Quantifying the Impact of the Environment on PCB Transmission Lines

Zaven Tashjian
President, Circuit Spectrum, Inc.

Kevin Chan
Applications Engineer, Circuit Spectrum, Inc.

CIRCUIT SPECTRUM

SWTW
IEEE SW Test Workshop
Semiconductor Wafer Test Workshop
June 10 - 13, 2012 | San Diego, California

Introduction

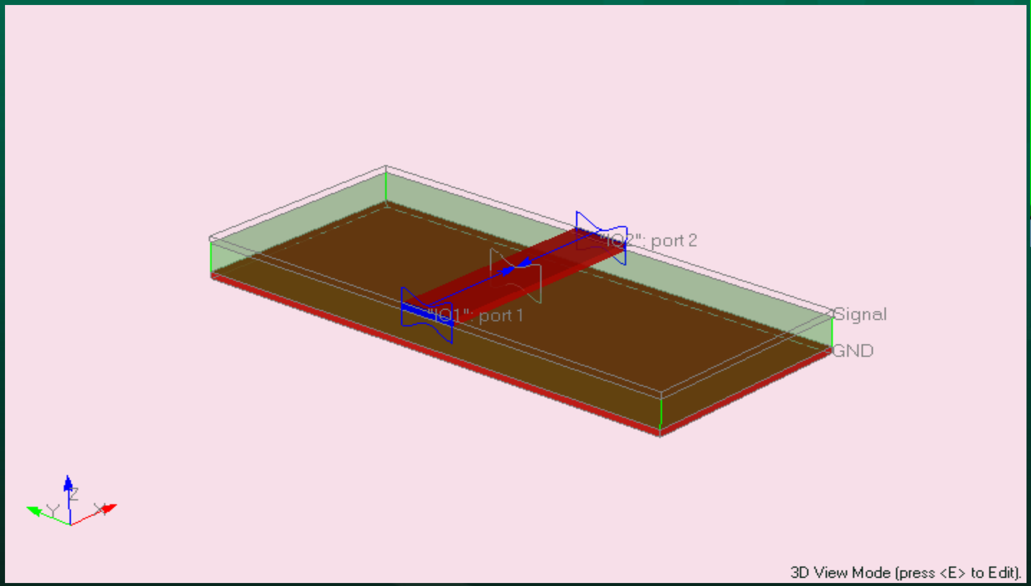
In the world of PCB design there are non-negotiable as well as unintentional and inadvertent conditions and situations that can impact signal and power integrity. Power integrity is outside the scope of this presentation. We have selected a few cases that can exist in the environment of transmission lines and we will present frequency-domain and time-domain results of their impact.

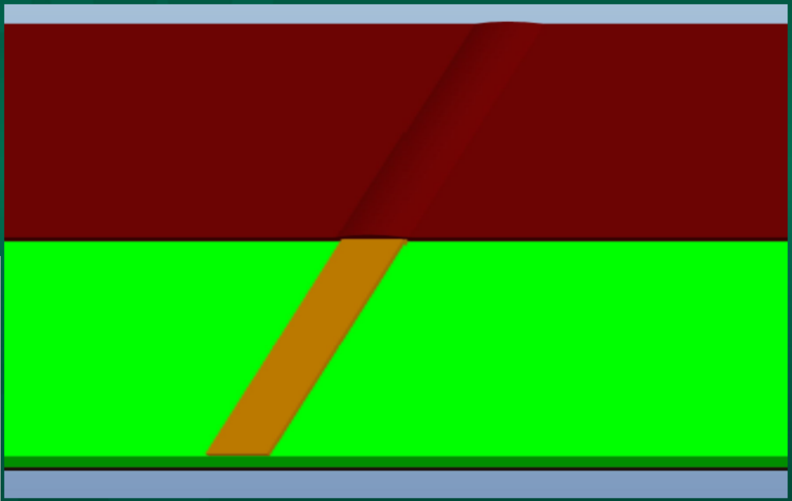
Outline

- Covered microstrip and embedded microstrip
- Voids in reference planes
- Line neckdown due to space constraints
- Excess floating metal in the vicinity
- Parallel conductor crosstalk
- Ultimate goal: Full signal path assessment
- Concluding remarks

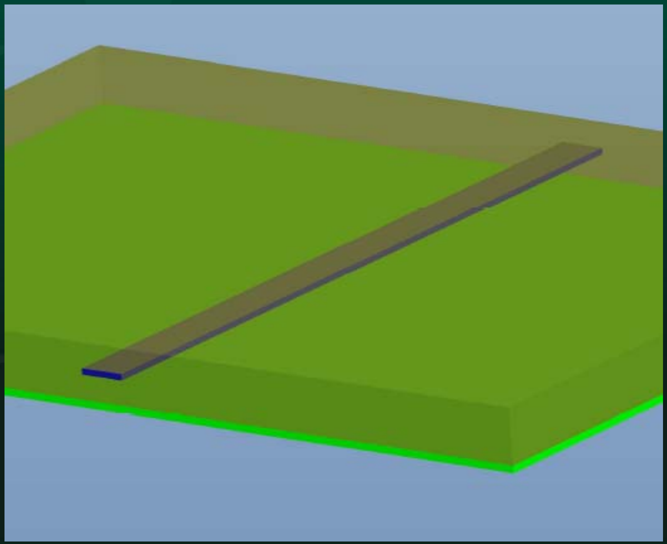
Microstrip vs. embedded microstrip

Contrast between uniform and nonuniform microstrip

