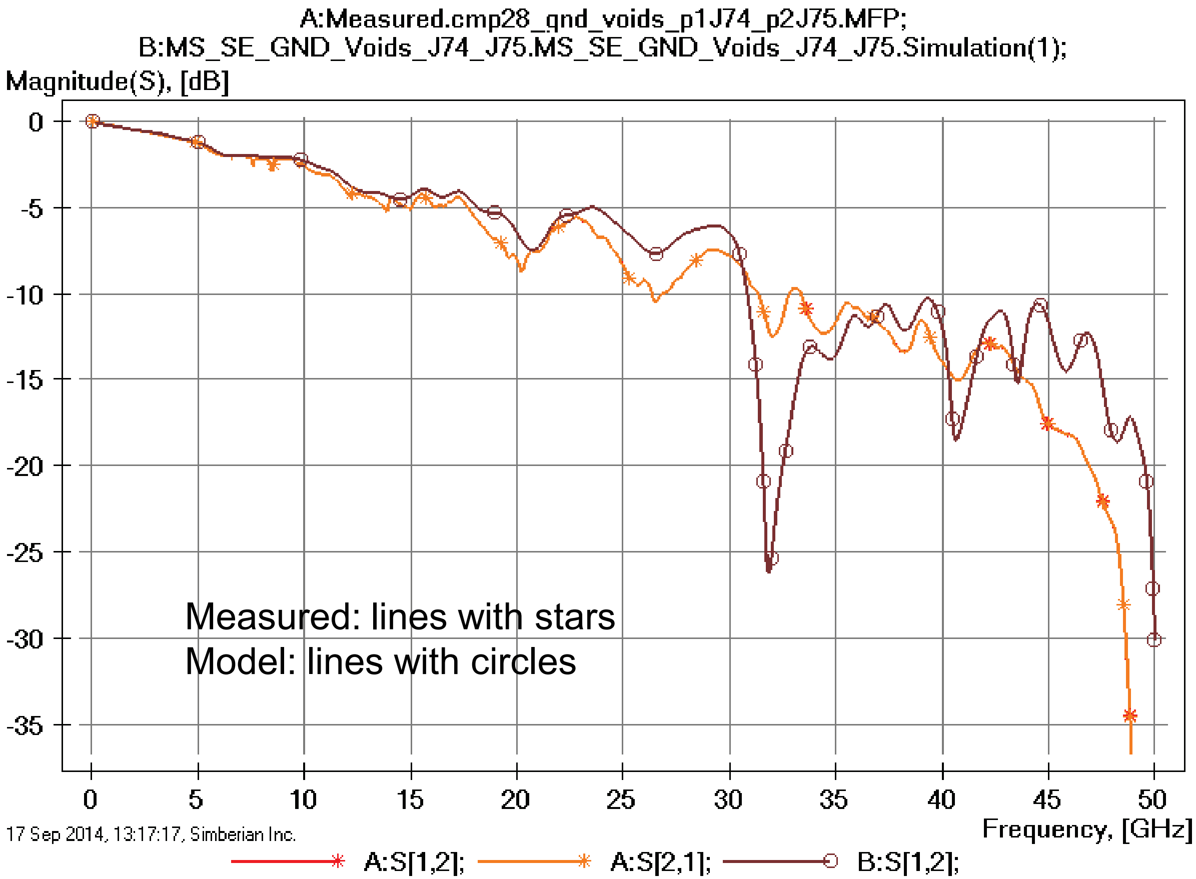
8) Microstrip line with voids in GND plane: Magnitude of S-parameters



Discrepancies above 20-25 GHz

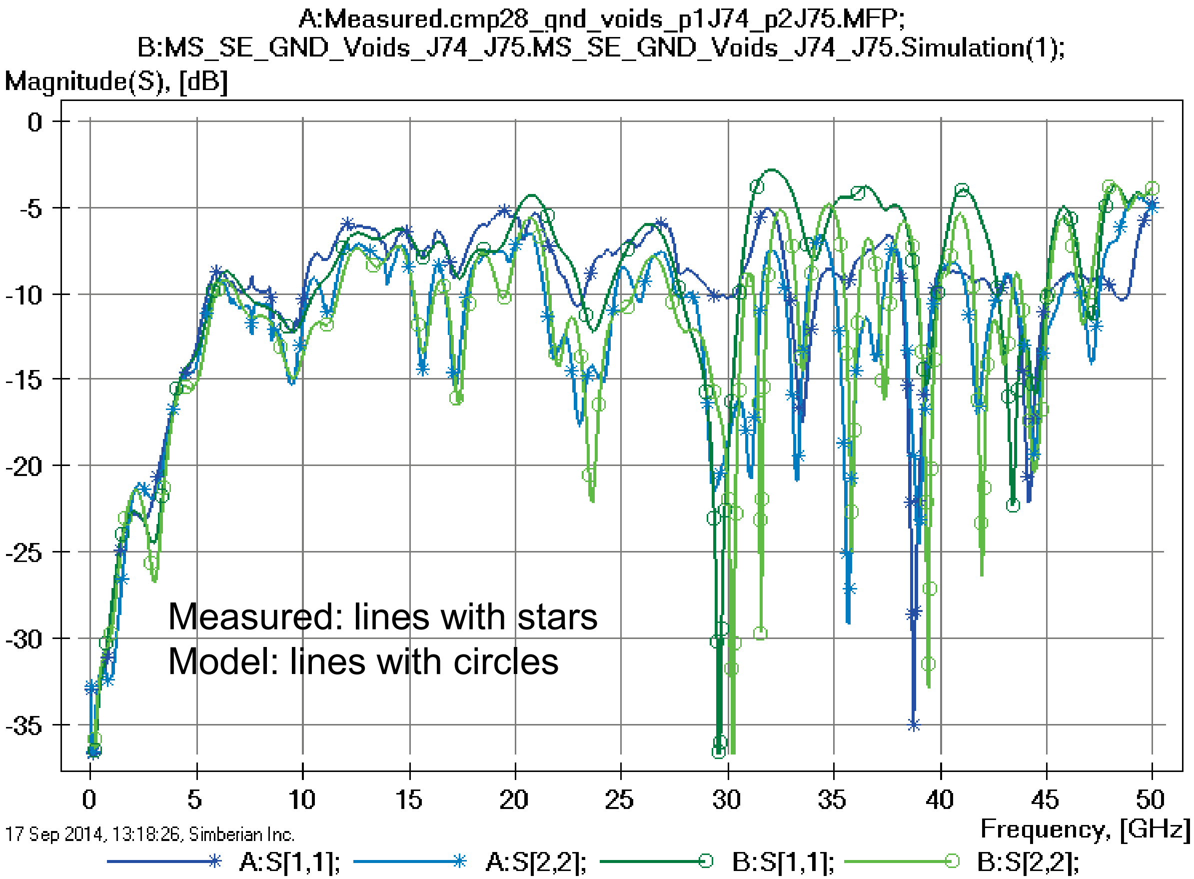
Not clear what causes substantial differences above 20-25 GHz;

8) Microstrip line with voids in GND plane : Magnitude of transmission parameter



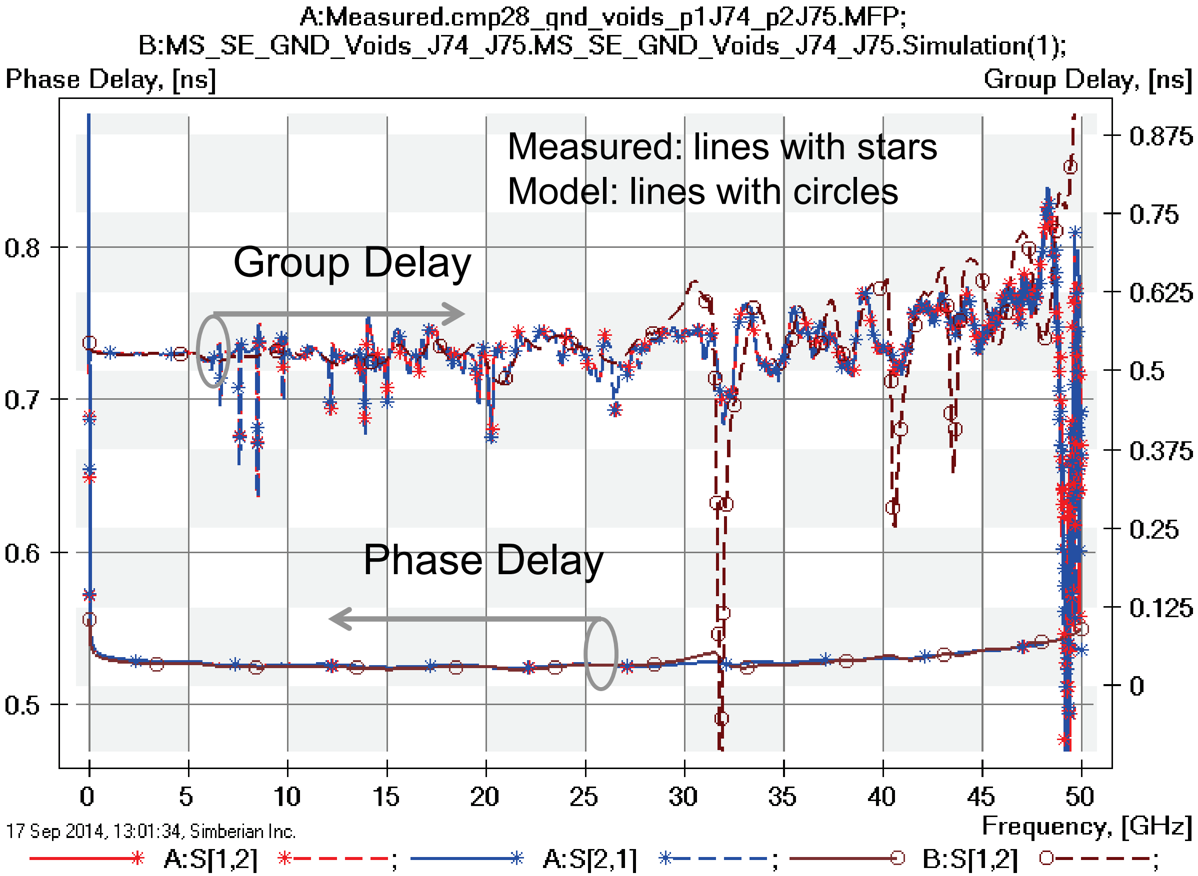
Not clear what causes substantial differences above 20 GHz;

8) Microstrip line with voids in GND plane : Magnitude of reflection parameter

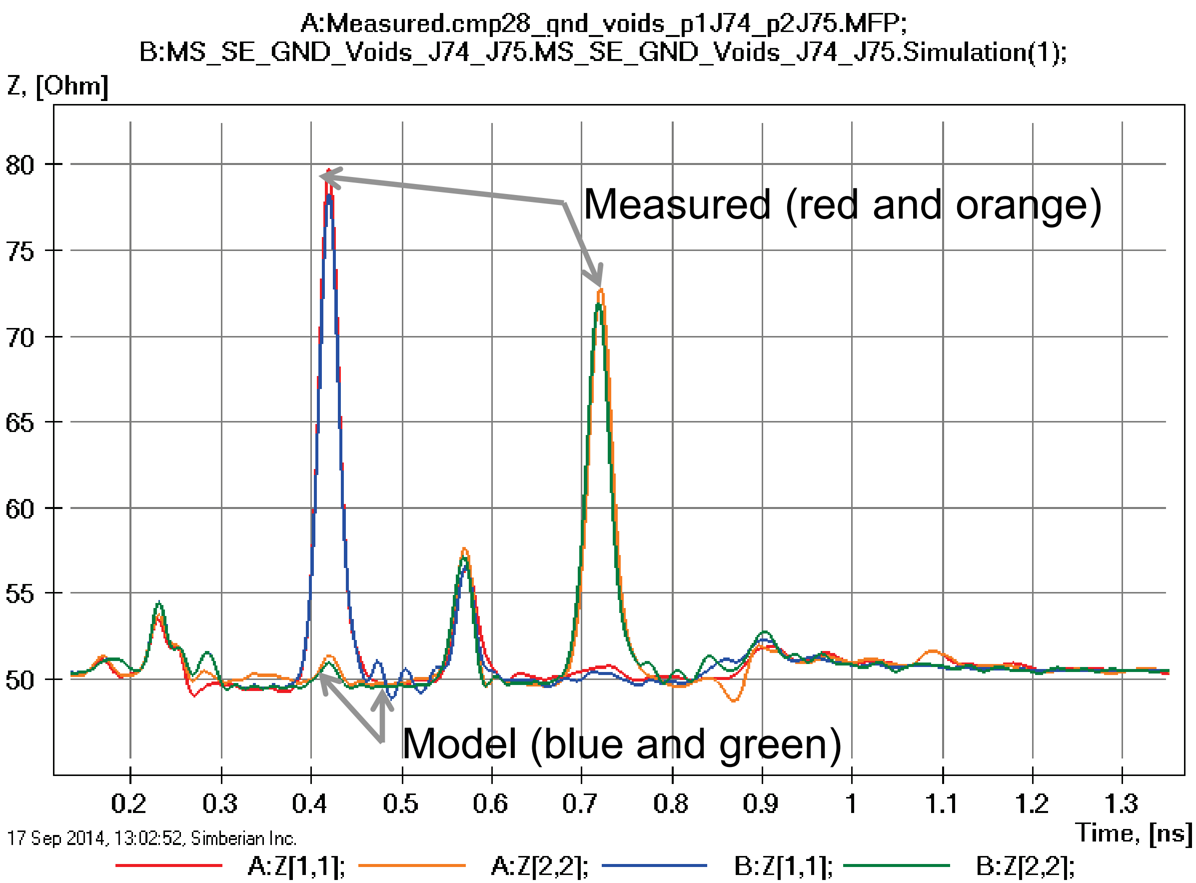


Not clear what causes substantial differences above 25-30 GHz;

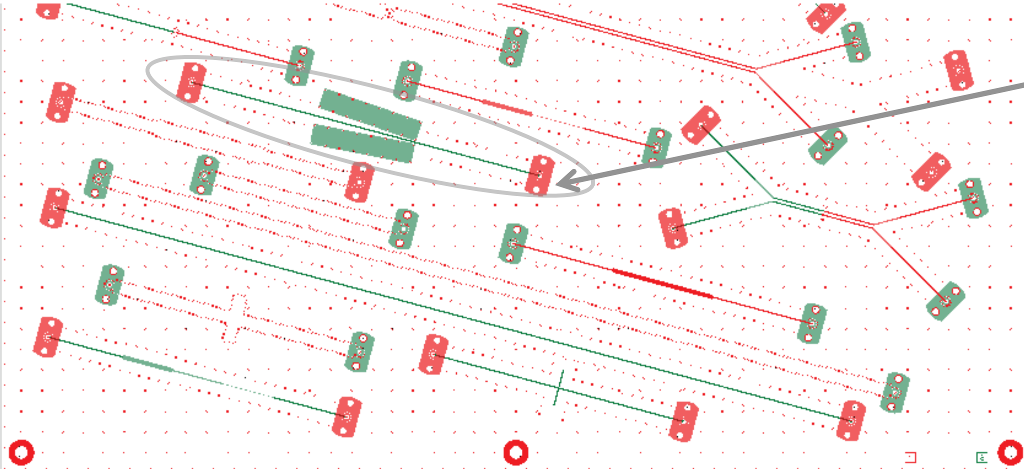
8) Microstrip line with voids in GND plane: Transmission phase and group delay



8) Microstrip line with voids in GND plane: TDR with 20 ps Gaussian step

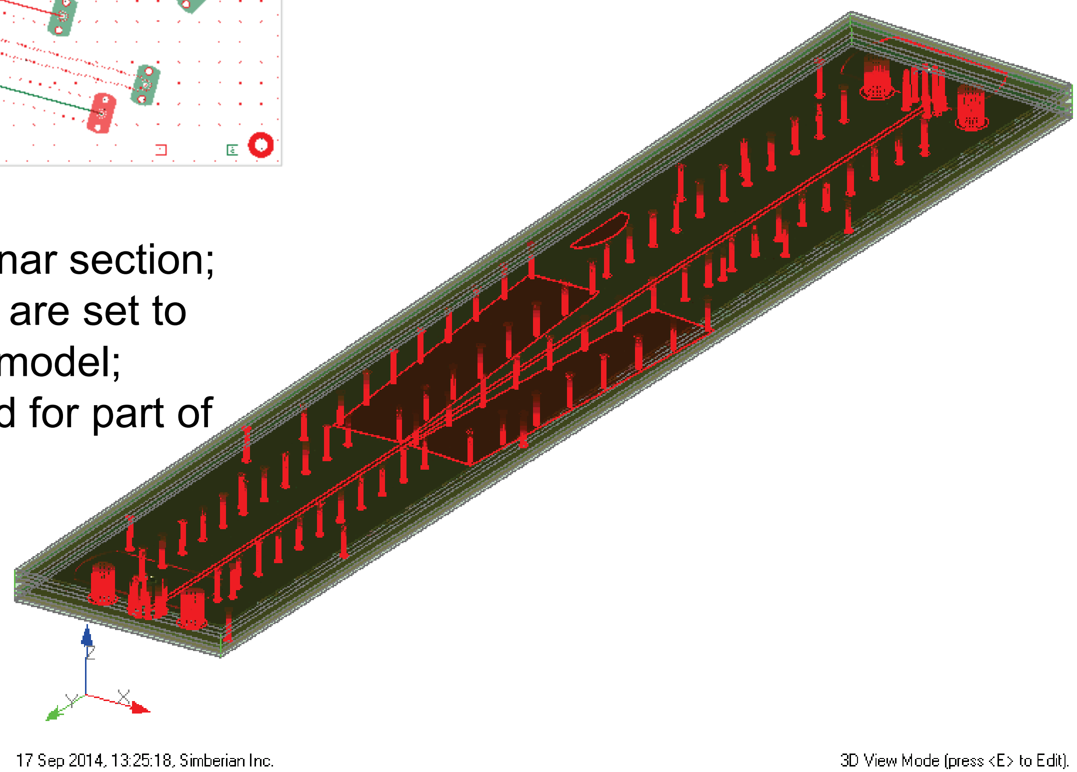


9) Microstrip with gradual coplanar section

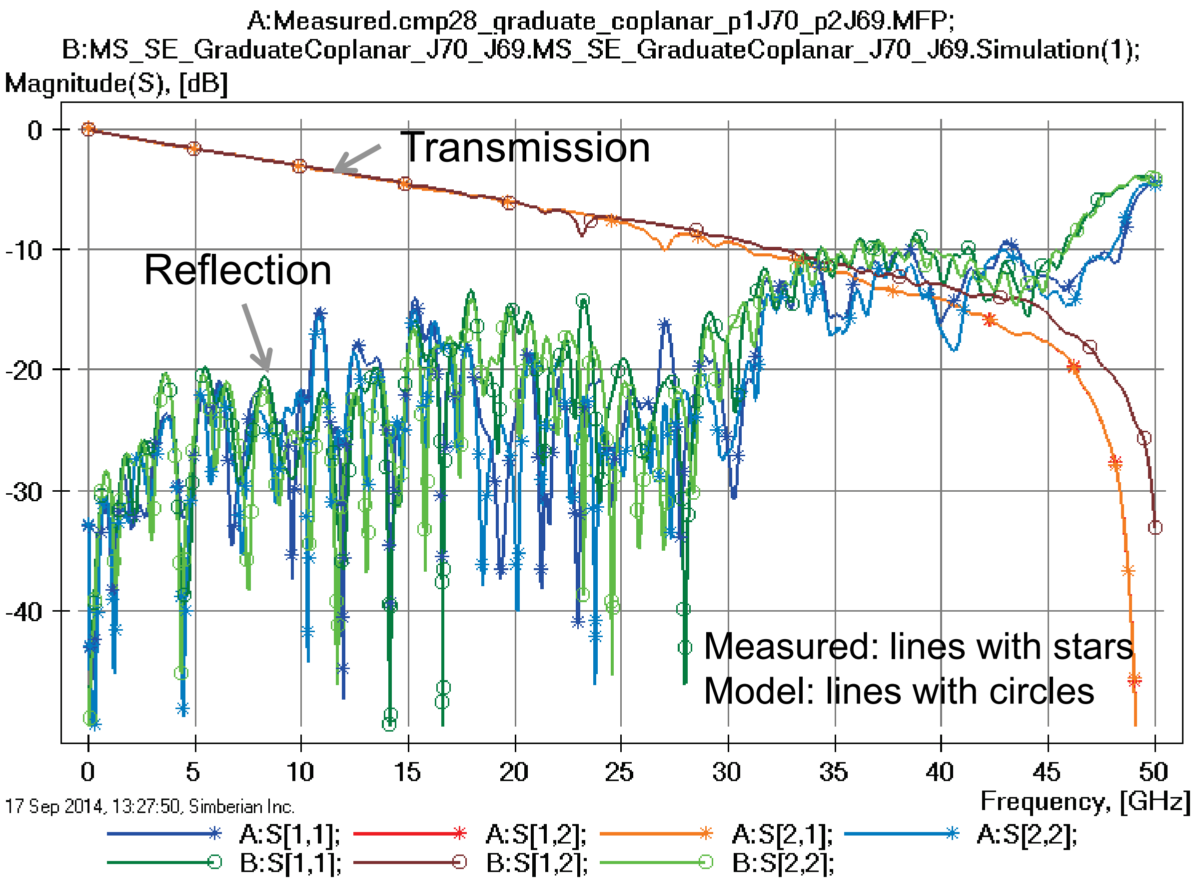


MS SE Gradual Coplanar (J69-J70)
Solution: 4_MicrostipSingle(2)
Measured:
cmp28_graduate_coplanar_p1J70_p2J69.s2p Selector/Project/Circuit:
MS_SE_GraduateCoplanar_J70_J69

Board Analyzer:
Trace width is adjusted outside of coplanar section;
2 discontinuity selector for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
Additional discontinuity selector is added for part of the gradual coplanar section;
See also notes in the solution;

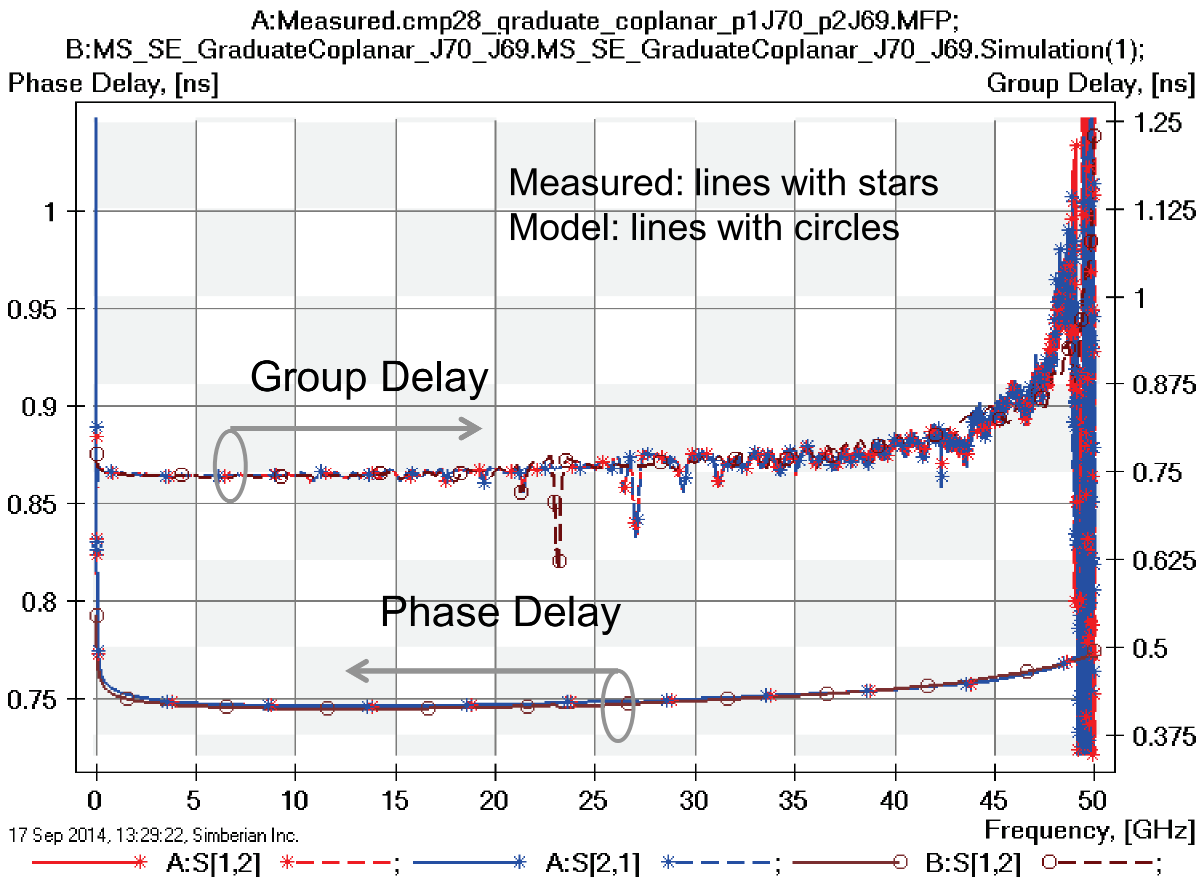


9) Microstrip with gradual coplanar section: Magnitude of S-parameters

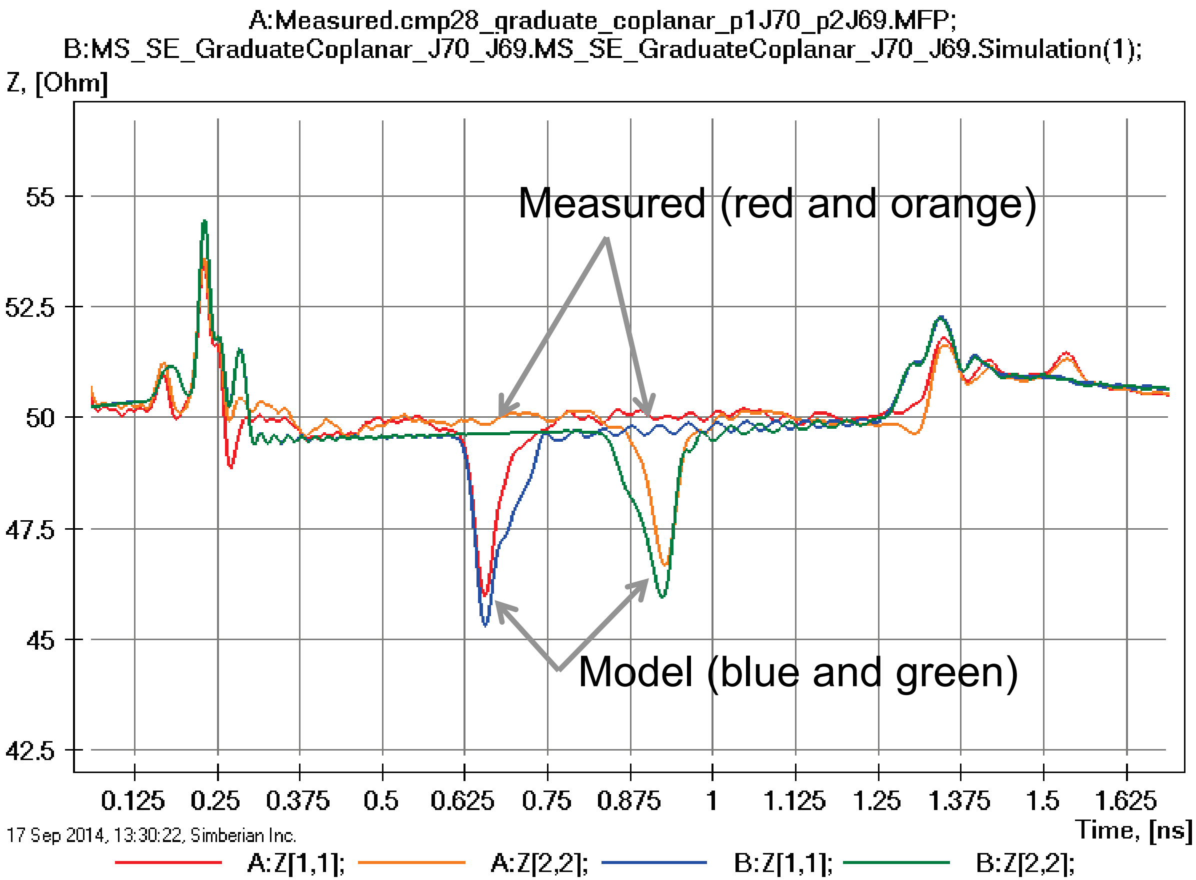


Loss of launch localization above 30 GHz explains additional insertion losses; Variation of trace width and dielectric properties explains differences in reflection losses;

9) Microstrip with gradual coplanar section: Transmission phase and group delay

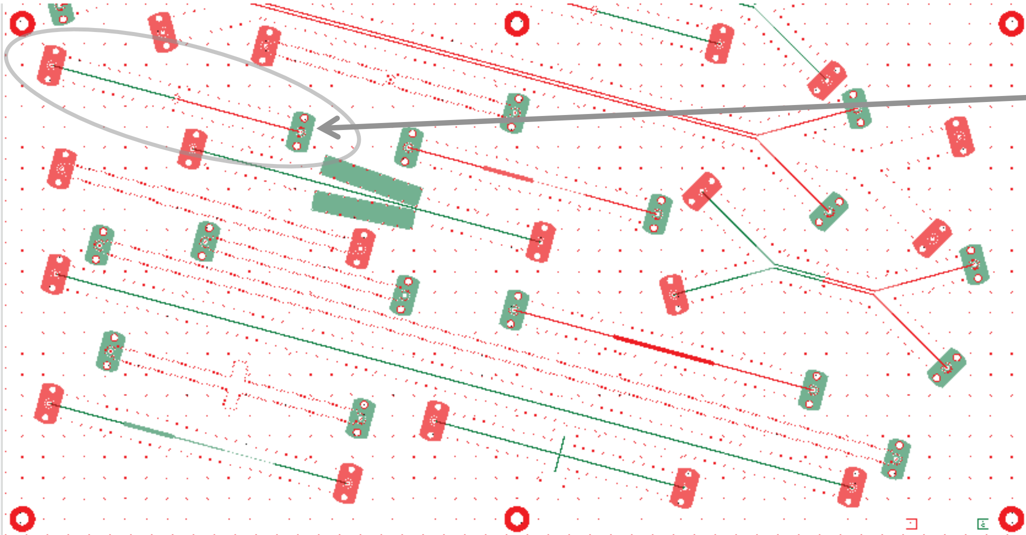


9) Microstrip with gradual coplanar section: TDR with 20 ps Gaussian step



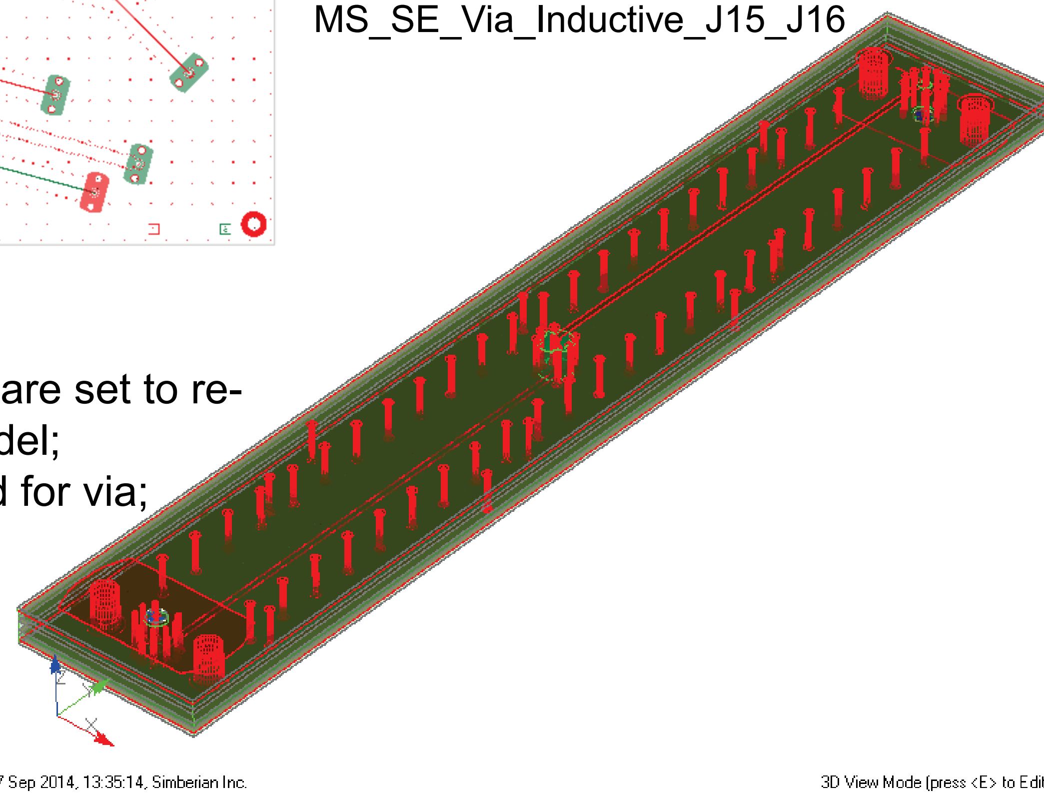
Trace width is not adjusted in the coplanar section;

10) Microstrip line with inductive via

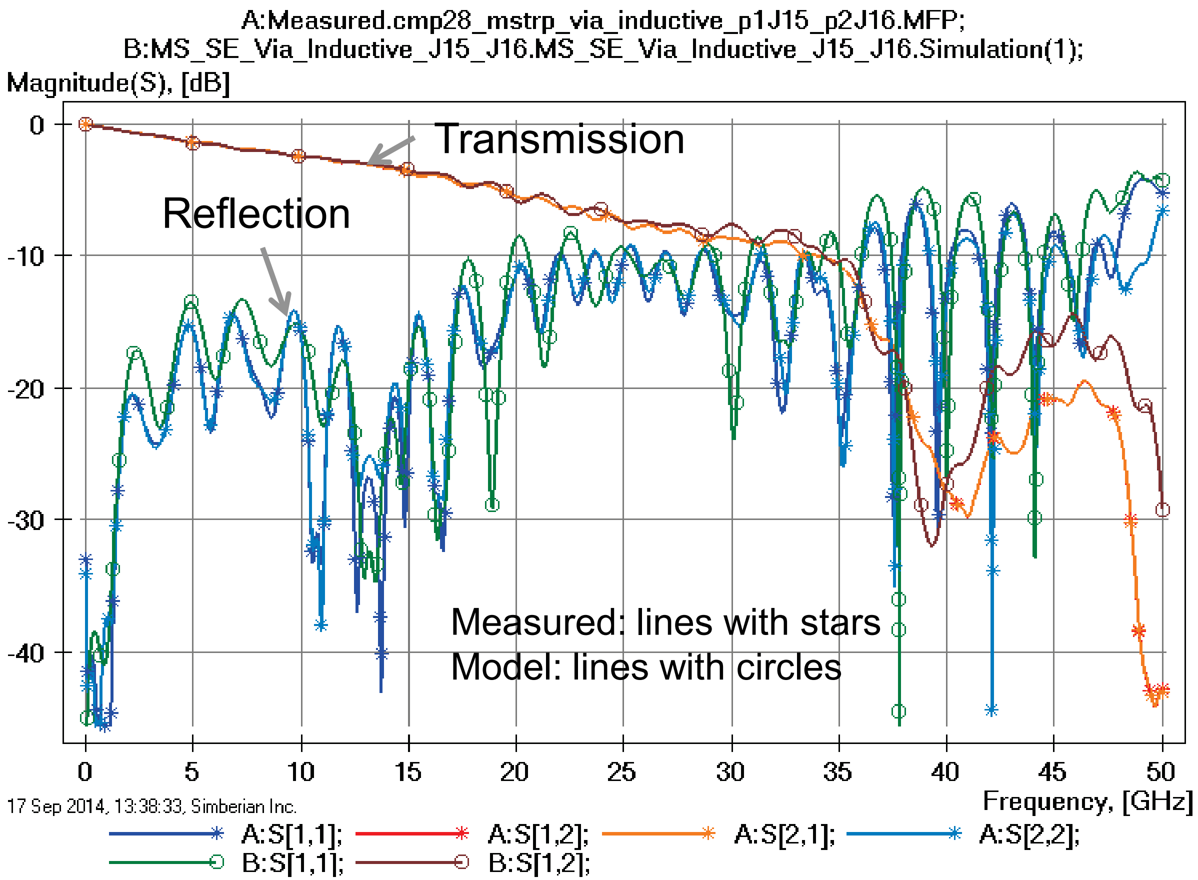


MS SE with inductive via (J15-J16)
Solution: 4_MicrostipSingle(2)
Measured:
cmp28_via_inductive_p1J15_p2J16.s2p
Selector/Project/Circuit:
MS_SE_Via_Inductive_J15_J16

Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
Additional discontinuity selector is added for via;
See also notes in the solution;

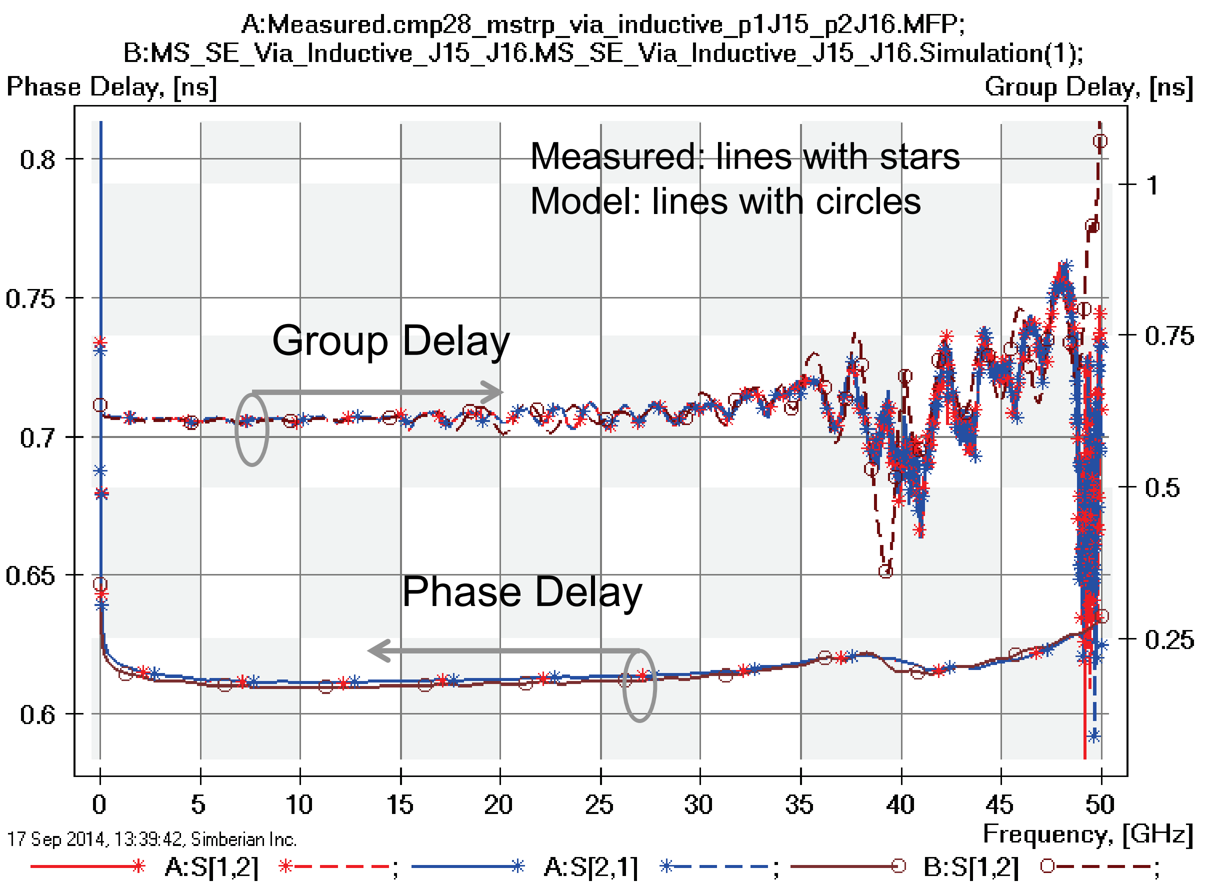


10) Microstrip line with inductive via: Magnitude of S-parameters

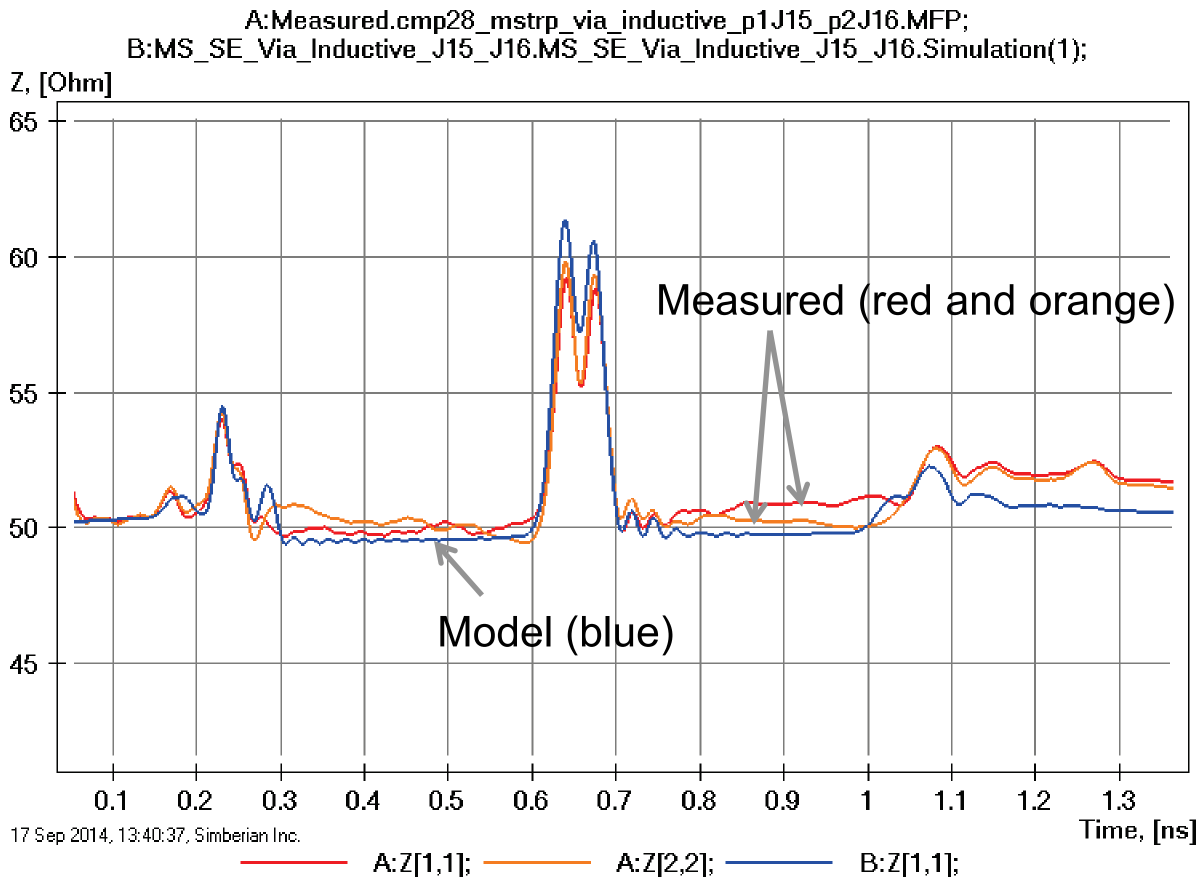


Loss of launch localization above 30 GHz explains additional insertion losses; Variation of trace width and dielectric properties explains differences in reflection losses;

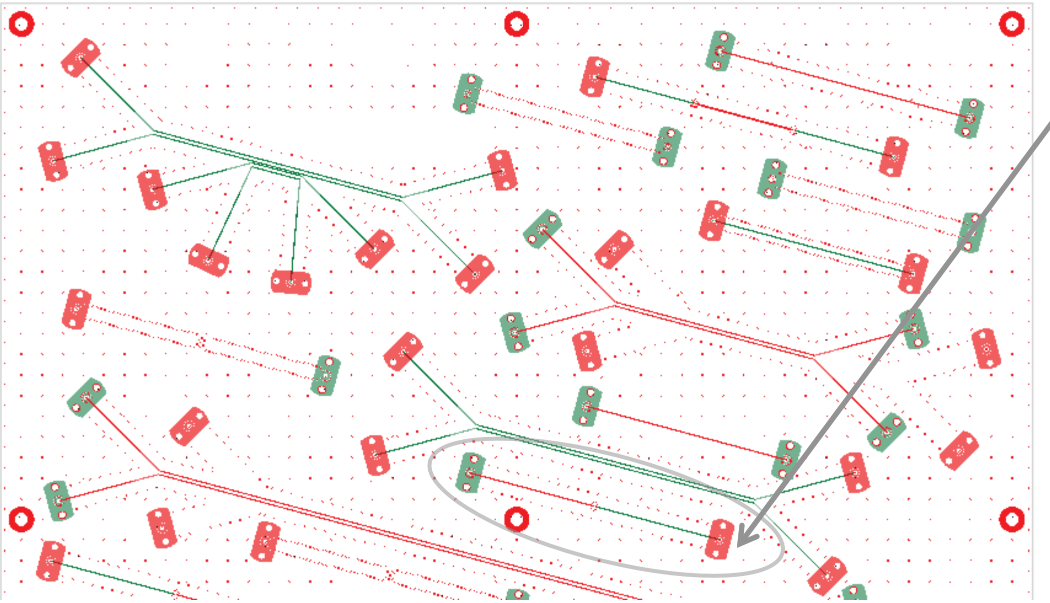
10) Microstrip line with inductive via: Transmission phase and group delay



10) Microstrip line with inductive via: TDR with 20 ps Gaussian step

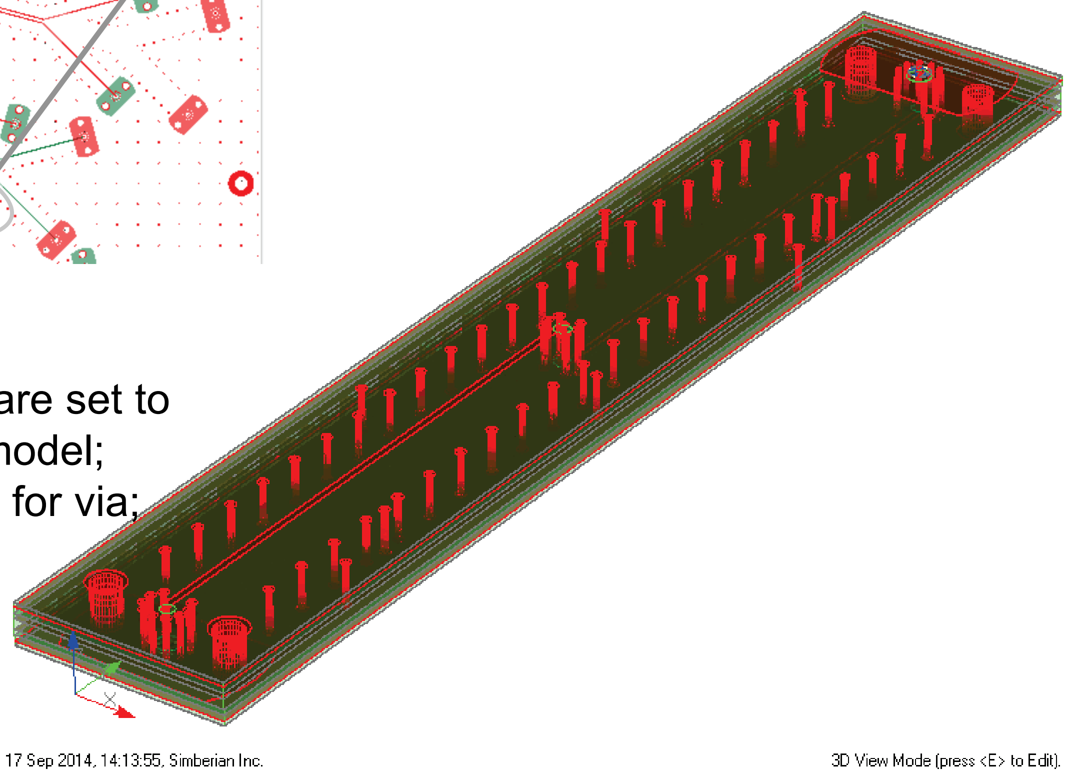


11) Microstrip line with capacitive via



MS SE with capacitive via (J19-J20)
Solution: 4_MicrostipSingle(2)
Measured:
cmp28_via_capacitive_p1J19_p2J20.s2p
Selector/Project/Circuit:
MS_SE_Via_Capacitive_J19_J20

Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
Additional discontinuity selector is added for via;
See also notes in the solution;



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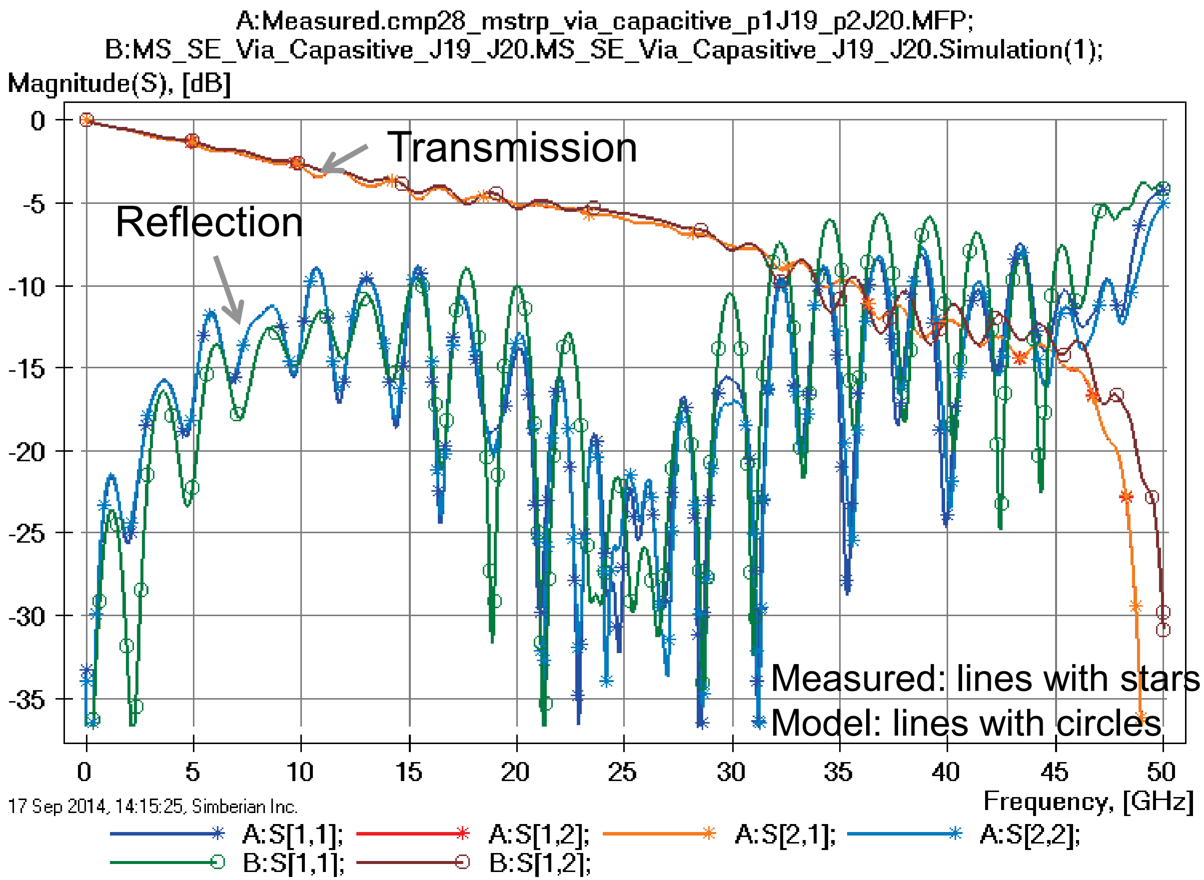
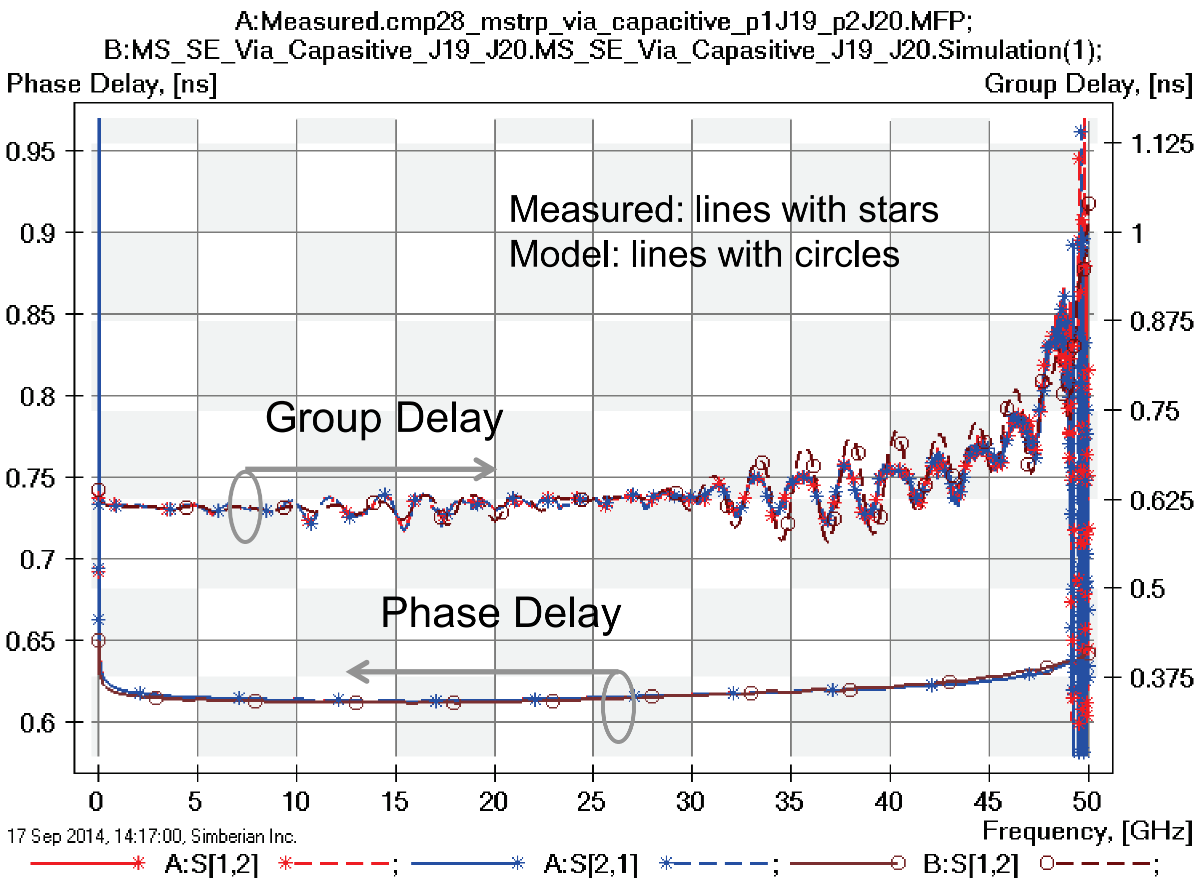
11) Microstrip line with capacitive via: Magnitude of S-parameters

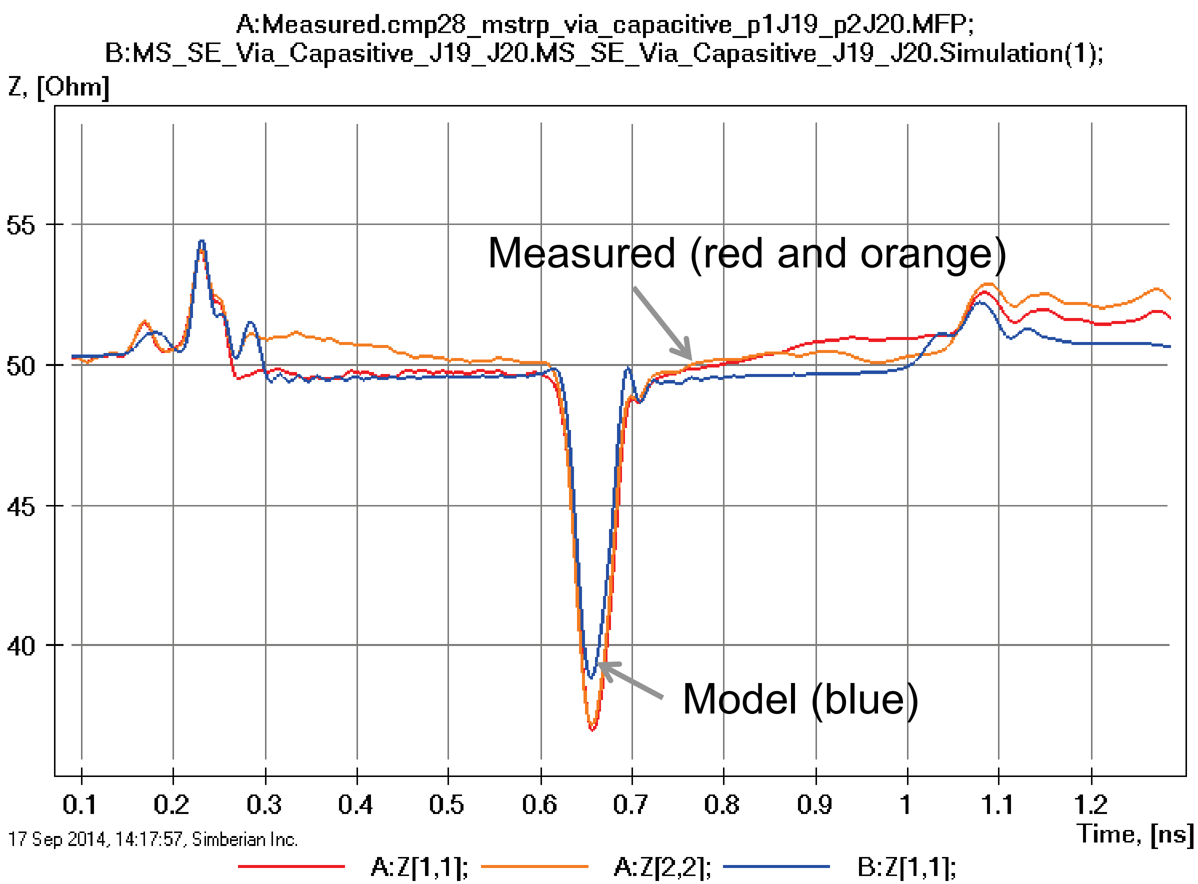


Loss of launch localization above 30 GHz explains additional insertion losses; Variation of trace width and dielectric properties explains differences in reflection losses;

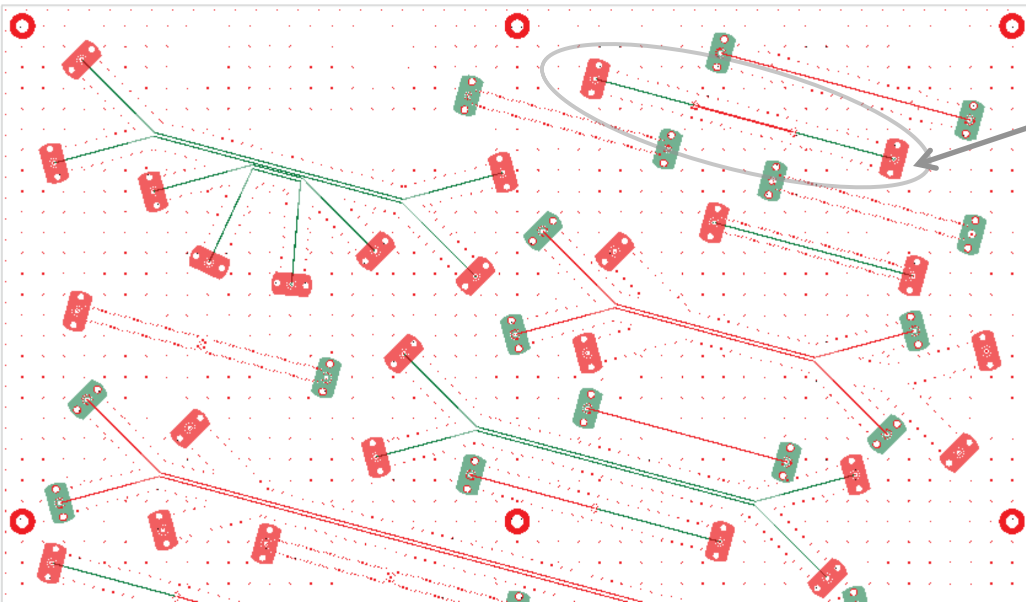
11) Microstrip line with capacitive via: Transmission phase and group delay



11) Microstrip line with capacitive via: TDR with 20 ps Gaussian step

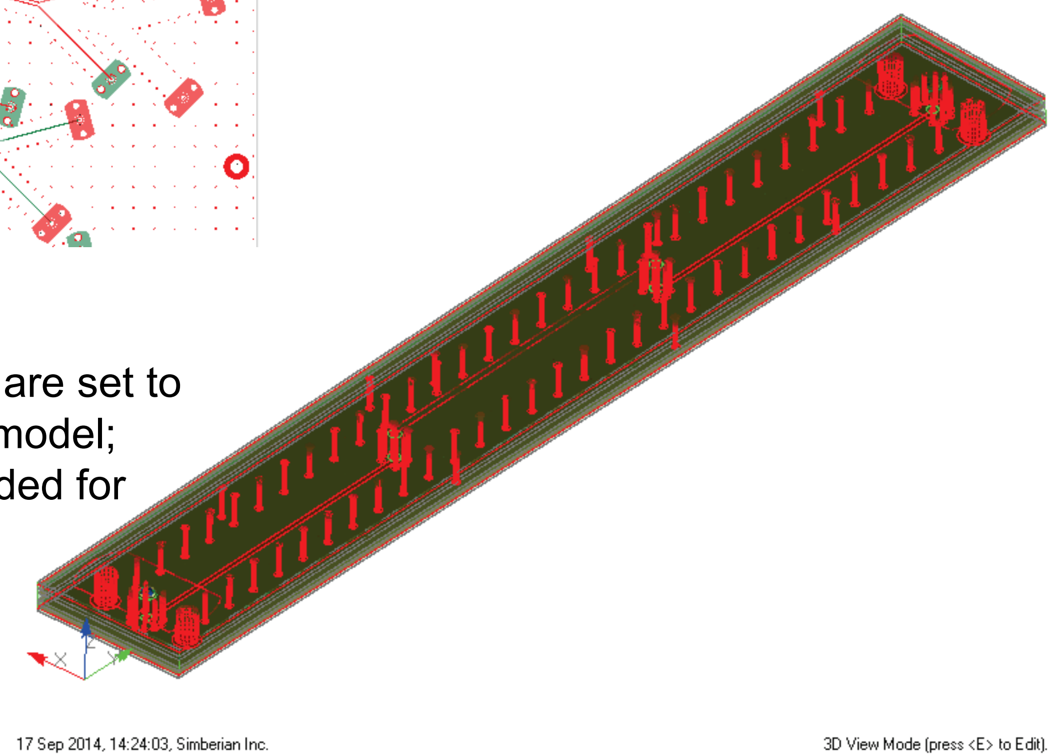


12) Microstrip line with two capacitive via

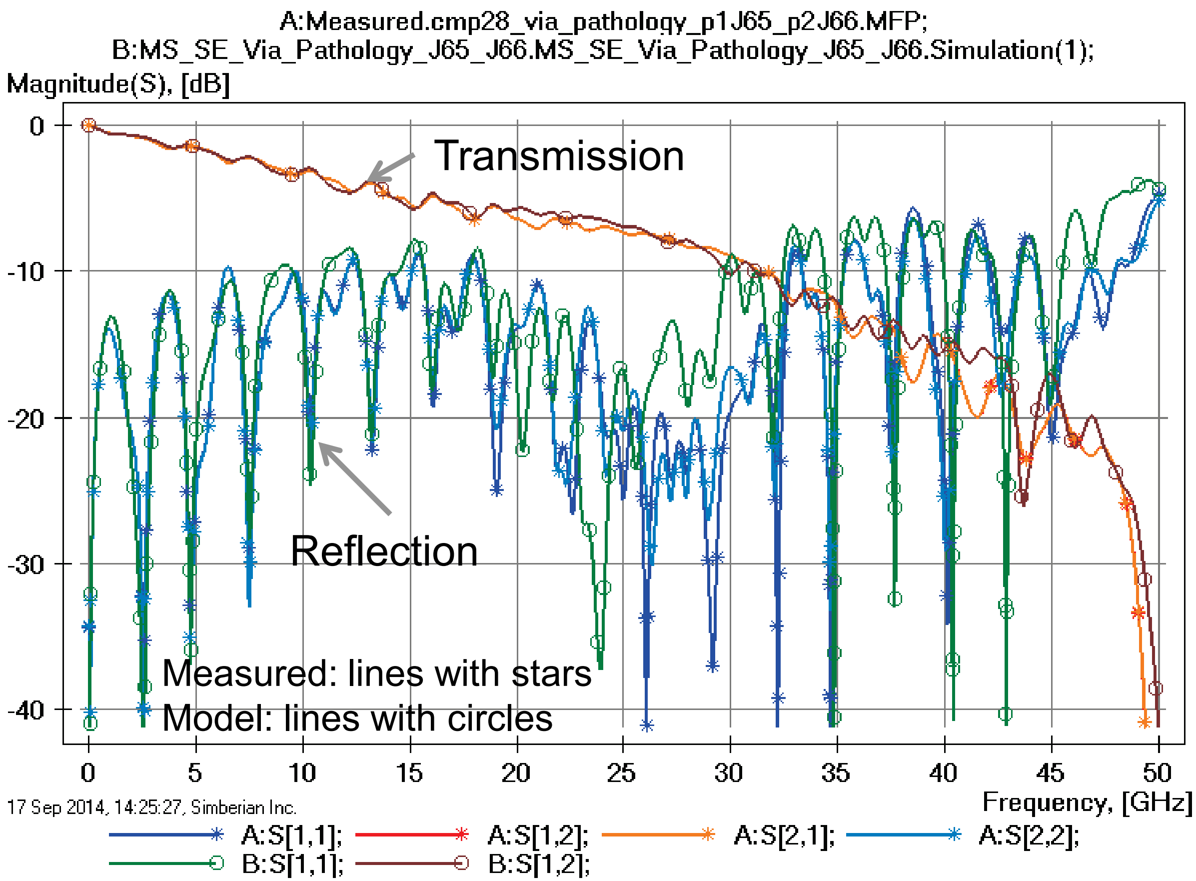


MS SE with 2 capacitive via (J65-J66)
Solution: 4_MicrostipSingle(2)
Measured:
cmp28_via_pathology_p1J65_p2J66.s2p
Selector/Project/Circuit:
MS_SE_Via_Pathology_J65_J66

Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
Additional discontinuity selectors are added for via (identical and re-used);
See also notes in the solution;

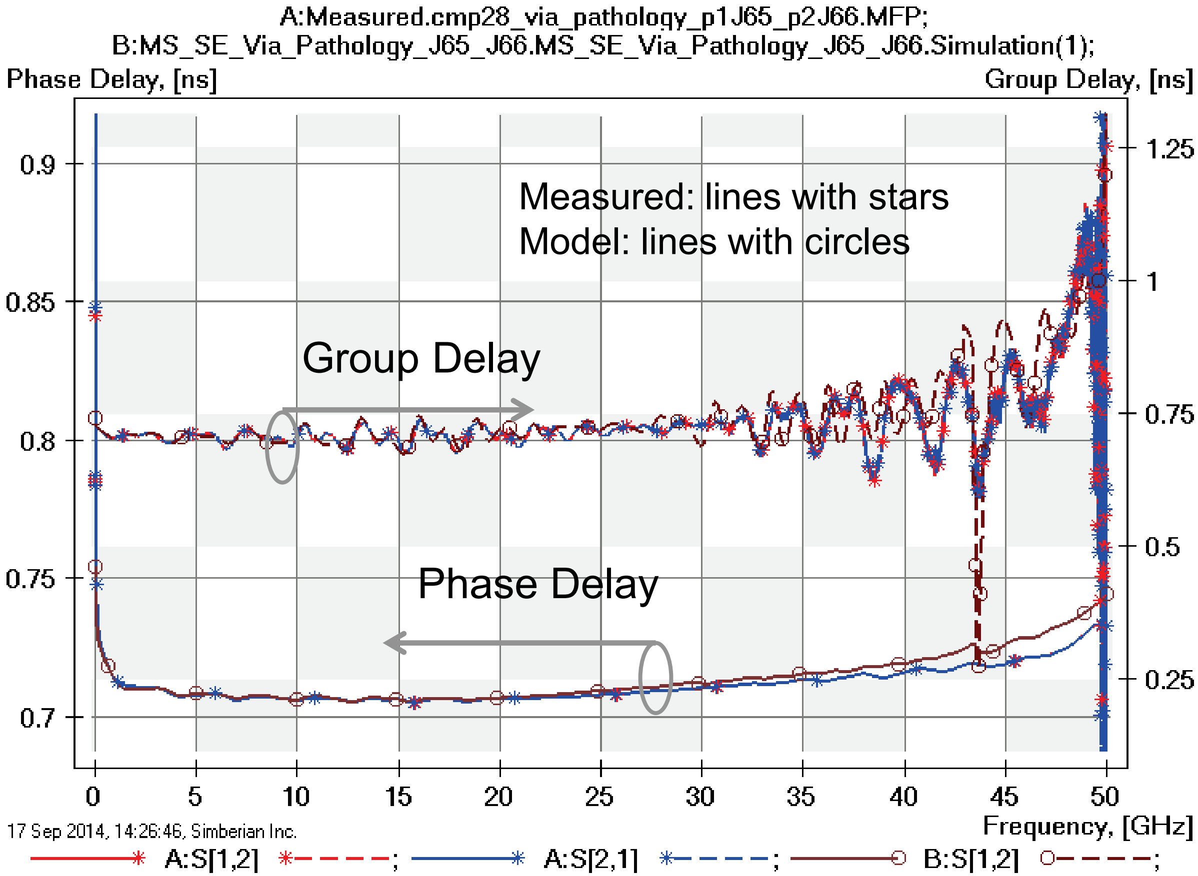


12) Microstrip line with two capacitive via: Magnitude of S-parameters

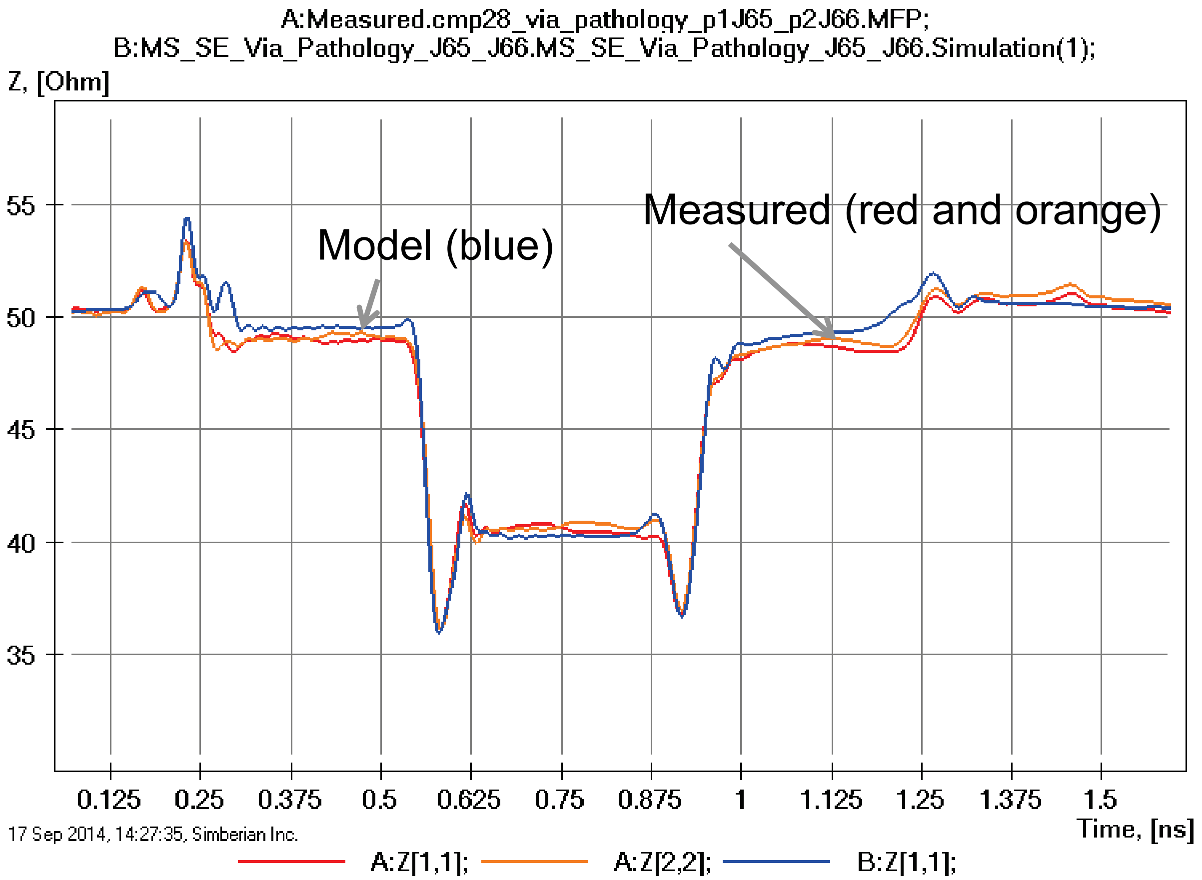


Loss of launch localization above 30 GHz explains additional insertion losses; Variation of trace width and dielectric properties explains differences in reflection losses;

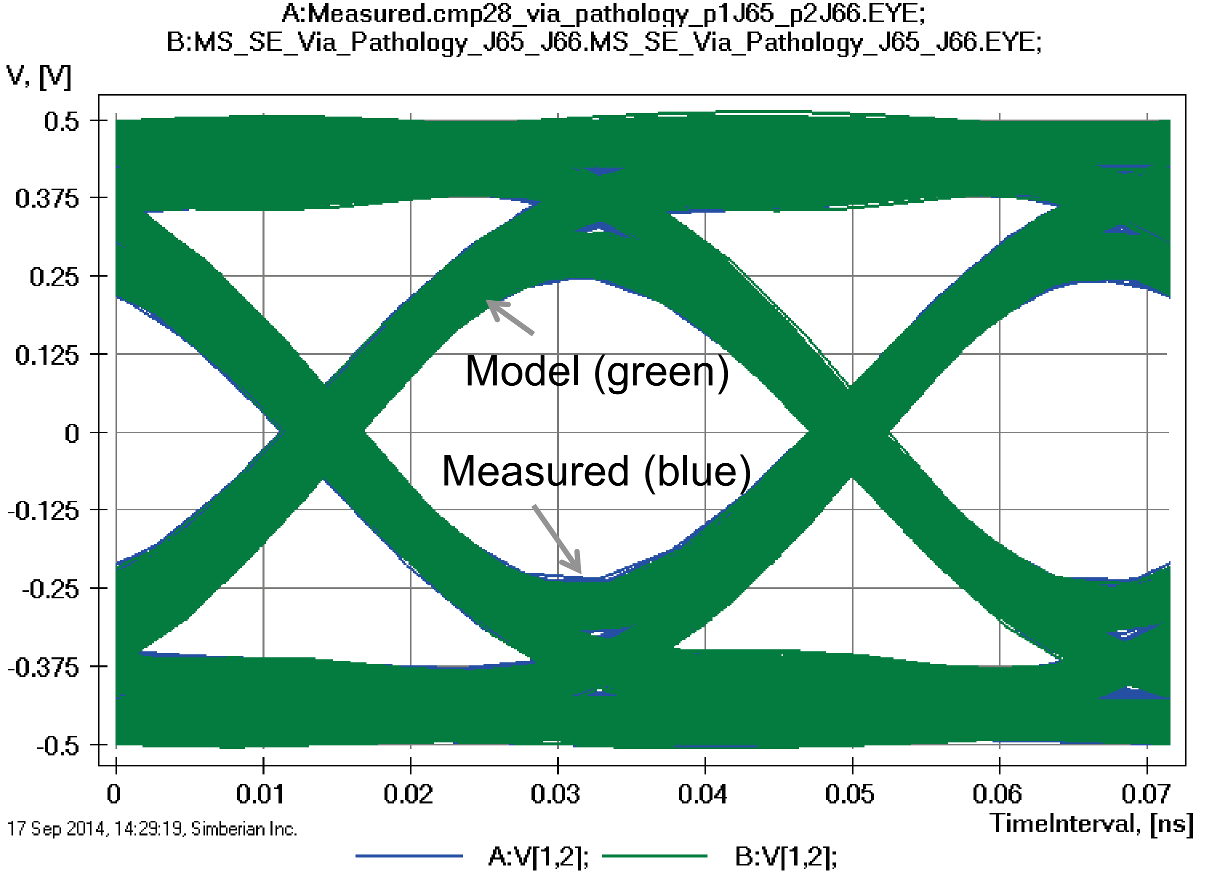
12) Microstrip line with two capacitive via: Transmission phase and group delay



12) Microstrip line with two capacitive via: TDR with 20 ps Gaussian step

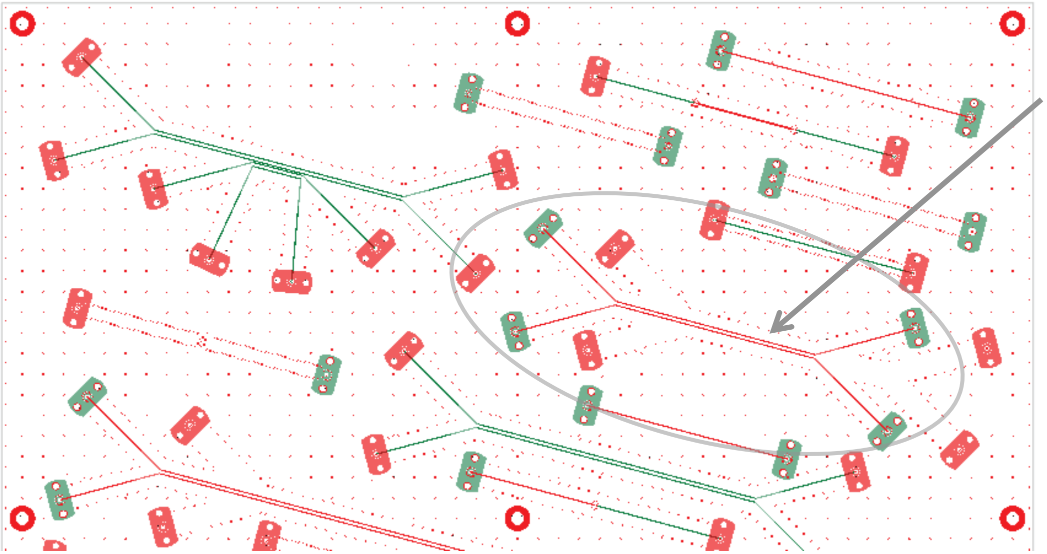


12) Microstrip line with two capacitive via: 28 Gbps PRBS, 25 ps rise/fall time



Eyes are on top of each other!

13) 2-inch microstrip differential line



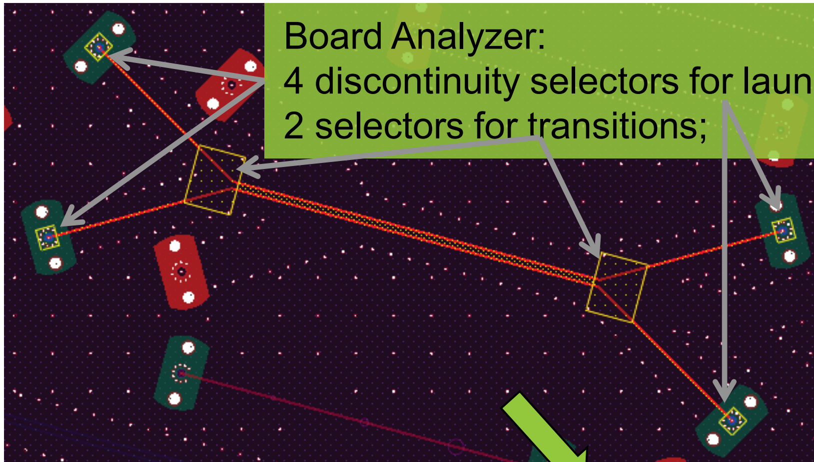
MS DF 2-inch segment (J33-J34-J37-J38)
Solution: 5_MicrostipDifferential(1)
Measured:
cmp28_mstrp_diff_2inch_J38J37J34J33.s4p
Selector/Project/Circuit: MS_DF_2inch

See notes on the decomposition in solution and on the next slide…

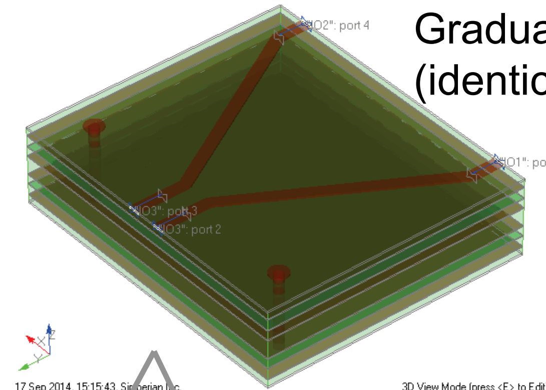
Board Analyzer:
Single-ended trace width is adjusted after the extraction;
4 discontinuity selectors for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
Additional 2 discontinuity selectors are added for transitions from single-ended to differential (identical and re-used);
See also notes in the solution;

13) 2-inch microstrip differential line: De-compositional analysis

Board Analyzer:
4 discontinuity selectors for launches;
2 selectors for transitions;

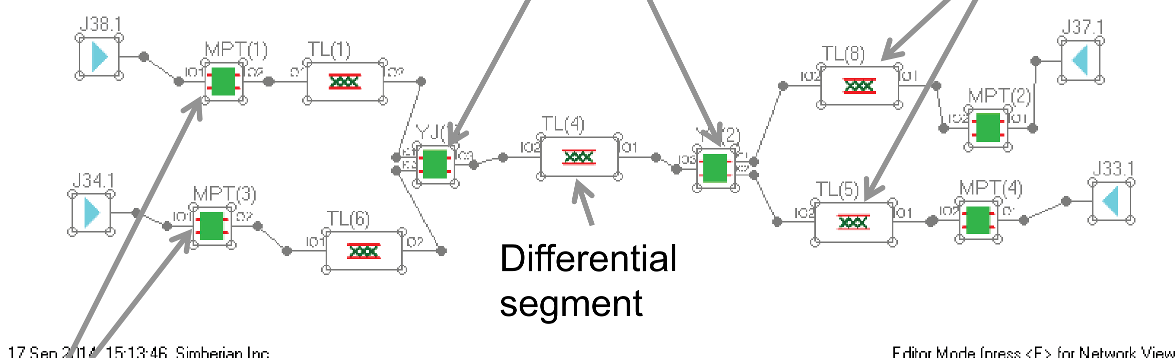


Auto-extraction



Gradual transition (identical on both ends)

Single-ended segments

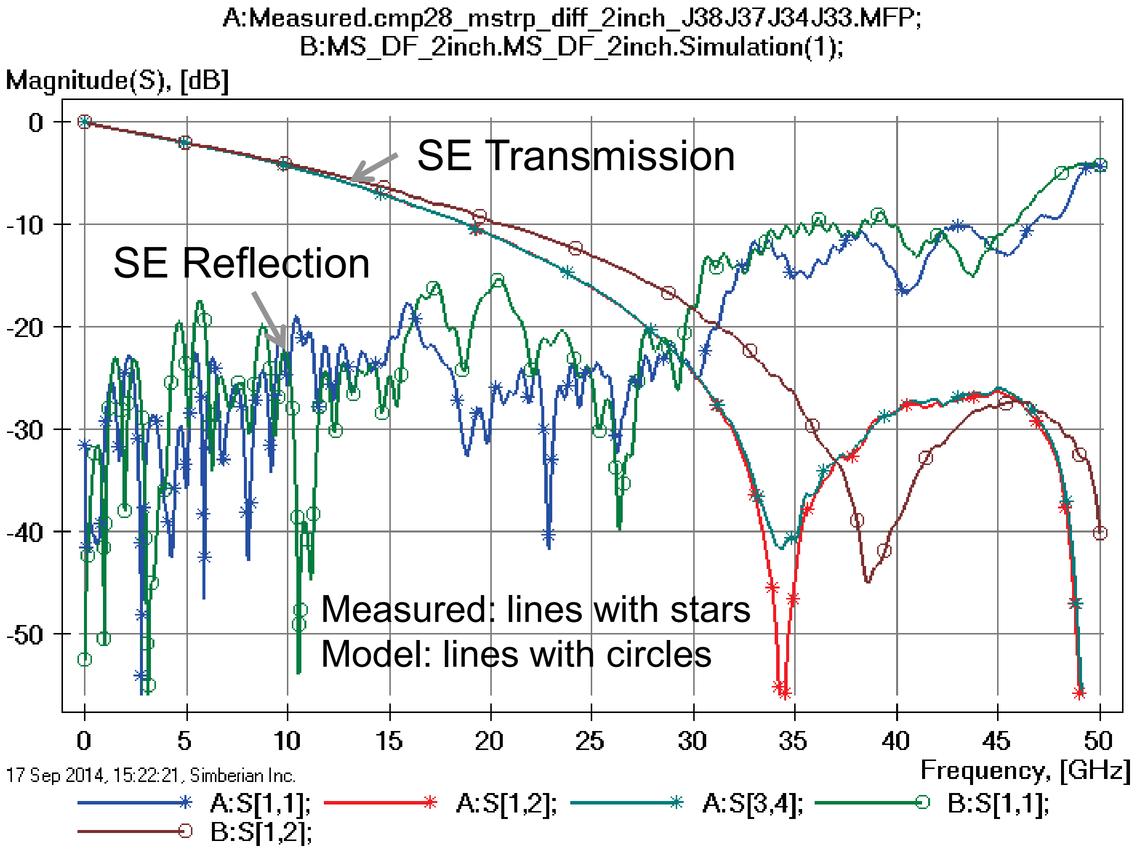


Differential segment

United Connector + Launch model from PCB/MS_ConnectorAndLaunch

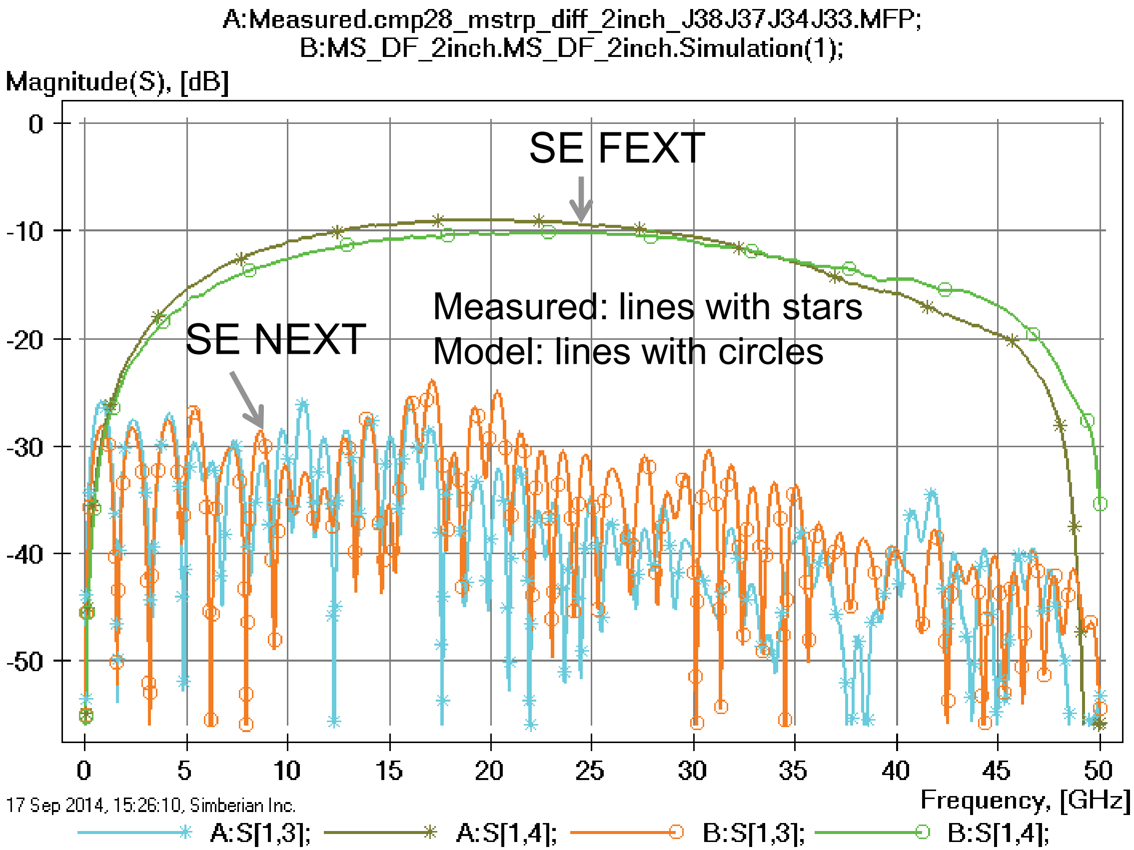
See also solution notes for MS DF 2-inch segment

13) 2-inch microstrip differential line: Single-ended transmission and reflection



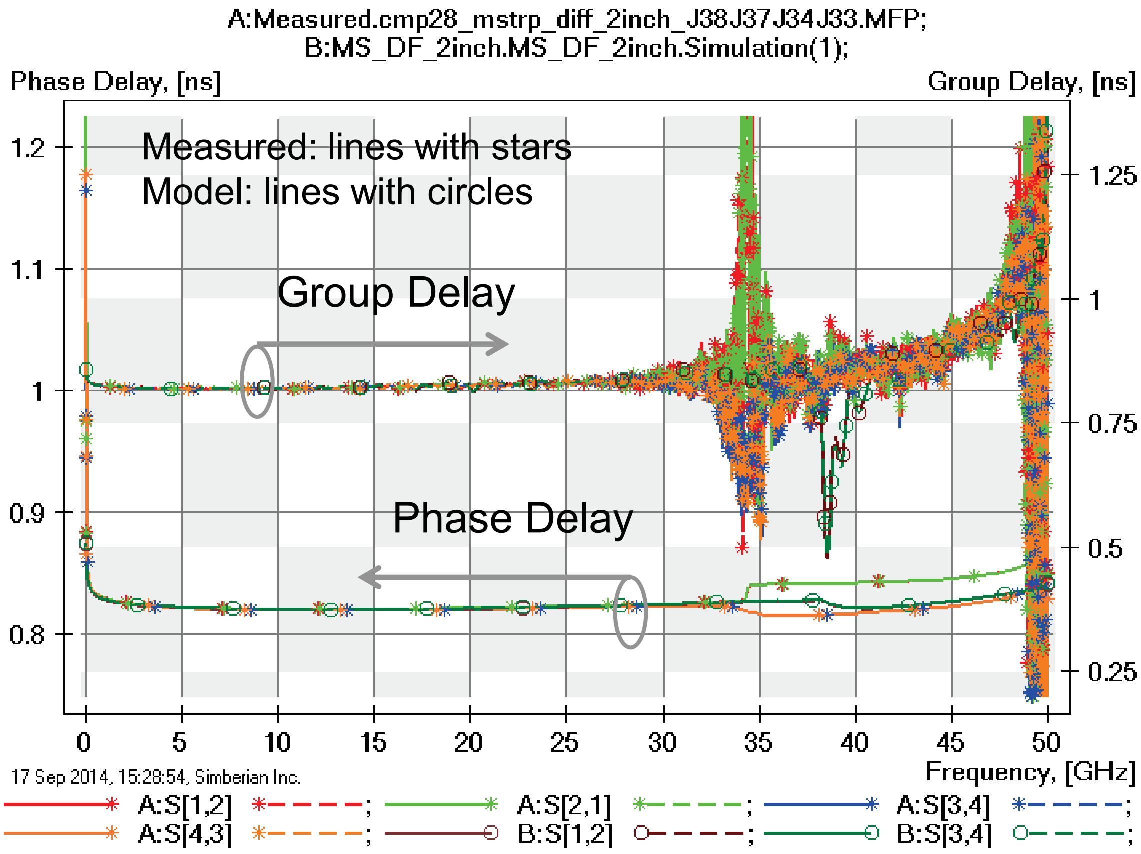
Difference in strip width and separation explains difference in transmission resonance; Variation of trace width and dielectric properties explains differences in reflection losses;

13) 2-inch microstrip differential line: Single-ended near and far end x-talk



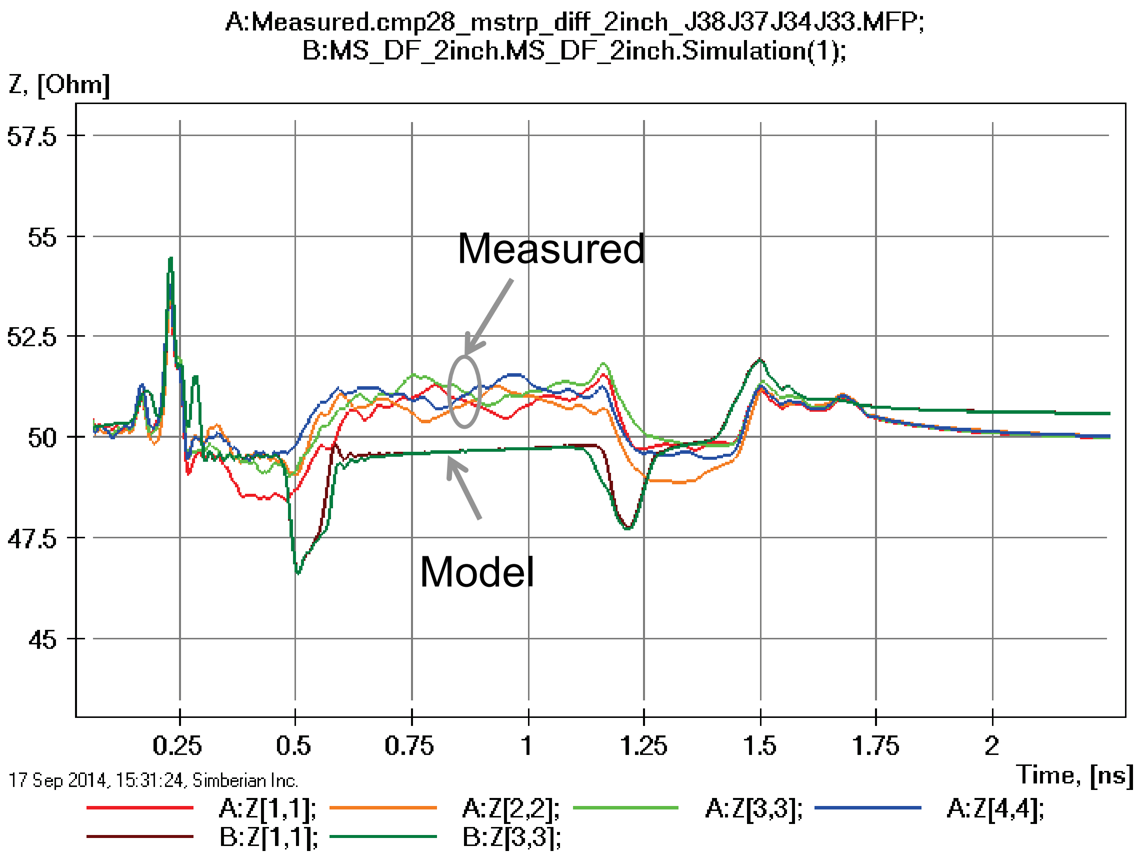
NEXT- near end cross-talk;
FEXT - far end cross-talk;

13) 2-inch microstrip differential line: SE transmission phase and group delay



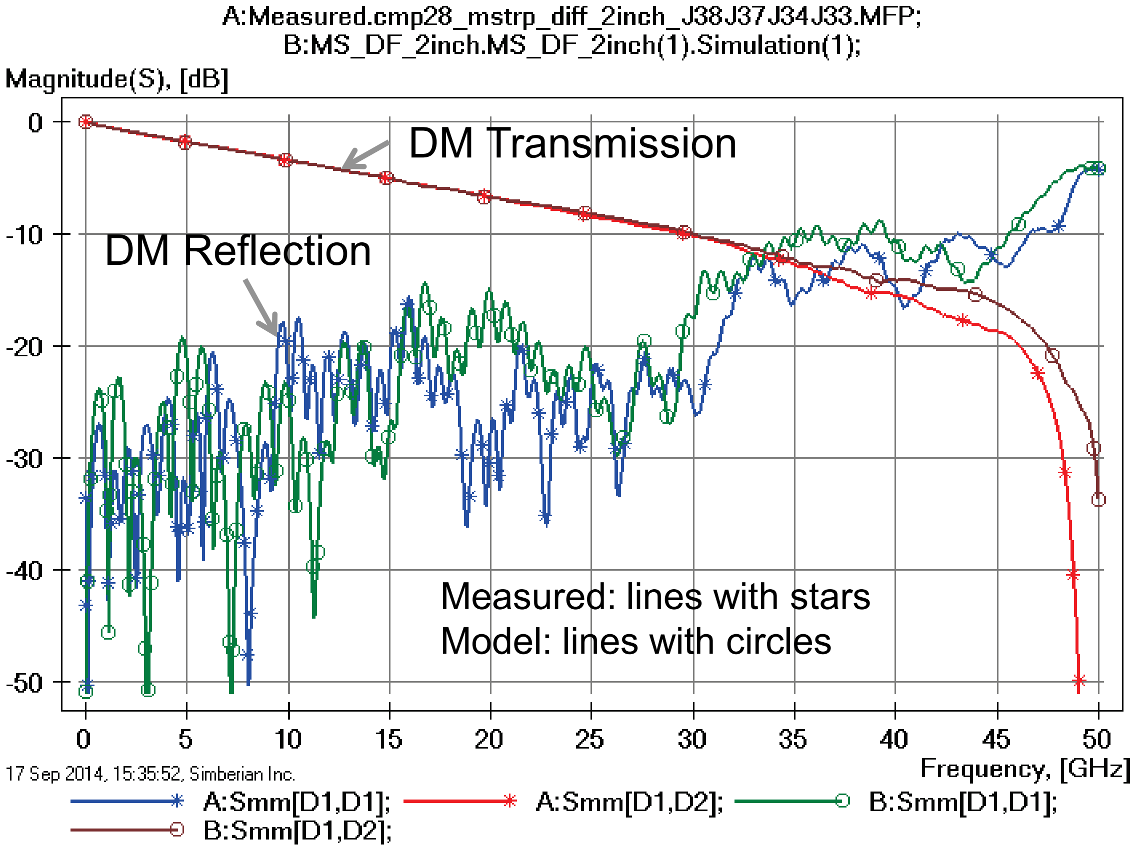
Some discrepancies above 30 GHz

13) 2-inch microstrip differential line: SE TDR with 20 ps Gaussian step



Model transitions have lower impedance due to no adjustments in trace width in the tapered polygonal section;

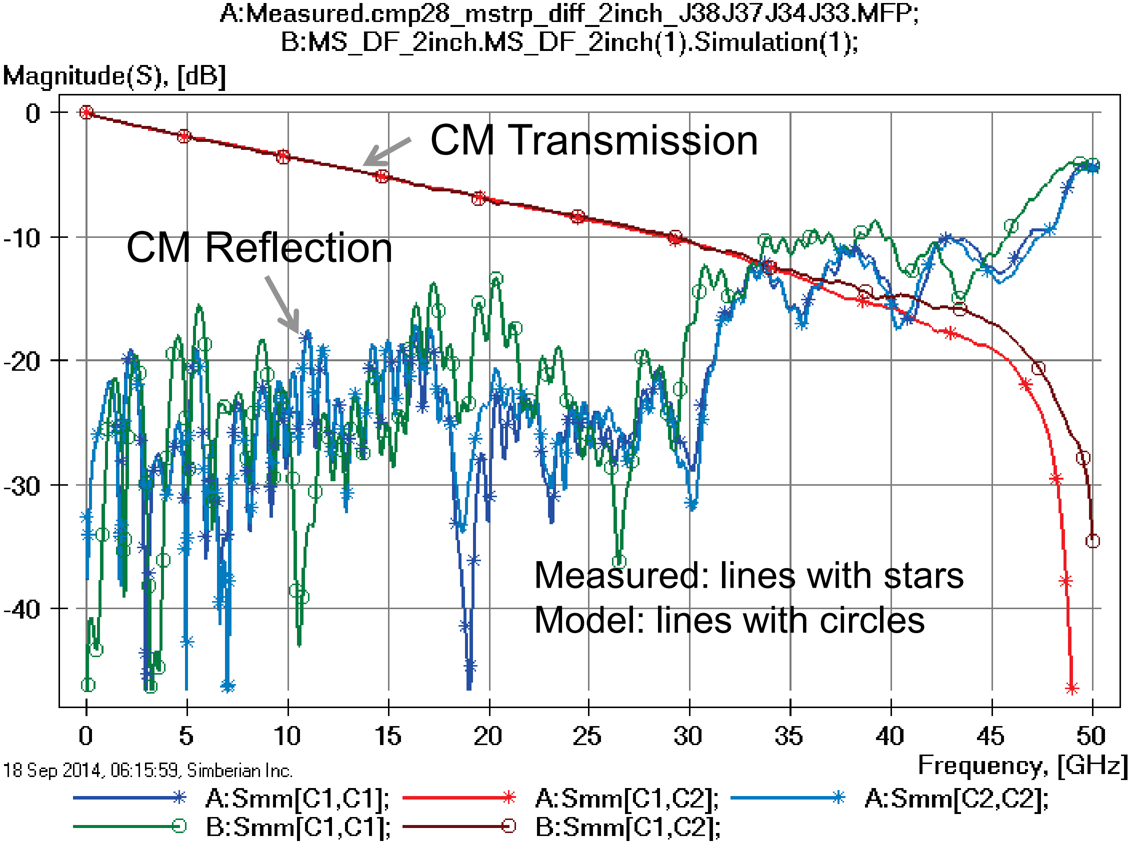
13) 2-inch microstrip differential line: Differential mode transmission and reflection



Loss of launch localization above 30 GHz explains additional insertion losses;
Variation of trace width, separation and dielectric properties explains differences in reflection losses;

DM – differential mode

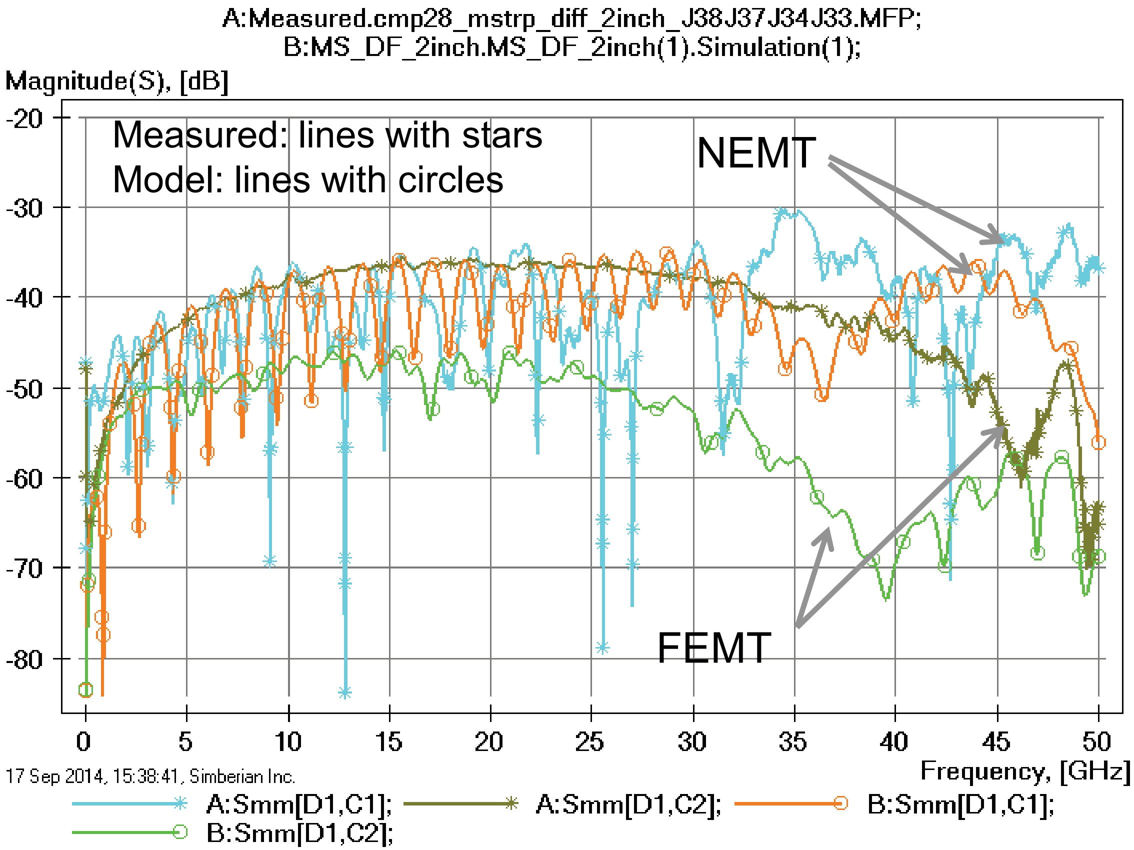
13) 2-inch microstrip differential line: Common mode transmission and reflection



Loss of launch localization above 30 GHz explains additional insertion losses;
Variation of trace width, separation and dielectric properties explains differences in reflection losses;

CM – common mode

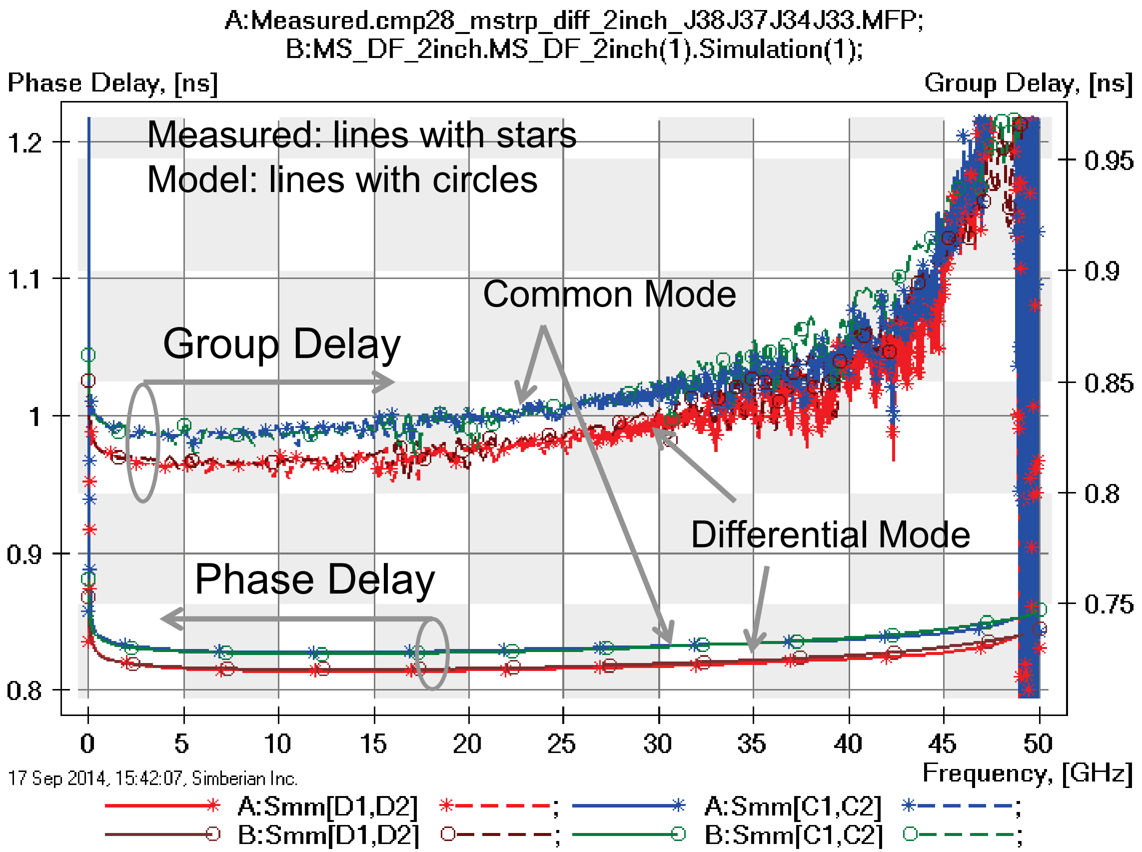
13) 2-inch microstrip differential line: Mixed mode transformation



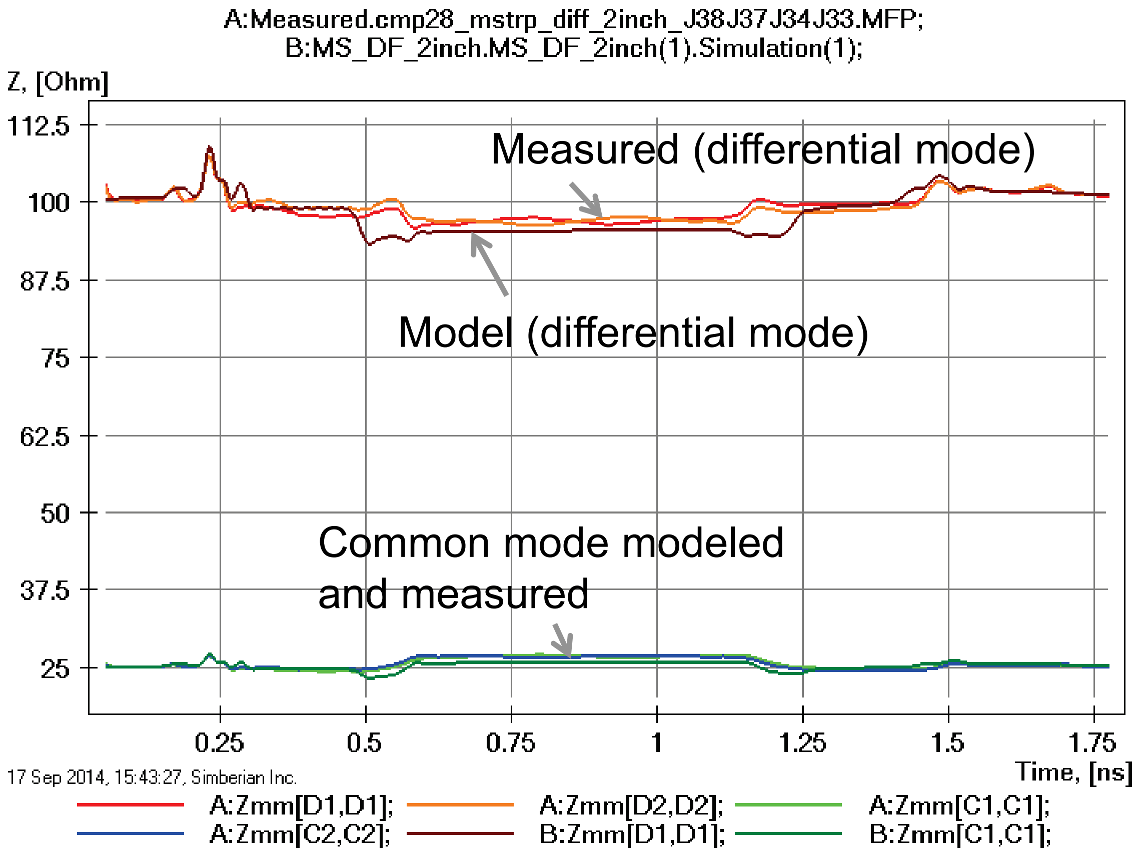
Difference below -30 dB – can be attributed to many things;

NEMT- near end differential to common mode transformation;
FEMT - far end differential to common mode transformation;

13) 2-inch microstrip differential line: DF transmission phase and group delay

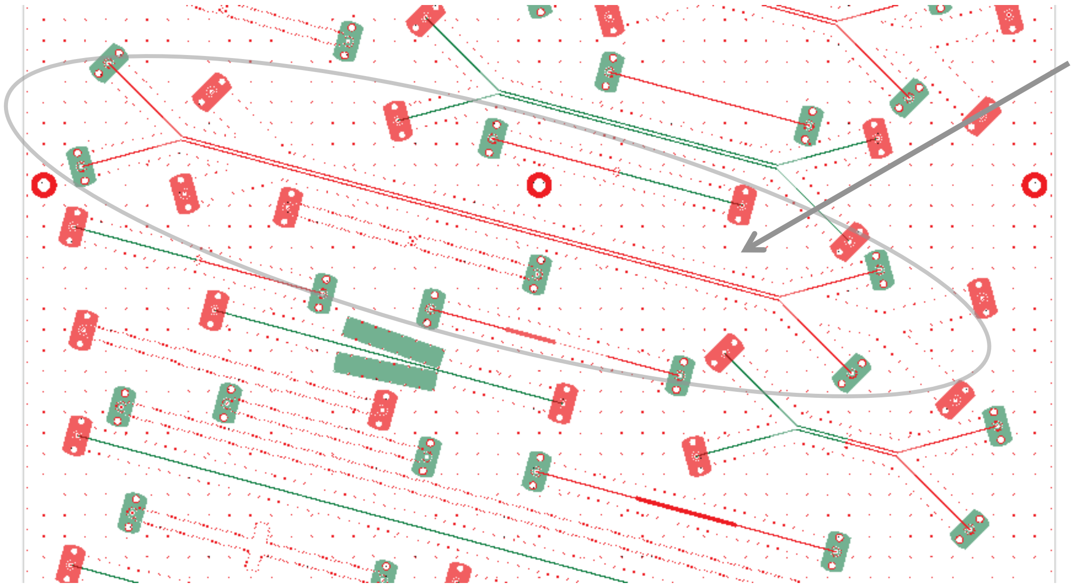


13) 2-inch microstrip differential line: MM TDR with 20 ps Gaussian step



Model transitions have lower impedance due to no adjustments in trace width in polygonal section;

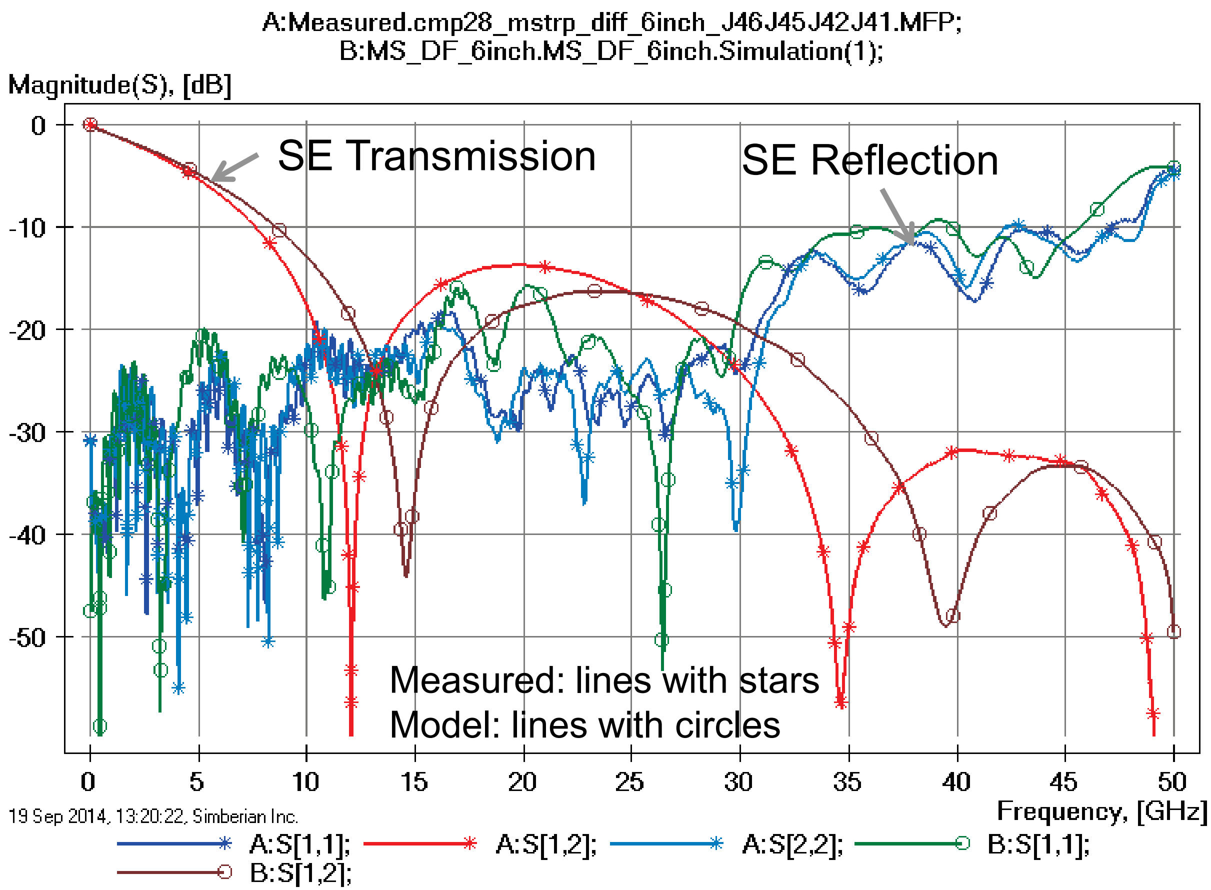
14) 6-inch microstrip differential line



MS DF 6-inch segment (J41-J42-J45-J46)
Solution: 5_MicrostipDifferential(1)
Measured:
cmp28_mstrp_diff_6inch_J46J45J42J41.s4p
Selector/Project/Circuit: MS_DF_6inch

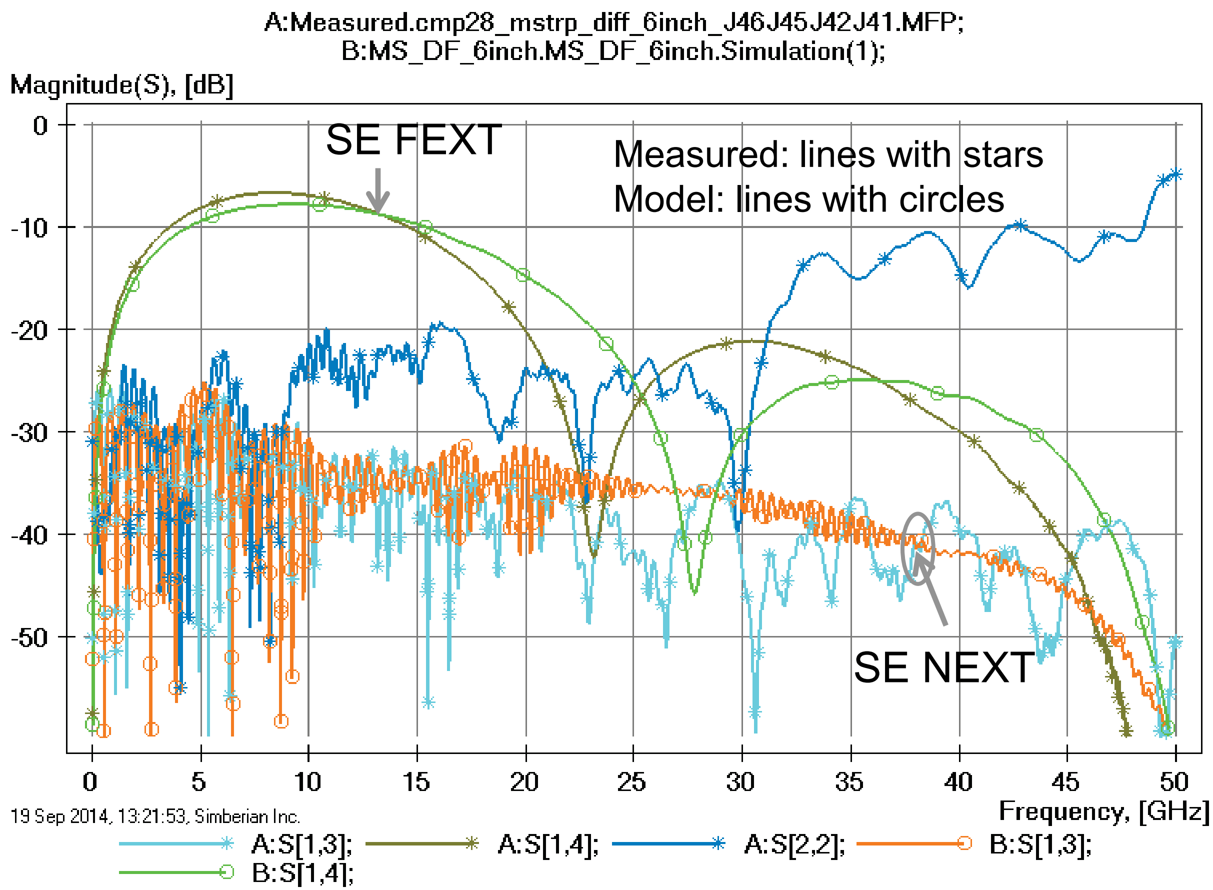
Board Analyzer:
Single-ended trace width is adjusted;
4 discontinuity selectors for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
Additional 2 discontinuity selectors are added for transitions from single-ended to differential (identical and re-used);
See also notes in the solution;

14) 6-inch microstrip differential line: Single-ended transmission and reflection



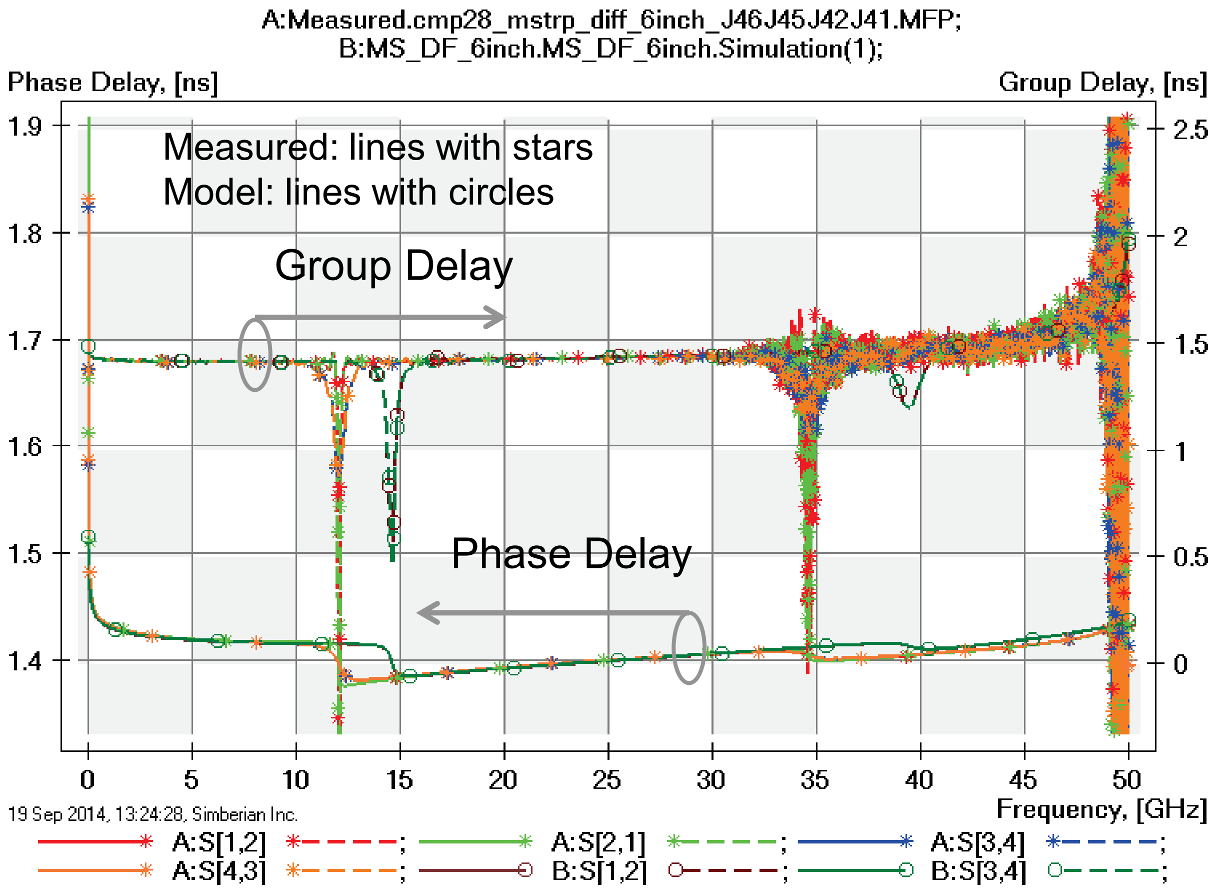
Difference in strip width and separation explains difference in transmission resonance; Variation of trace width and dielectric properties explains differences in reflection losses;

14) 6-inch microstrip differential line: Single-ended near and far end x-talk

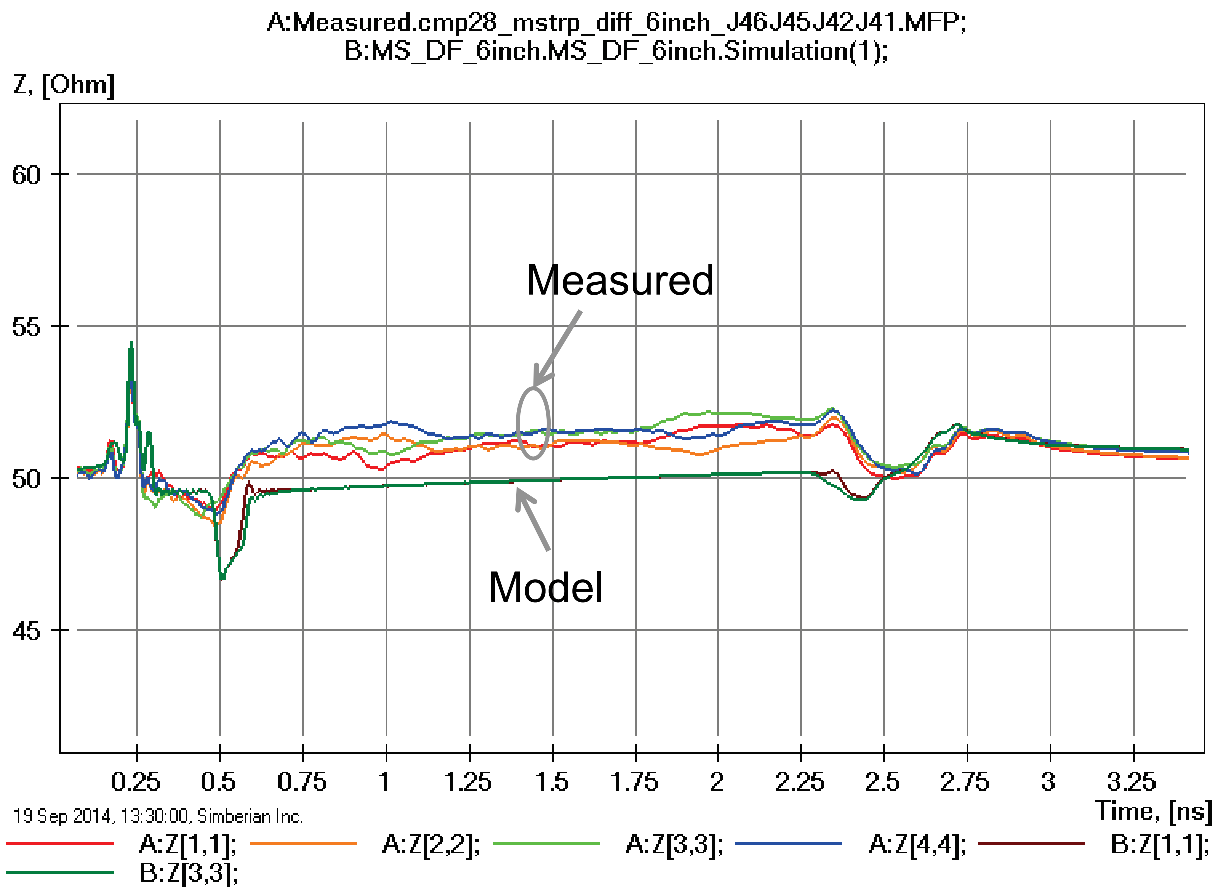


NEXT- near end cross-talk;
FEXT - far end cross-talk;

14) 6-inch microstrip differential line: SE transmission phase and group delay

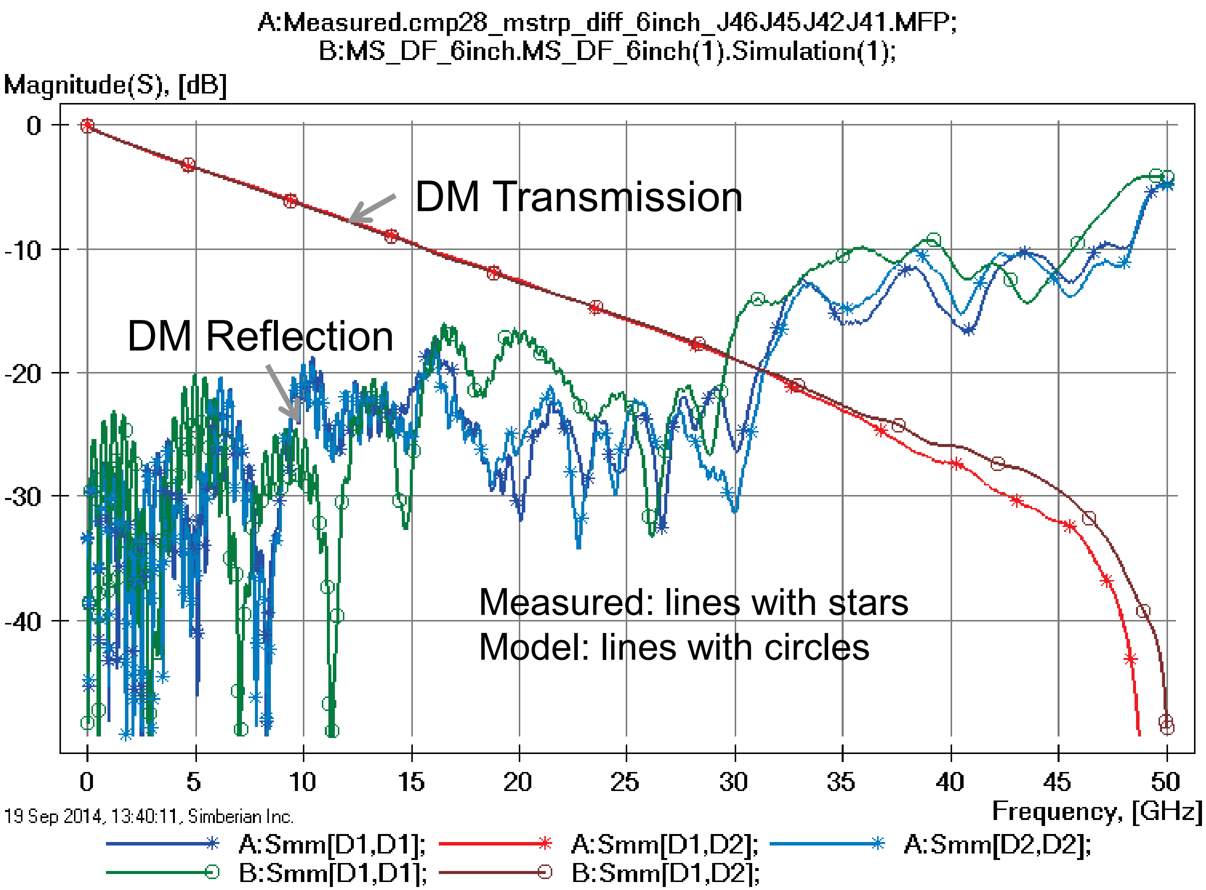


14) 6-inch microstrip differential line: SE TDR with 20 ps Gaussian step



Model transitions have lower impedance due to no adjustments in trace width in the tapered polygonal section;

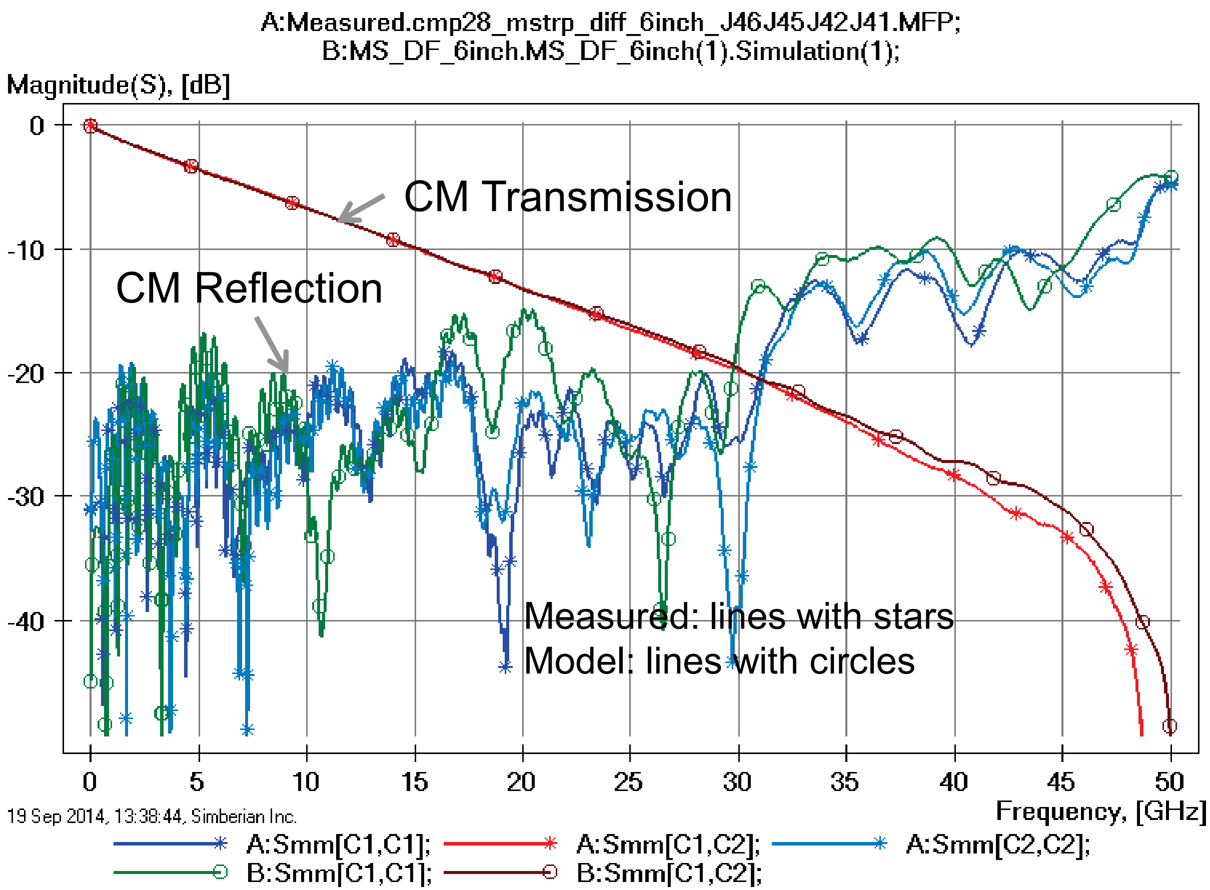
14) 6-inch microstrip differential line: Differential mode transmission and reflection



Loss of launch localization above 30 GHz explains additional insertion losses;
Variation of trace width, separation and dielectric properties explains differences in reflection losses;

DM – differential mode

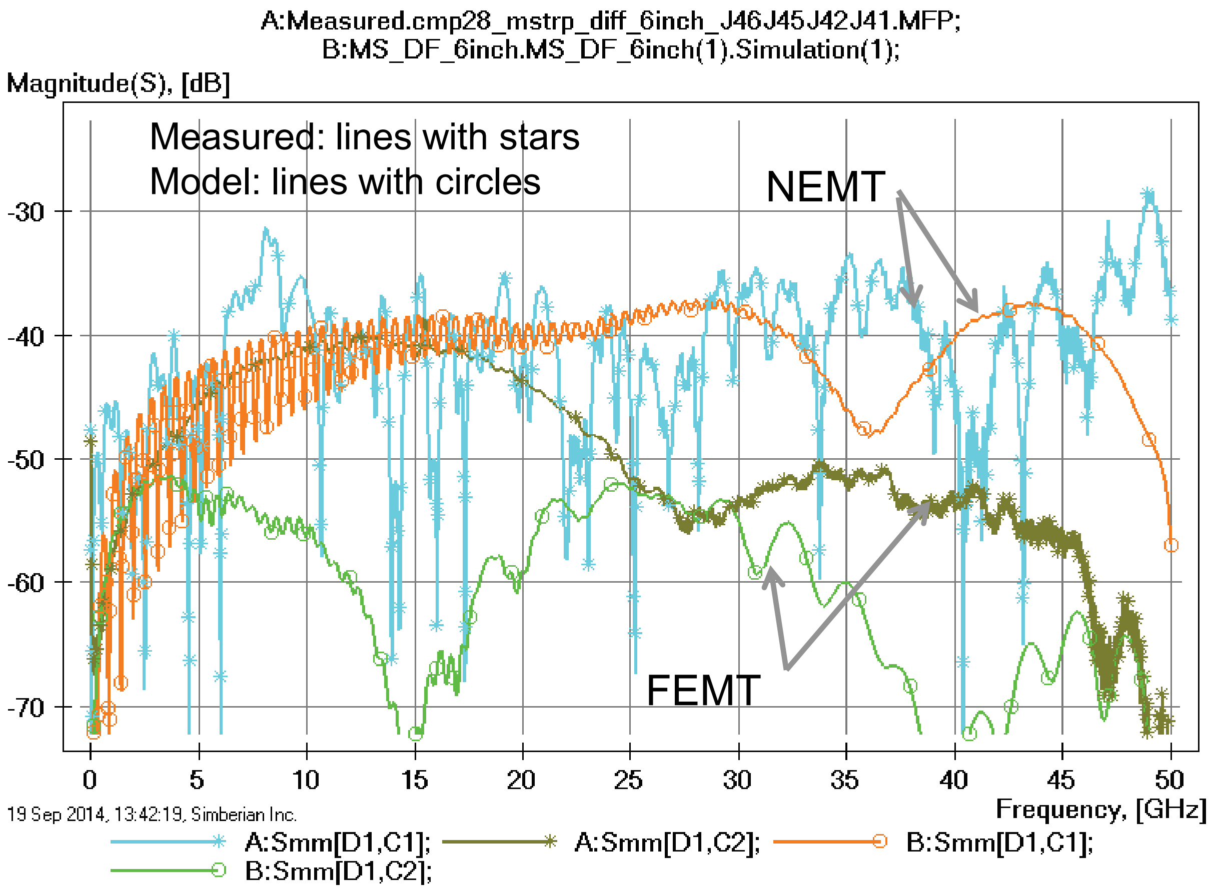
14) 6-inch microstrip differential line: Common mode transmission and reflection



Loss of launch localization above 30 GHz explains additional insertion losses;
Variation of trace width, separation and dielectric properties explains differences in reflection losses;

CM – common mode

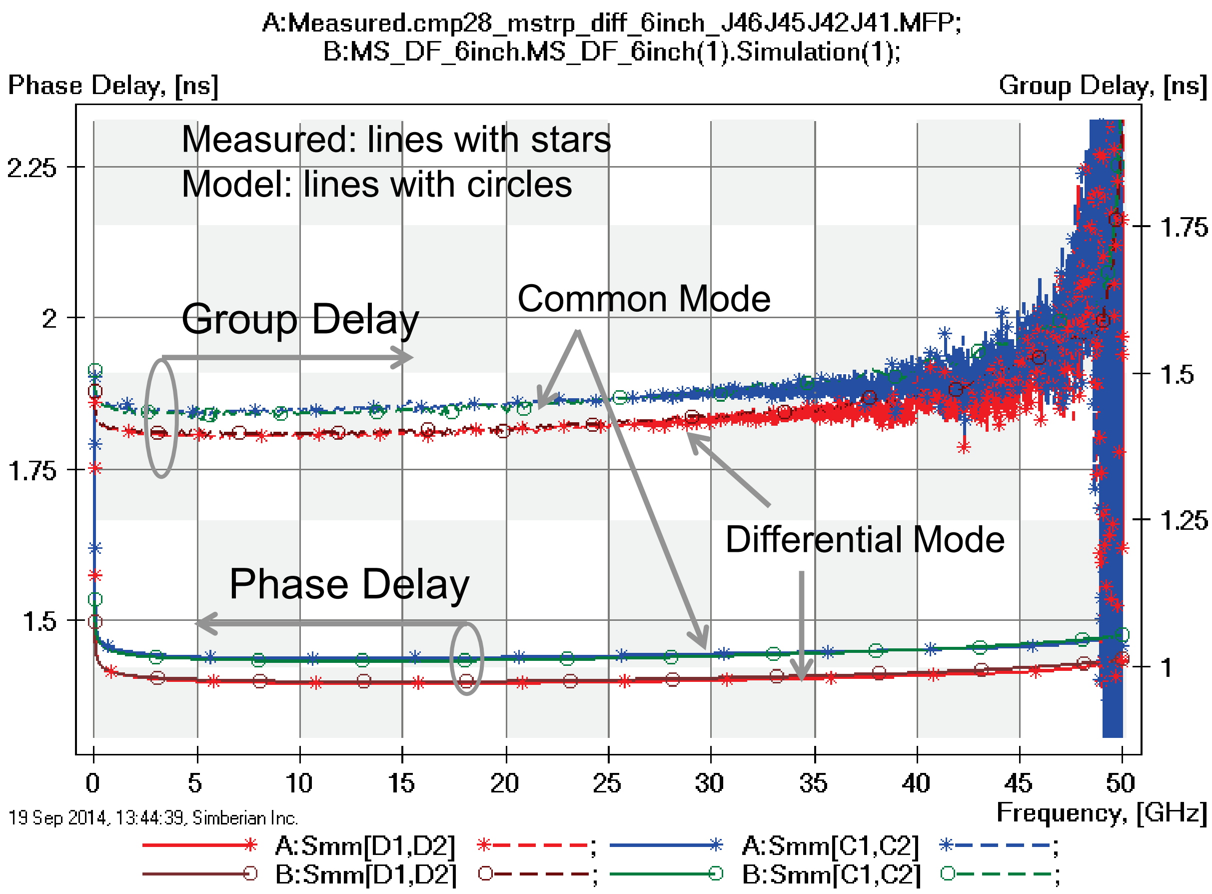
14) 6-inch microstrip differential line: Mixed mode transformation



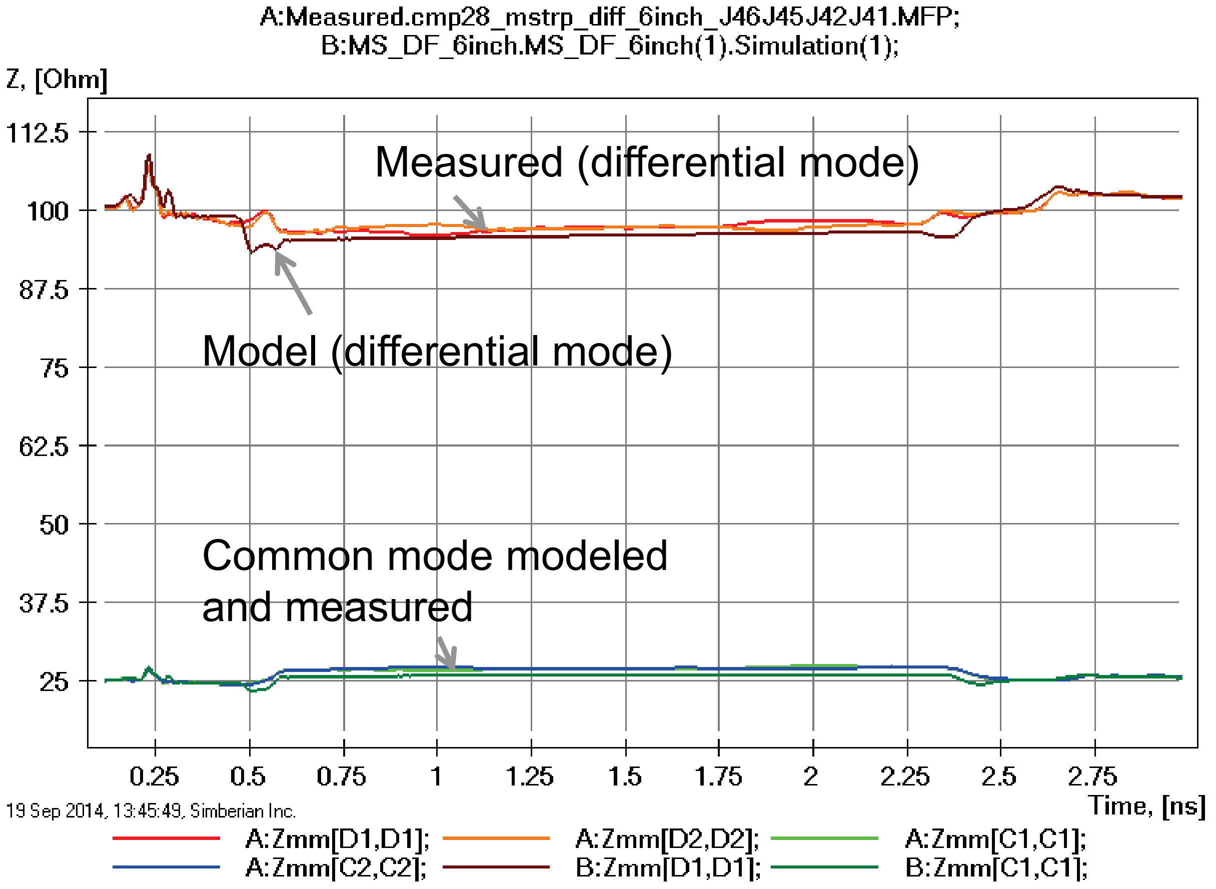
Difference below -30 dB – can be attributed to many things;

NEMT- near end differential to common mode transformation; FEMT - far end differential to common mode transformation;

14) 6-inch microstrip differential line: DF transmission phase and group delay

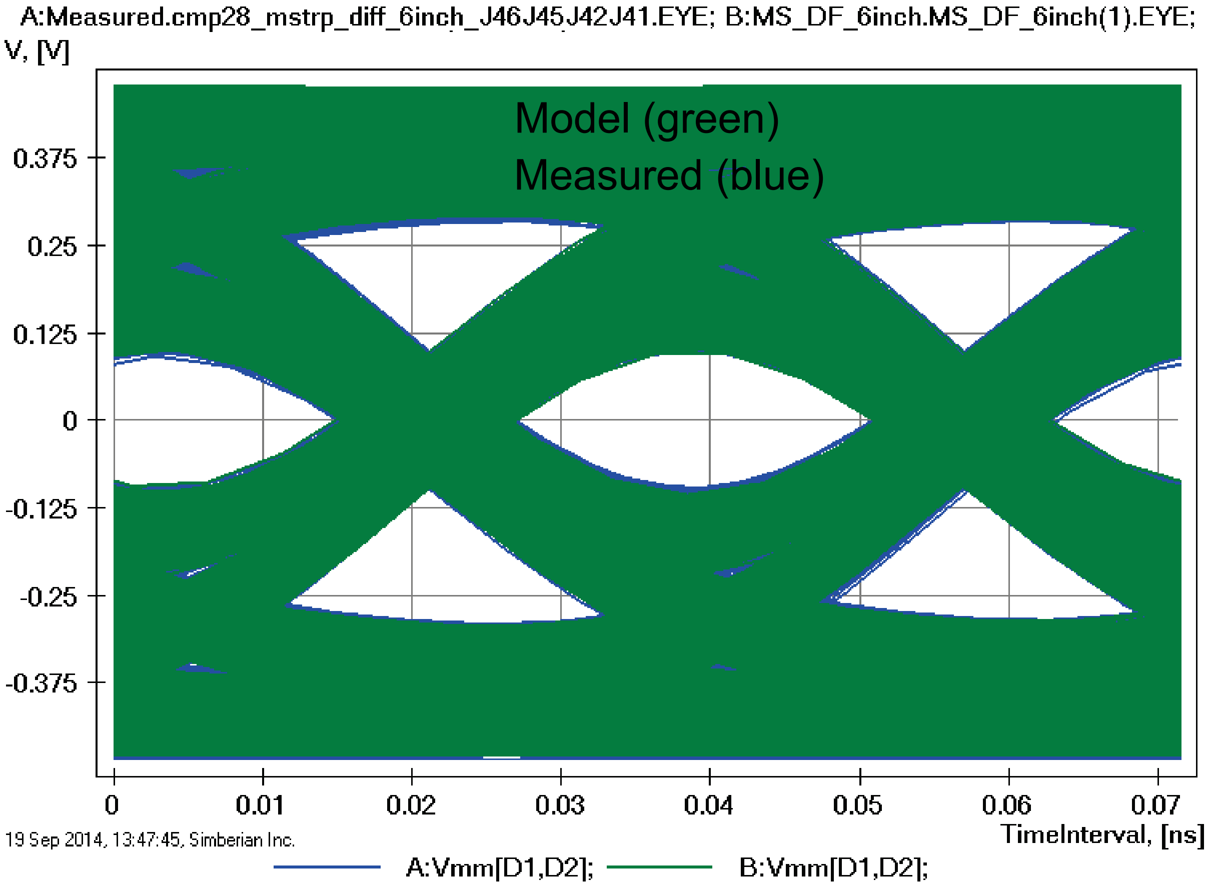


14) 6-inch microstrip differential line: MM TDR with 20 ps Gaussian step



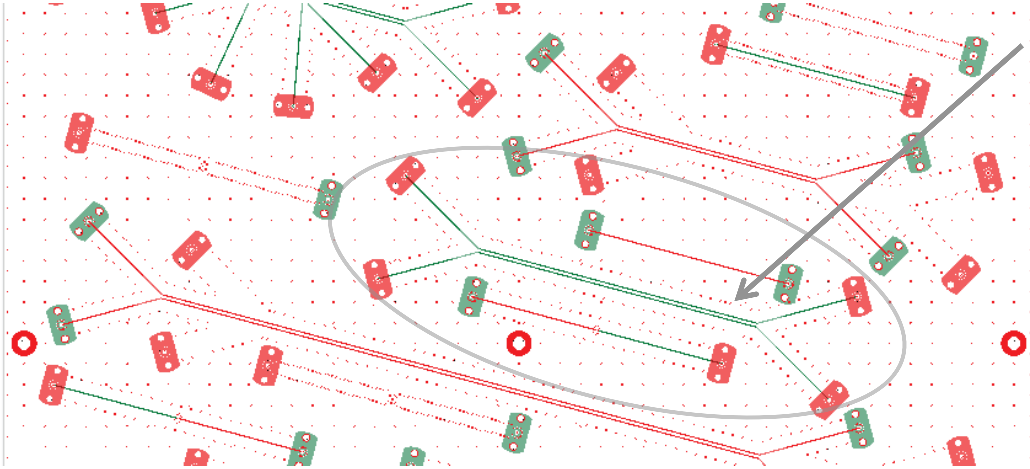
Model transitions have lower impedance due to no adjustments in trace width in polygonal section;

14) 6-inch microstrip differential line: 28 Gbps PRBS, 25 ps rise/fall time



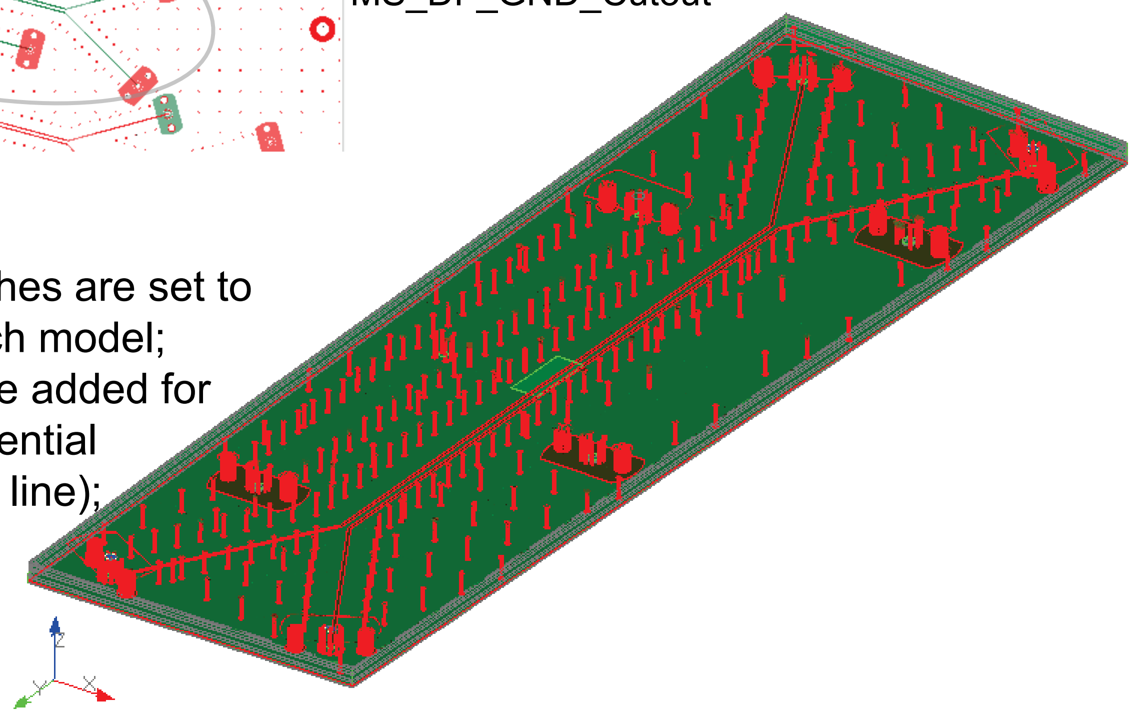
Eyes are on top of each other!

15) Microstrip differential line with void

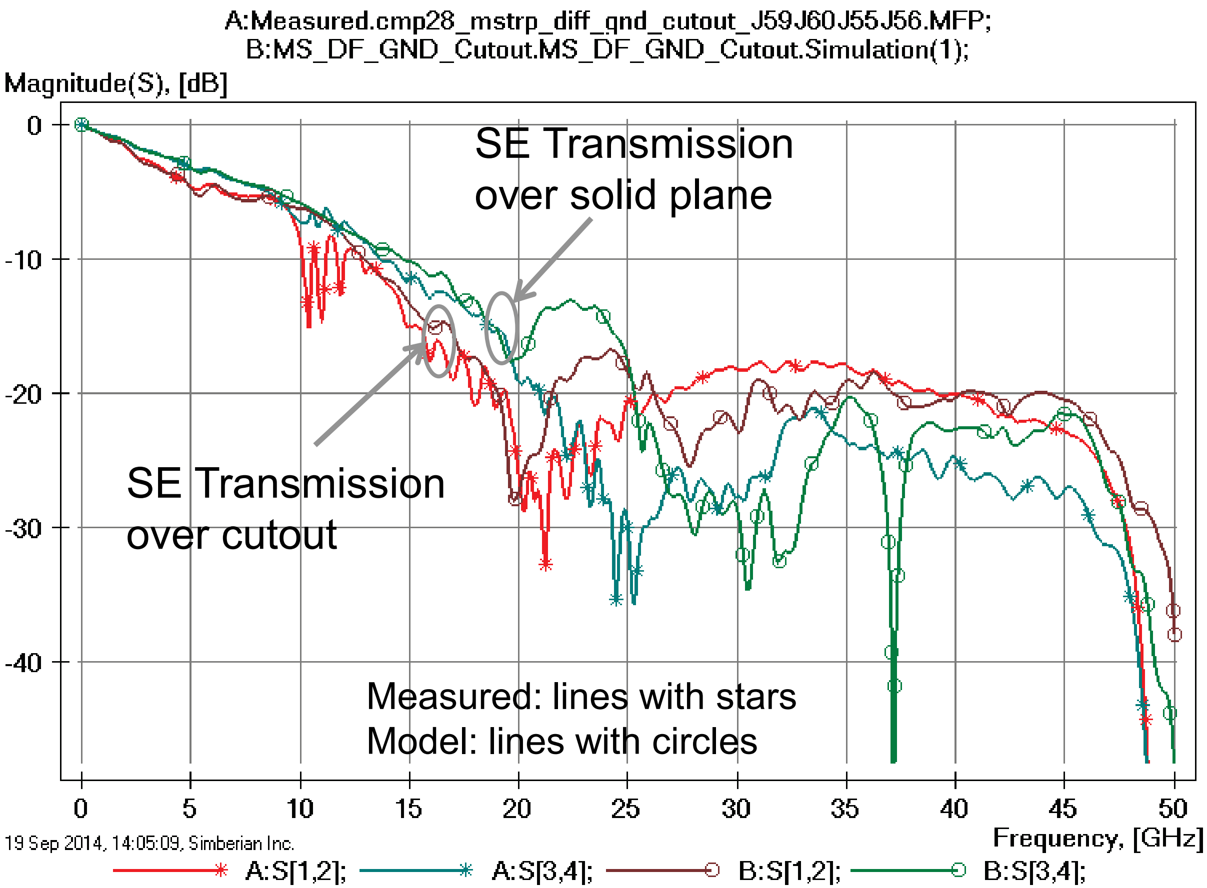


MS DF segment with void in GND plane (J55-J56-J59-J60)
Solution: 6_MicrostipDifferential(2)
Measured: cmp28_mstrp_diff_gnd_cutout_J59J60J55J56.s4p Selector/Project/Circuit: MS_DF_GND_Cutout

Board Analyzer:
Single-ended trace width is adjusted;
4 discontinuity selectors for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
Additional 2 discontinuity selectors are added for transitions from single-ended to differential (identical and re-used from 2-inch diff line);
See also notes in the solution;

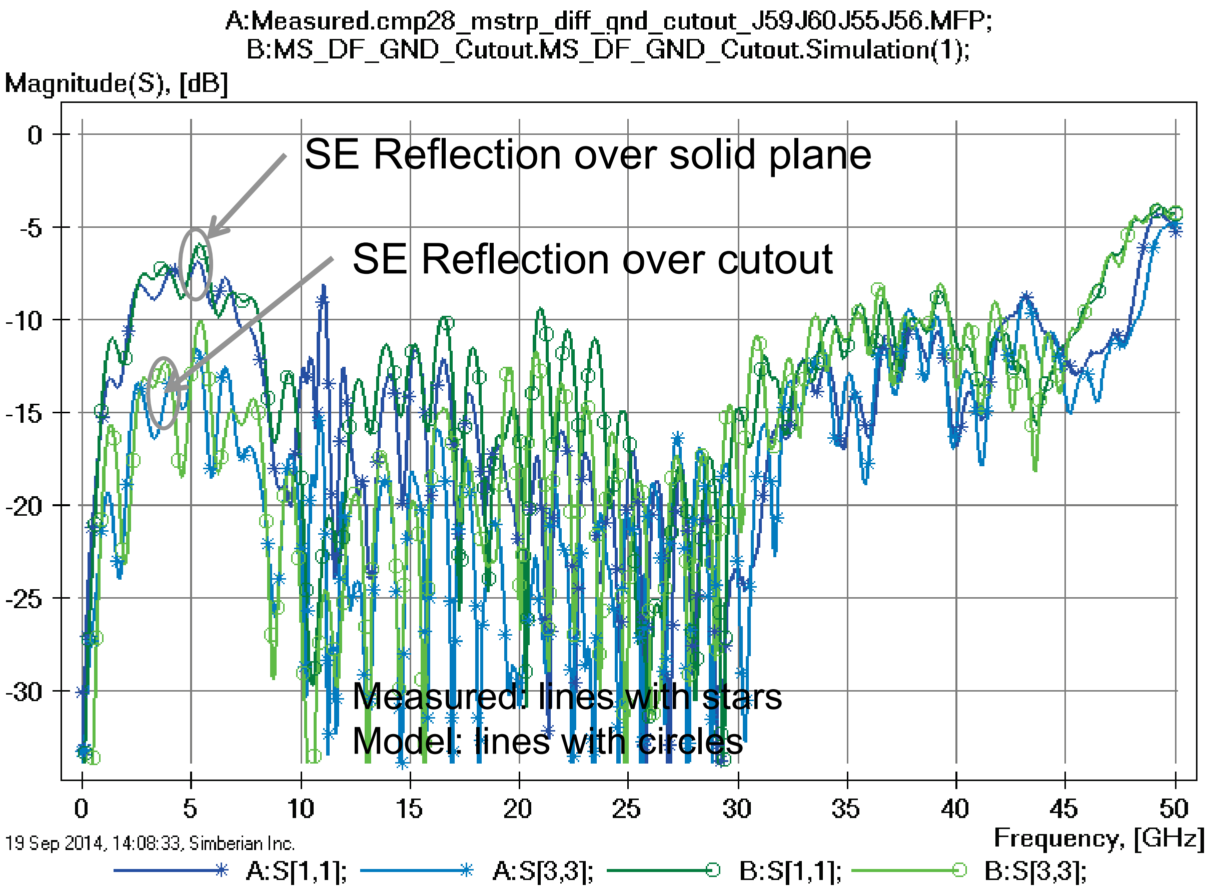


15) Microstrip differential line with void: Single-ended transmission



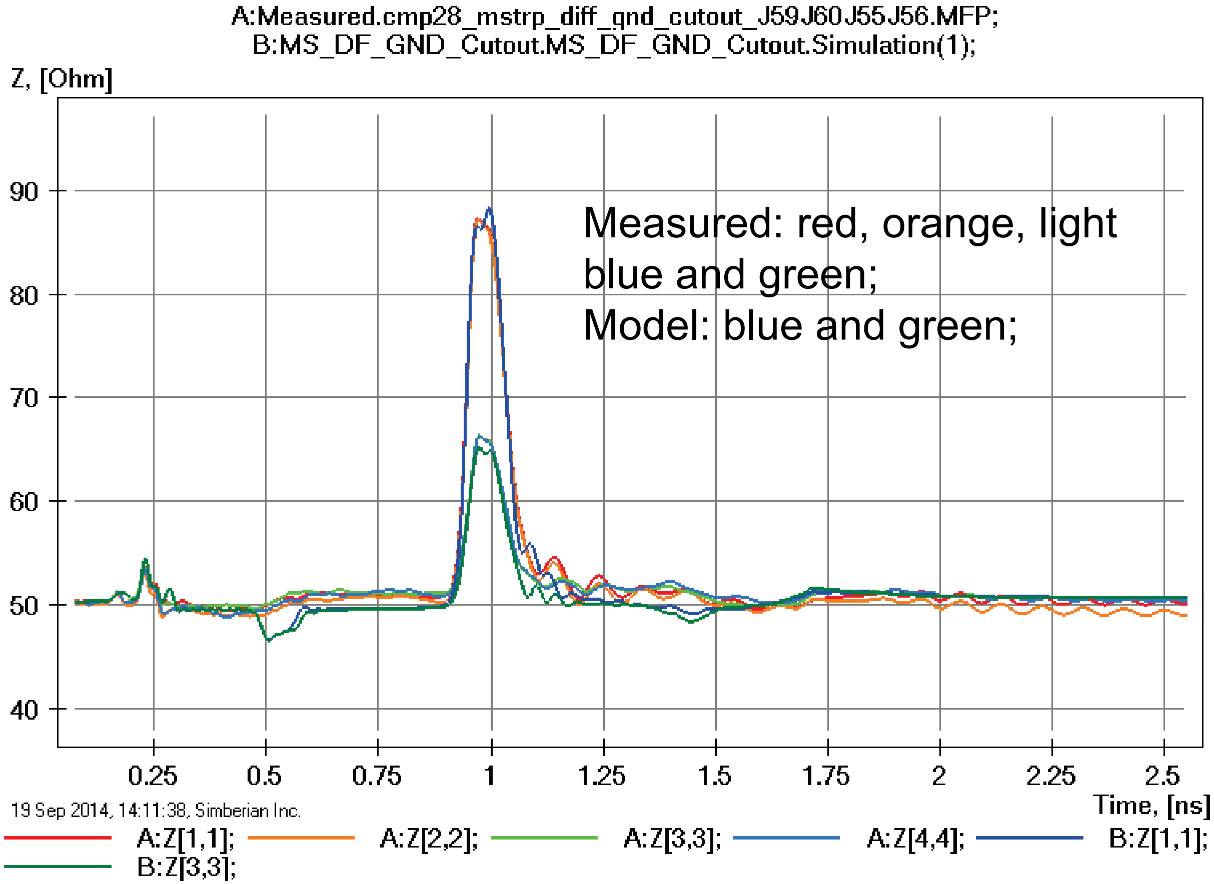
Difference in strip width and separation explains difference in transmission;

15) Microstrip differential line with void: Single-ended reflection



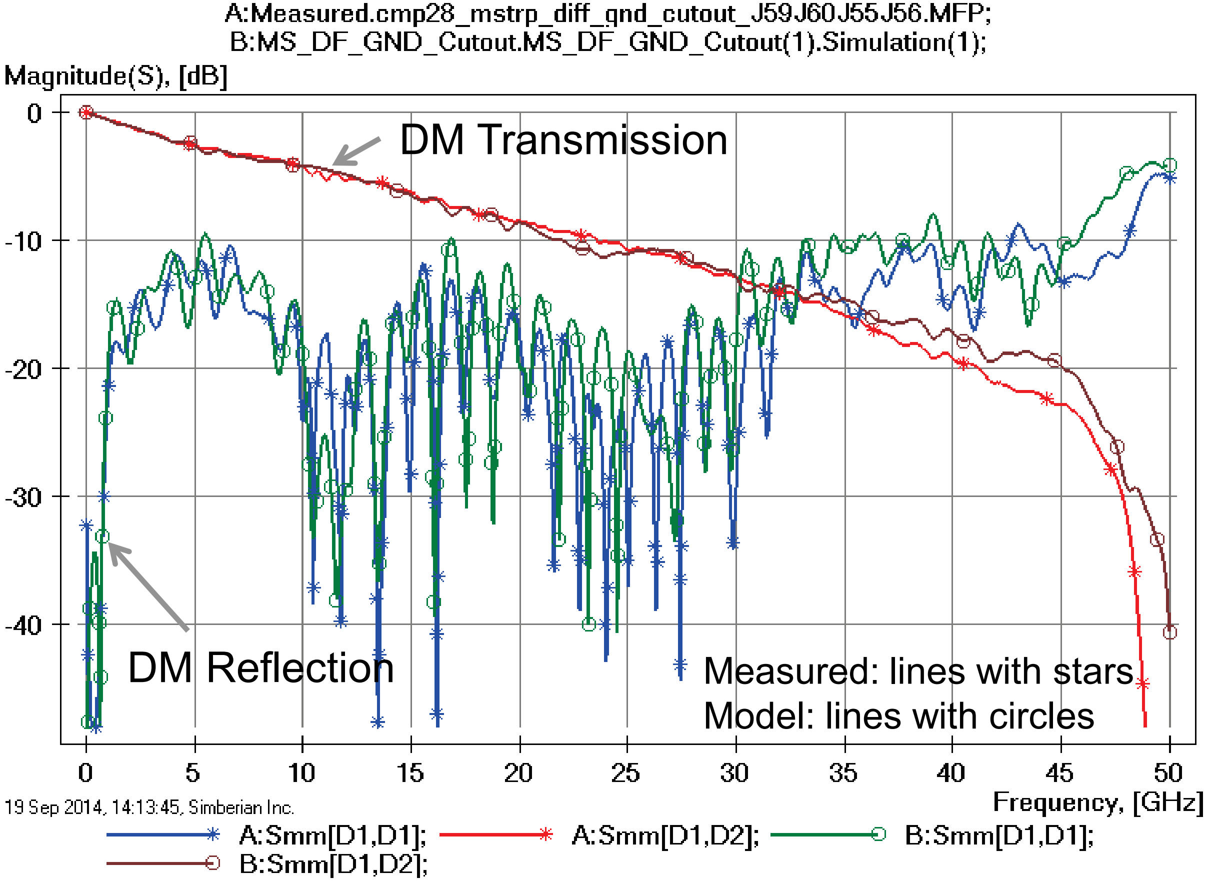
Difference in strip width, separation and dielectric properties explains difference in reflection;

15) Microstrip differential line with void: SE TDR with 20 ps Gaussian step



Model transitions have lower impedance due to no adjustments in trace width in the tapered polygonal section;

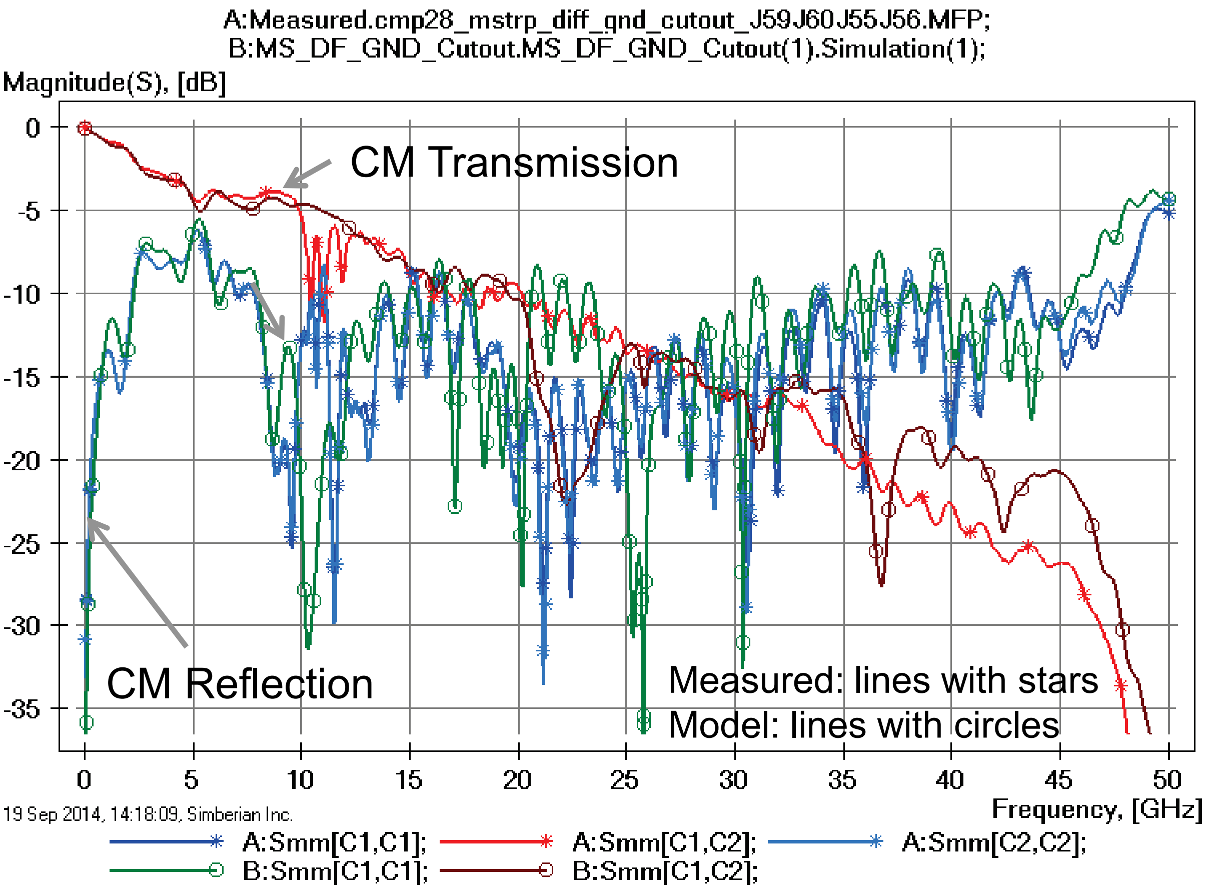
15) Microstrip differential line with void: Differential mode transmission and reflection



Loss of launch localization above 30 GHz explains additional insertion losses;
Variation of trace width, separation and dielectric properties explains differences in reflection losses;

DM – differential mode

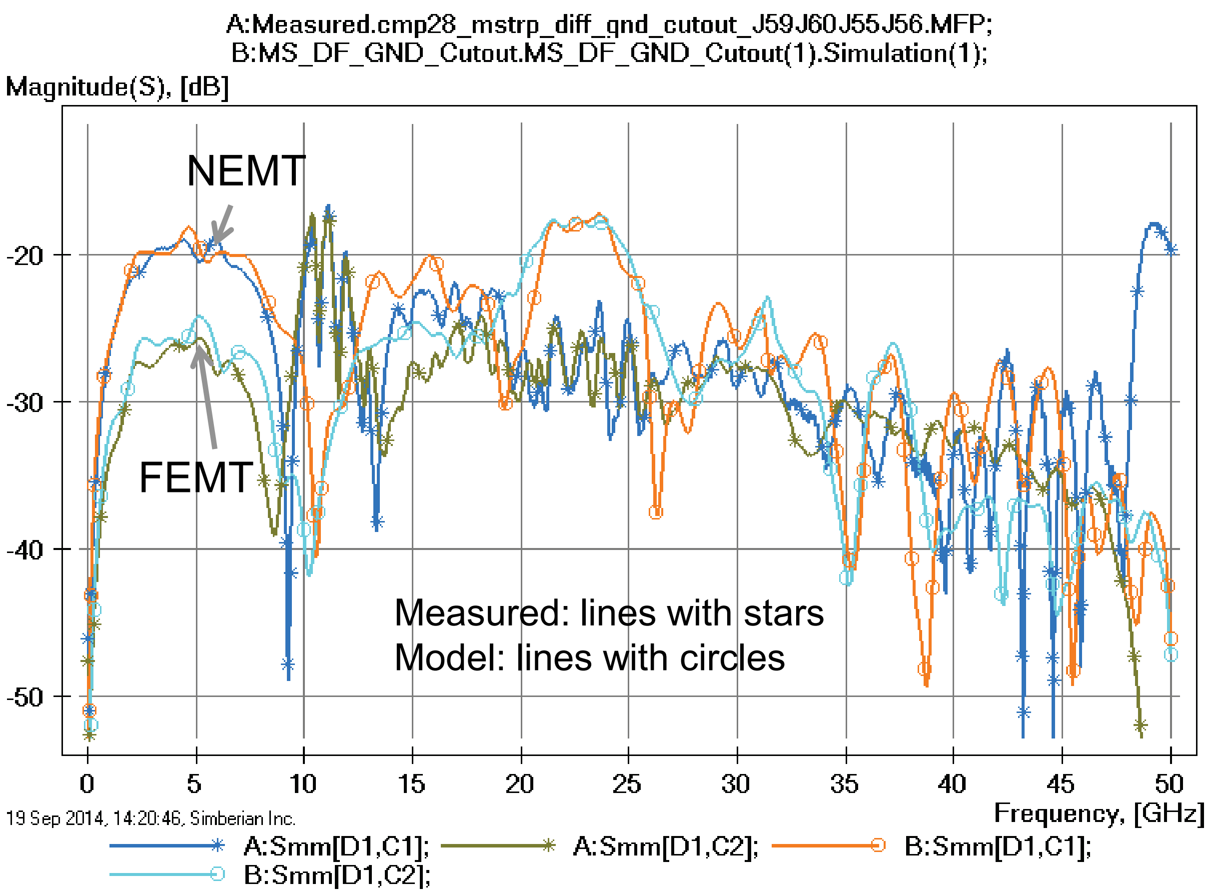
15) Microstrip differential line with void: Common mode transmission and reflection



Loss of launch localization above 30 GHz explains additional insertion losses;
Variation of trace width, separation and dielectric properties explains differences in reflection losses;

CM – common mode

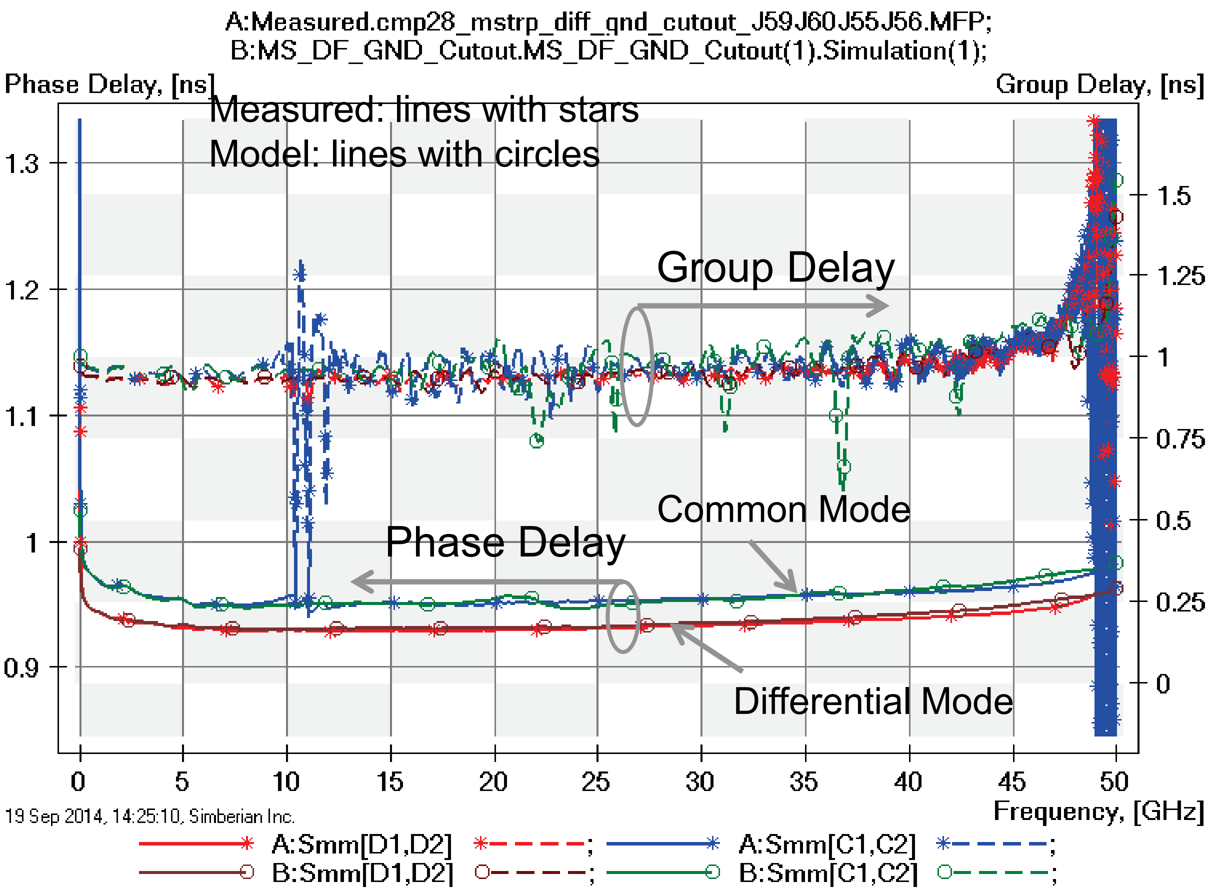
15) Microstrip differential line with void: Mixed mode transformation



Difference below -30 dB – can be attributed to many things;

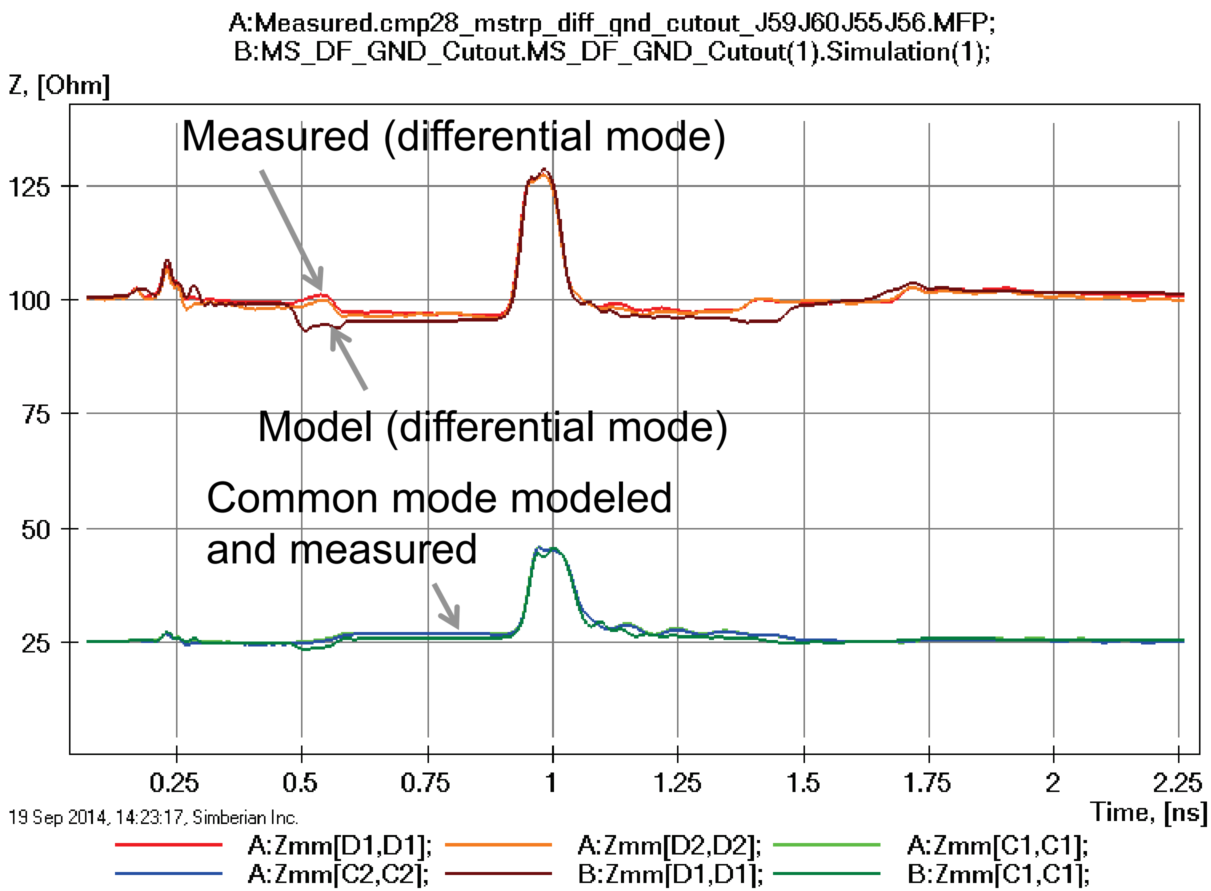
NEMT- near end differential to common mode transformation; FEMT - far end differential to common mode transformation;

15) Microstrip differential line with void: DF transmission phase and group delay



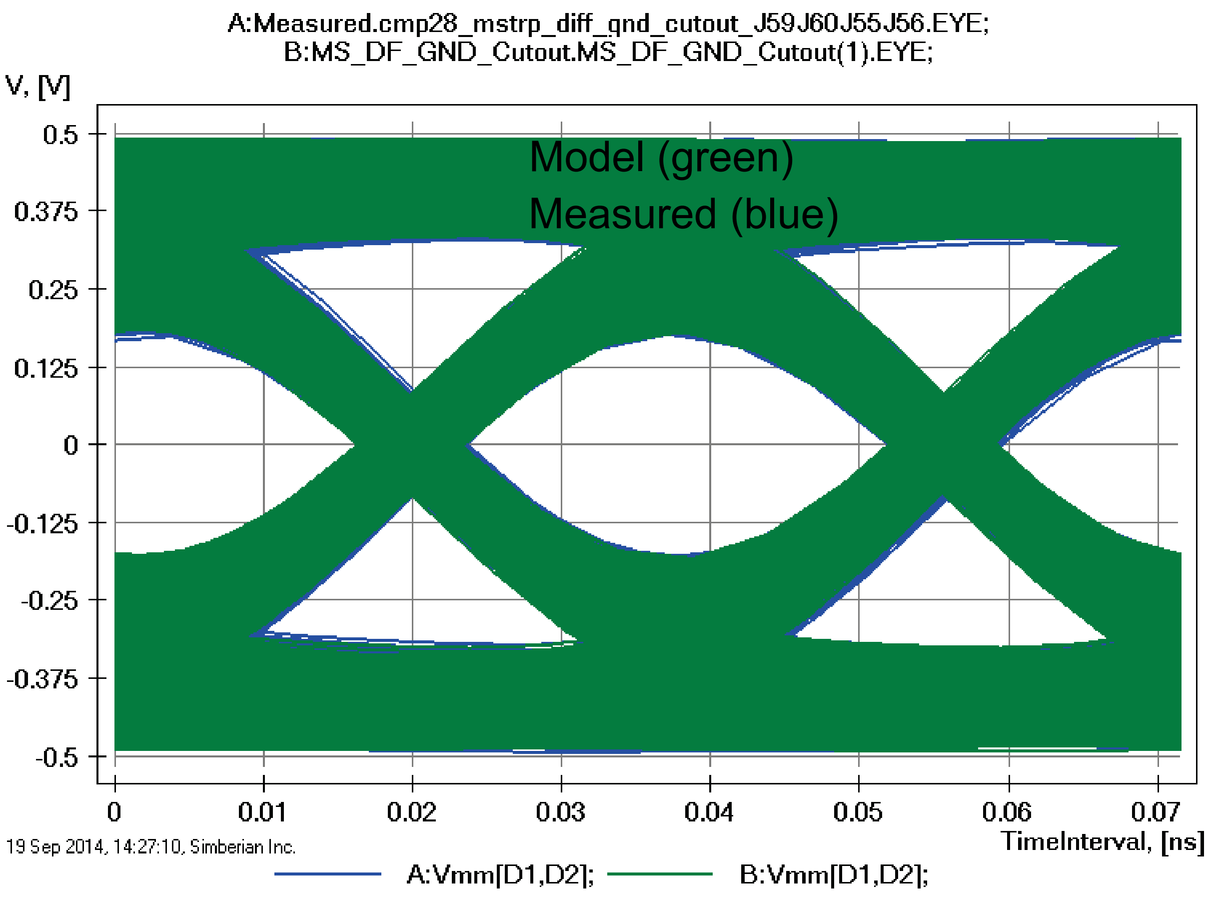
Group delay is too noisy to make conclusions

15) Microstrip differential line with void: MM TDR with 20 ps Gaussian step



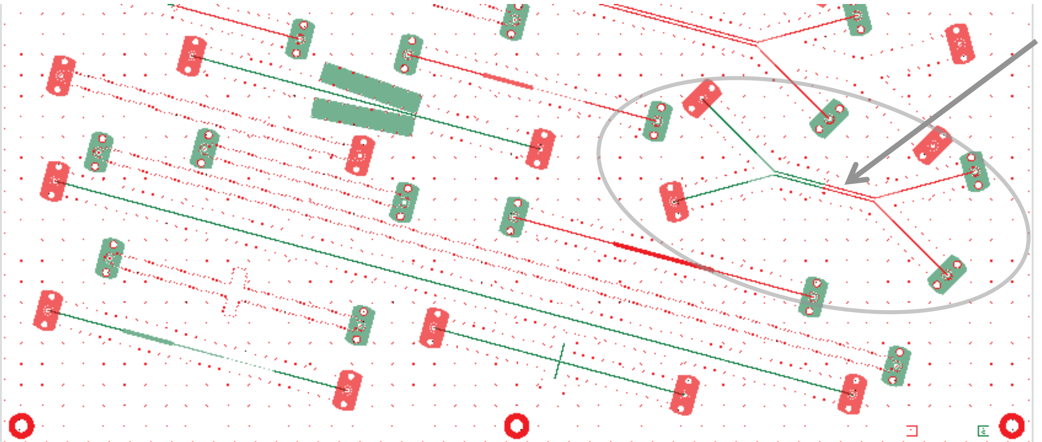
Model transitions have lower impedance due to no adjustments in trace width in polygonal section;

15) Microstrip differential line with void: 28 Gbps PRBS, 25 ps rise/fall time



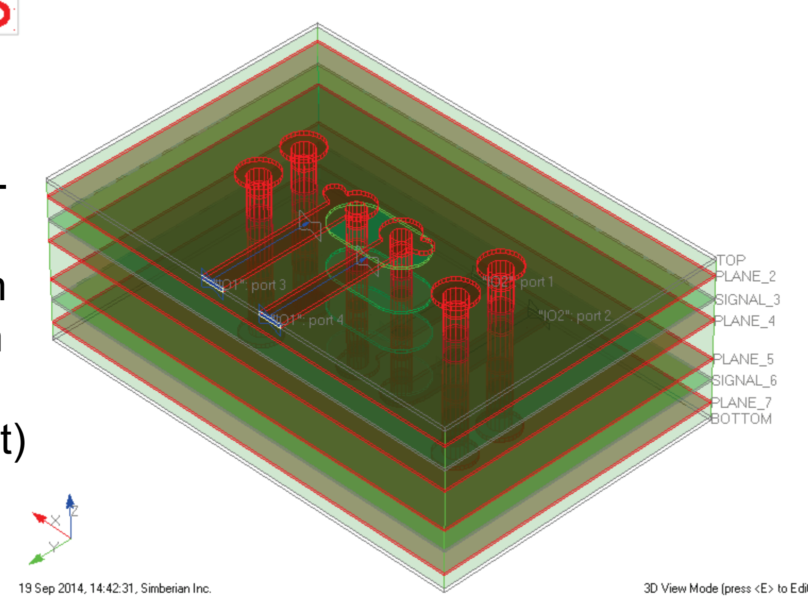
Eyes are on top of each other!

16) Microstrip differential line with vias

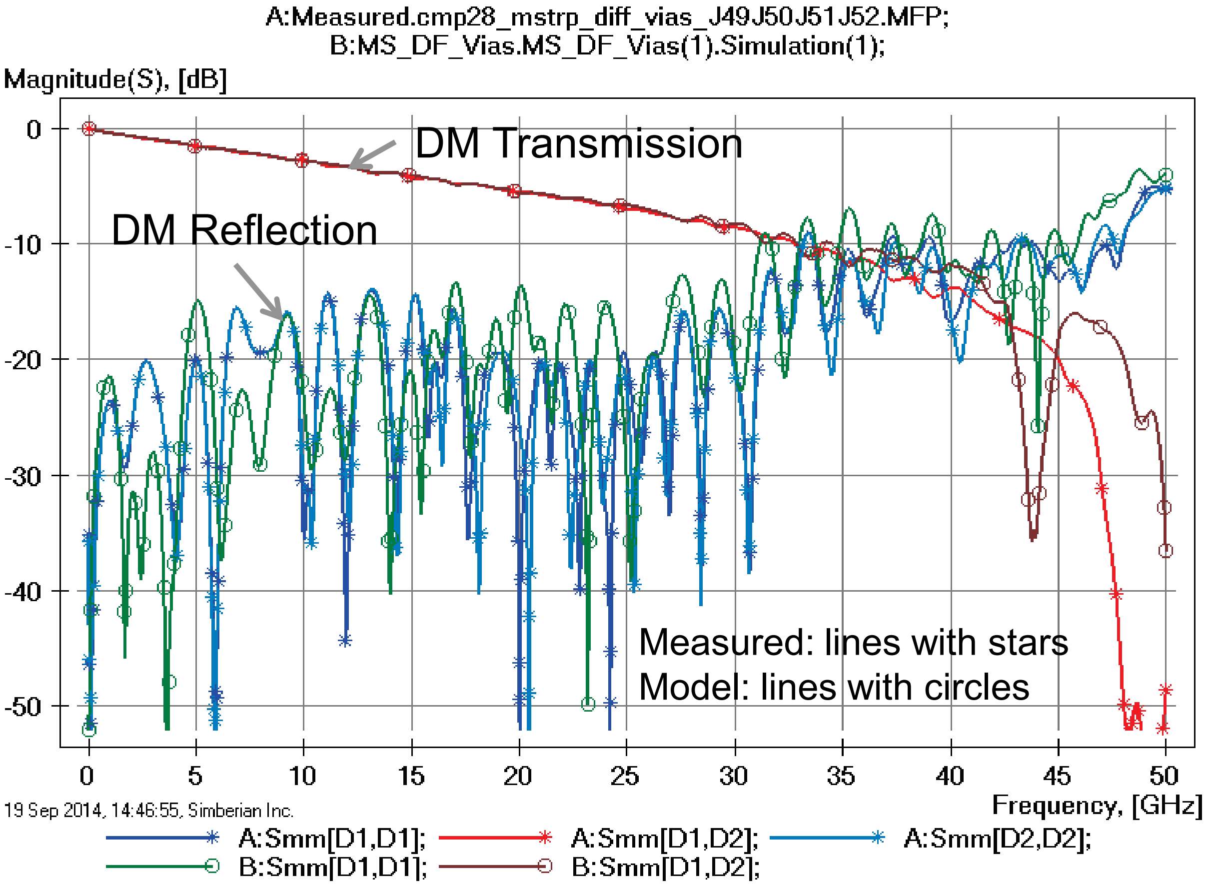


MS DF segment with void in GND plane (J55-J56-J59-J60)
Solution: 6_MicrostipDifferential(2)
Measured: cmp28_mstrp_diff_vias_J49J50J51J52.s4p
Selector/Project/Circuit: MS_DF_Vias

Board Analyzer:
Single-ended trace width is adjusted;
4 discontinuity selectors for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
2 discontinuity selectors are added for transitions from single-ended to differential (identical and re-used from 2-inch diff line);
Additional selector created for vias (shown on the right)
See also notes in the solution;



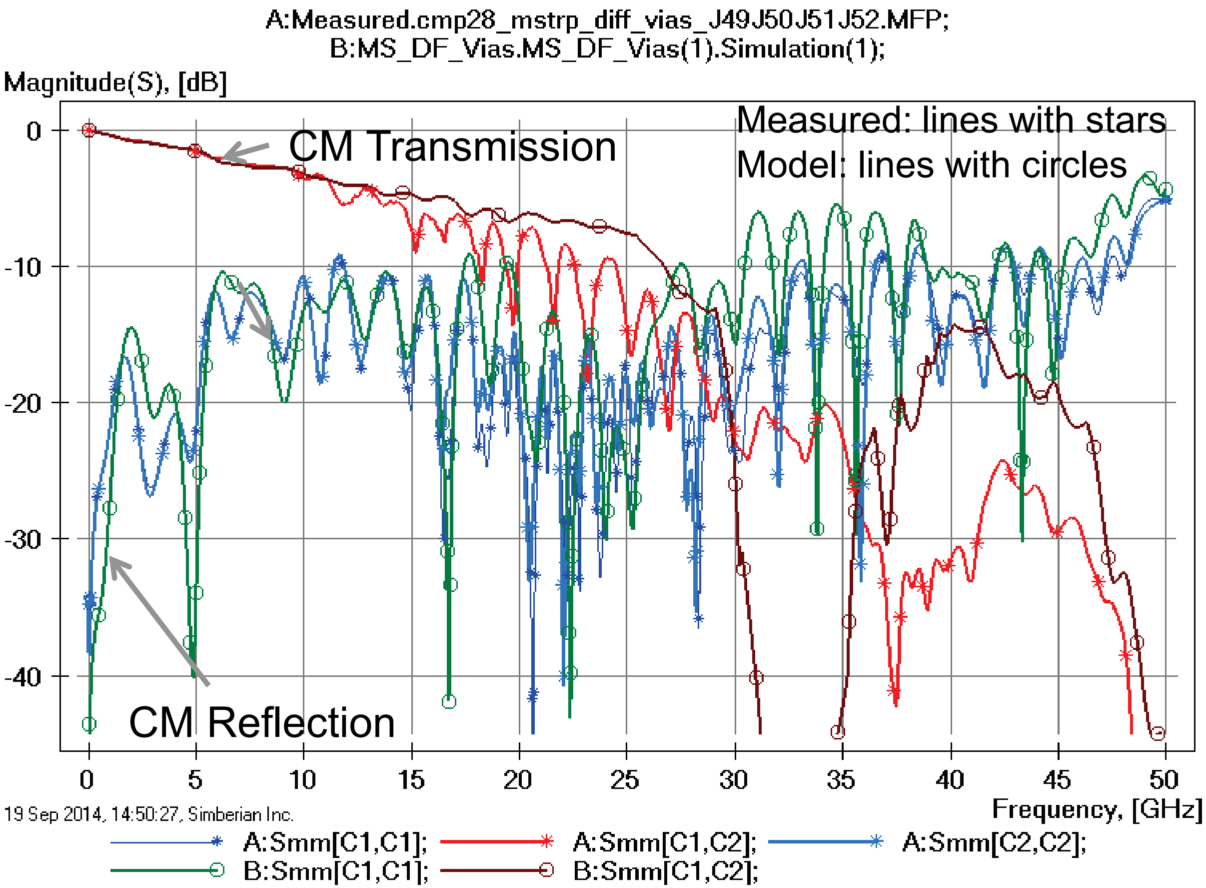
16) Microstrip differential line with vias: Differential mode transmission and reflection



Loss of launch localization above 30 GHz explains additional insertion losses;
Variation of trace width, separation and dielectric properties explains differences in reflection losses;

DM – differential mode

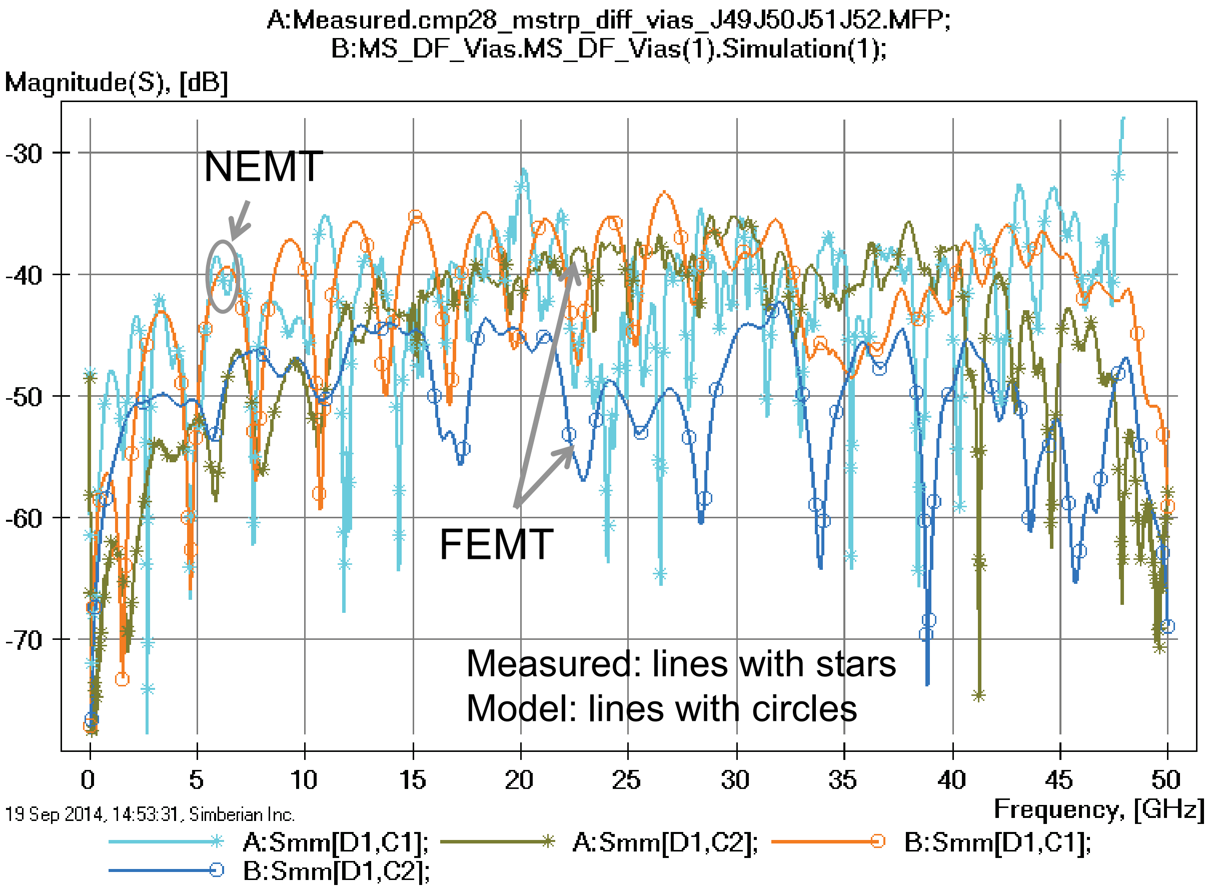
16) Microstrip differential line with vias: Common mode transmission and reflection



Loss of common mode localization above 15-20 GHz explains additional insertion losses;
Variation of trace width, separation and dielectric properties explains differences in reflection losses;

CM – common mode

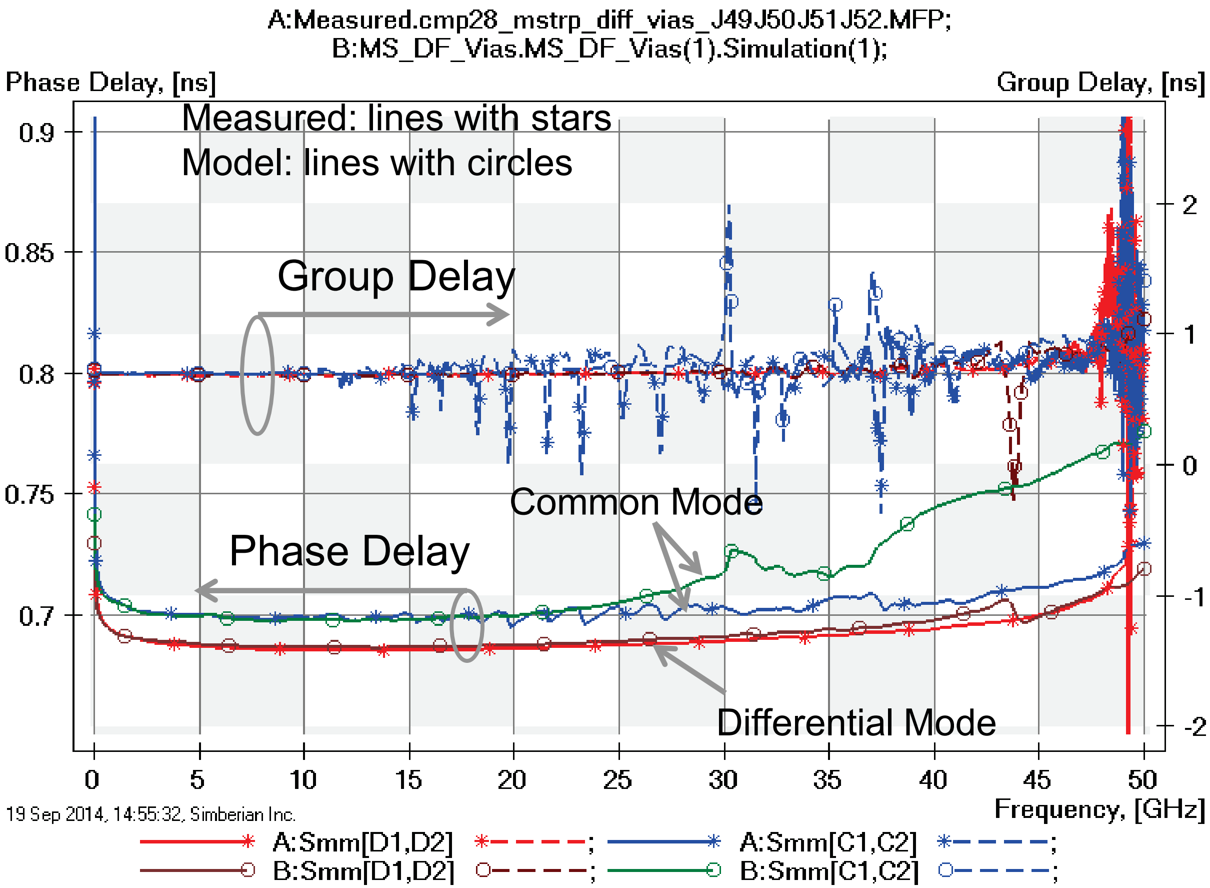
16) Microstrip differential line with vias: Mixed mode transformation



Difference below -30 dB – can be attributed to many things;

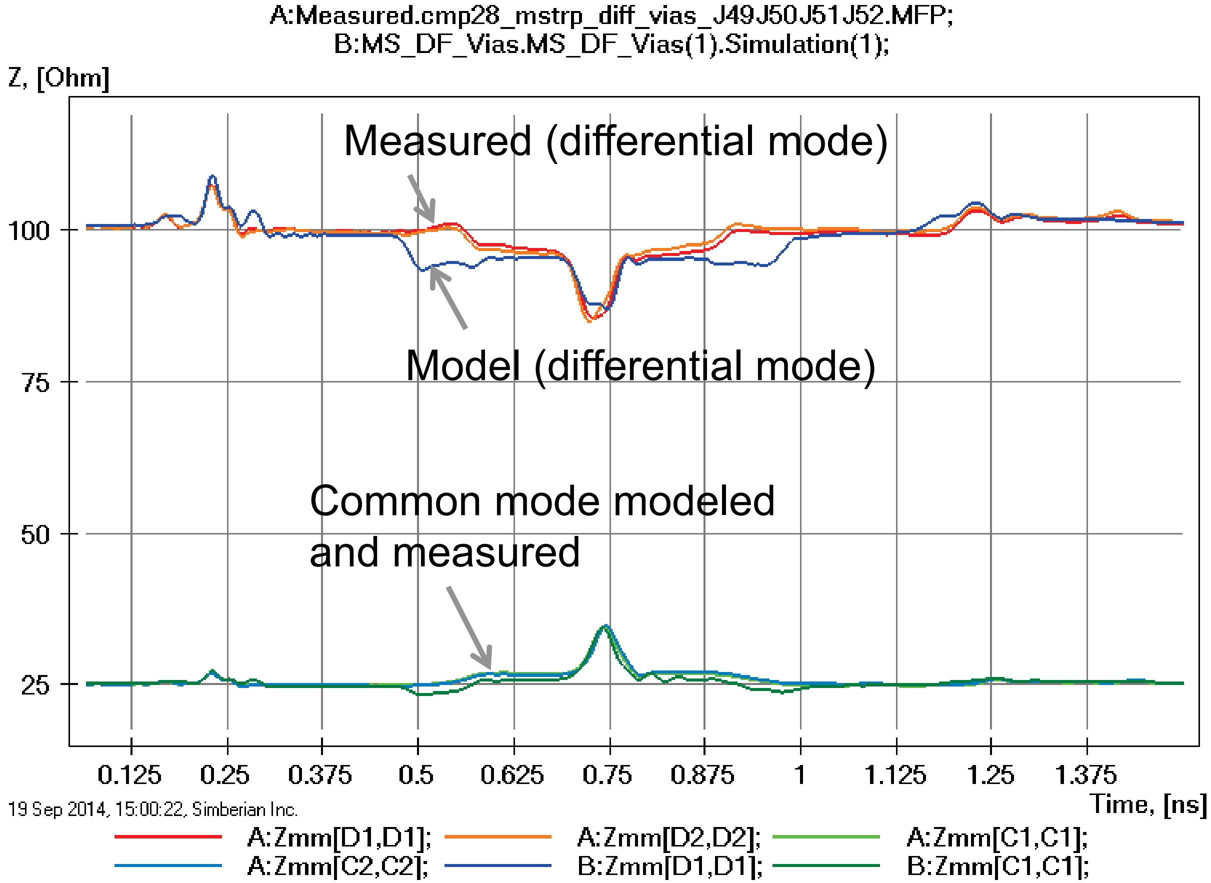
NEMT- near end differential to common mode transformation; FEMT - far end differential to common mode transformation;

16) Microstrip differential line with vias: DF transmission phase and group delay



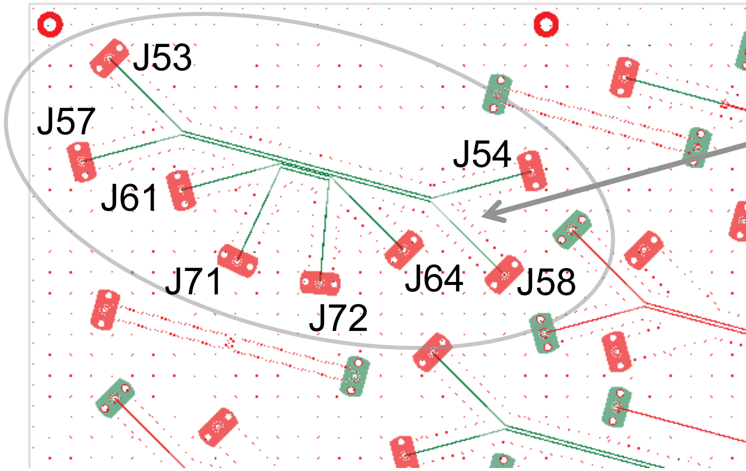
Differential mode is OK;
Discrepancies in common above 20 GHz;

16) Microstrip differential line with vias: Differential TDR with 20 ps Gaussian step



Model transitions have lower impedance due to no adjustments in trace width in polygonal section;

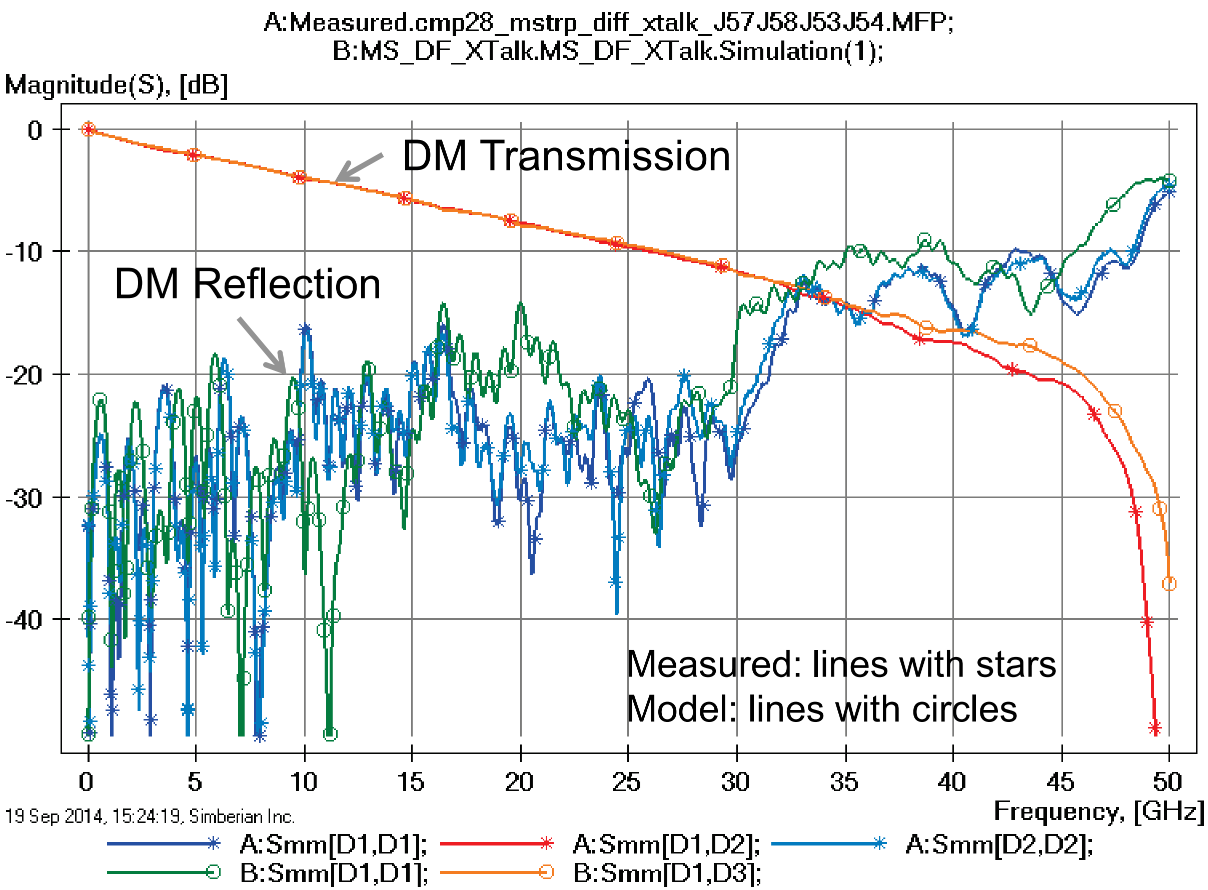
17) X-talk in differential microstrip

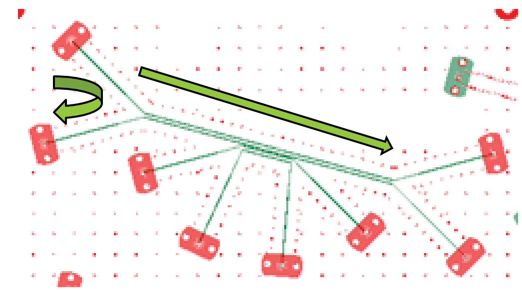


MS DF segment with cross-talk (J53-J54-J57-J58-J61-J64-J71-J72)
Solution: 7_MicrostipDifferentialXTalk(3)
Measured:
Through Long: mp28_mstrp_diff_xtalk_J57J64J53J72.s4p
Through Short: cmp28_mstrp_diff_xtalk_J71J72J61J64.s4p
NEXT Left: cmp28_mstrp_diff_xtalk_J57J71J53J61.s4p
NEXT Right: cmp28_mstrp_diff_xtalk_J72J58J64J54.s4p
FEXT Left-Right: cmp28_mstrp_diff_xtalk_J57J72J53J64.s4p
FEXT Right-Left: cmp28_mstrp_diff_xtalk_J71J58J61J54.s4p
Selector/Project/Circuit: MS_DF_XTalk

Board Analyzer:
Single-ended trace width is adjusted;
8 discontinuity selectors for the launches are set to re-use PCB/MS_ConnectorAndLaunch model;
2 discontinuity selectors are added for transitions from single-ended to differential (identical and re-used);
2 discontinuity selectors are added for transitions to differential coupled section (identical and re-used);
PORT NUMERATION CORRESPONDENSE (DS for pins are created in this order):
Pins J53 and J57 - Port 1 and 2 (differential port 1, common port 5);
Pins J61 and J71 - Port 3 and 4 (differential port 2, common port 6);
Pins J54 and J58 - Port 5 and 6 (differential port 3, common port 7);
Pins J64 and J72 - Port 7 and 8 (differential port 4, common port 8);
See also notes in the solution;

17) X-talk in differential microstrip: Long section transmission and reflection

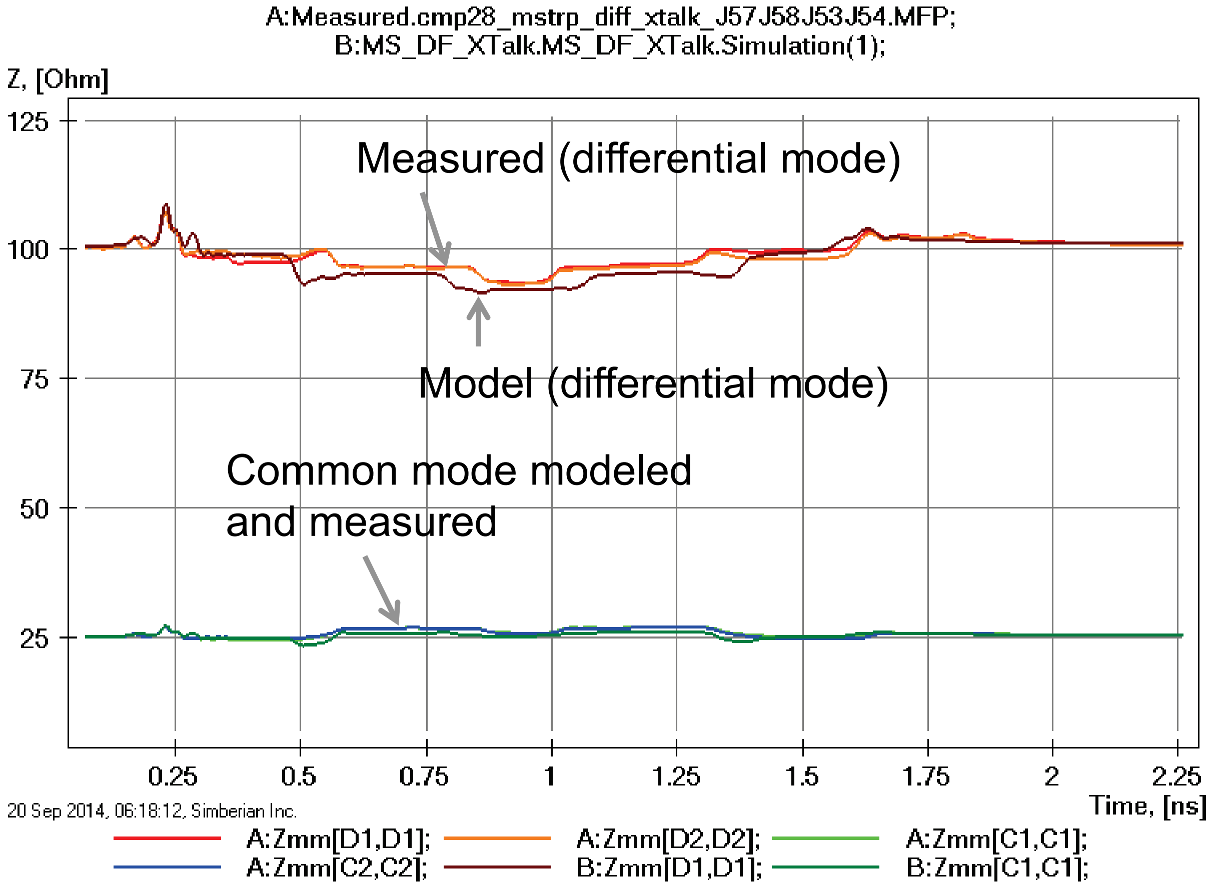


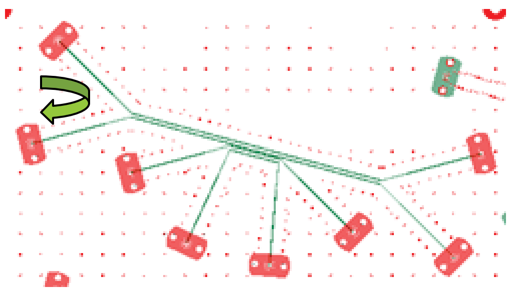


Loss of launch localization above 30 GHz explains additional insertion losses;
Variation of trace width, separation and dielectric properties explains differences in reflection losses;

DM – differential mode

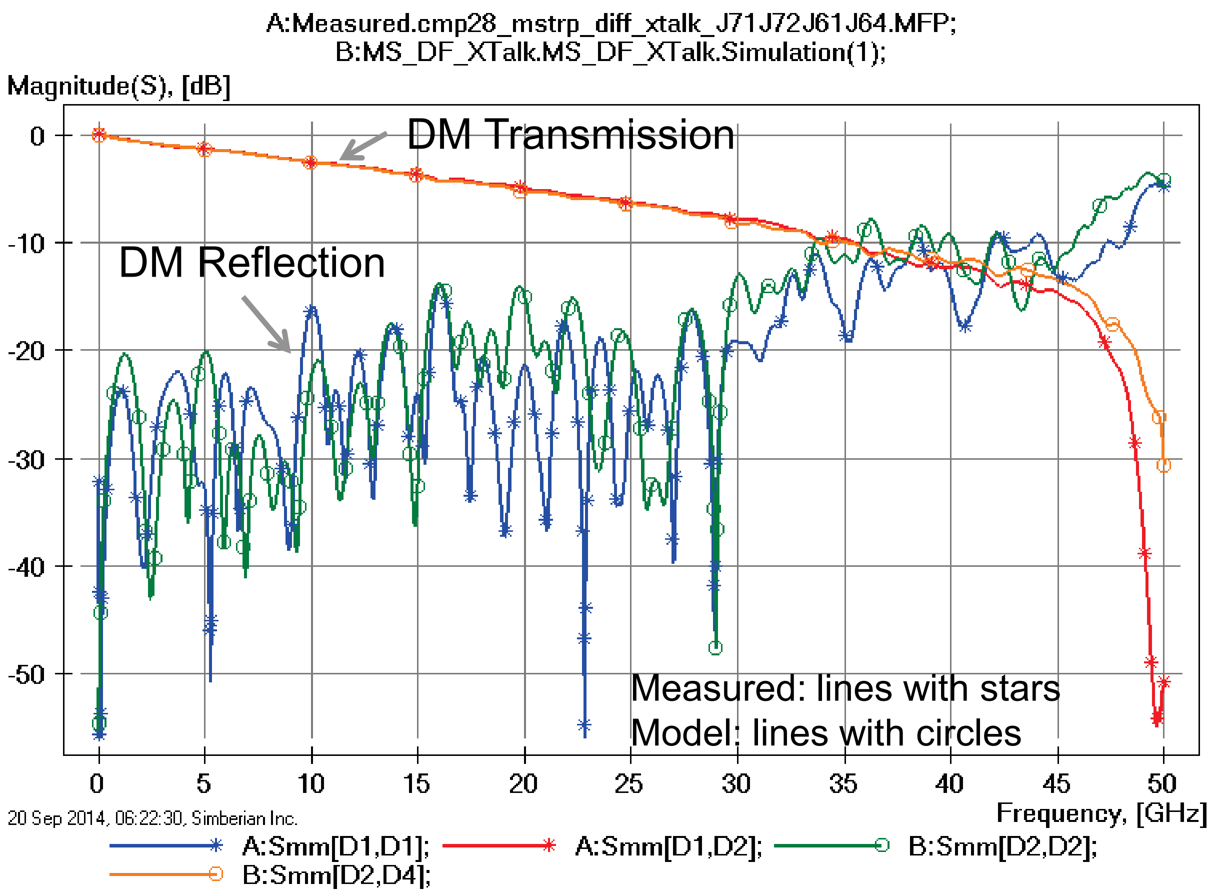
17) X-talk in differential microstrip: Long section TDR with 20 ps Gaussian step

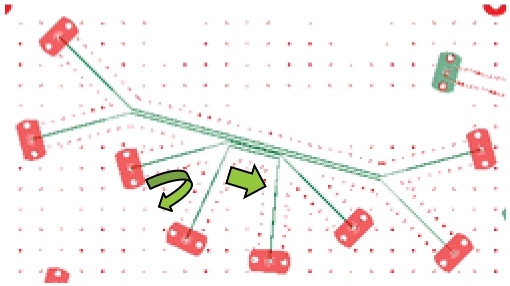




Model transitions have lower impedance due to no adjustments in trace width in polygonal section;

17) X-talk in differential microstrip: Short section transmission and reflection

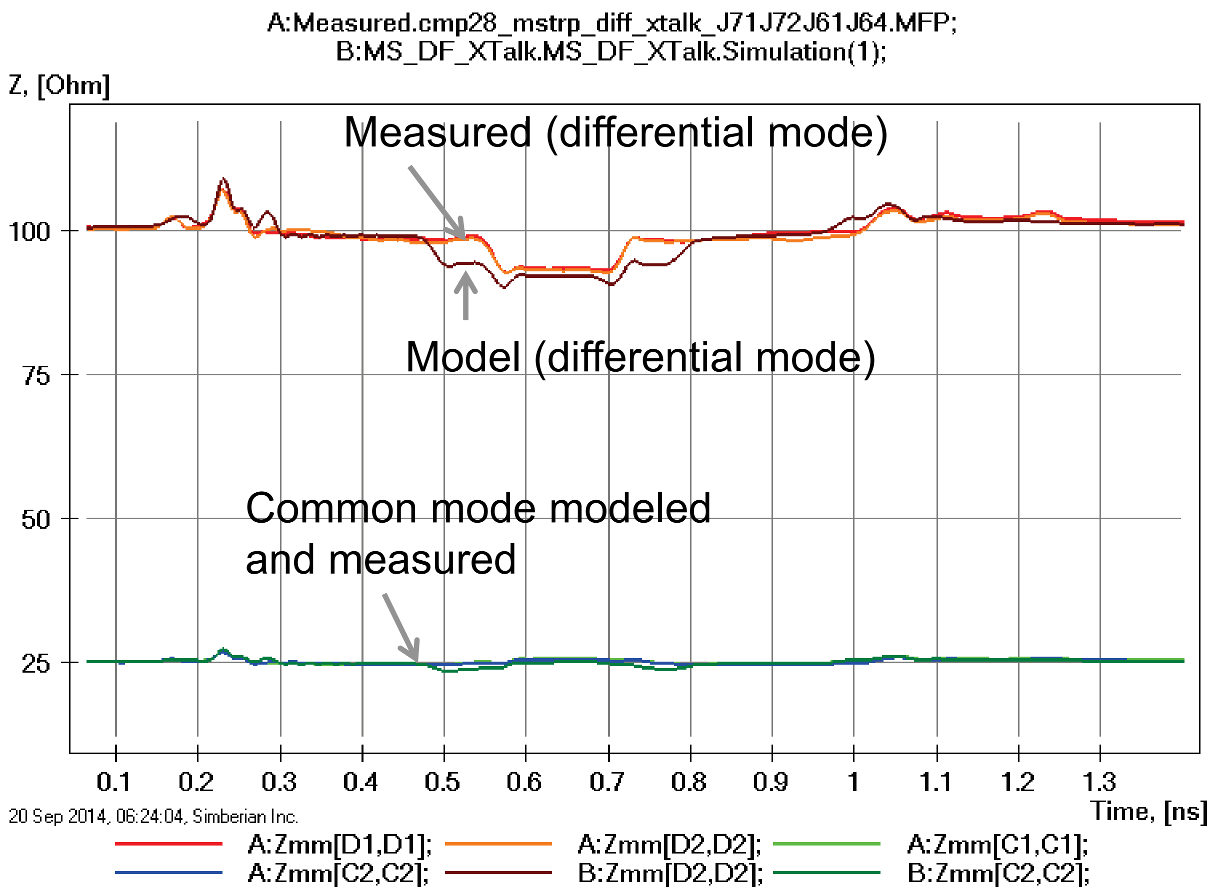


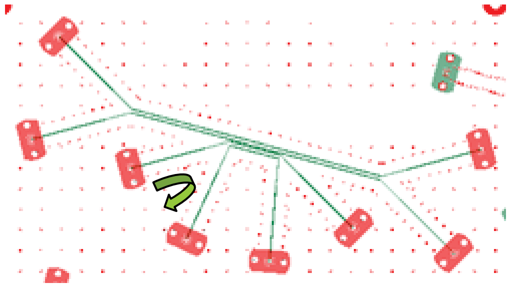


Loss of launch localization above 30 GHz explains additional insertion losses;
Variation of trace width, separation and dielectric properties explains differences in reflection losses;

DM – differential mode

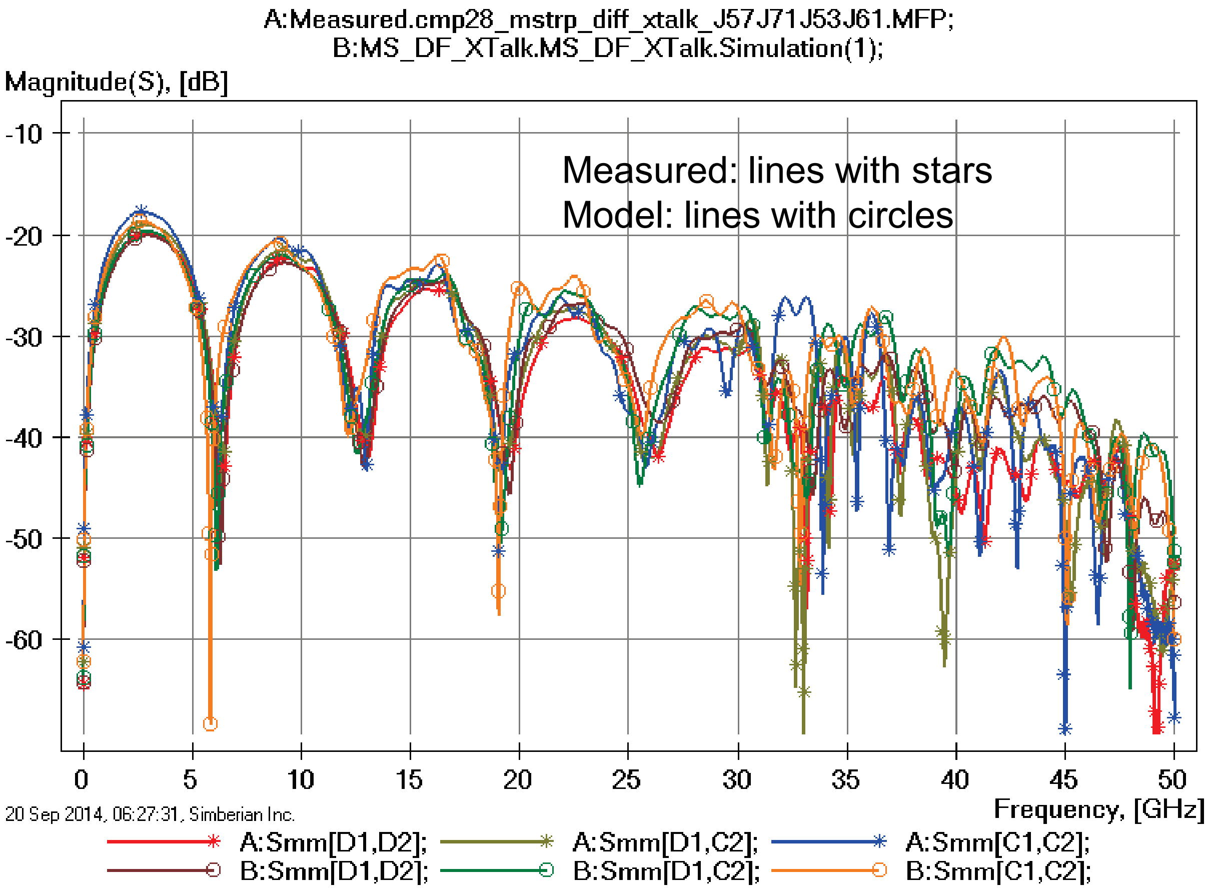
17) X-talk in differential microstrip: Short section TDR with 20 ps Gaussian step

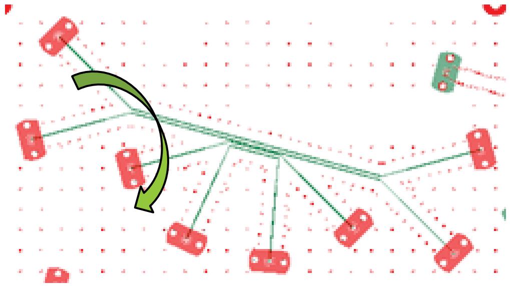




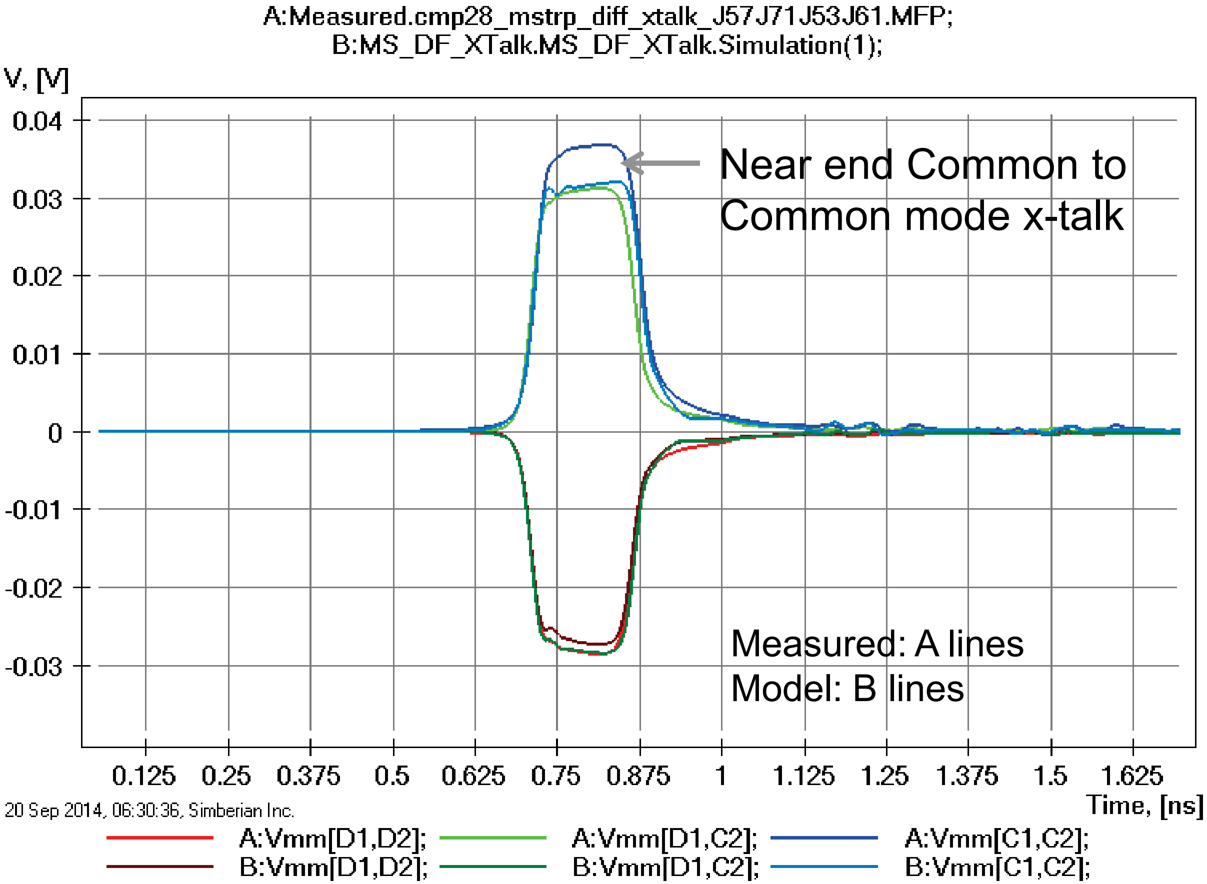
Model transitions have lower impedance due to no adjustments in trace width in polygonal section;

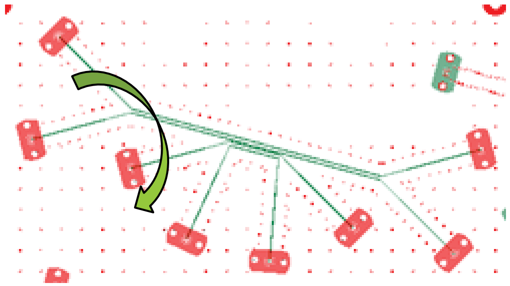
17) X-talk in differential microstrip: Near end mixed-mode X-talk





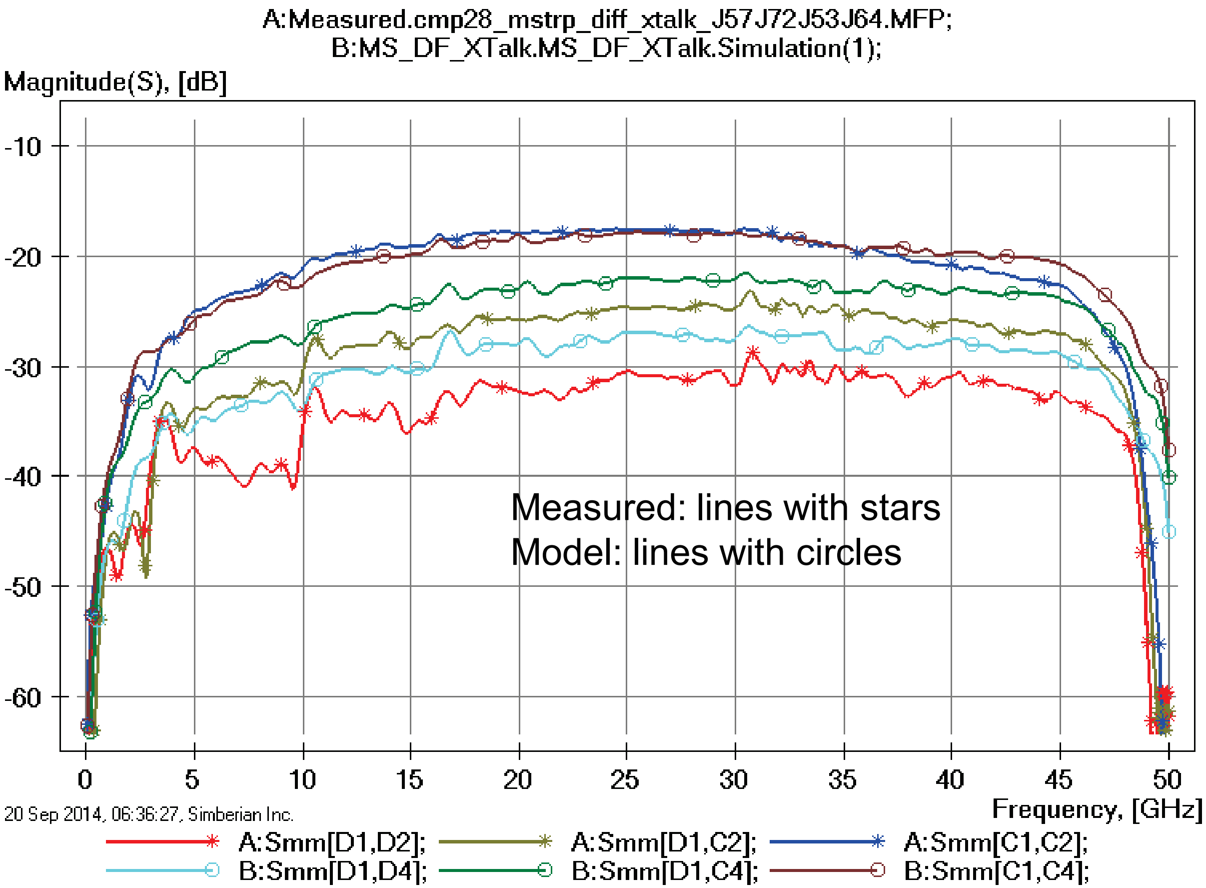
17) X-talk in differential microstrip: Mixed-mode NEXT TDR with 20 ps Gaussian step

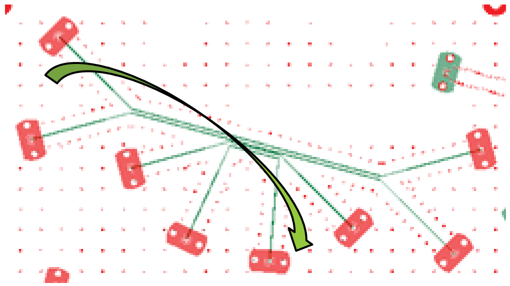




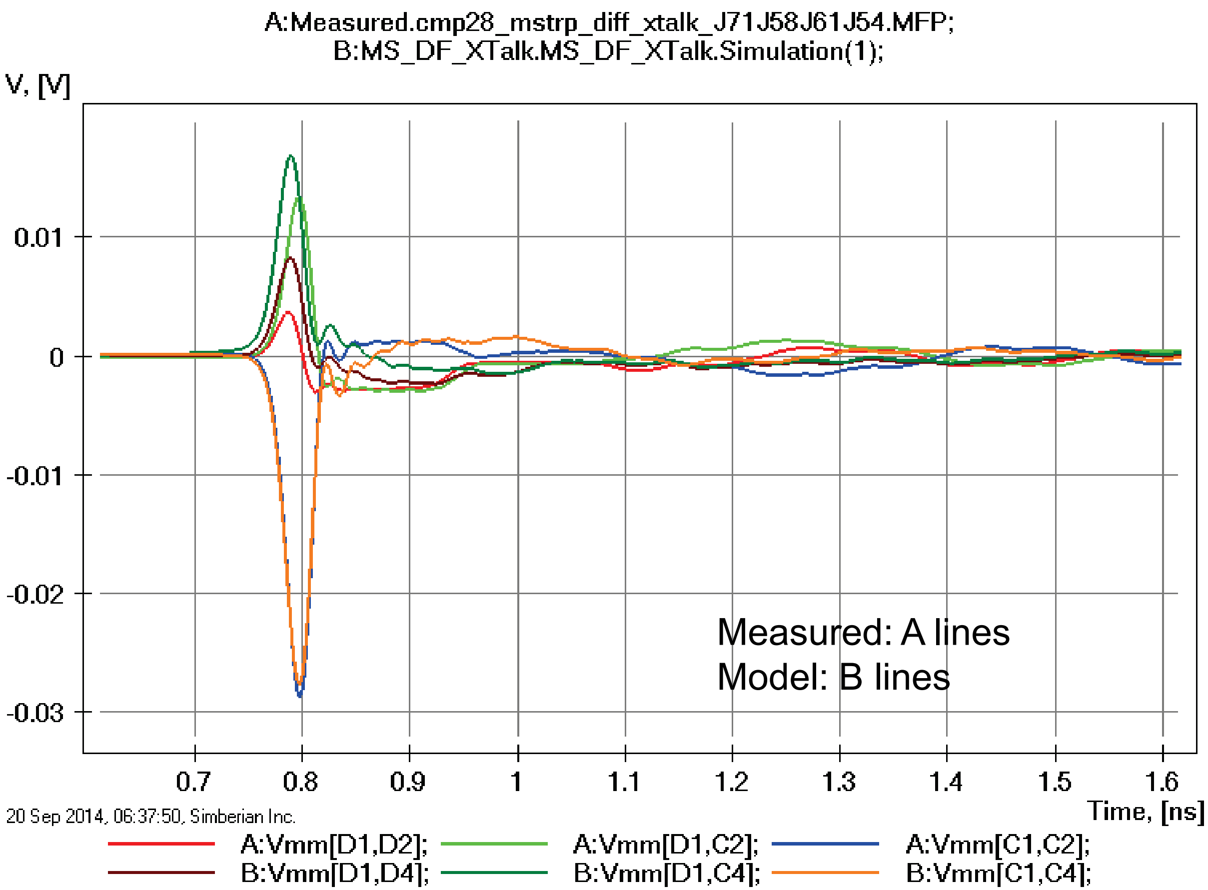
Larger common mode NEXT;

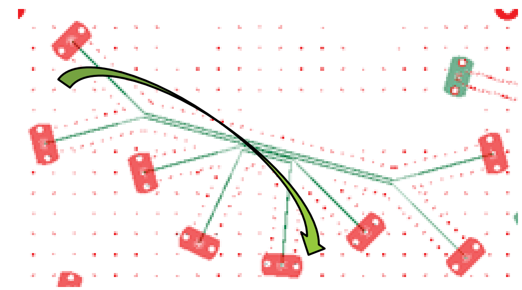
17) X-talk in differential microstrip: Far end mixed-mode X-talk



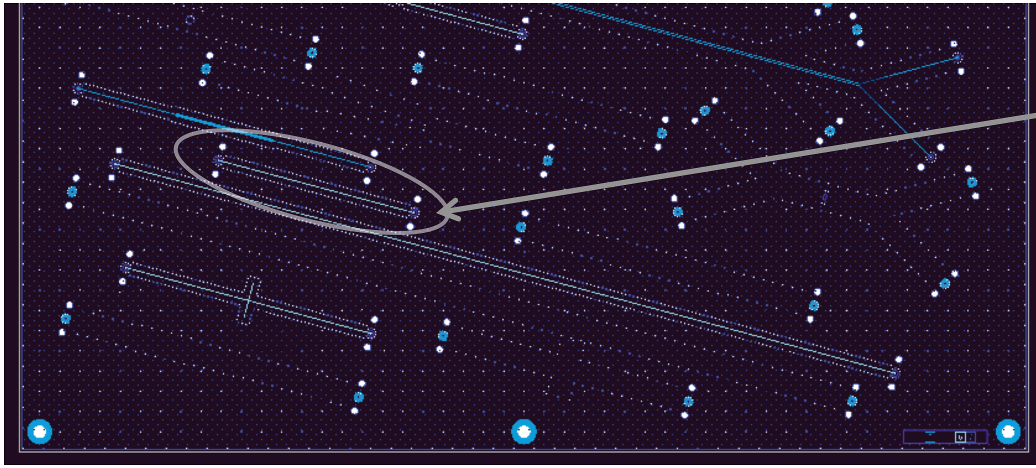


17) X-talk in differential microstrip: Mixed-mode NEXT TDR with 20 ps Gaussian step





18) 2-inch strip line segment



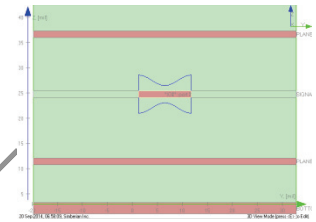
SL SE 2-inch segment (J5-J6)
Solution: 8_StipSingle(1)
Measured:
cmp28_strpl_2in_50ohm_p1J6_p2J5.s2p
Selector/Project/Circuit: SL_SE_2inch_J6J5

Board Analyzer:
Trace width is adjusted (11 to 10.5 mil);
2 discontinuity selector for the launches (identical);
See also notes on next slide and in the solution;

18) 2-inch strip line segment: De-compositional analysis

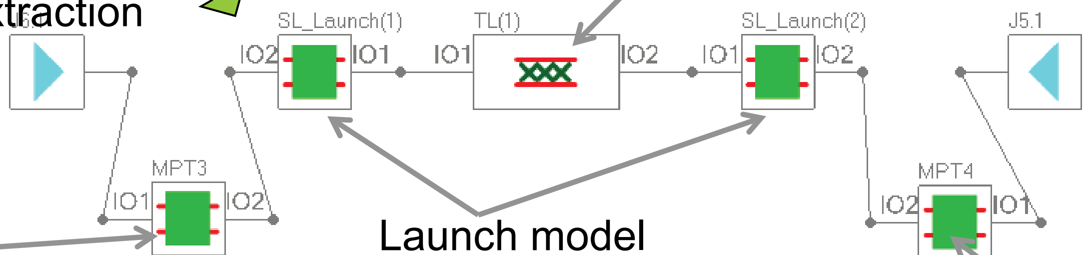
Board Analyzer:
2 discontinuity selectors
with coaxial ports

Trace width is adjusted in BA



Simbeor SFS

Auto-extraction

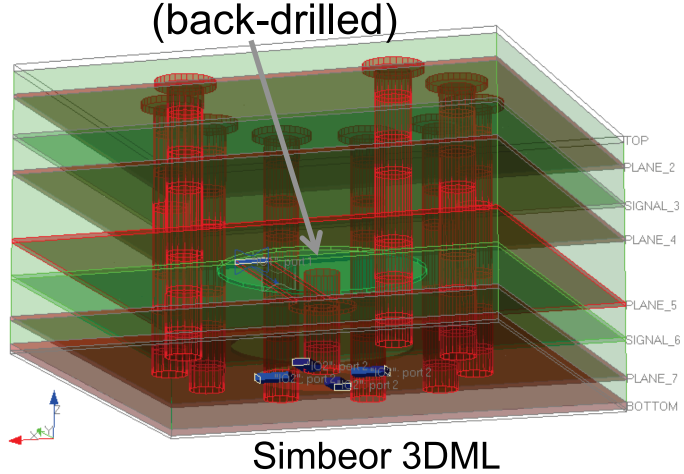


Connector + adapter model (added)

Launch model (back-drilled)

Connector + adapter model (added)

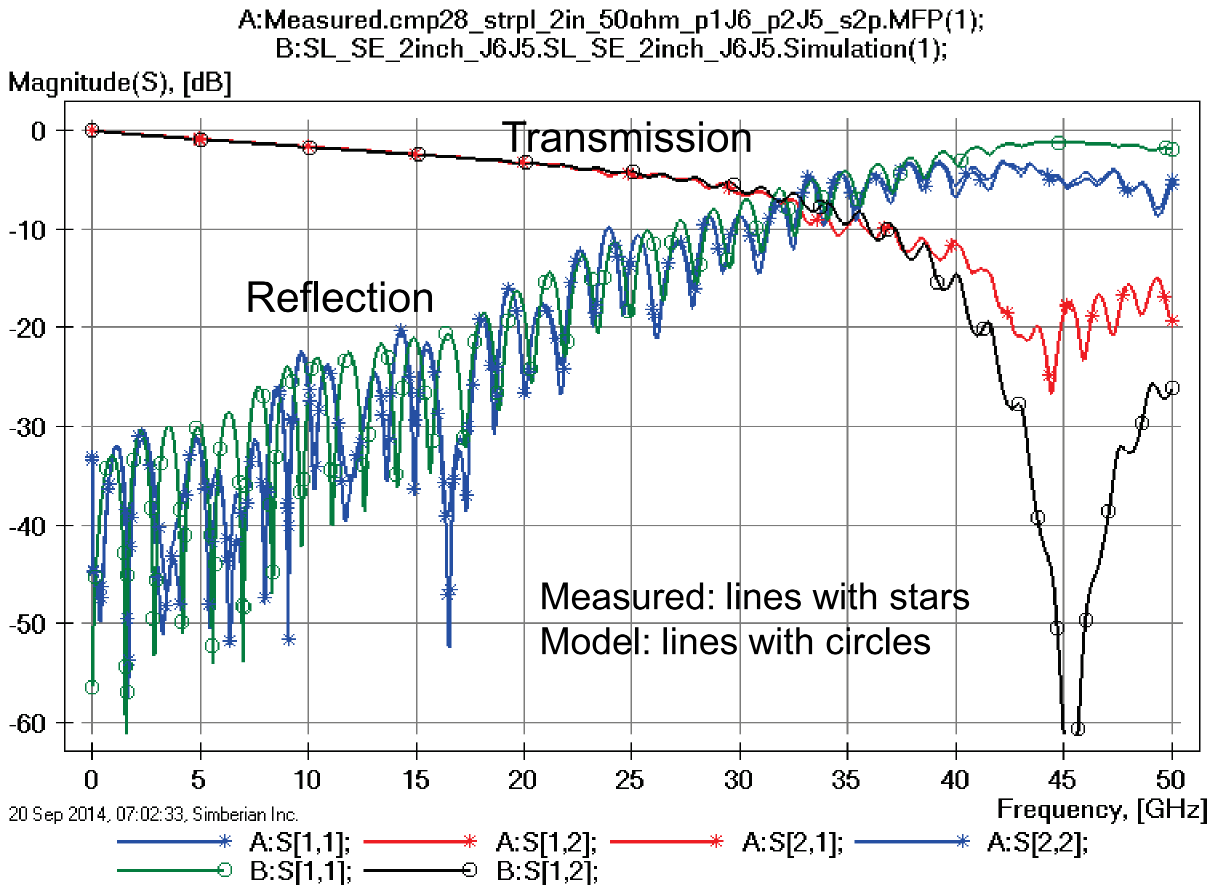
Connector + Launch are also simulated separately in PCB/SL_ConnectorAndLaunch for further reuse



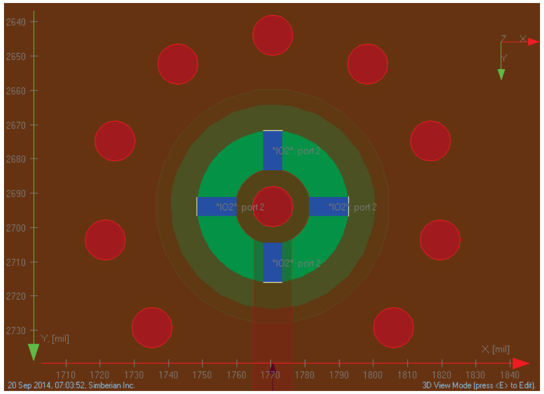
Simbeor 3DML

See also solution notes for SL SE 2-inch segment

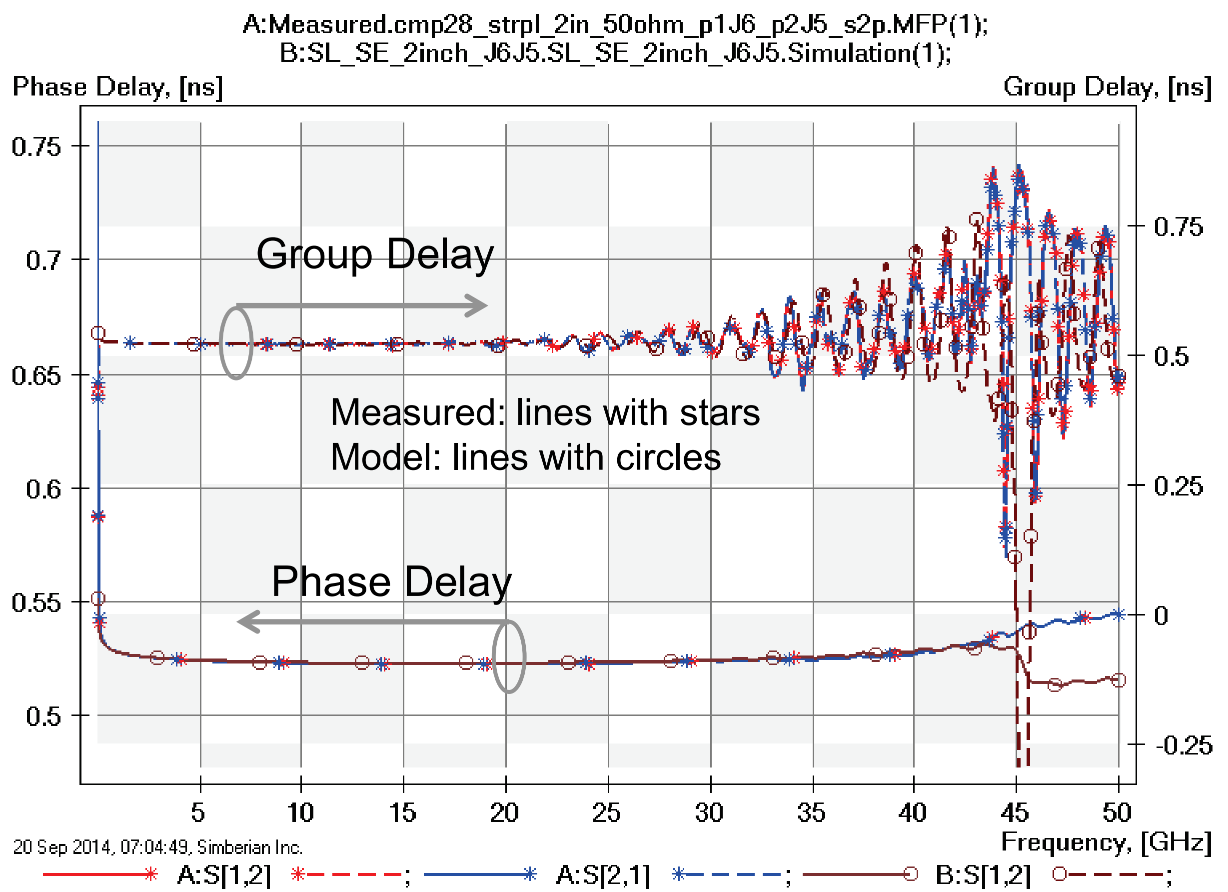
18) 2-inch strip line segment: Magnitude of S-parameters



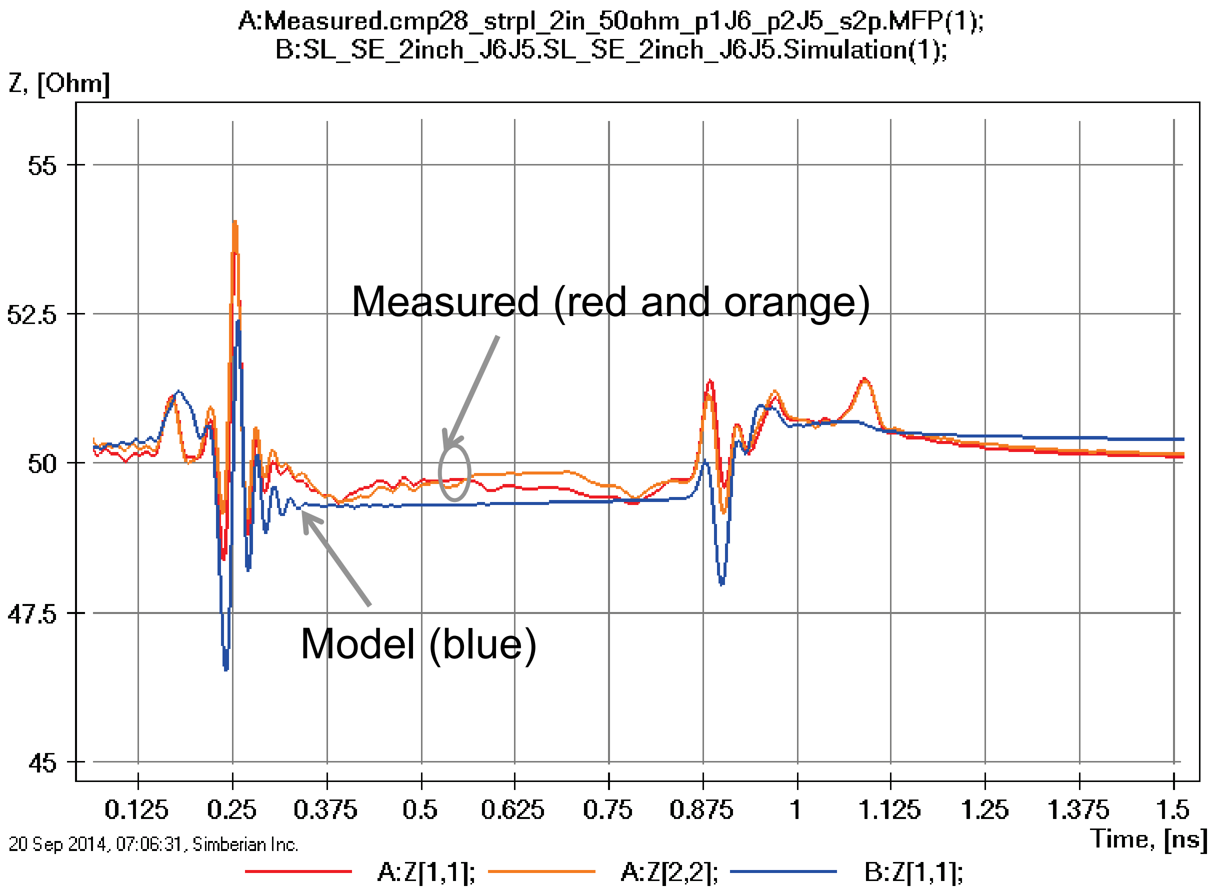
MS Launch looses the localization at about 30 GHz: Distance from signal via to stitching vias is about quarter of wavelength at 30 GHz – we cannot expect correlation above that frequency! Though, the impedance of the return path remains low due to plenty of stitching vias.



18) 2-inch strip line segment: Transmission phase and group delay

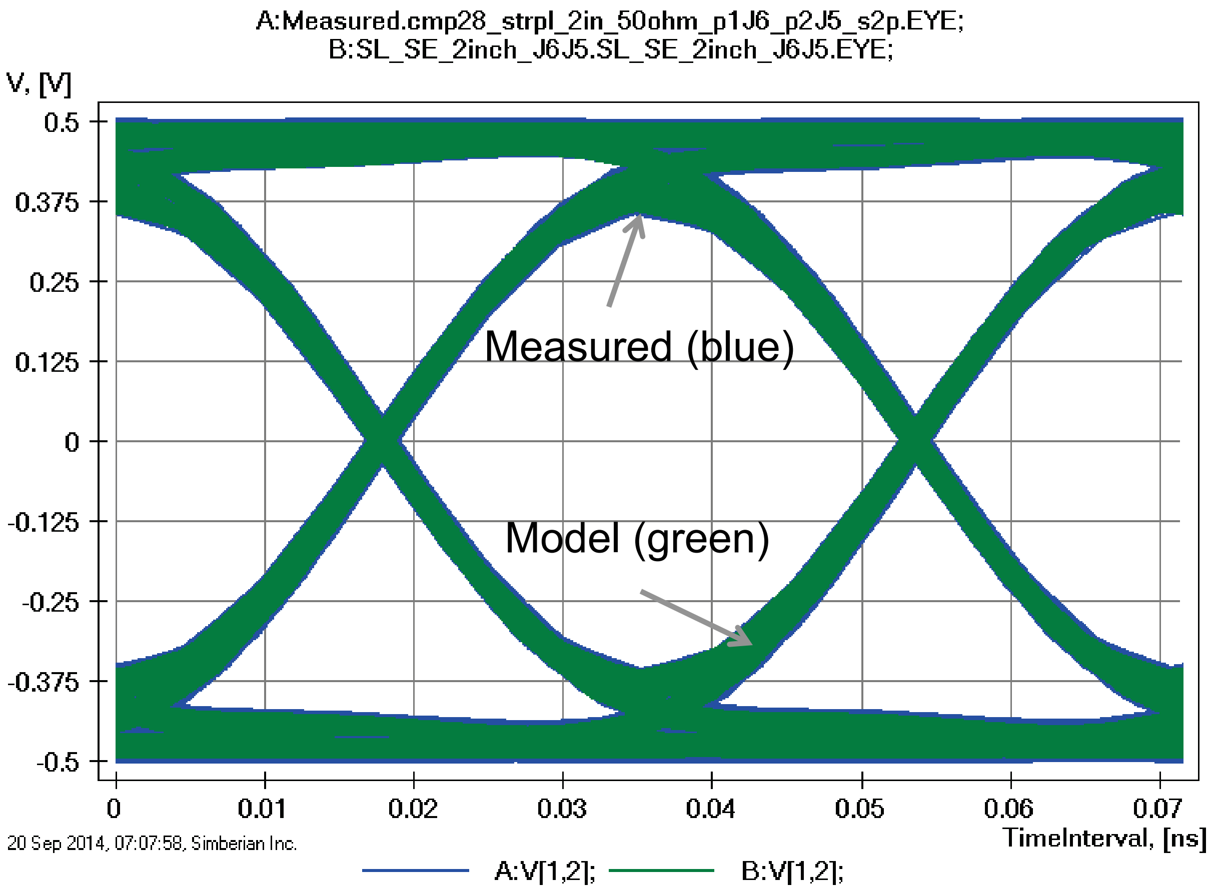


18) 2-inch strip line segment: TDR with 20 ps Gaussian step



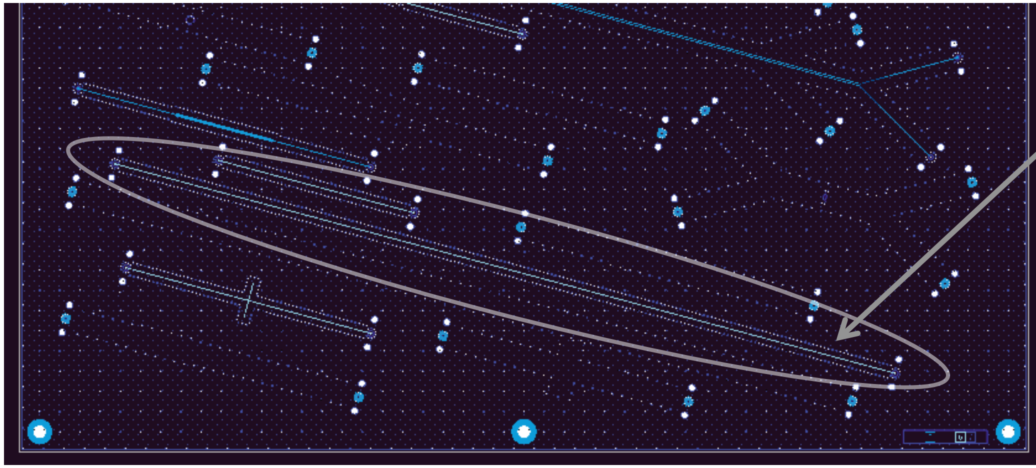
Variations of impedance along the traces visible here indicates that either trace width is varying or dielectric is inhomogeneous (or both); This is not accounted for in the model and explains differences in the reflection.

18) 2-inch strip line segment: 28 Gbps PRBS, 25 ps rise/fall time



Eyes are on top of each other!

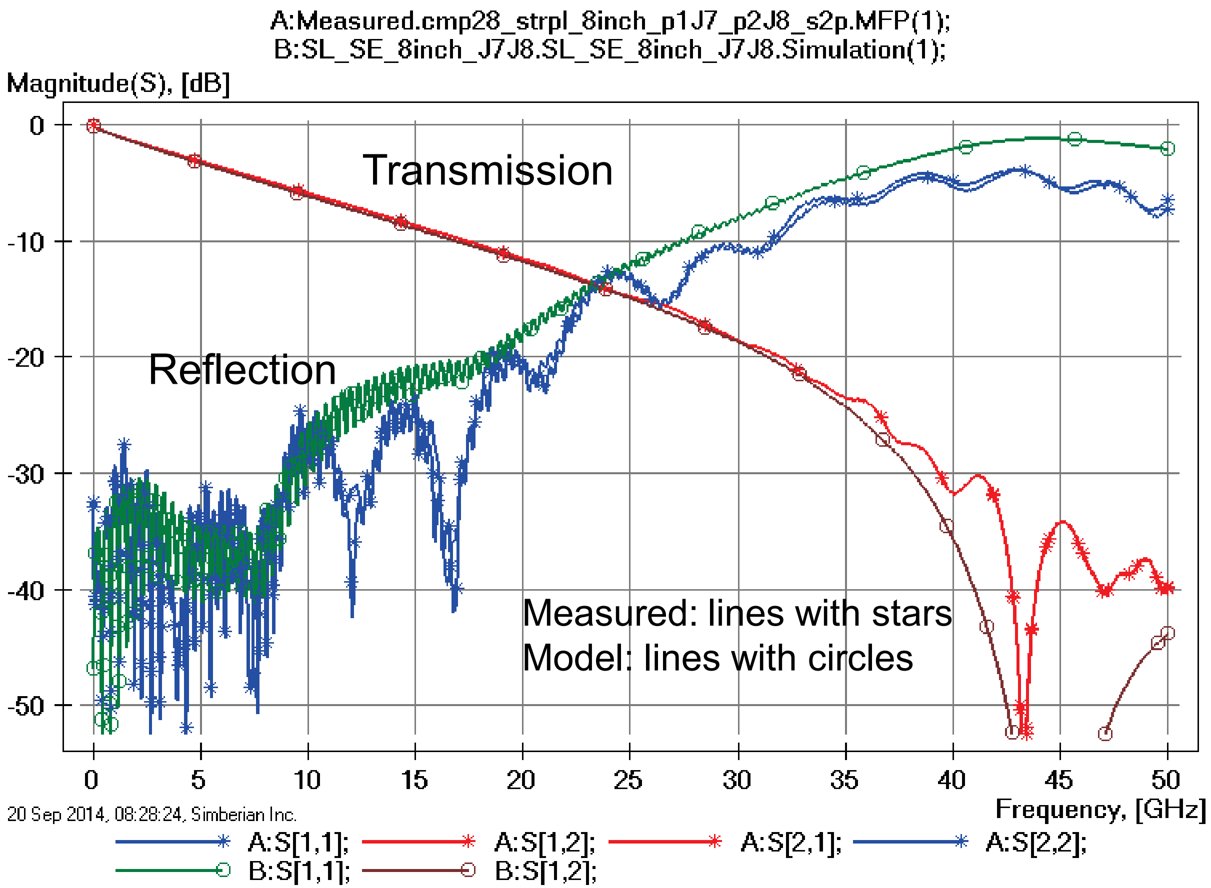
19) 8-inch strip line segment



SL SE 8-inch segment (J7-J8)
Solution: 8_StipSingle(1)
Measured:
cmp28_strpl_8inch_p1J7_p2J8.s2p
Selector/Project/Circuit: SL_SE_8inch_J7J8

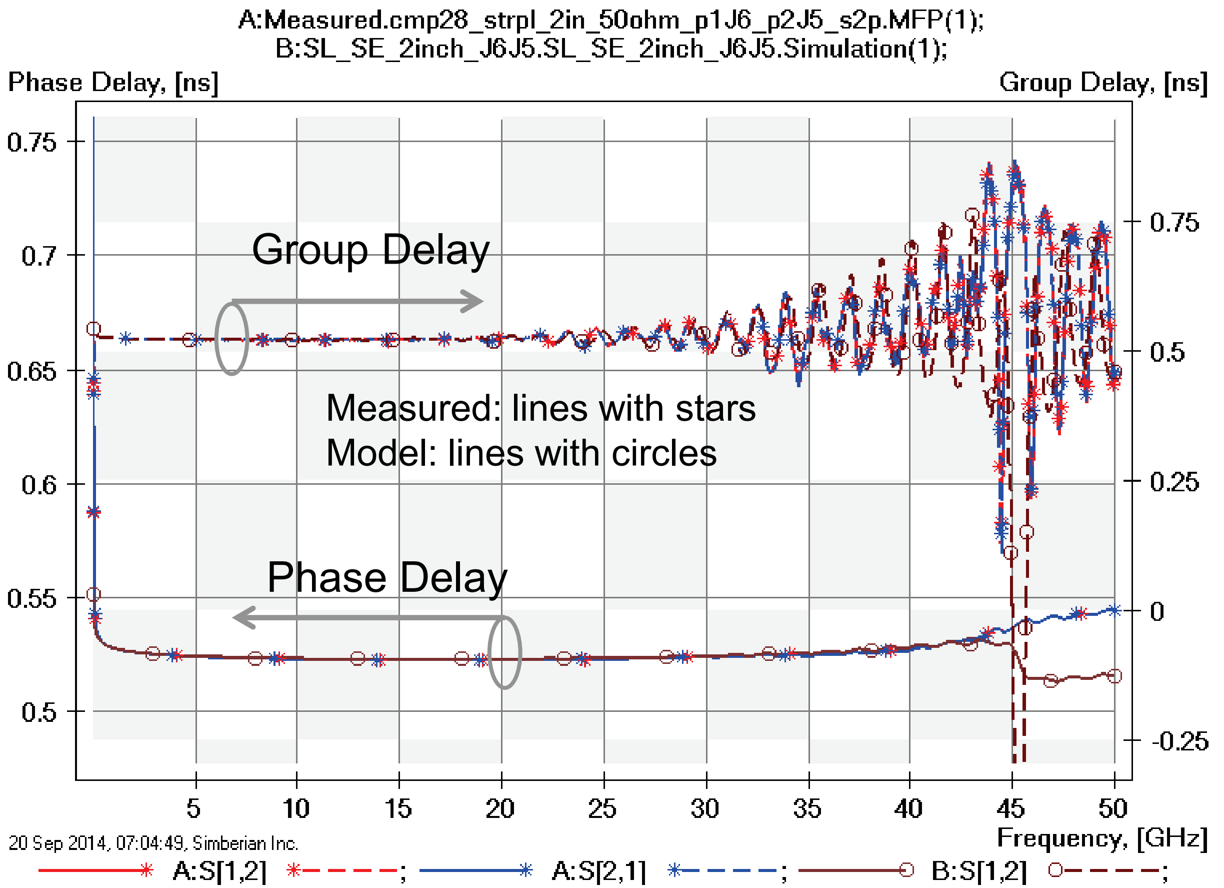
Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches (identical and set to re-use PCB\SL_ConnectorAndLaunch constructed with launch model from 2-inch segment analysis);
See also notes in the solution;

19) 8-inch strip line segment: Magnitude of S-parameters

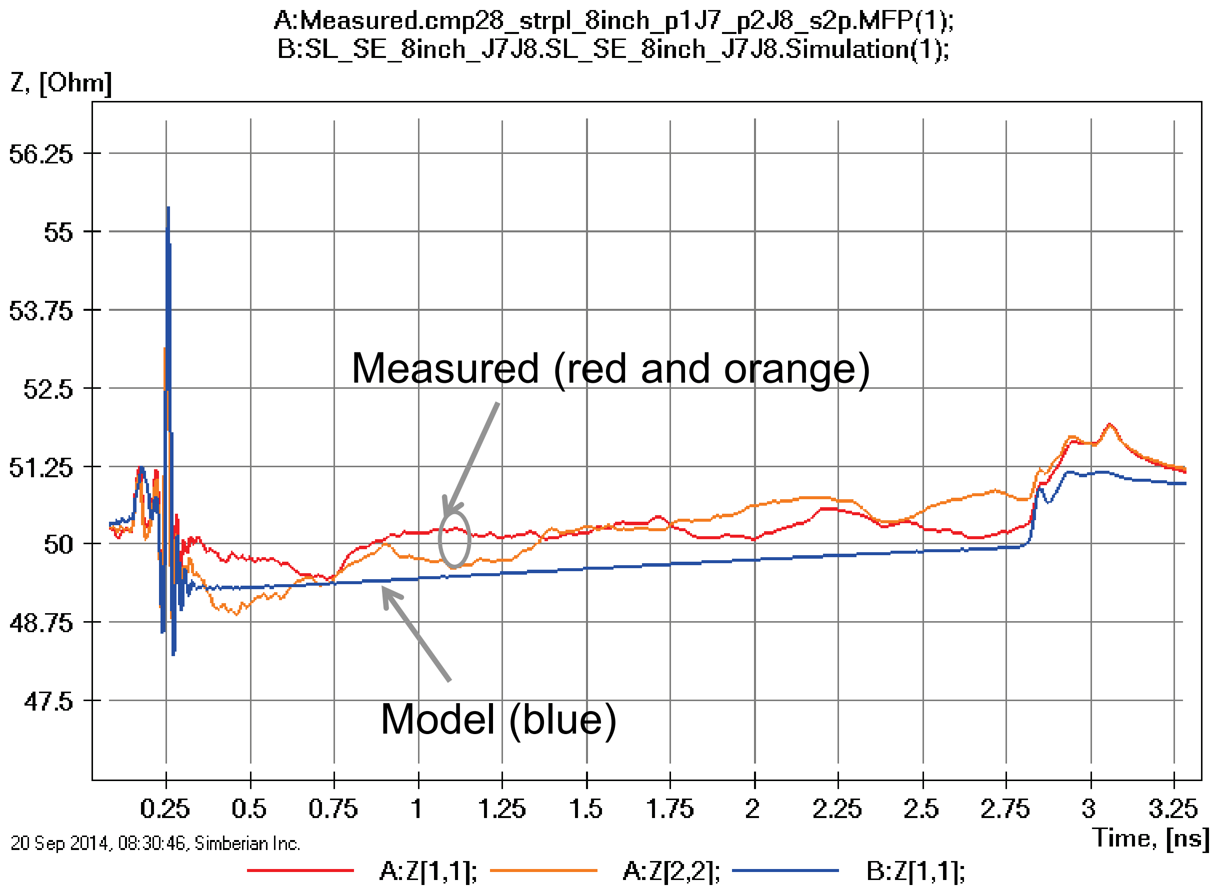


Loss of launch localization above 30 GHz explains additional insertion losses; Differences in back-drilling, variation of trace width and dielectric properties explains differences in reflection losses;

19) 8-inch strip line segment: Transmission phase and group delay

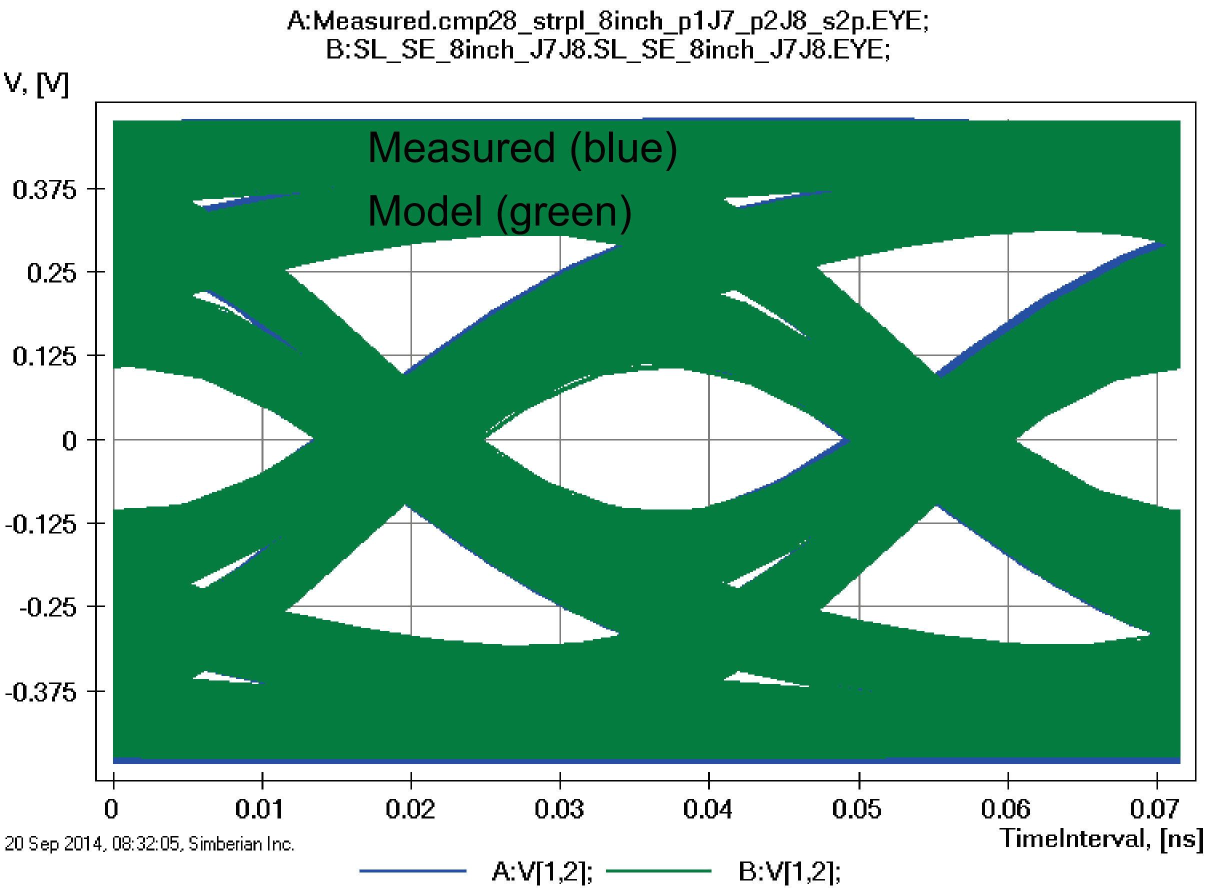


19) 8-inch strip line segment: TDR with 20 ps Gaussian step



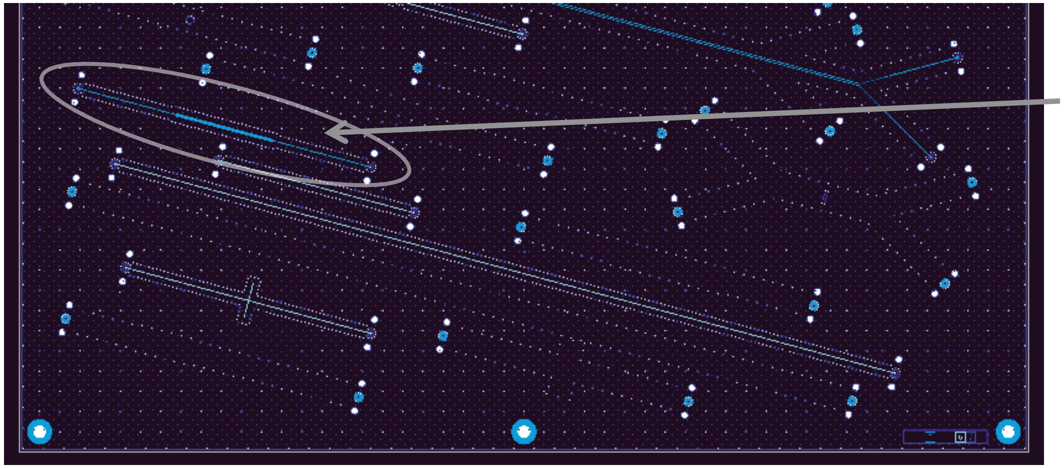
Variations of impedance along the traces visible here indicates that either trace width is varying or dielectric is inhomogeneous (or both); This is not accounted for in the model and explains differences in the reflection.

19) 8-inch strip line segment: 28 Gbps PRBS, 25 ps rise/fall time



Eyes are on top of each other!

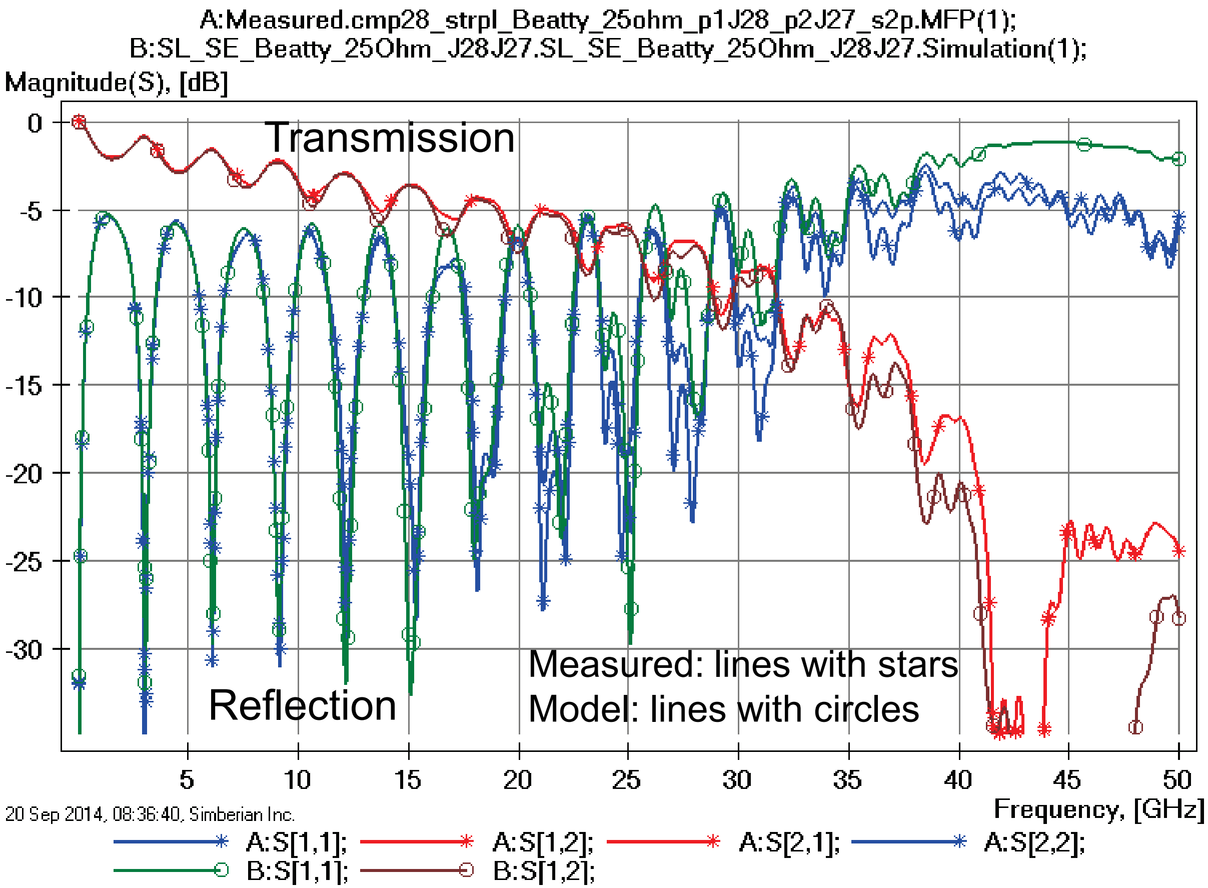
20) Strip 25-Ohm Beatty standard



SL SE Beatty standard (J27-J28)
Solution: 8_StipSingle(1)
Measured:
cmp28_strpl_Beatty_25ohm_p1J28_p2J27.s2p
Selector/Project/Circuit:
SL_SE_Beatty_25Ohm_J28J27

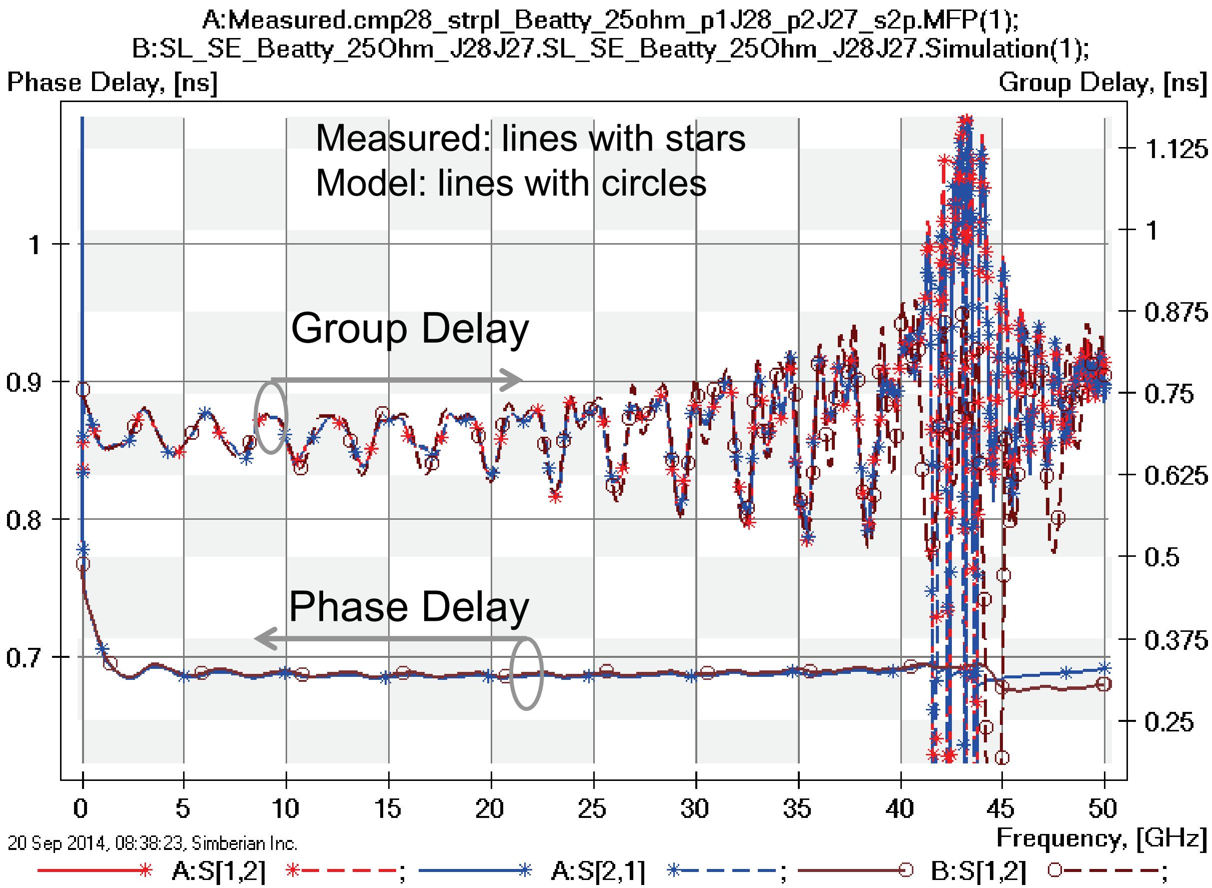
Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches (identical and set to re-use PCB\SL_ConnectorAndLaunch constructed with launch model from 2-inch segment analysis);
Additional 2 discontinuity selectors created for steps (identical and re-used);
See also notes in the solution;

20) Strip 25-Ohm Beatty standard: Magnitude of S-parameters

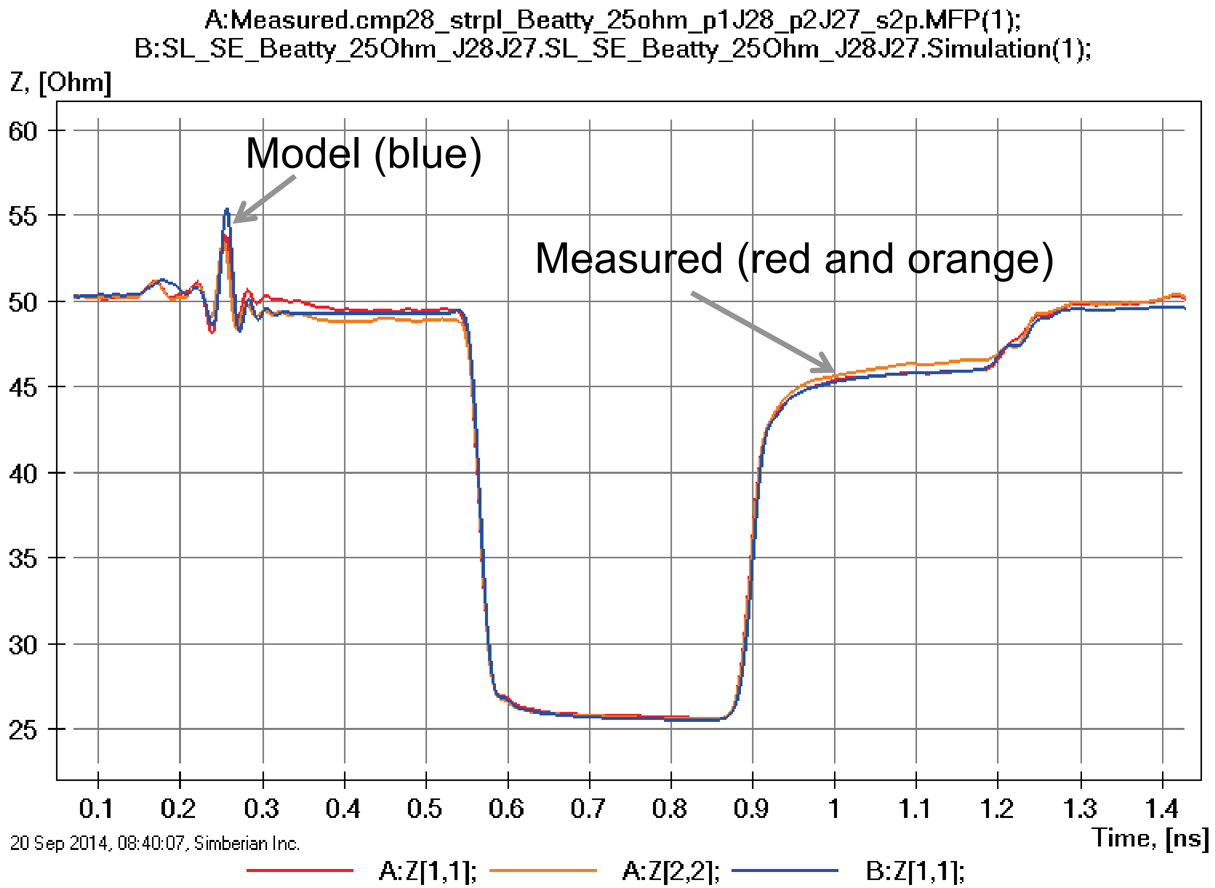


Loss of launch localization above 30 GHz explains additional insertion losses; Differences in back-drilling, variation of trace width and dielectric properties explains differences in reflection losses;

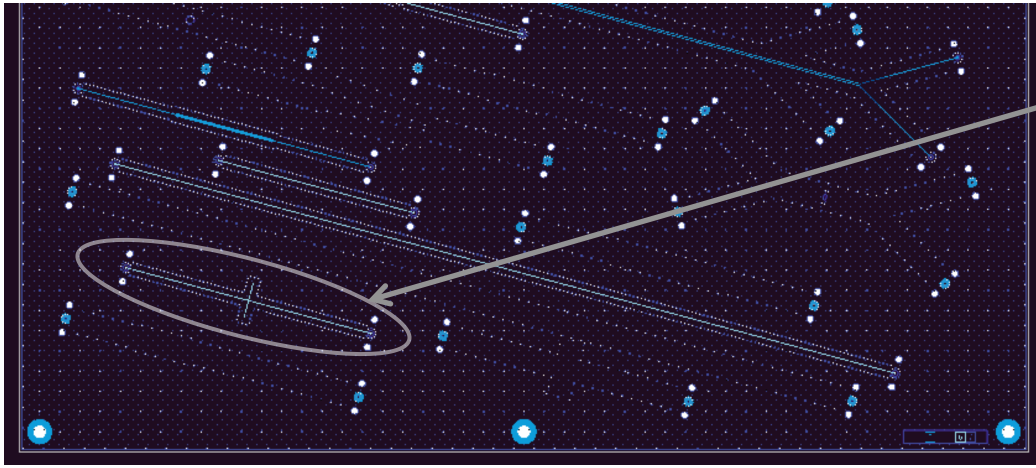
20) Strip 25-Ohm Beatty standard: Transmission phase and group delay



20) Strip 25-Ohm Beatty standard: TDR with 20 ps Gaussian step



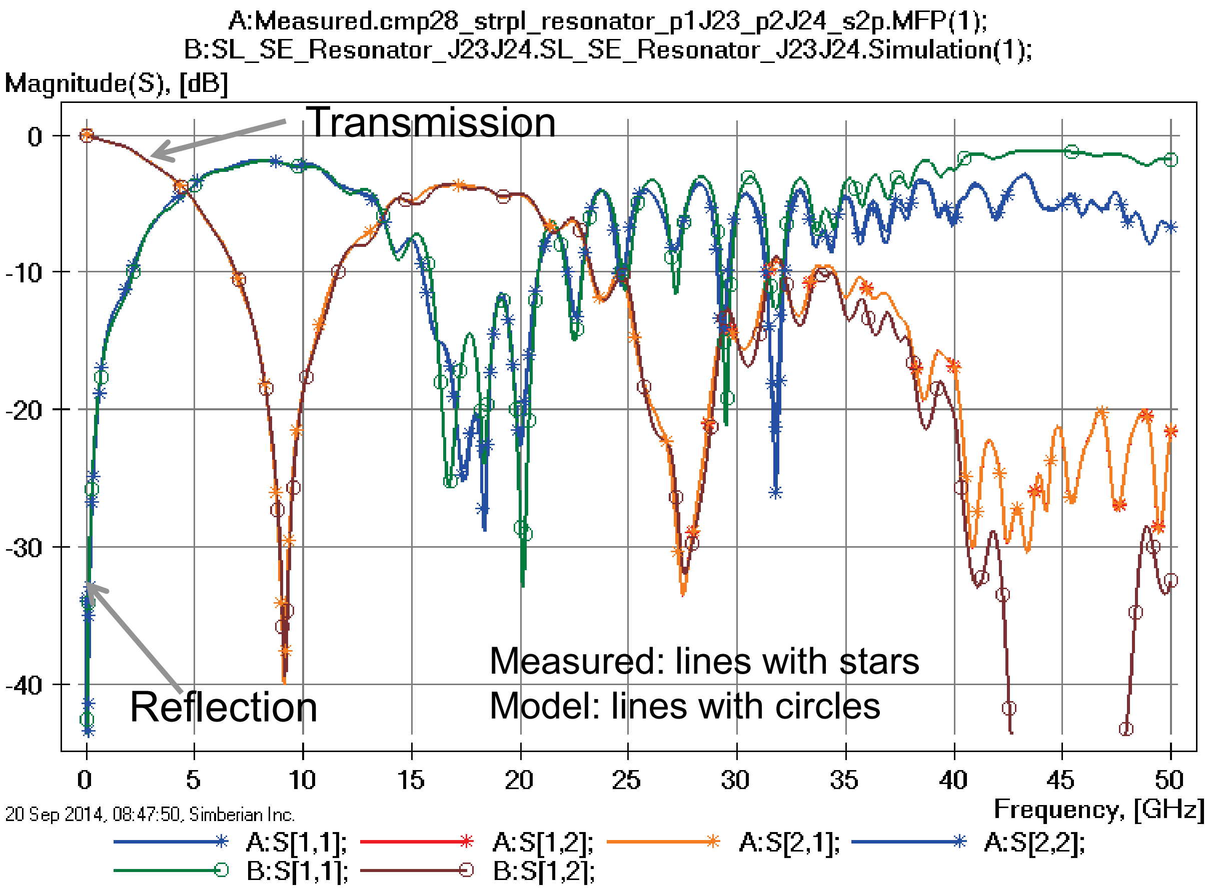
21) Strip stub resonator



SL SE strip stub resonator (J23-J24)
Solution: 8_StipSingle(1)
Measured:
cmp28_strpl_resonator_p1J23_p2J24.s2p
Selector/Project/Circuit:
SL_SE_Resonator_J23J24

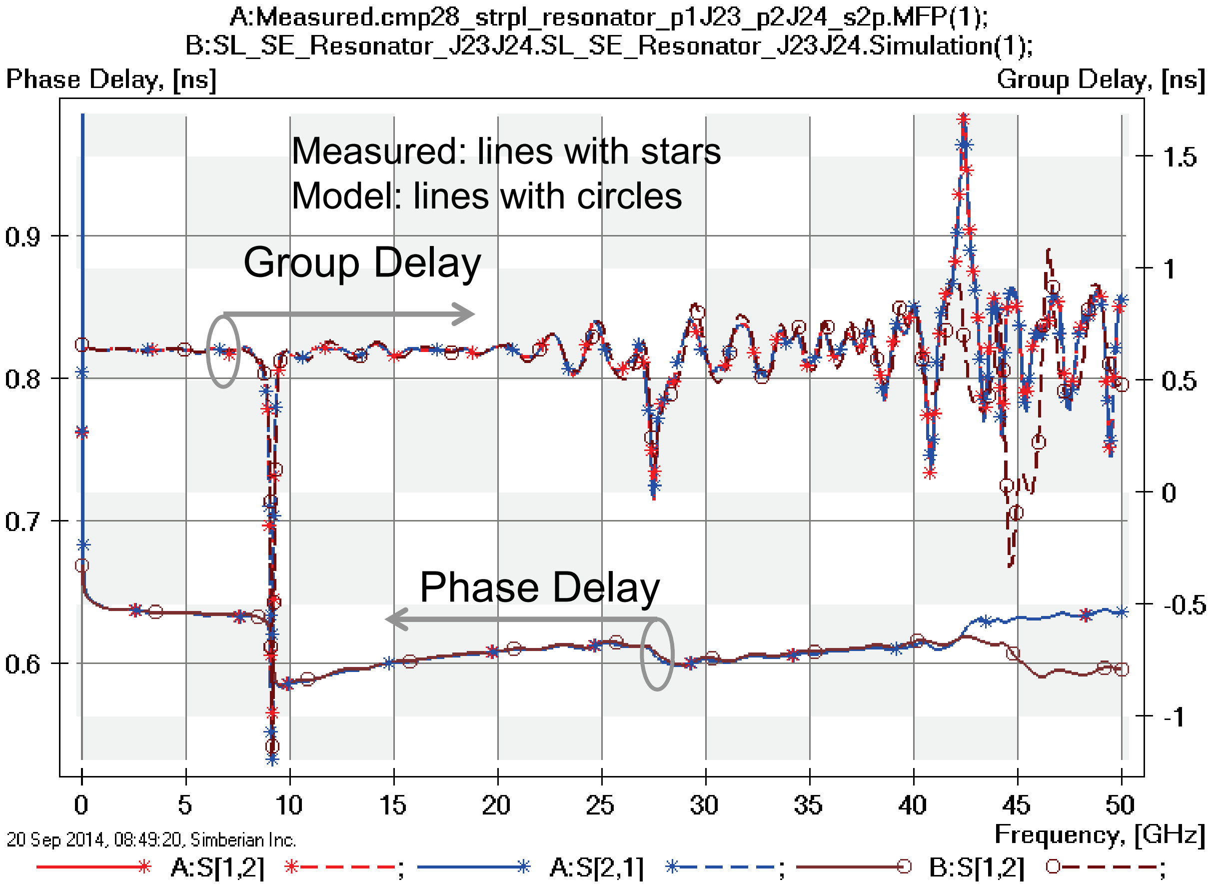
Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches (identical and set to re-use PCB\SL_ConnectorAndLaunch constructed with launch model from 2-inch segment analysis);
Additional discontinuity selector is created for X-junction and 2 discontinuity selectors are created for open-ends (identical and re-used);
See also notes in the solution;

21) Strip stub resonator: Magnitude of S-parameters

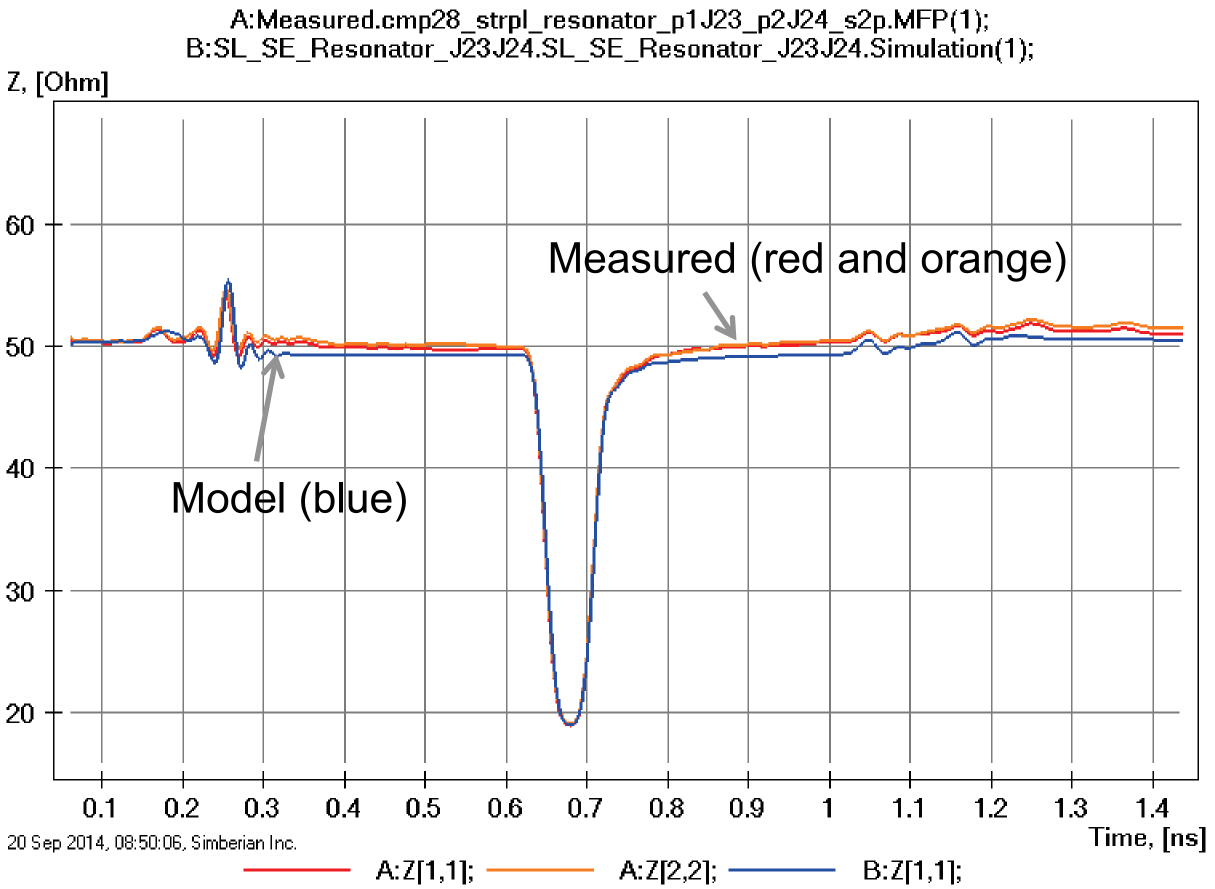


Loss of launch localization above 30 GHz explains additional insertion losses; Differences in back-drilling, variation of trace width and dielectric properties explains differences in reflection losses;

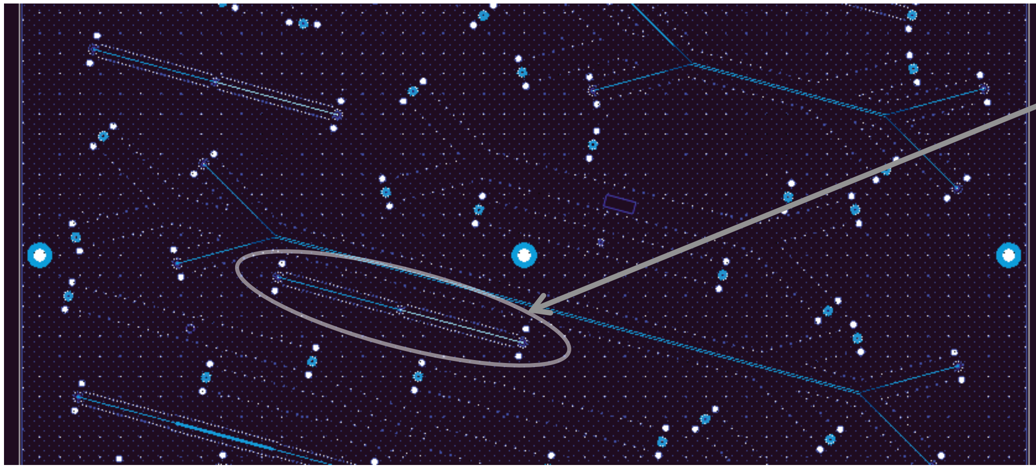
21) Strip stub resonator: Transmission phase and group delay



21) Strip stub resonator: TDR with 20 ps Gaussian step



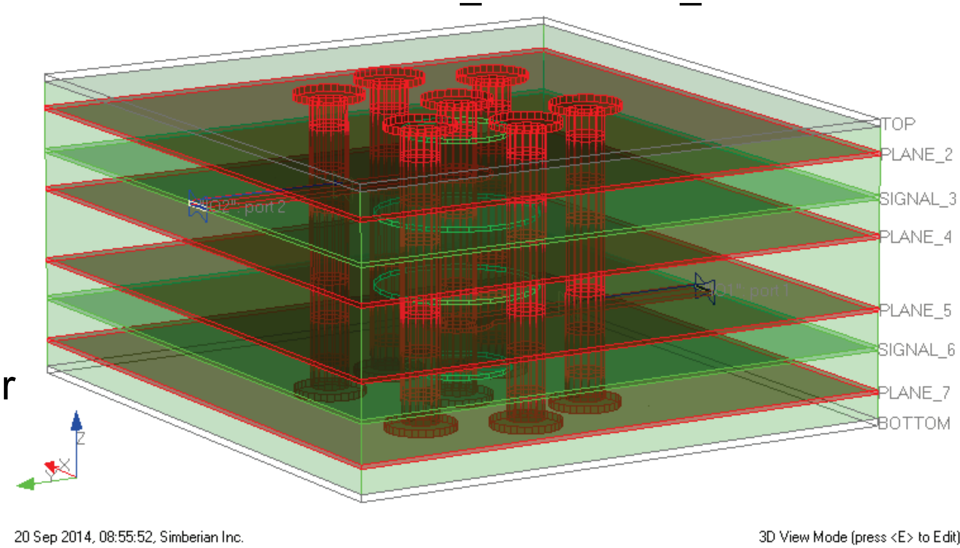
22) Strip line with capacitive via



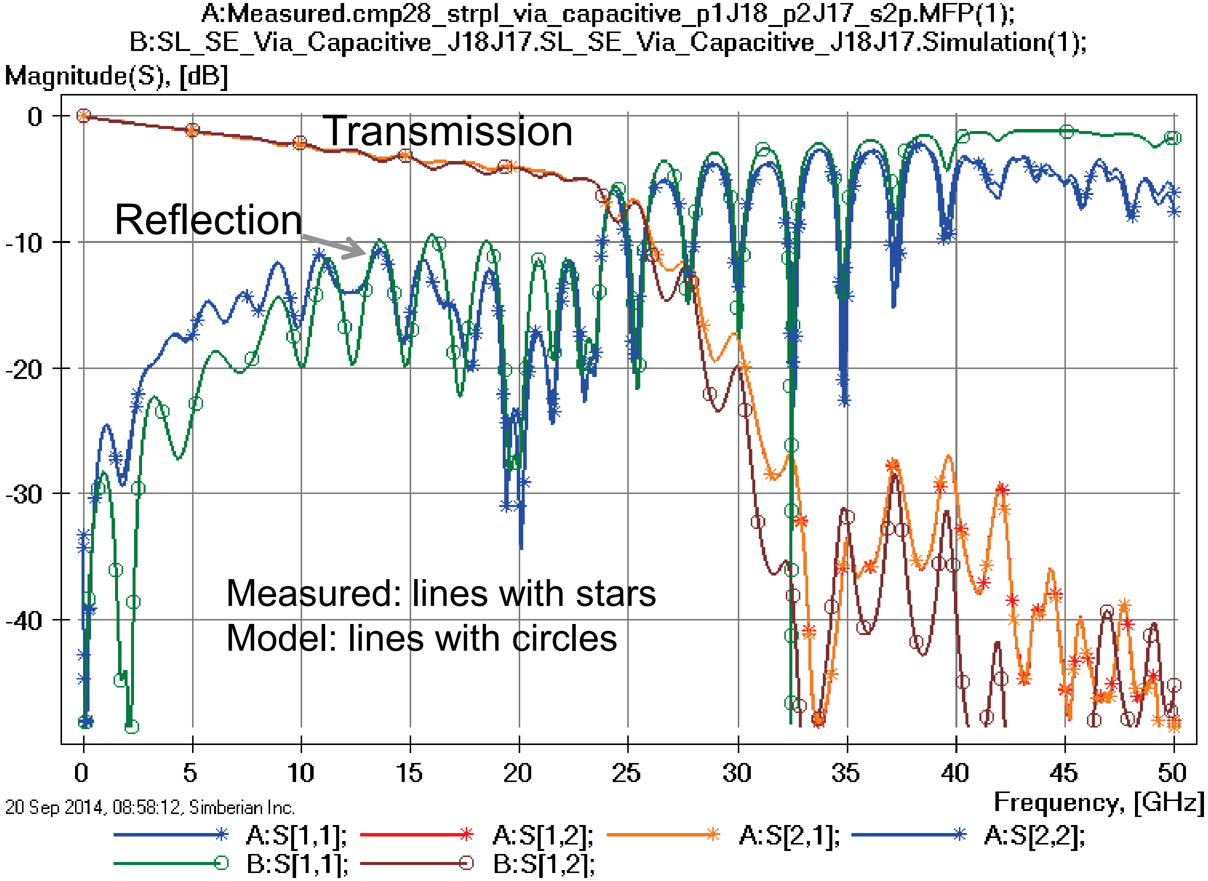
SL SE strip with capacitive via (J17-J18)
Solution: 9_StipSingle(2)
Measured:
cmp28_strpl_via_capacitive_p1J18_p2J17.s2p
Selector/Project/Circuit:
SL_SE_Via_Capacitive_J18J17

Via has stubs and small anti-pads in PLANE_2 and Plane_7

Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches (identical and set to re-use PCB\SL_ConnectorAndLaunch constructed with launch model from 2-inch segment analysis);
Additional discontinuity selector is created for via (shown on the right);
See also notes in the solution;

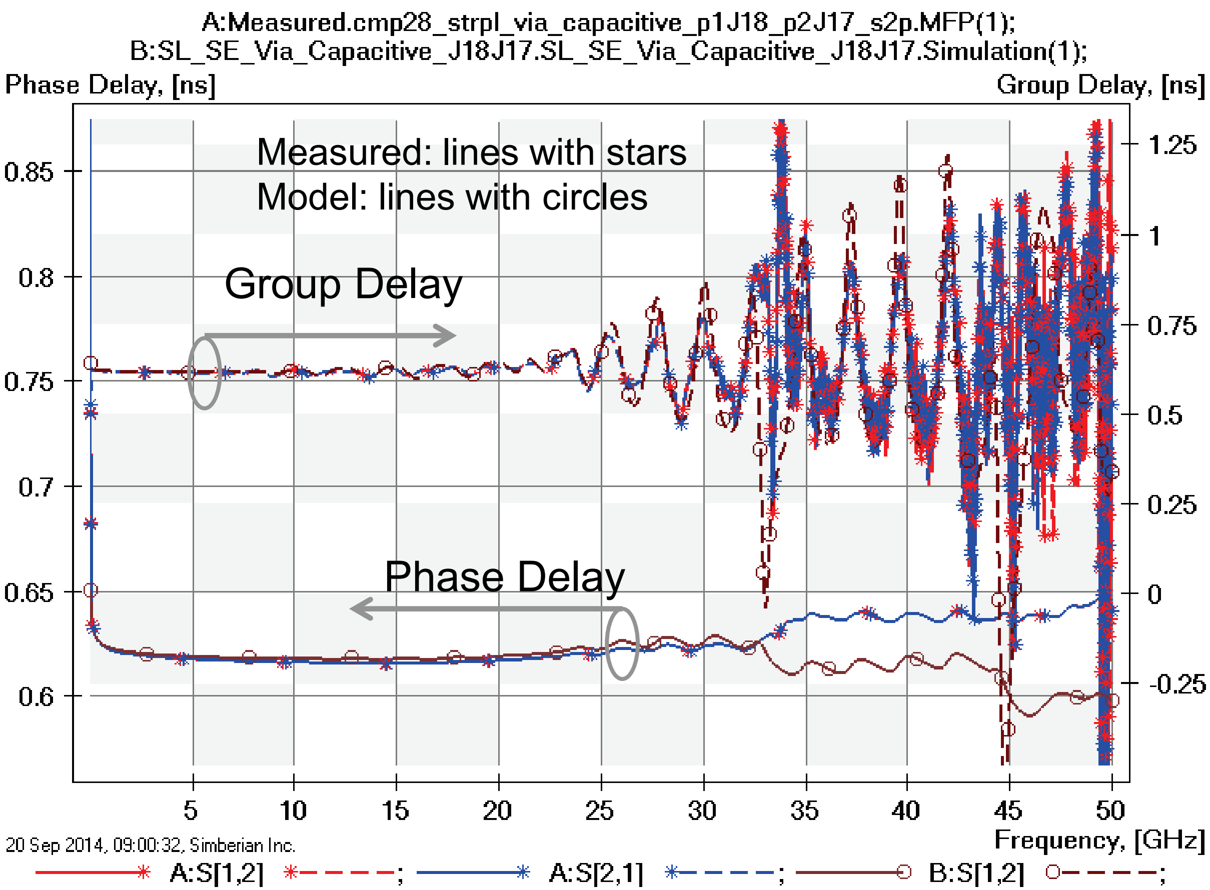


22) Strip line with capacitive via: Magnitude of S-parameters



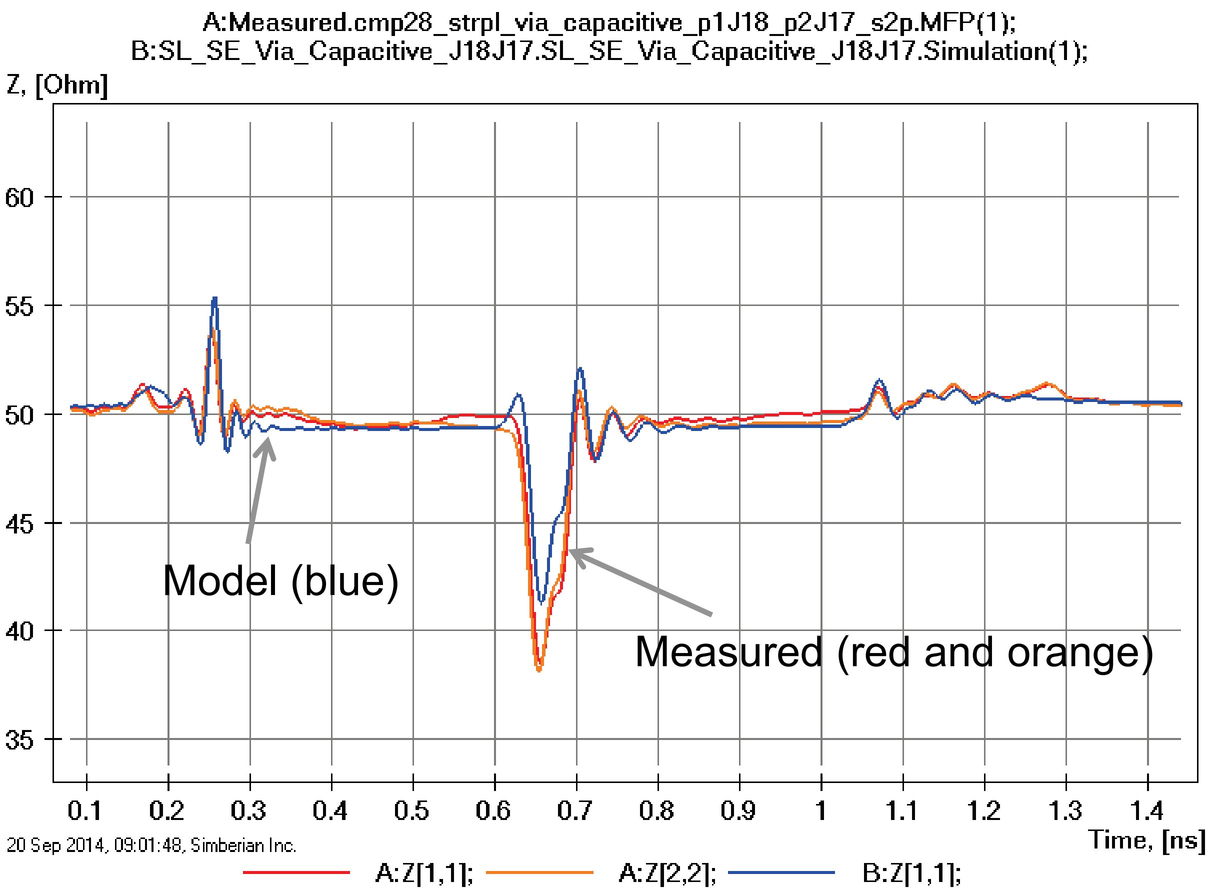
Loss of launch localization above 30 GHz explains additional insertion losses; Variation of via geometry explains differences in reflection losses;

22) Strip line with capacitive via: Transmission phase and group delay



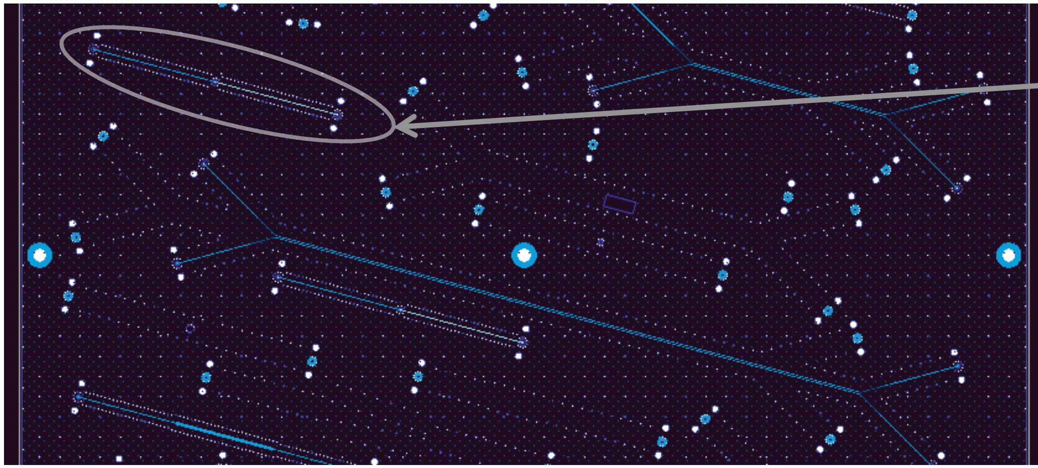
Discrepancies above 30 GHz

22) Strip line with capacitive via: TDR with 20 ps Gaussian step



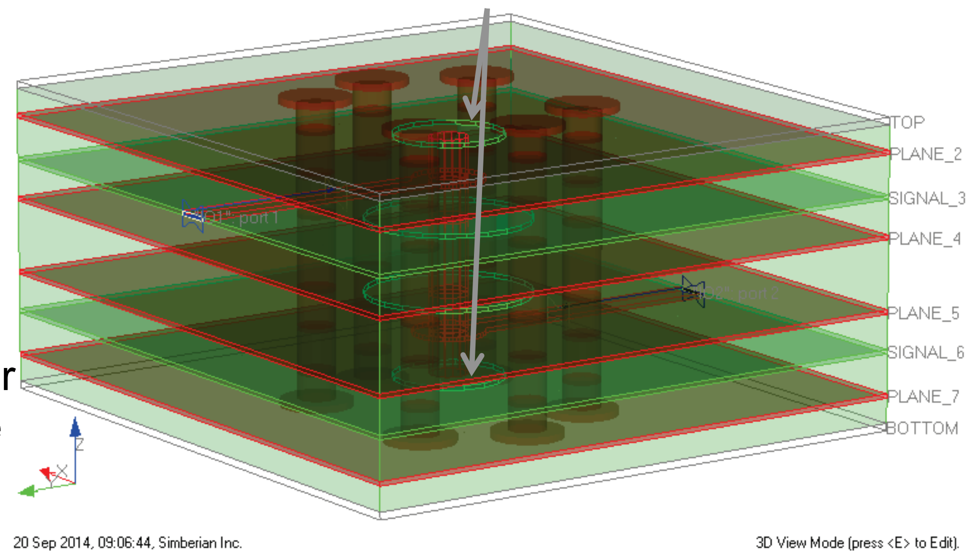
Variations of via geometry may explain additional capacitance (off-center drilling for instance);

23) Strip line with back-drilled via



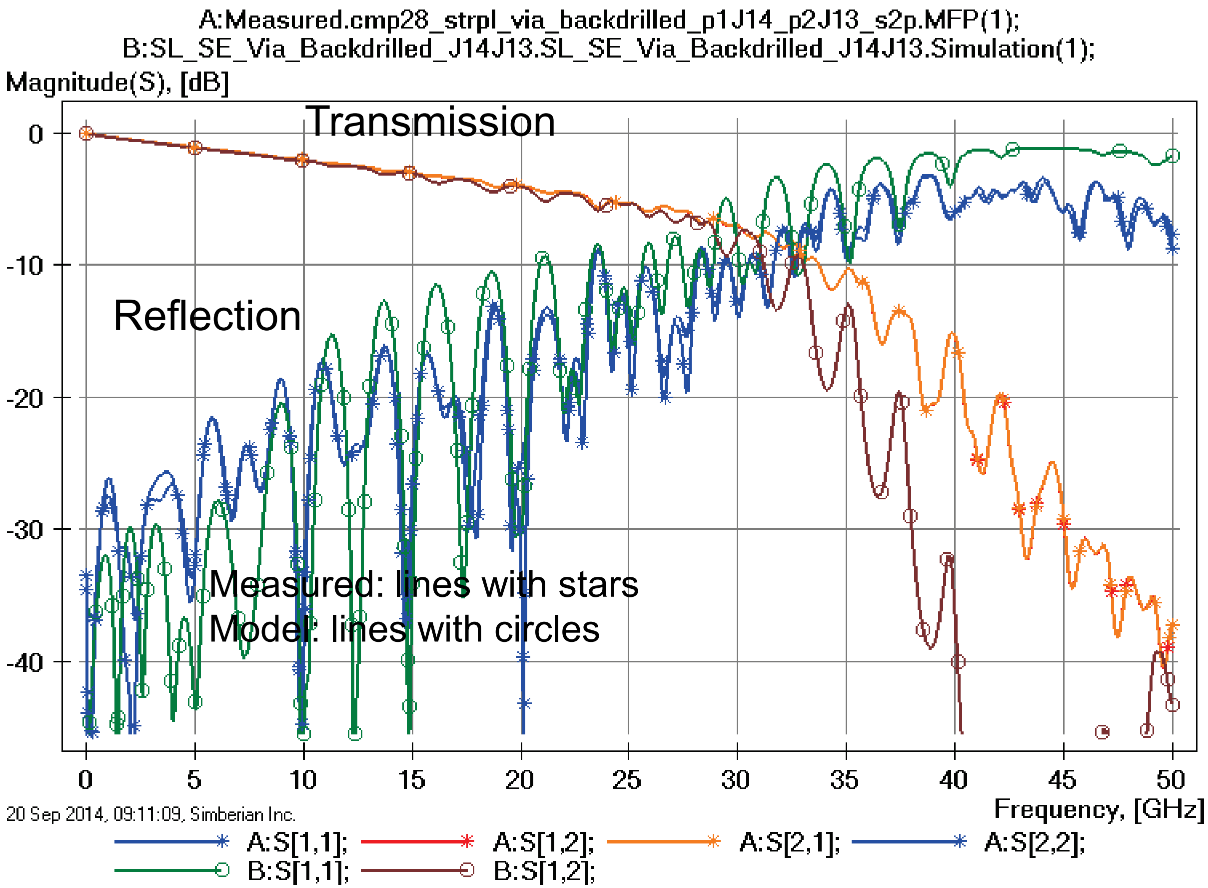
SL SE strip with back-drilled via (J13-J14)
Solution: 9_StipSingle(2)
Measured:
cmp28_strpl_via_backdrilled_p1J14_p2J13.s2p
Selector/Project/Circuit:
SL_SE_Via_Backdrilled_J14J13

Via barrel span is from PLANE_2
to Plane_7 (worst case back-drill)



Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches (identical and set to re-use PCB\SL_ConnectorAndLaunch constructed with launch model from 2-inch segment analysis);
Additional discontinuity selector is created for via and edited after extraction (shown on the right);
See also notes in the solution;

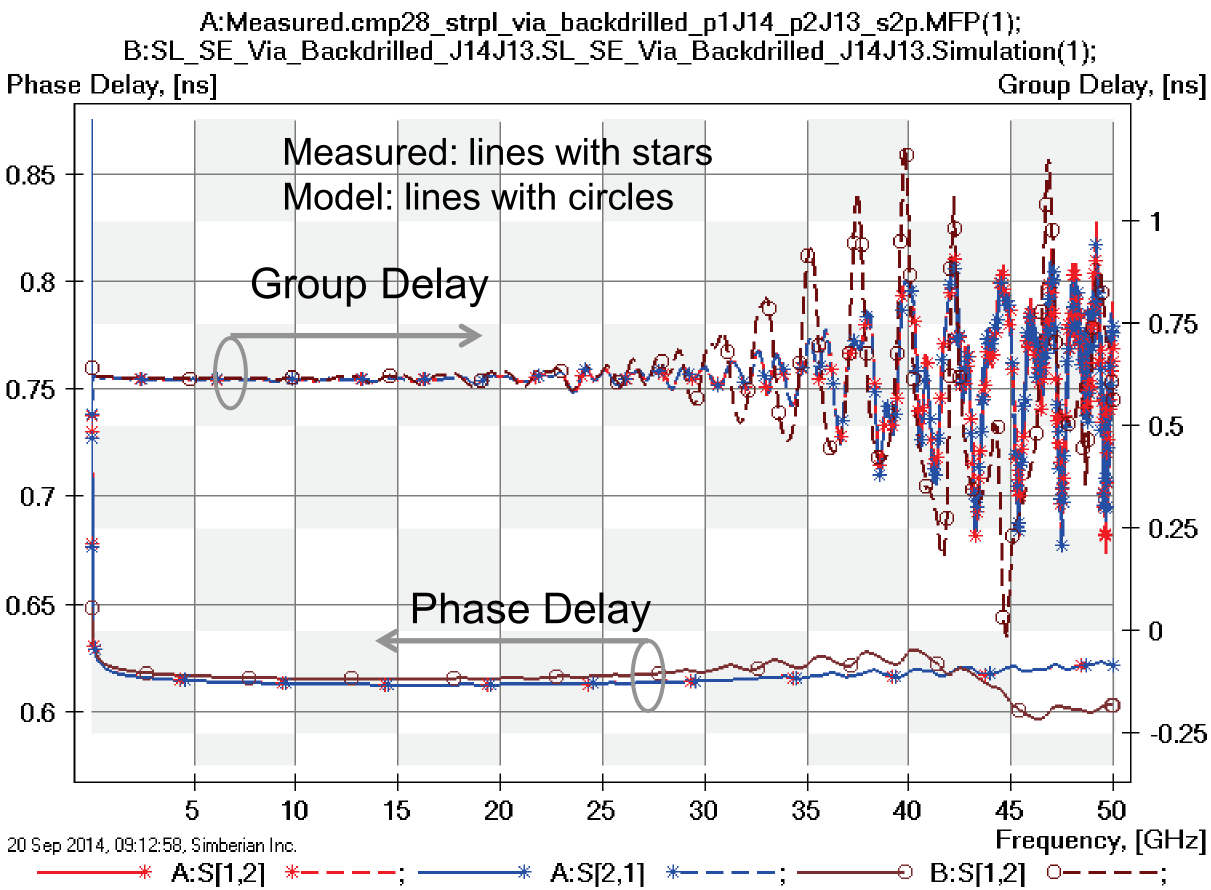
23) Strip line with back-drilled via: Magnitude of S-parameters



Discrepancies above 30 GHz

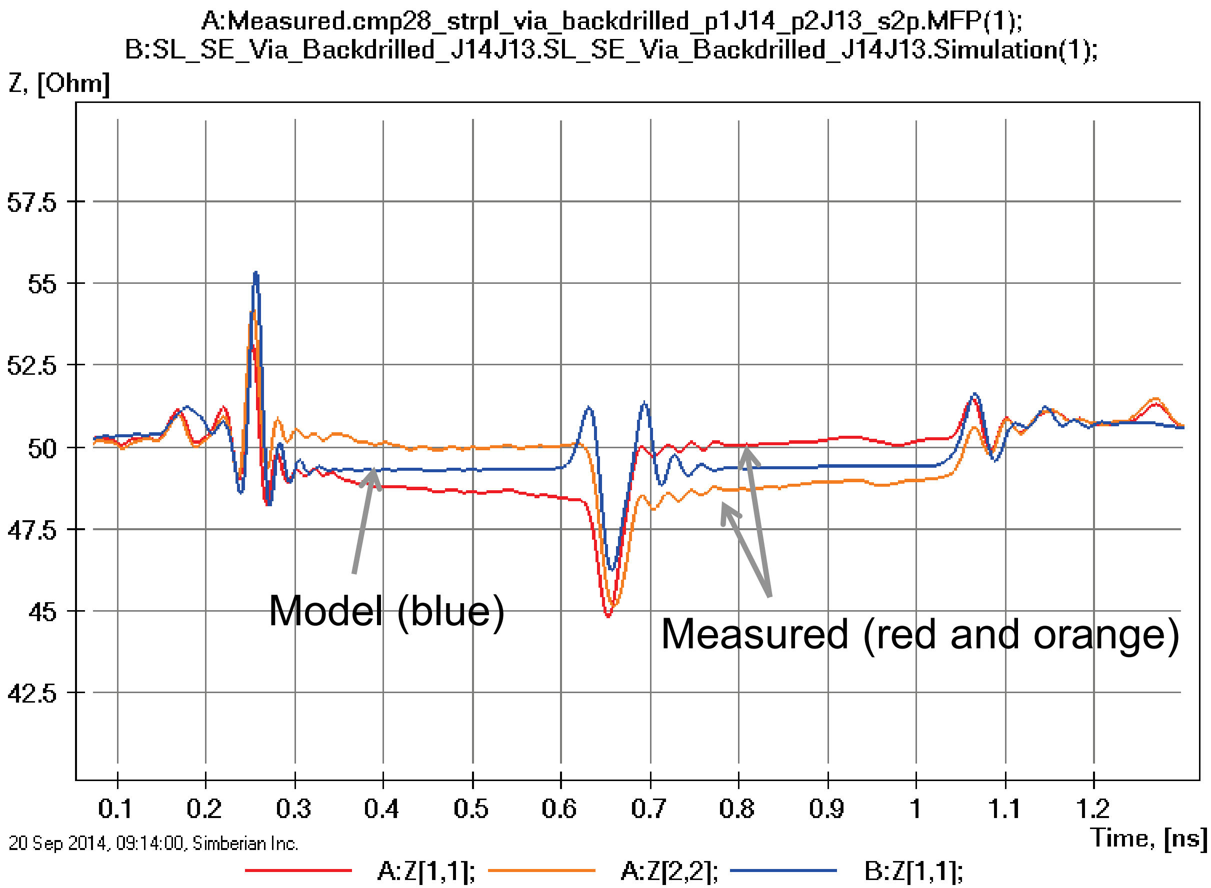
Variation of via geometry (back-drilling) explains differences both in insertion and reflection losses;

23) Strip line with back-drilled via: Transmission phase and group delay



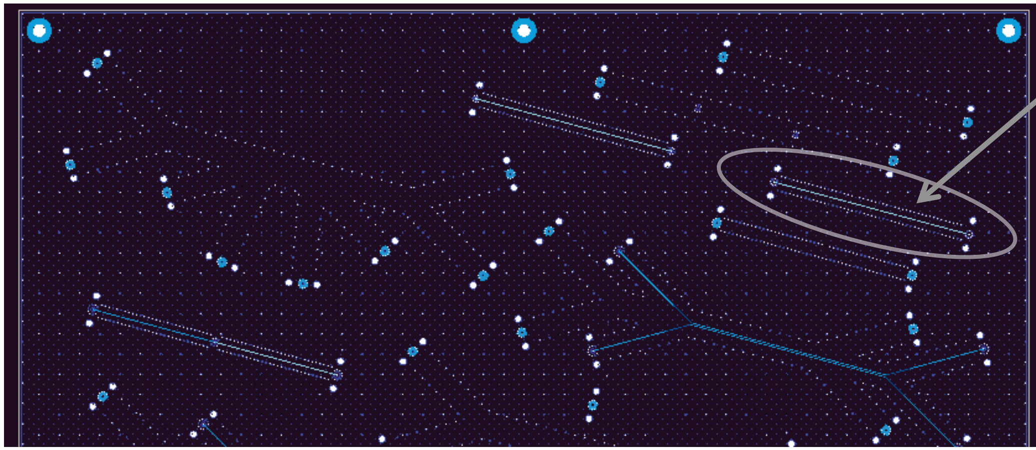
Discrepancies above 30 GHz

23) Strip line with back-drilled via: TDR with 20 ps Gaussian step



Variations of via back-drilling and trace geometry explains differences;

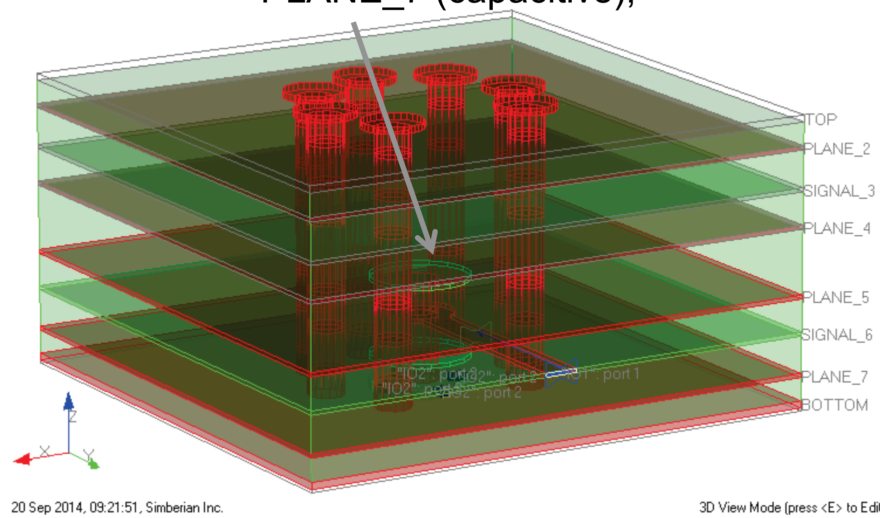
24) 2-inch strip line with capacitive launch



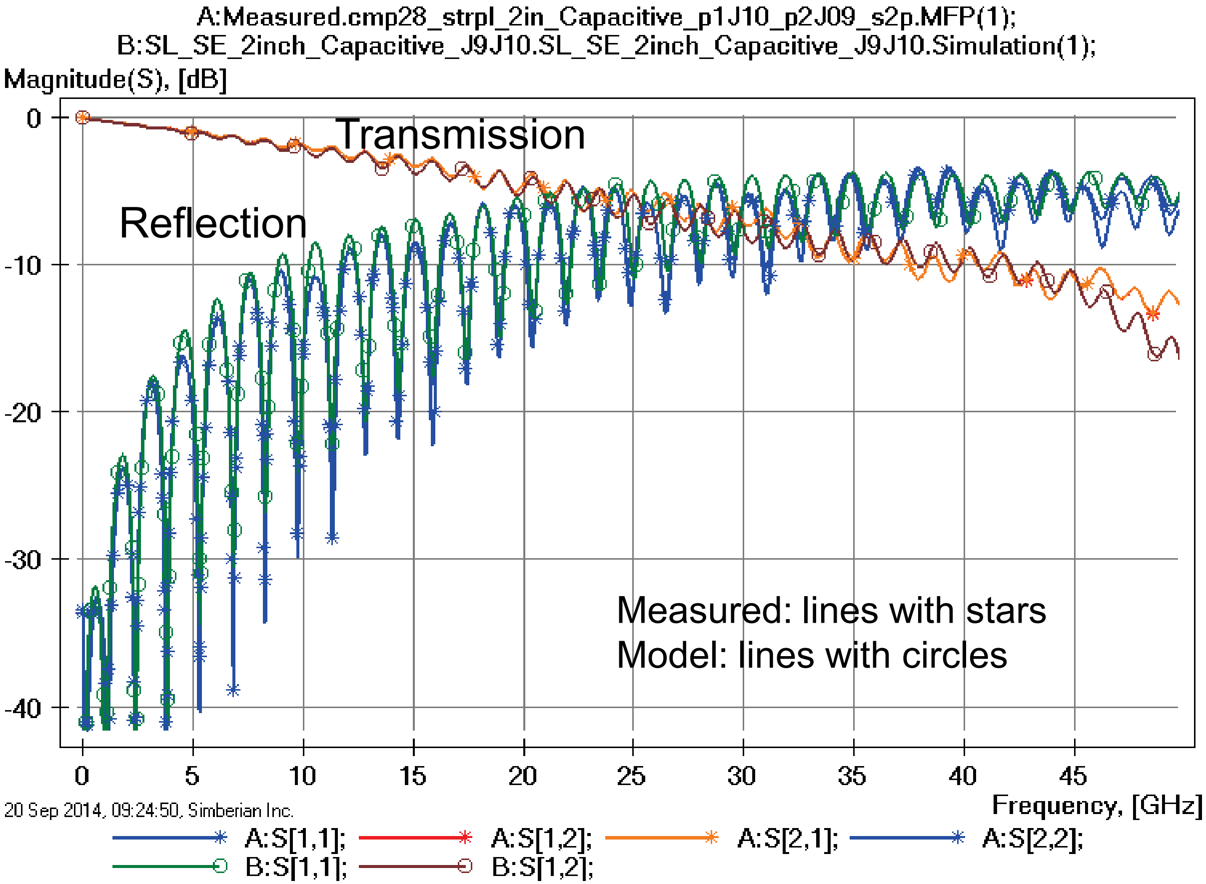
SL SE 2 in strip with capacitive launch (J9-J10)
Solution: 9_StipSingle(2)
Measured:
cmp28_strpl_2in_Capacitive_p1J10_p2J09.s2p
Selector/Project/Circuit:
SL_SE_2inch_Capacitive_J9J10

Via barrel is reduced to PLANE_5;
Small anti-pads in PLANE_5 and PLANE_7 (capacitive);

Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches are created and edited after extraction to account for the back-drilling (identical and set to re-used);
Connector models are added to linear network after the extraction;
See also notes in the solution;

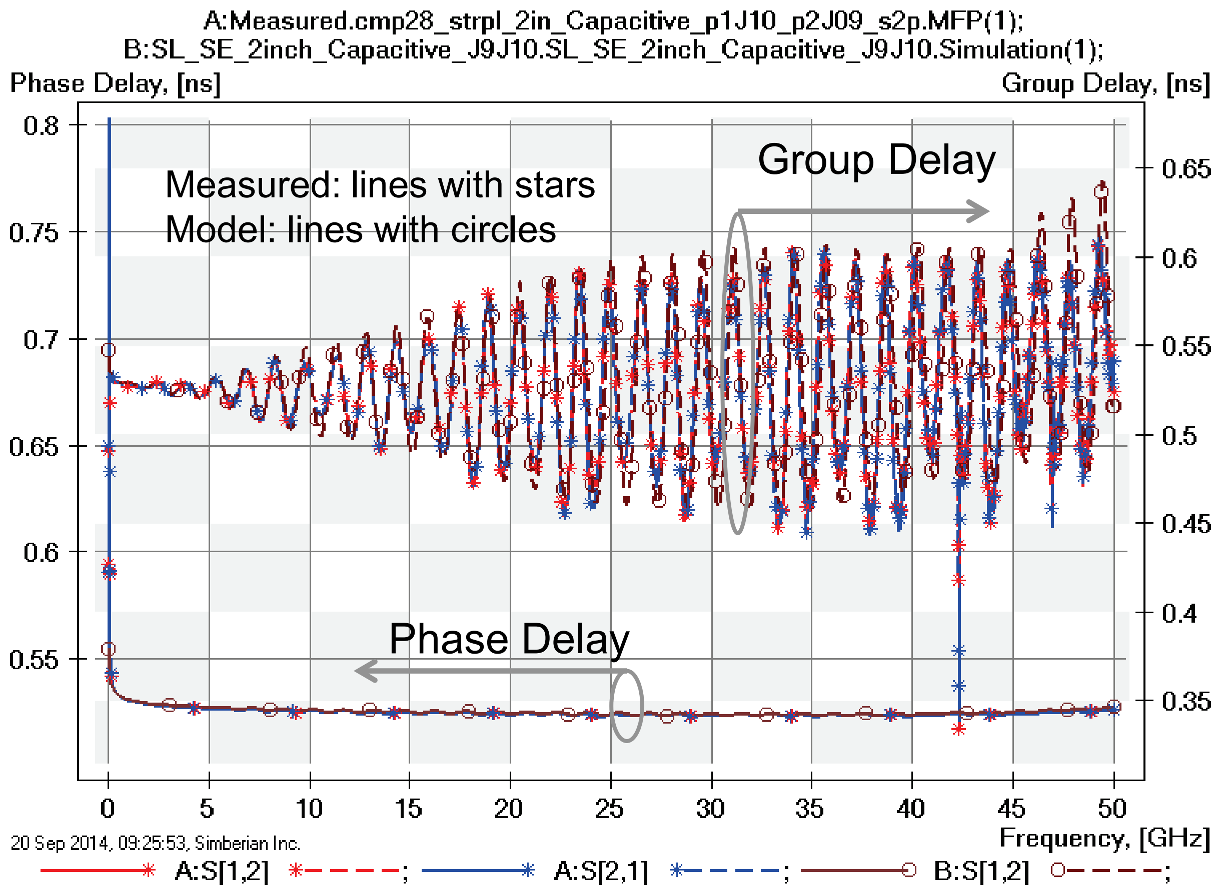


24) 2-inch strip line with capacitive launch: Magnitude of S-parameters

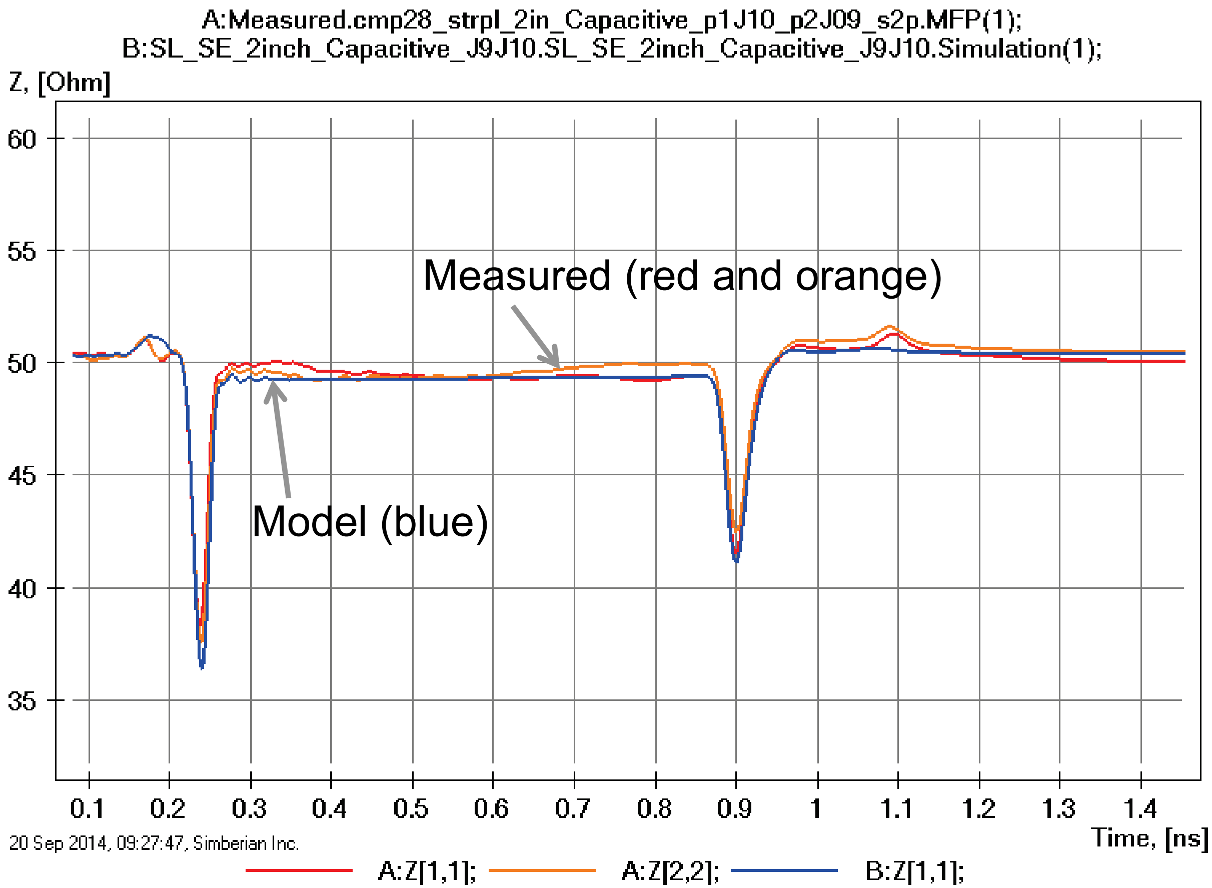


Variation of via geometry (back-drilling) explains differences both in insertion and reflection losses;

24) 2-inch strip line with capacitive launch: Transmission phase and group delay

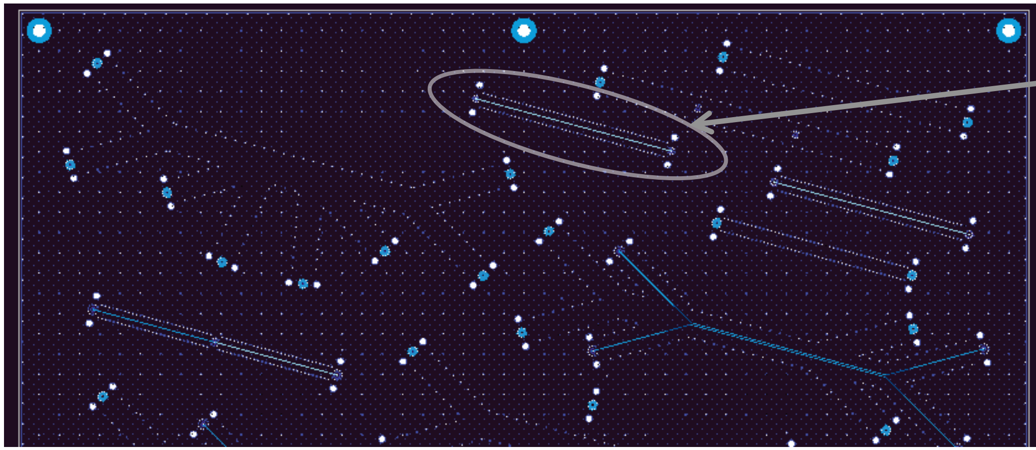


24) 2-inch strip line with capacitive launch: TDR with 20 ps Gaussian step



Variations of via back-drilling and trace geometry explains differences;

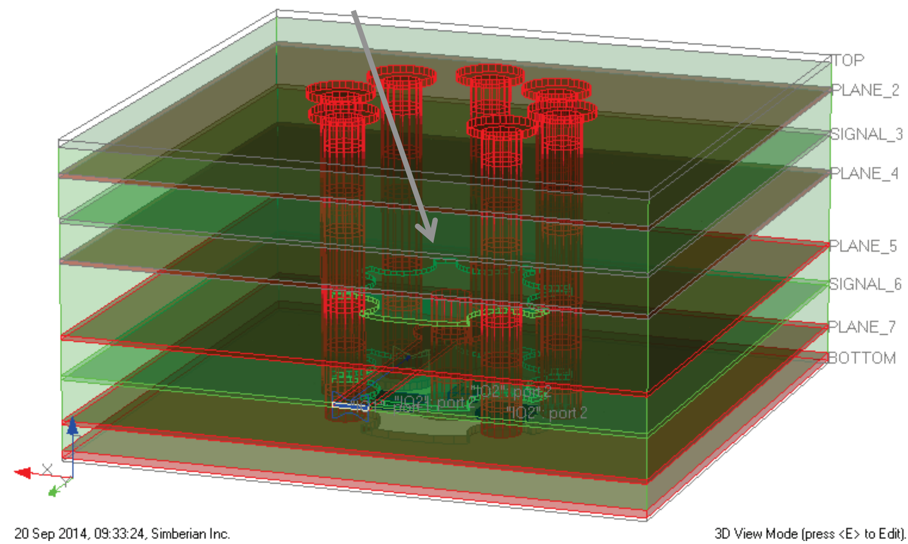
25) 2-inch strip line with inductive launch



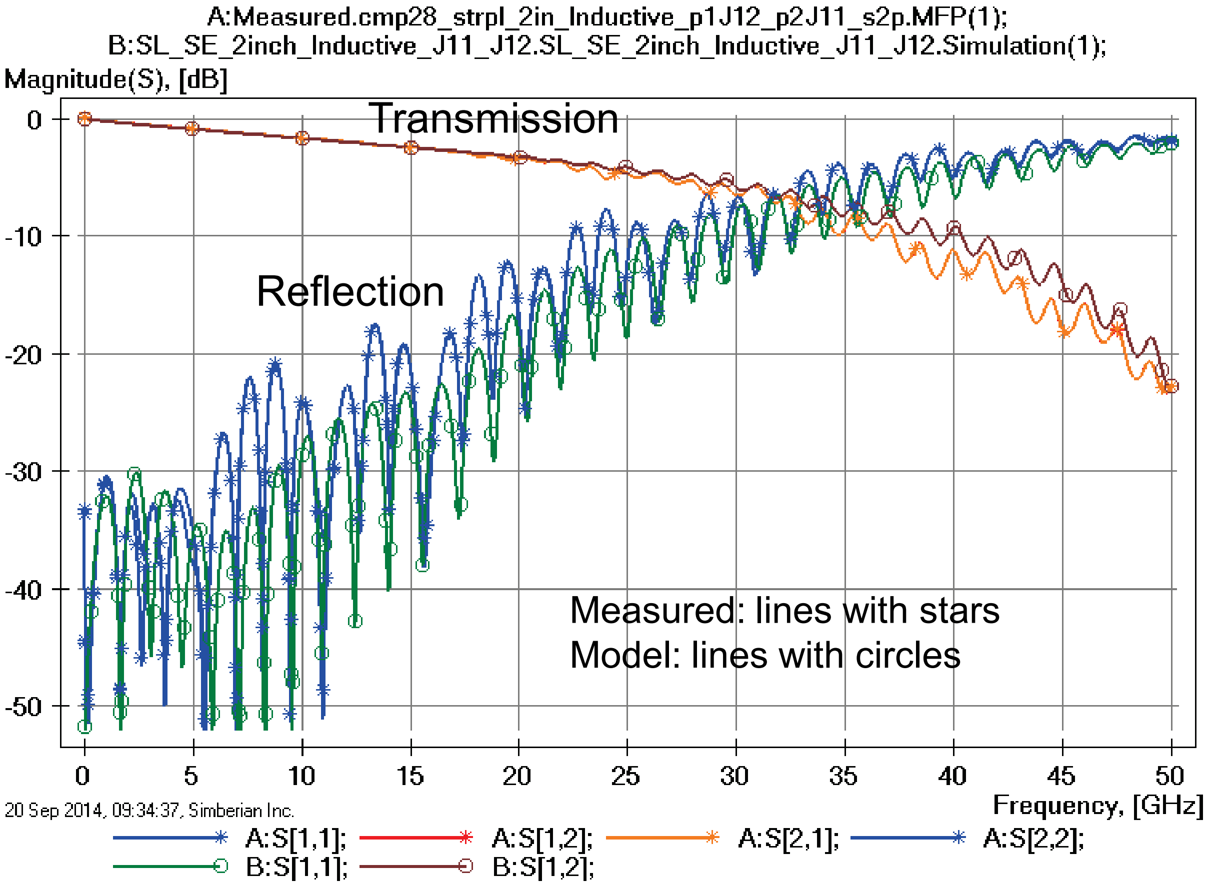
SL SE 2 in strip with inductive launch (J11-J12)
Solution: 9_StipSingle(2)
Measured:
cmp28_strpl_2in_Inductive_p1J12_p2J11.s2p
Selector/Project/Circuit:
SL_SE_2inch_Inductive_J11J12

Board Analyzer:
Trace width is adjusted;
2 discontinuity selector for the launches are created and edited after extraction to account for the back-drilling (identical and set to re-used);
Connector models are added to linear network after the extraction;
See also notes in the solution;

Via barrel is reduced to PLANE_5;
Large anti-pads in PLANE_5 and PLANE_7 (inductive);

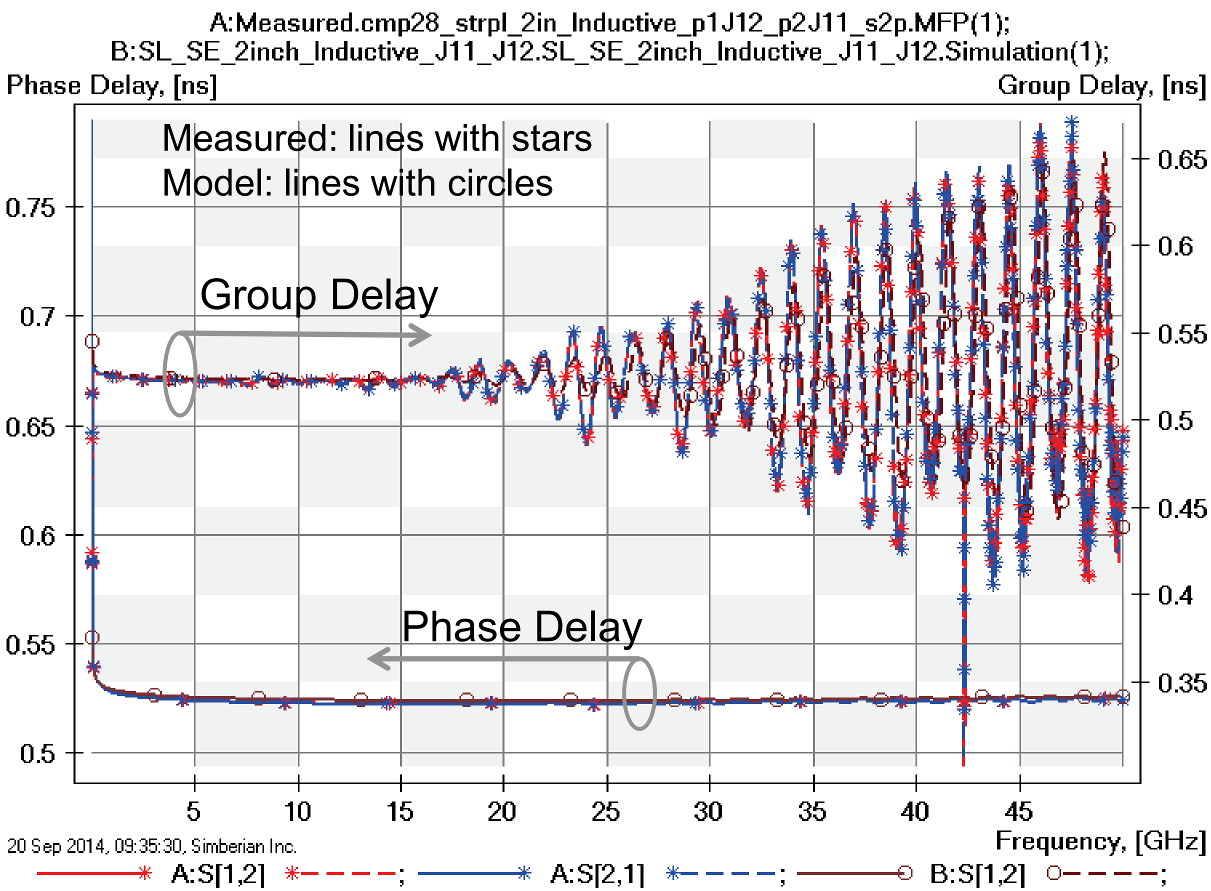


25) 2-inch strip line with inductive launch: Magnitude of S-parameters

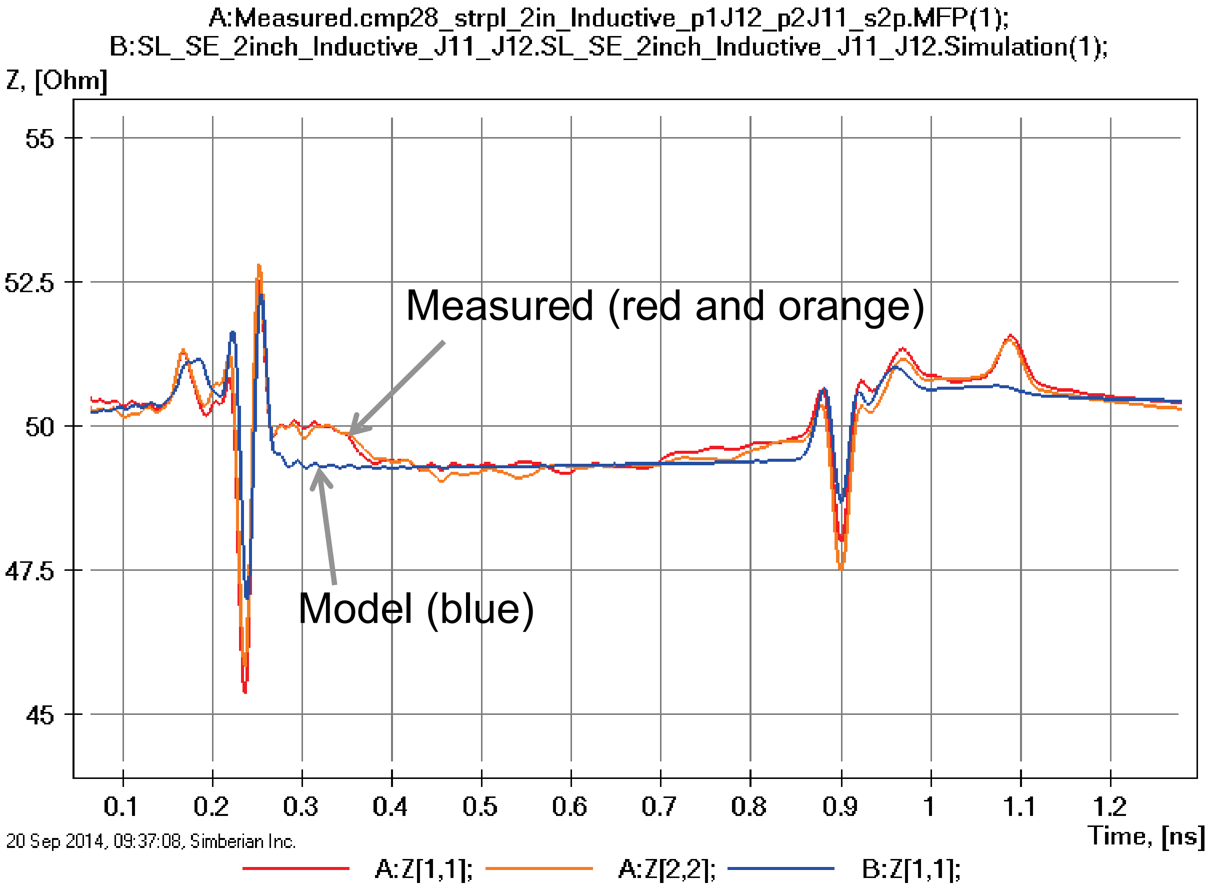


Variation of via geometry (back-drilling) explains differences both in insertion and reflection losses;

25) 2-inch strip line with inductive launch: Transmission phase and group delay

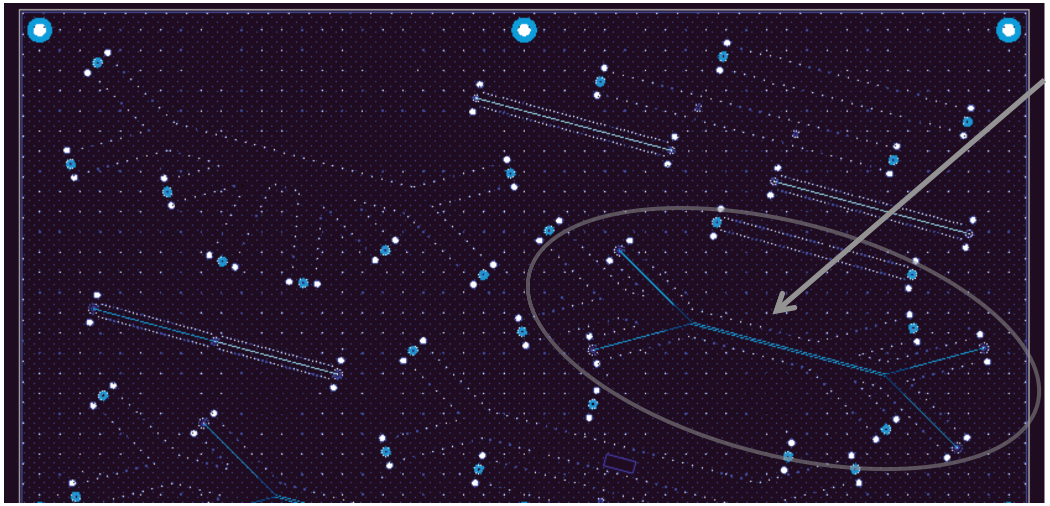


25) 2-inch strip line with inductive launch: TDR with 20 ps Gaussian step



Variations of via back-drilling and trace geometry explains differences;

26) 2-inch strip differential line

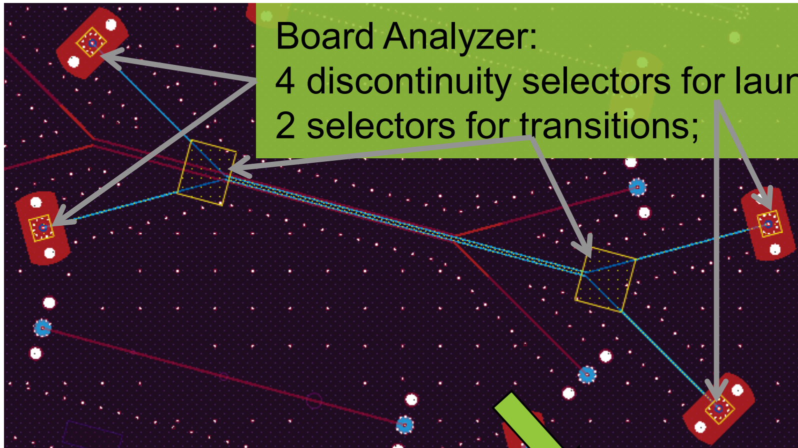


SL DF 2-inch segment (J35-J36-J39-J40)
Solution: 10_StipDifferential(1)
Measured:
cmp28_strpl_diff_2inch_J39J40J35J36.s4p
Selector/Project/Circuit: SL_DF_2inch

See notes on the decomposition in solution and on the next slide…

Board Analyzer:
Single-ended trace width is adjusted after the extraction;
4 discontinuity selectors for the launches are set to re-use PCB/SL_ConnectorAndLaunch model;
Additional 2 discontinuity selectors are added for transitions from single-ended to differential (identical and re-used);
See also notes in the solution;

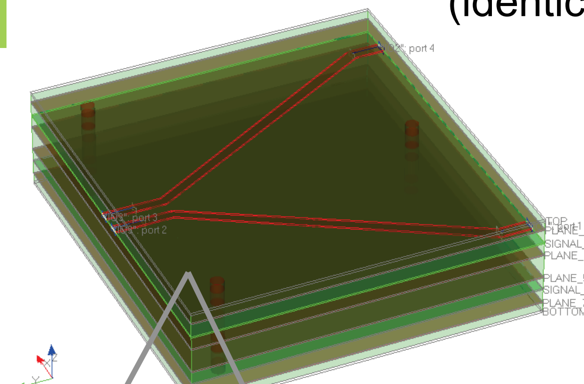
26) 2-inch strip differential line: De-compositional analysis



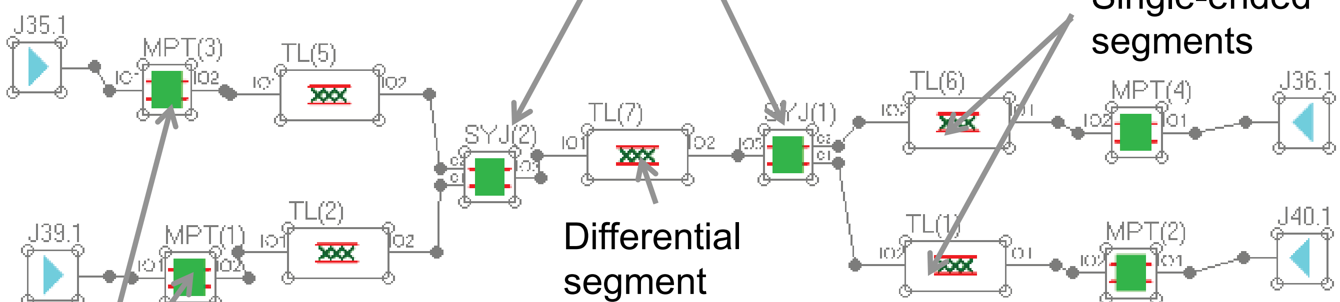
Board Analyzer:
4 discontinuity selectors for launches;
2 selectors for transitions;

Auto-extraction

Gradual transition
(identical on both ends)



Single-ended segments

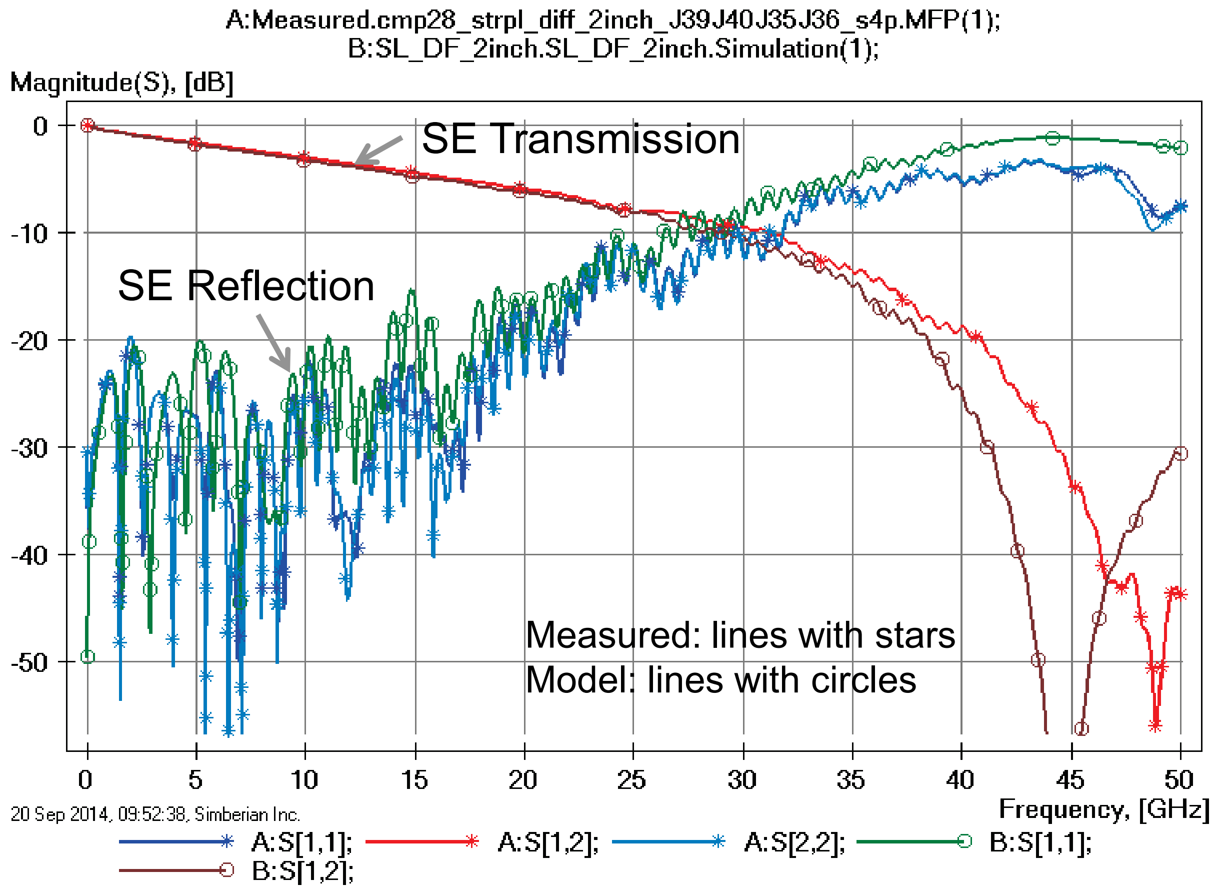


Differential segment

United Connector + Launch model from PCB/SL_ConnectorAndLaunch

See also solution notes for MS DF 2-inch segment

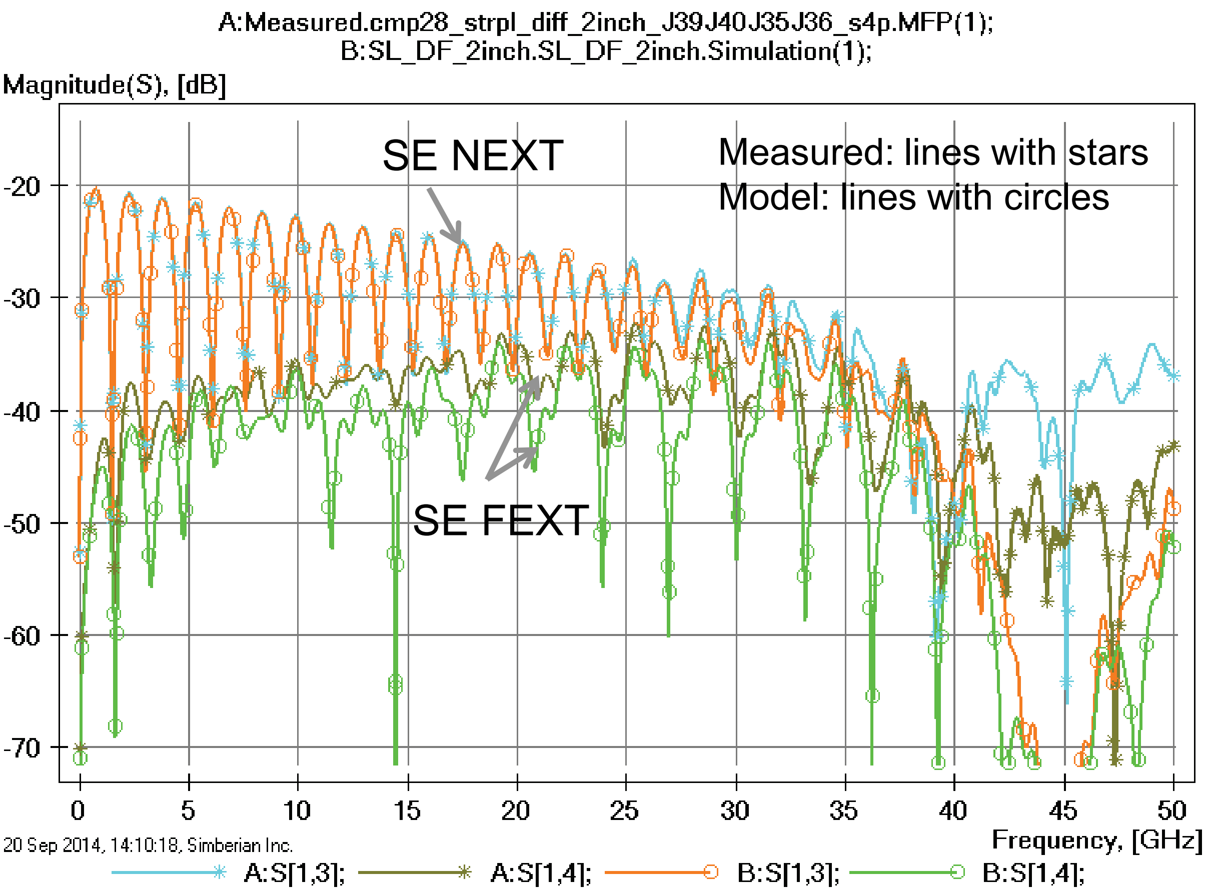
26) 2-inch strip differential line: Single-ended transmission and reflection



Discrepancies above 30 GHz

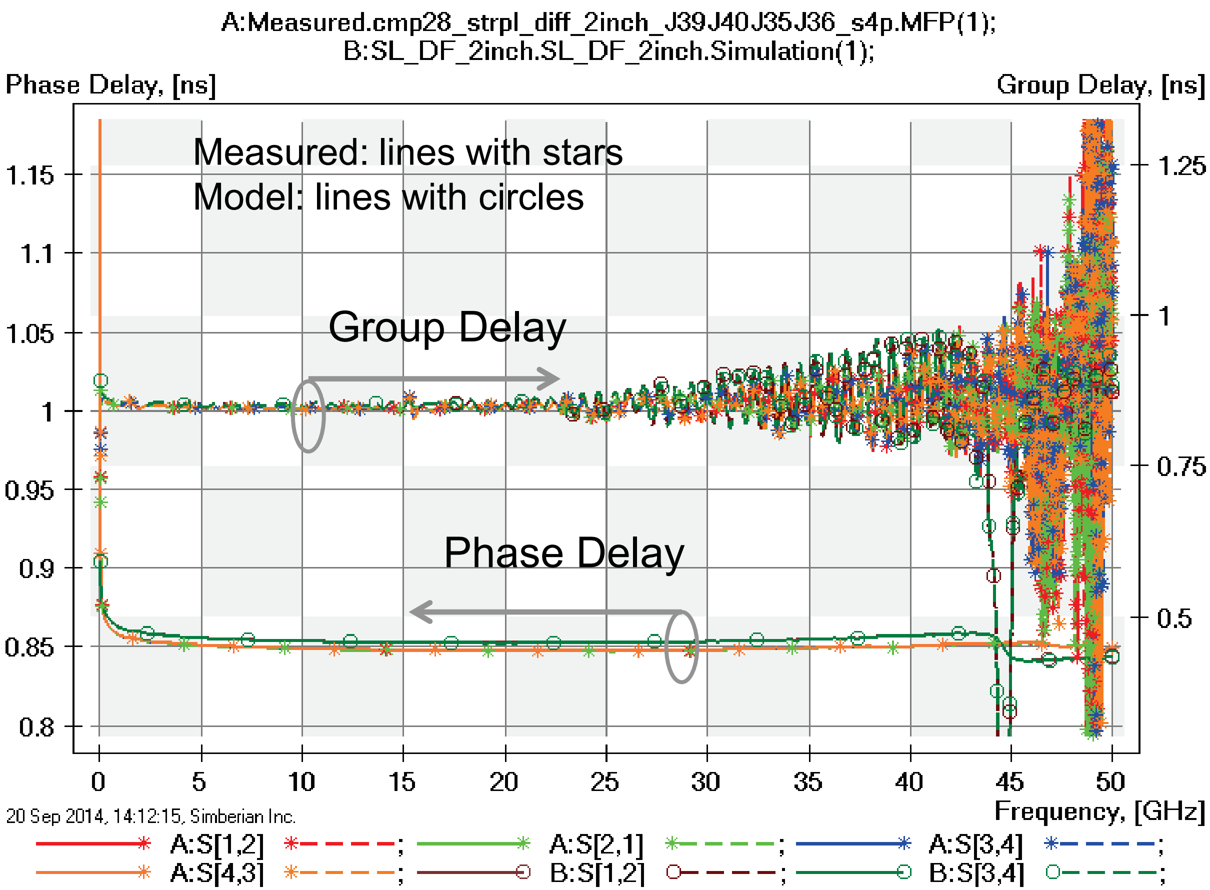
Loss of localization and difference in launch geometry (back-drilling) explain difference in transmission and reflection;

26) 2-inch strip differential line: Single-ended near and far end x-talk



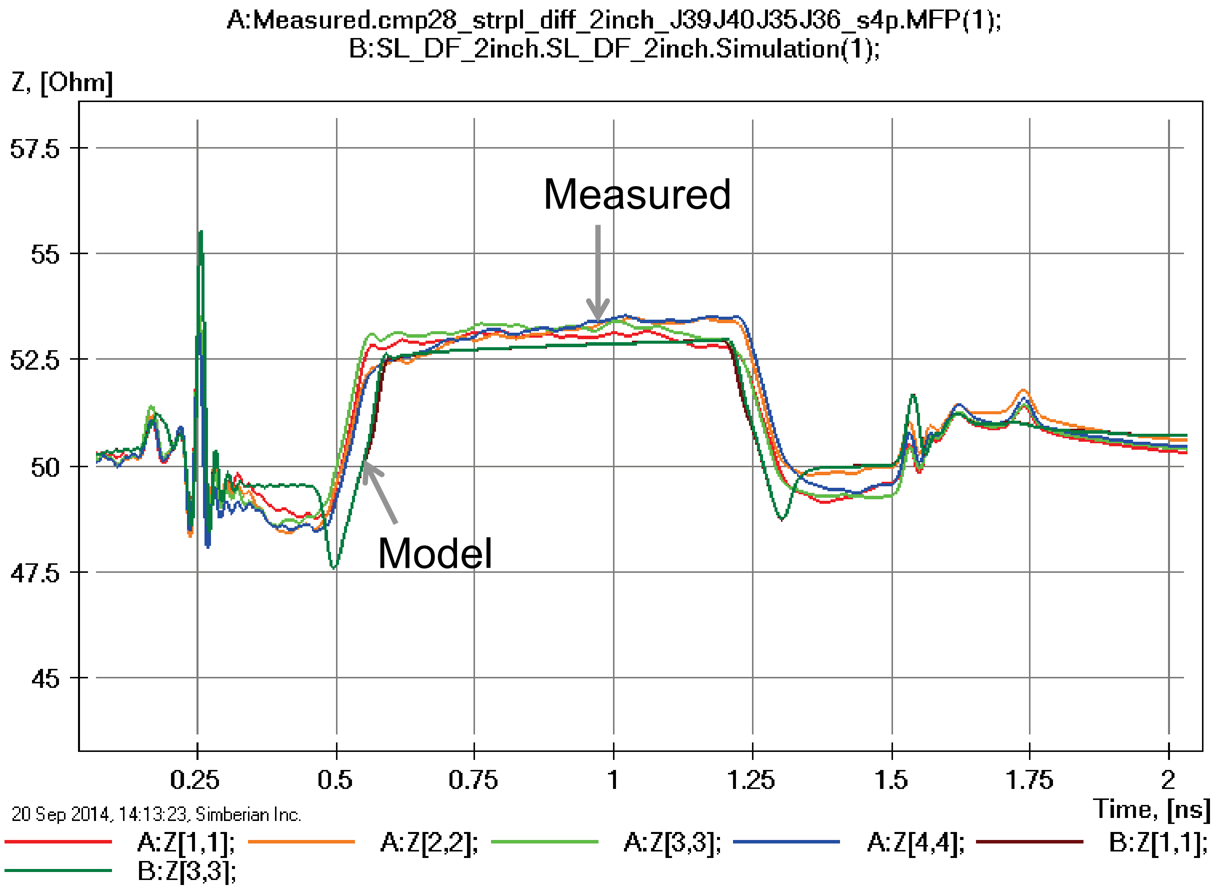
NEXT- near end cross-talk;
FEXT - far end cross-talk;

26) 2-inch strip differential line: SE transmission phase and group delay



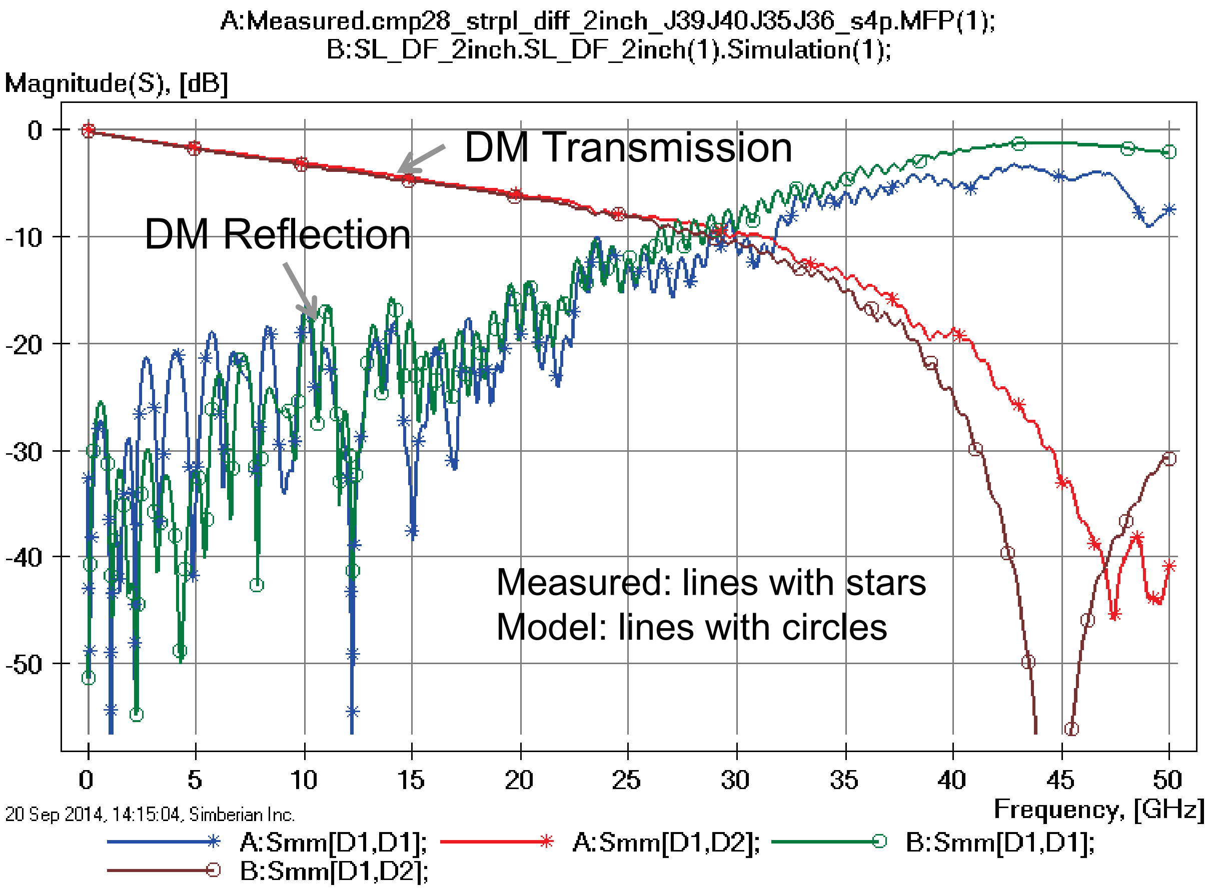
Discrepancies above 40 GHz

26) 2-inch strip differential line: SE TDR with 20 ps Gaussian step



Model transitions have lower impedance due to no adjustments in trace width in the tapered polygonal section;

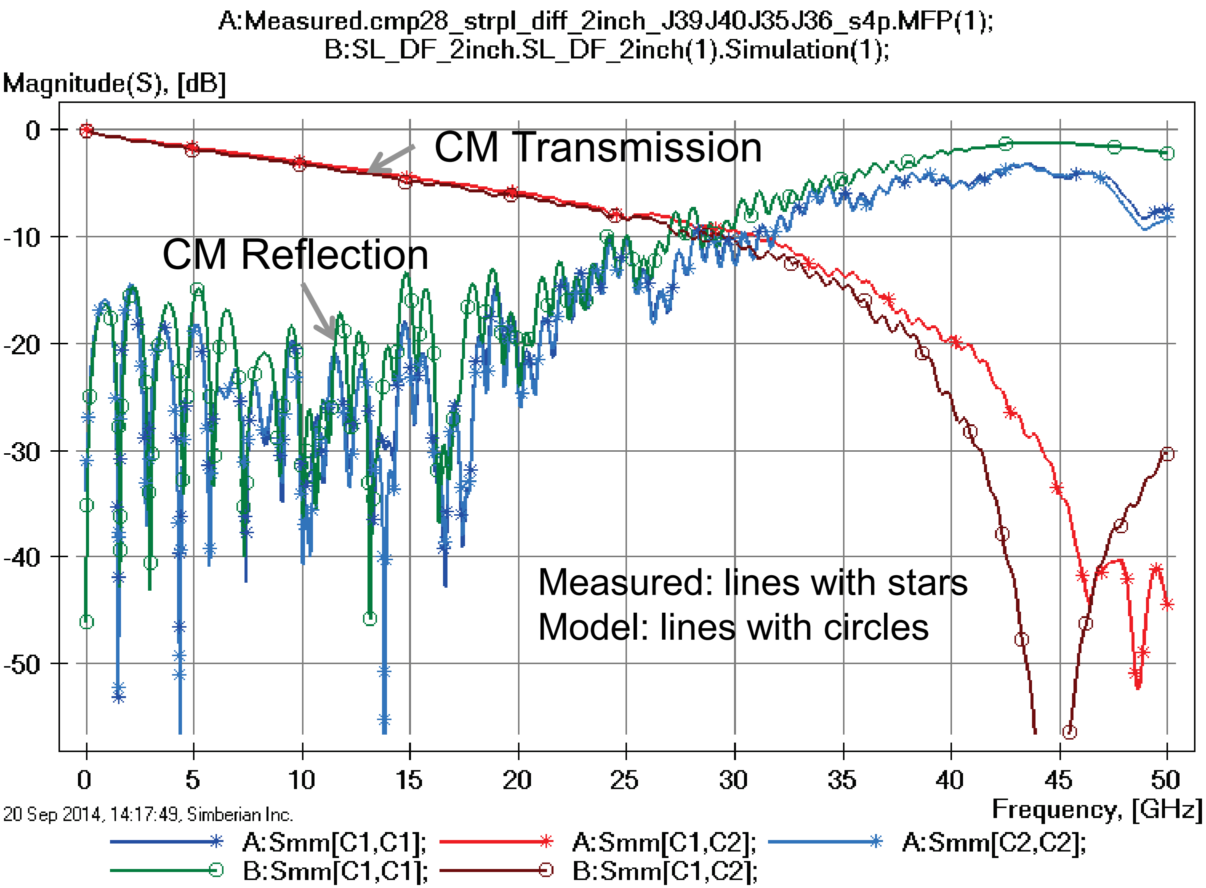
26) 2-inch strip differential line: Differential mode transmission and reflection



Loss of launch localization above 30 GHz explains additional insertion losses;
Variations in back-drilling, trace width, separation and dielectric properties explains differences in reflection losses;

DM – differential mode

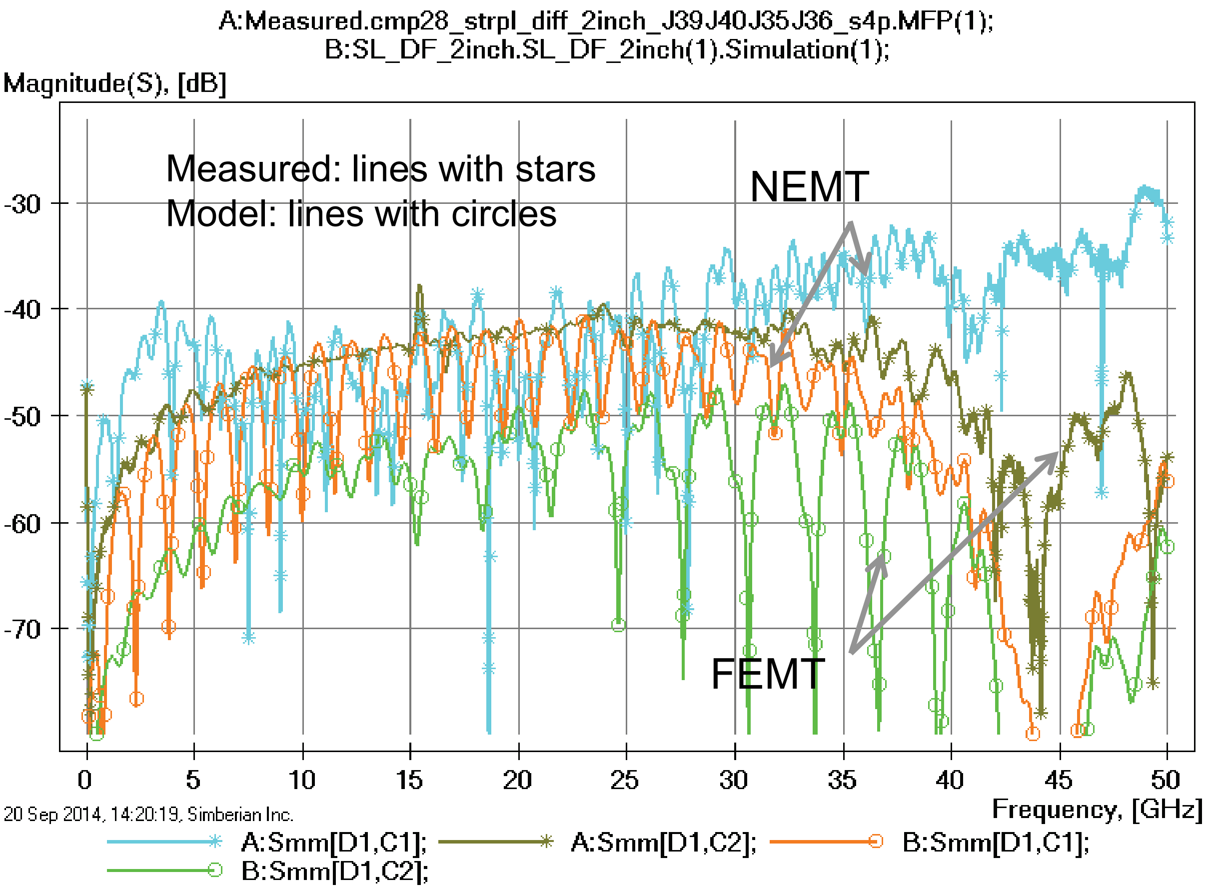
26) 2-inch strip differential line: Common mode transmission and reflection



Loss of launch localization above 30 GHz explains additional insertion losses;
Variations in back-drilling, trace width, separation and dielectric properties explains differences in reflection losses;

CM – common mode

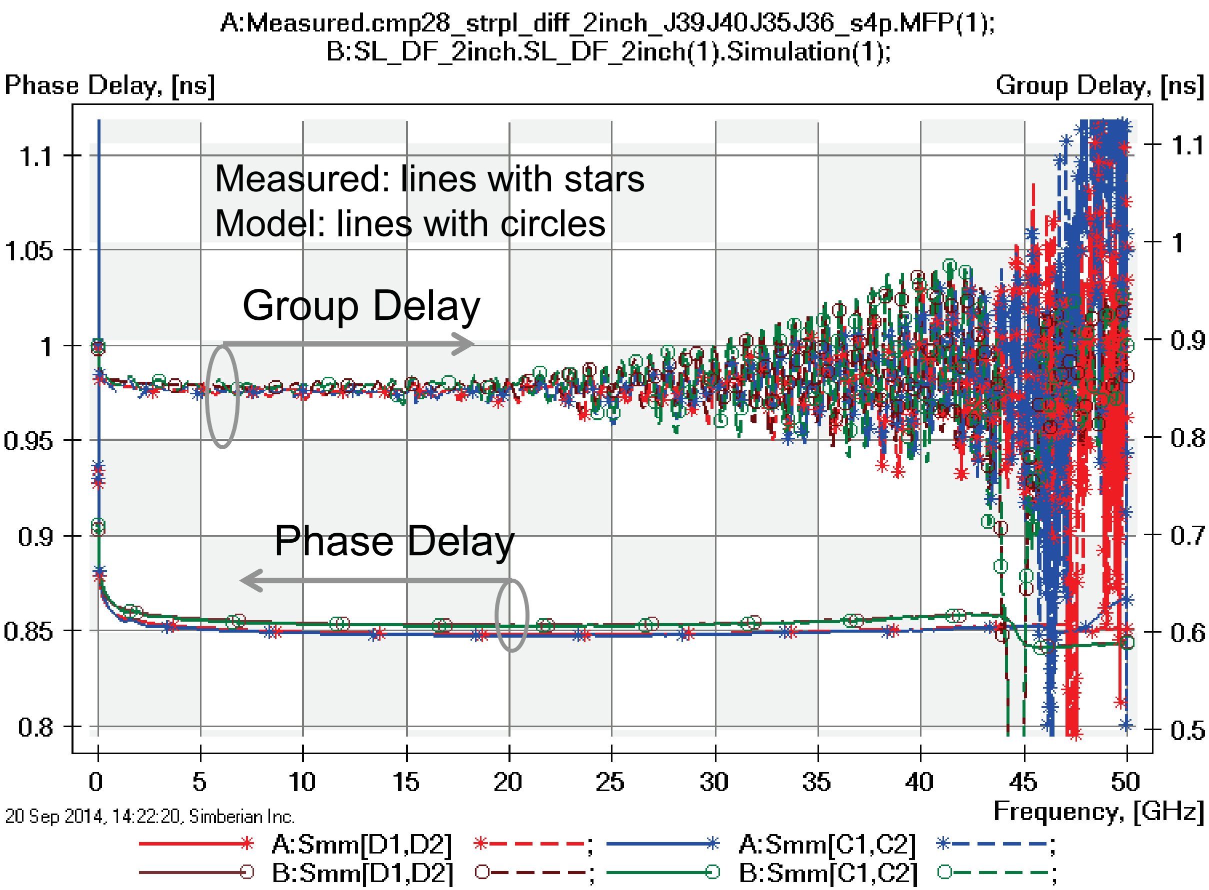
26) 2-inch strip differential line: Mixed mode transformation



Difference below -30 dB – can be attributed to many things;

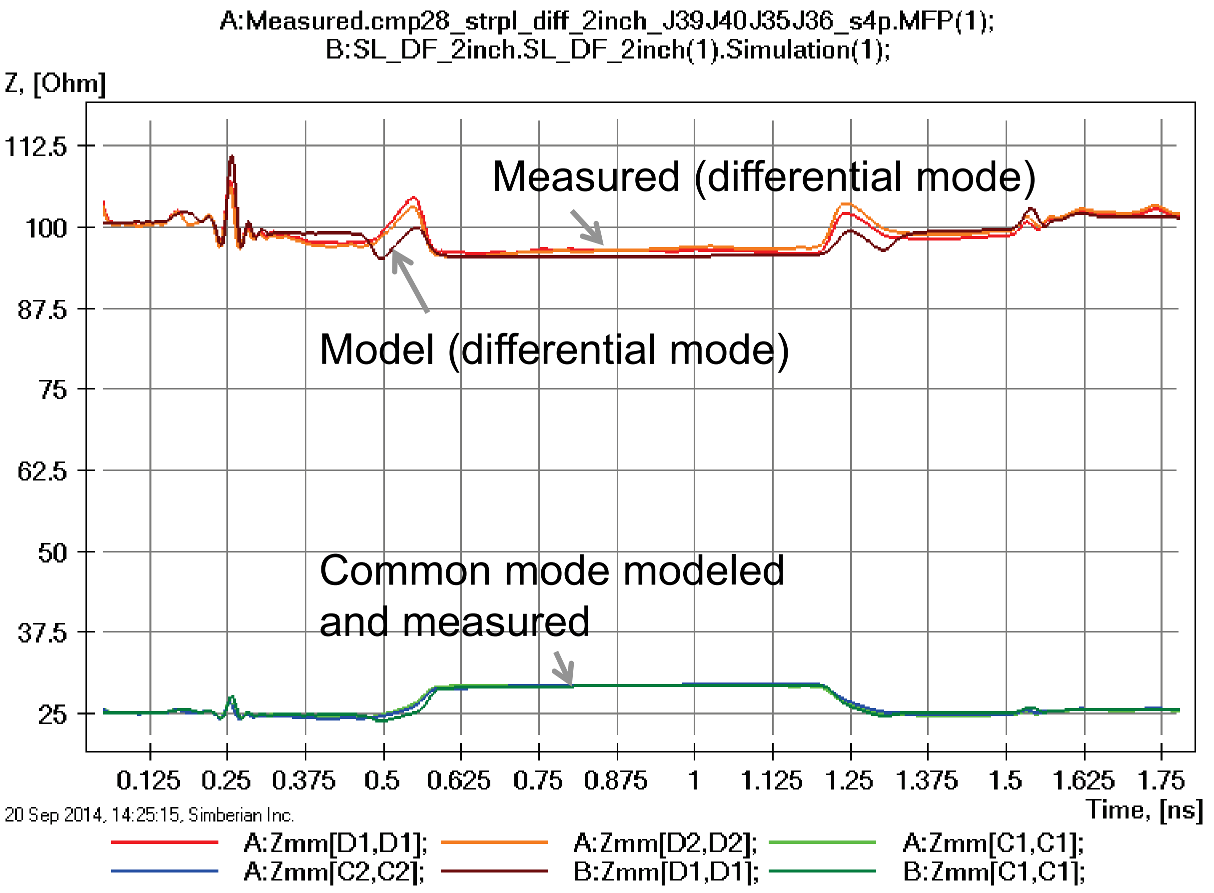
NEMT- near end differential to common mode transformation; FEMT - far end differential to common mode transformation;

26) 2-inch strip differential line: DF transmission phase and group delay



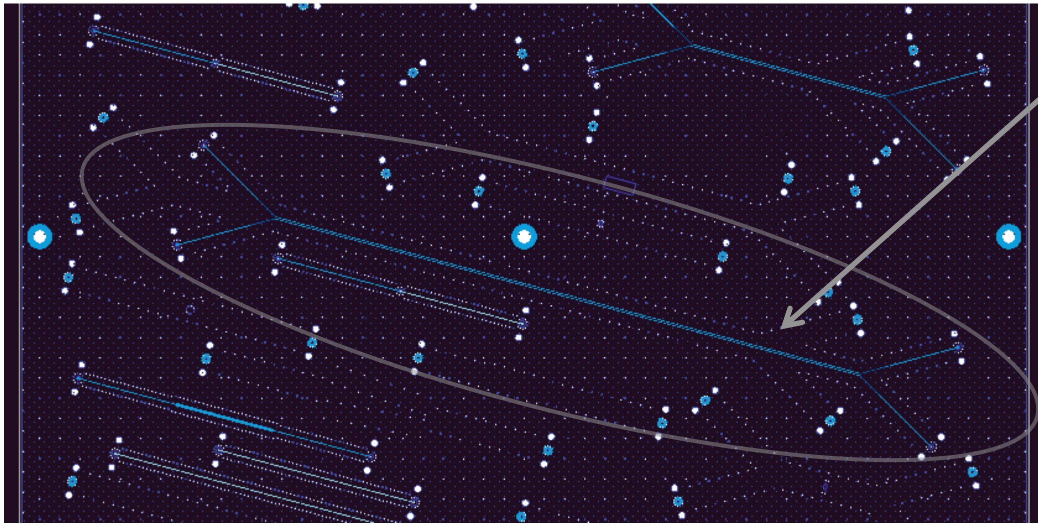
Discrepancies above 40 GHz;
About 5 ps difference due to resin between strips?

26) 2-inch strip differential line: MM TDR with 20 ps Gaussian step



Model transitions have lower impedance due to no adjustments in trace width in polygonal section;

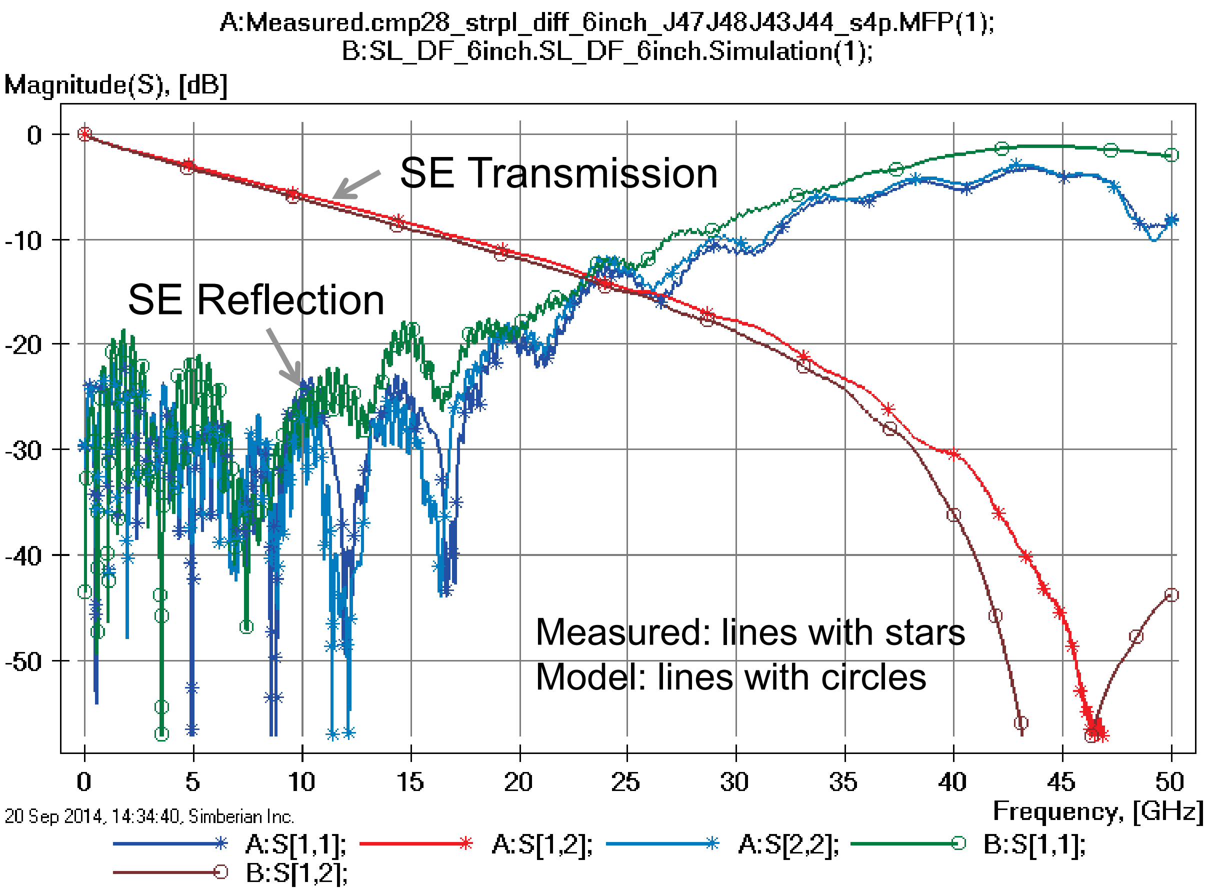
27) 6-inch strip differential line



SL DF 6-inch segment (J43-J44-J47-J48)
Solution: 10_StipDifferential(1)
Measured:
cmp28_strpl_diff_6inch_J47J48J43J44.s4p
Selector/Project/Circuit: SL_DF_6inch

Board Analyzer:
Single-ended trace width is adjusted after the extraction;
4 discontinuity selectors for the launches are set to re-use PCB/SL_ConnectorAndLaunch model;
Additional 2 discontinuity selectors are added for transitions from single-ended to differential (identical and re-used from analysis of 2-inch segment);
See also notes in the solution;

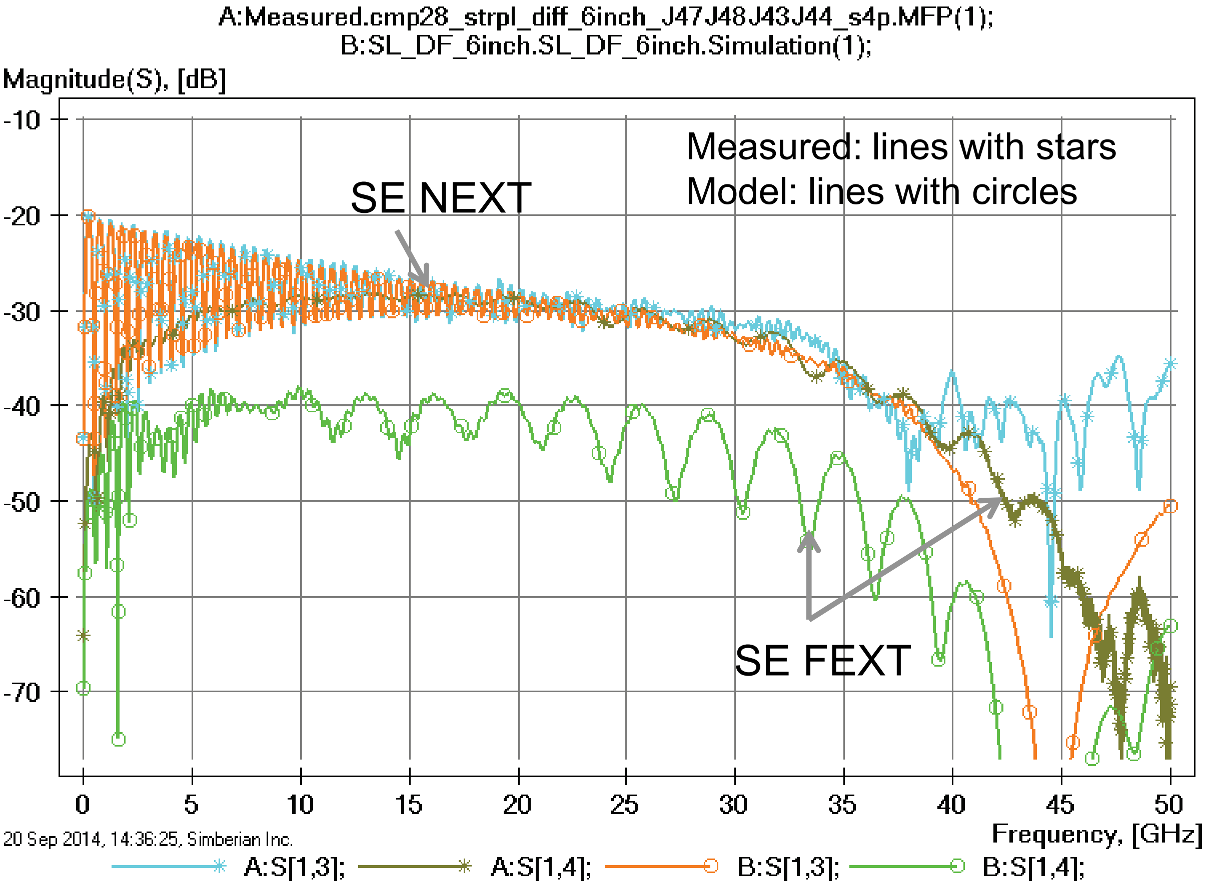
27) 6-inch strip differential line: Single-ended transmission and reflection



Discrepancies above 35 GHz

Loss of localization and difference in launch geometry (back-drilling) explain difference in transmission and reflection;

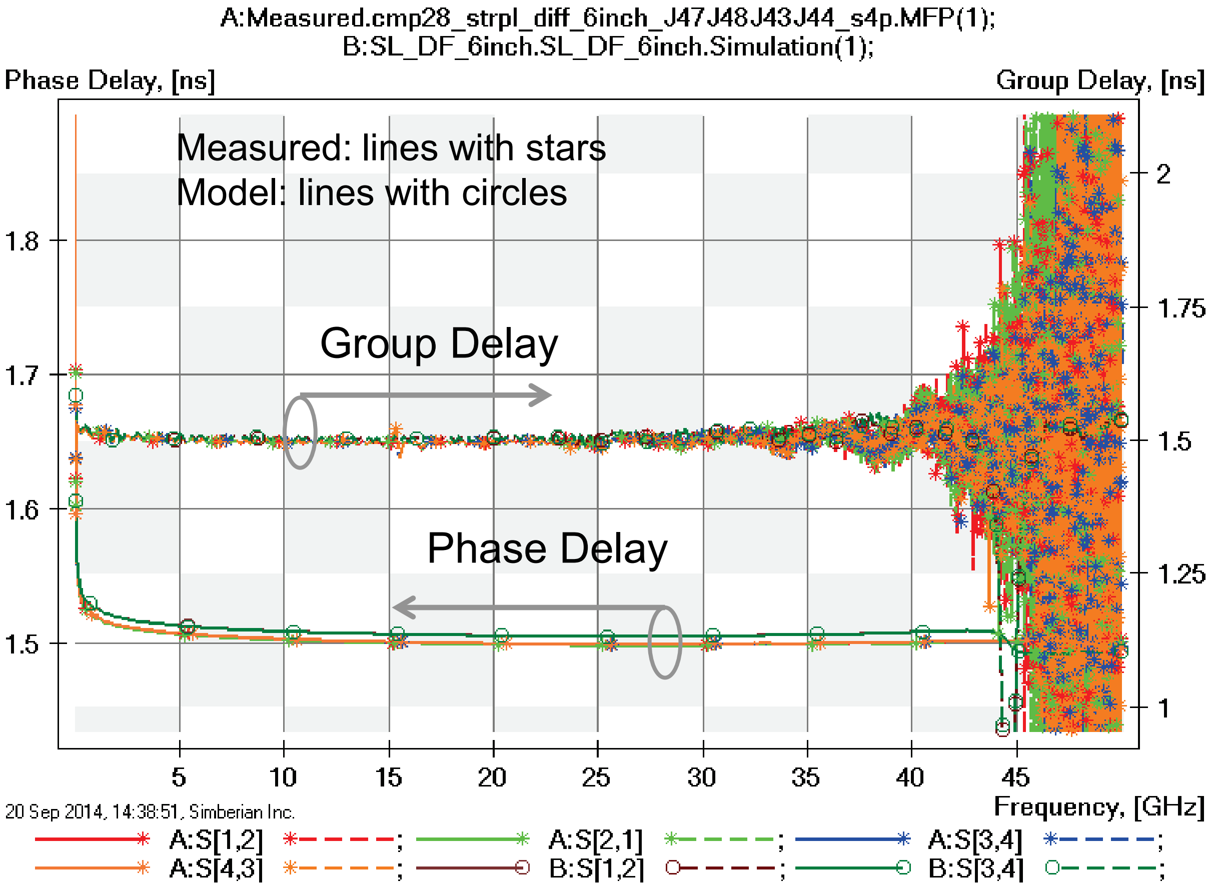
27) 6-inch strip differential line: Single-ended near and far end x-talk



Difference in FEXT indicates inhomogeneity of dielectric (resin between strips);

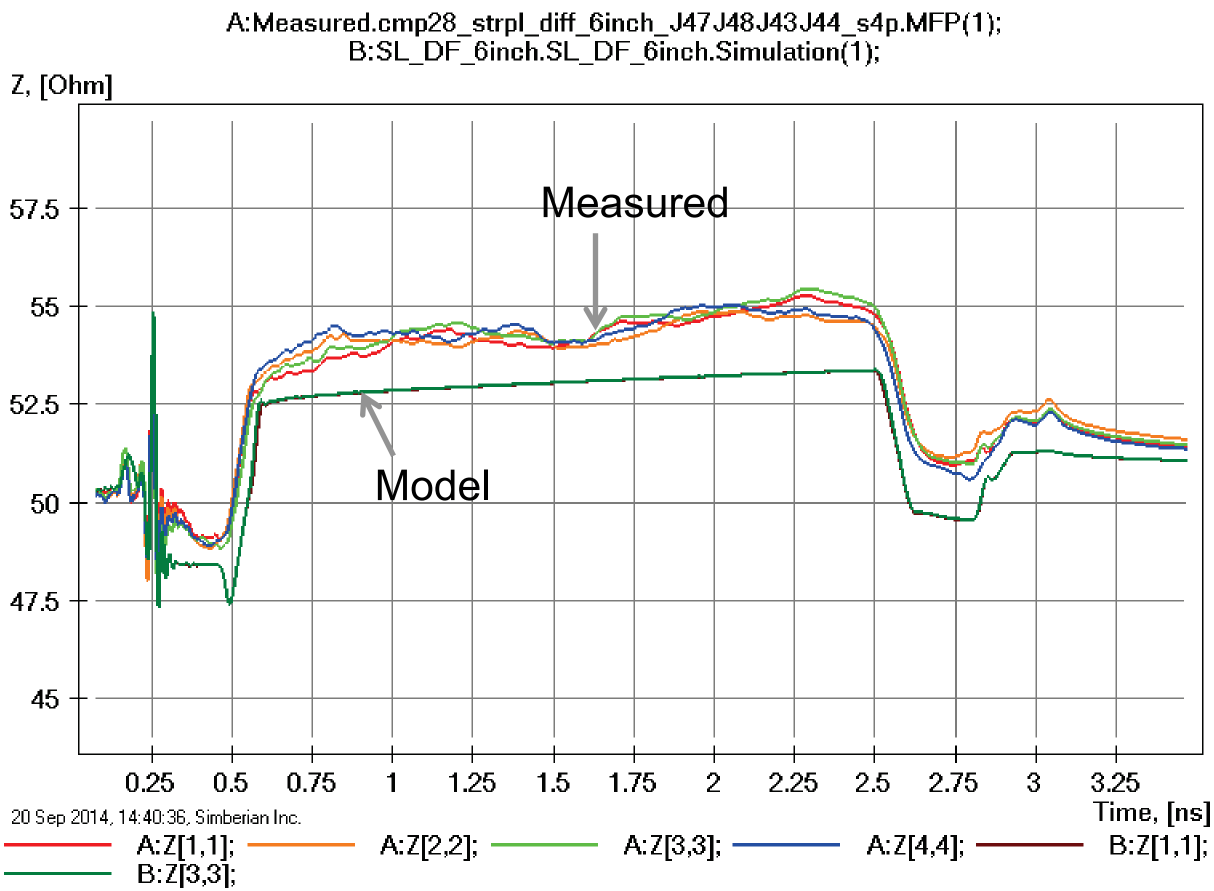
NEXT- near end cross-talk;
FEXT - far end cross-talk;

27) 6-inch strip differential line: SE transmission phase and group delay



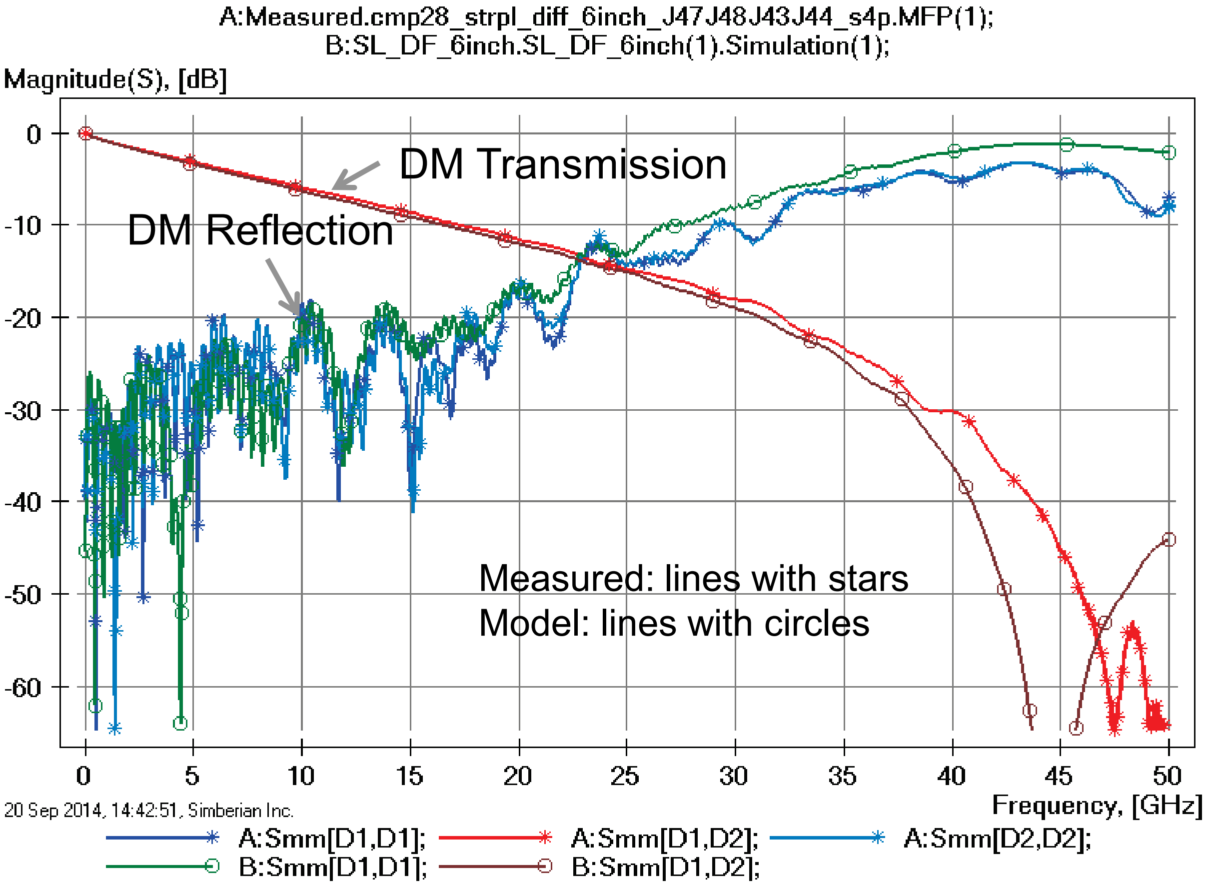
About 7 ps difference in phase delay due to resin between strips?

27) 6-inch strip differential line: SE TDR with 20 ps Gaussian step



Model impedance is lower by about 1 Ohm;

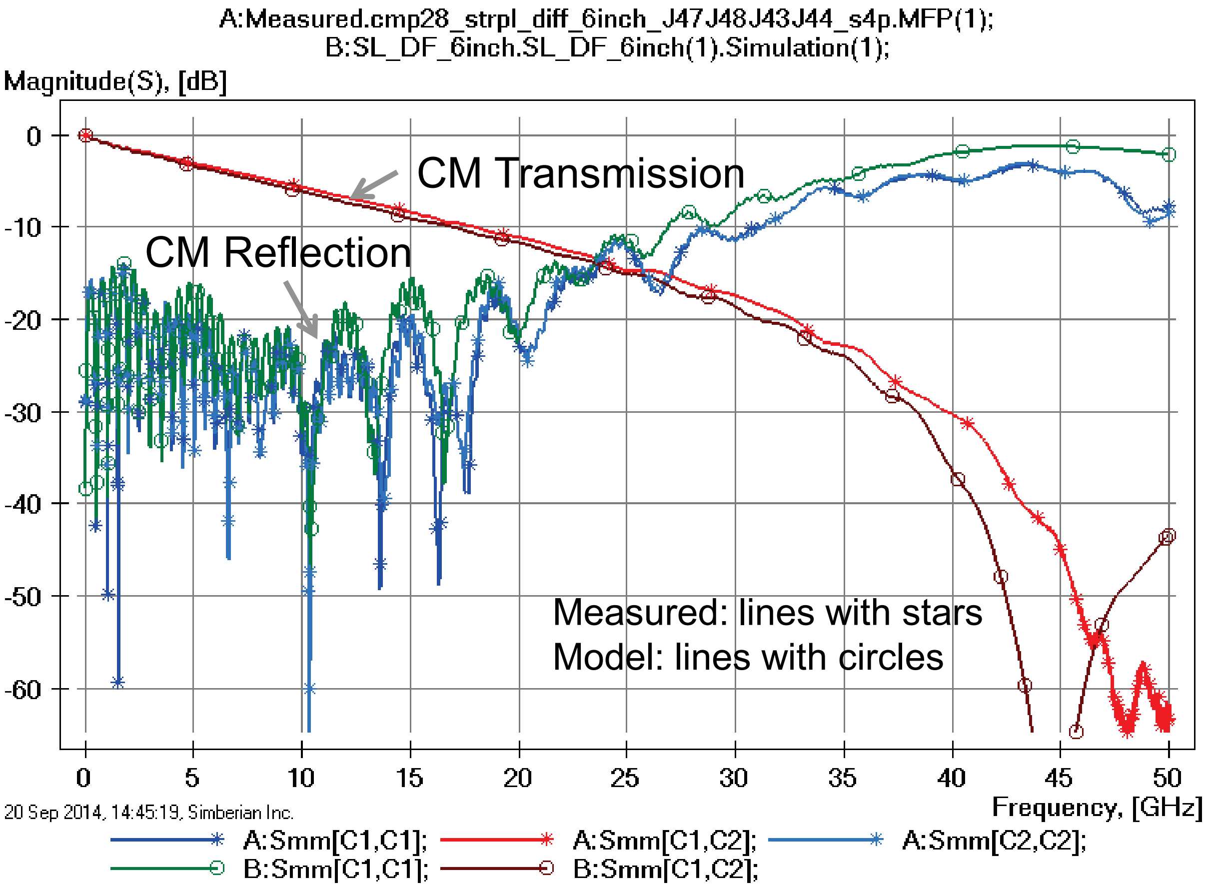
27) 6-inch strip differential line: Differential mode transmission and reflection



Loss of launch localization above 30 GHz explains additional insertion losses;
Variations in back-drilling, trace width, separation and dielectric properties explains differences in reflection losses;

DM – differential mode

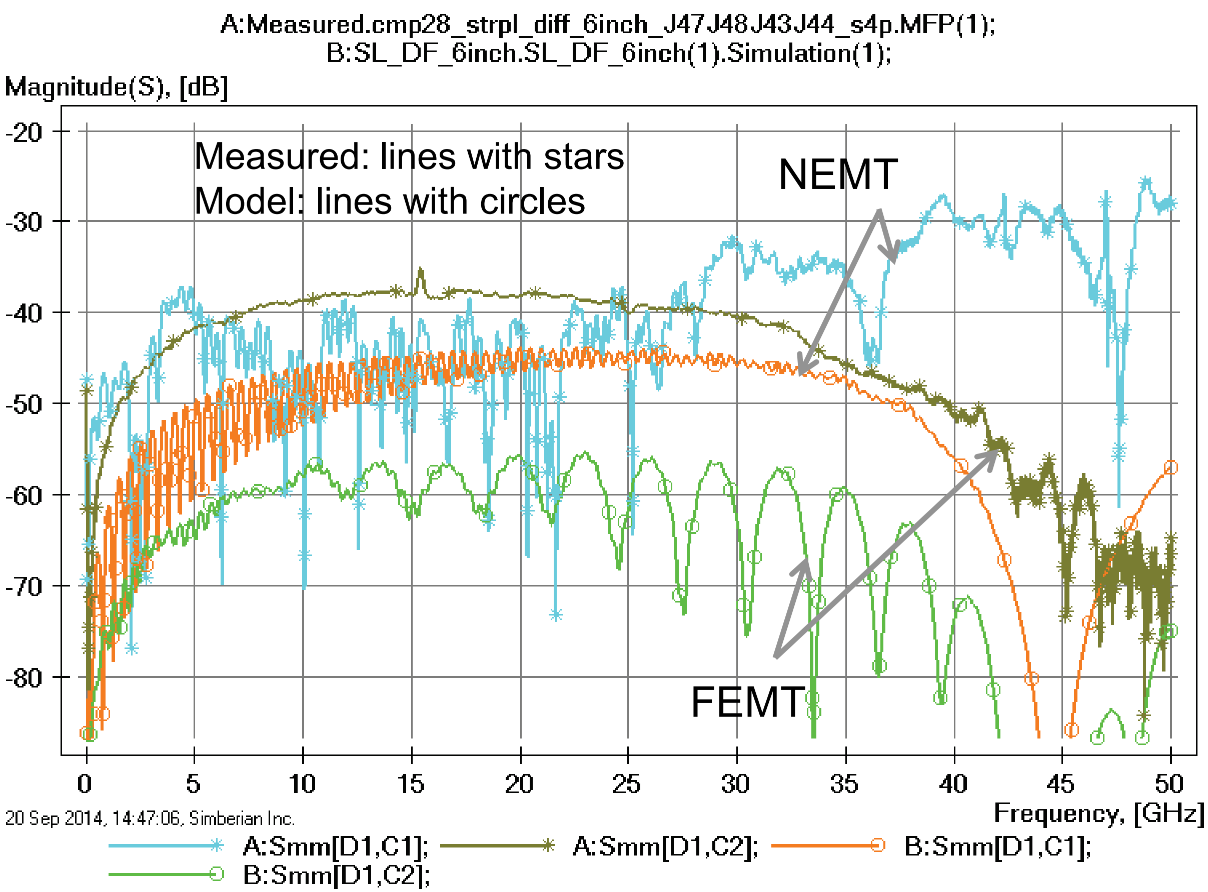
27) 6-inch strip differential line: Common mode transmission and reflection



Loss of launch localization above 30 GHz explains additional insertion losses;
Variations in back-drilling, trace width, separation and dielectric properties explains differences in reflection losses;

CM – common mode

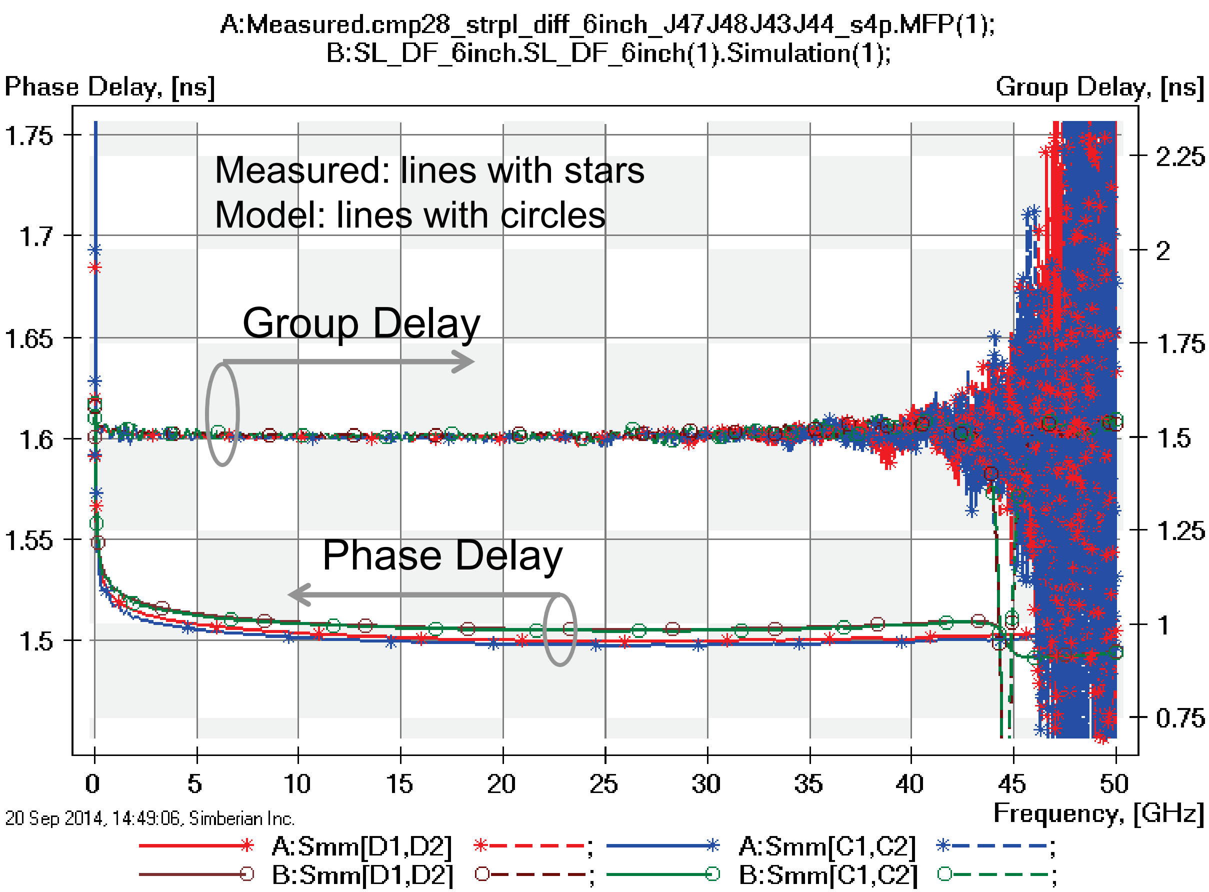
27) 6-inch strip differential line: Mixed mode transformation



Difference below -30 dB – can be attributed to many things;

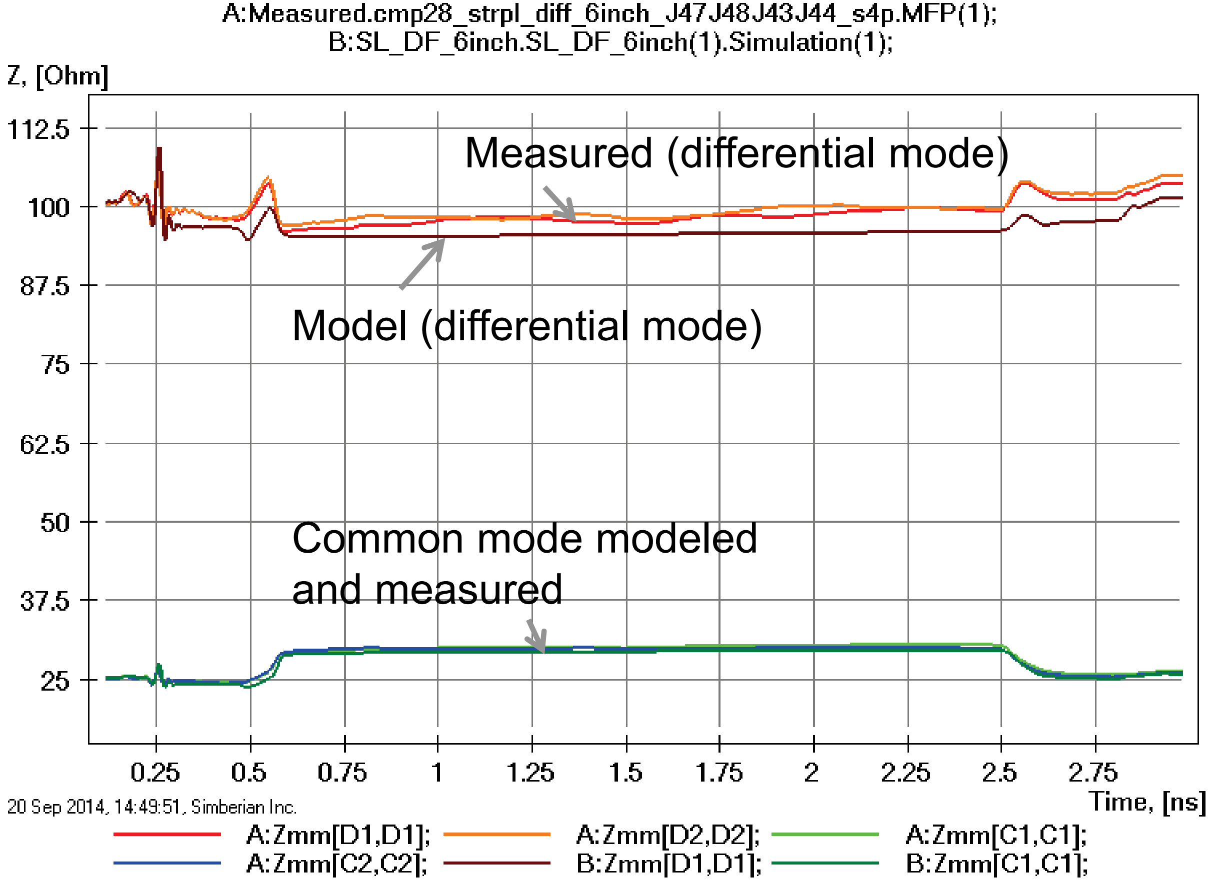
NEMT- near end differential to common mode transformation; FEMT - far end differential to common mode transformation;

27) 6-inch strip differential line: DF transmission phase and group delay



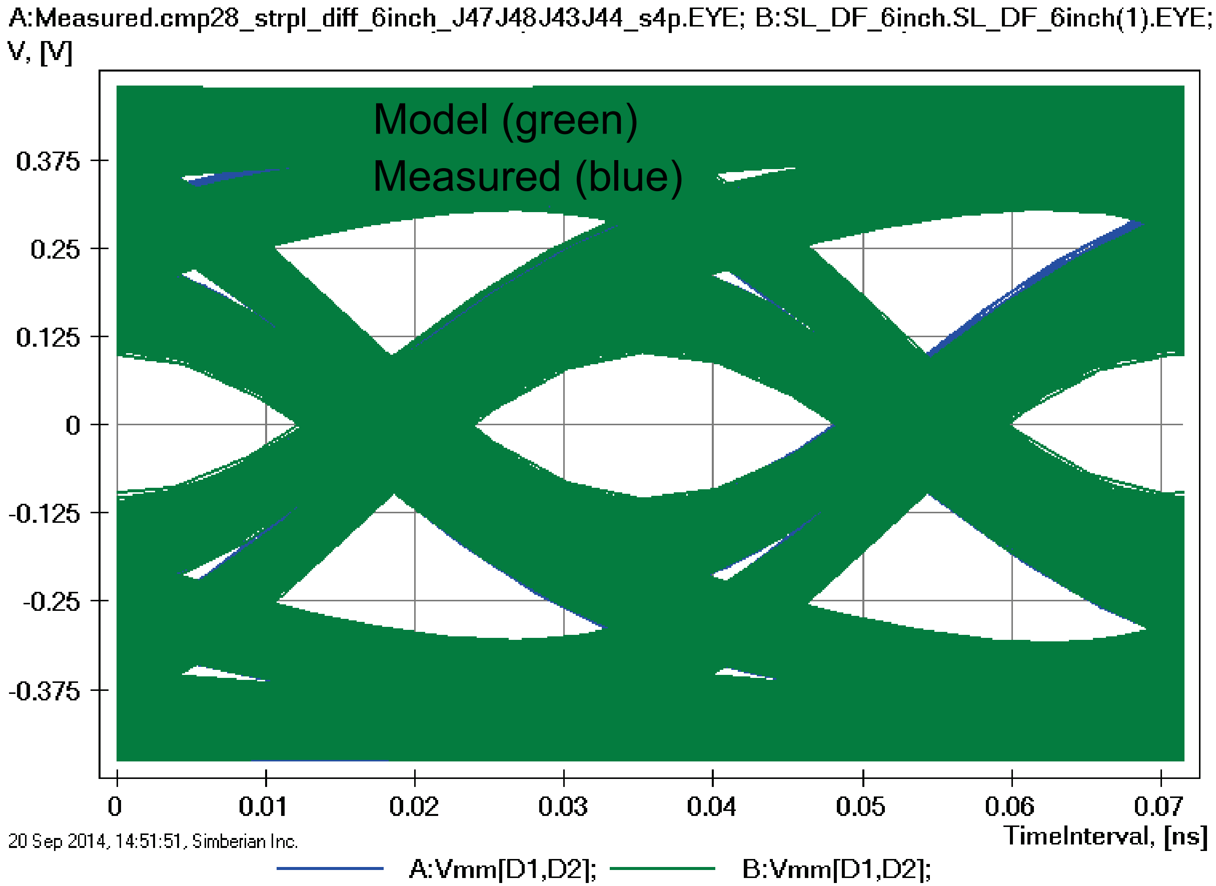
About 7 ps difference due to resin between strips?

27) 6-inch strip differential line: MM TDR with 20 ps Gaussian step



Lower differential mode impedance either because of trace width or separation or both;

27) 6-inch strip differential line: 28 Gbps PRBS, 25 ps rise/fall time



Eyes are on top of each other!

Conclusion

- CMP-28 validation platform is used here to illustrate systematic interconnect analysis to measurement validation process with Simbeor software
- It is shown that Simbeor software is accurate, productive and cost-efficient solution for design of interconnects up to 50 GHz and beyond
  - Less then 5 min analysis setup time per structure, simulation runs from minutes to few hours
  - To feel the difference, simply try another signal integrity software and compare results for all structures in frequency (magnitude and phase) and in time domain
  - Compare the analysis setup time…
  - Compare the cost of the tools…
  - And optimize your interconnect design flow with Simbeor
- Simbeor is #1 in the price-performance!

Contacts and resources

- Wild River Technology web site and contacts: *http://wildrivertech.com*
  - CMP-28/32 or newer versions
- Simberian web site and contacts *www.simberian.com*
  - Demo-videos http://www.simberian.com/ScreenCasts.php
  - App notes http://www.simberian.com/AppNotes.php
  - Technical papers http://kb.simberian.com/Publications.php
  - Presentations http://kb.simberian.com/Presentations.php
  - Download Simbeor® from www.simberian.com and try it on your problems for 15 days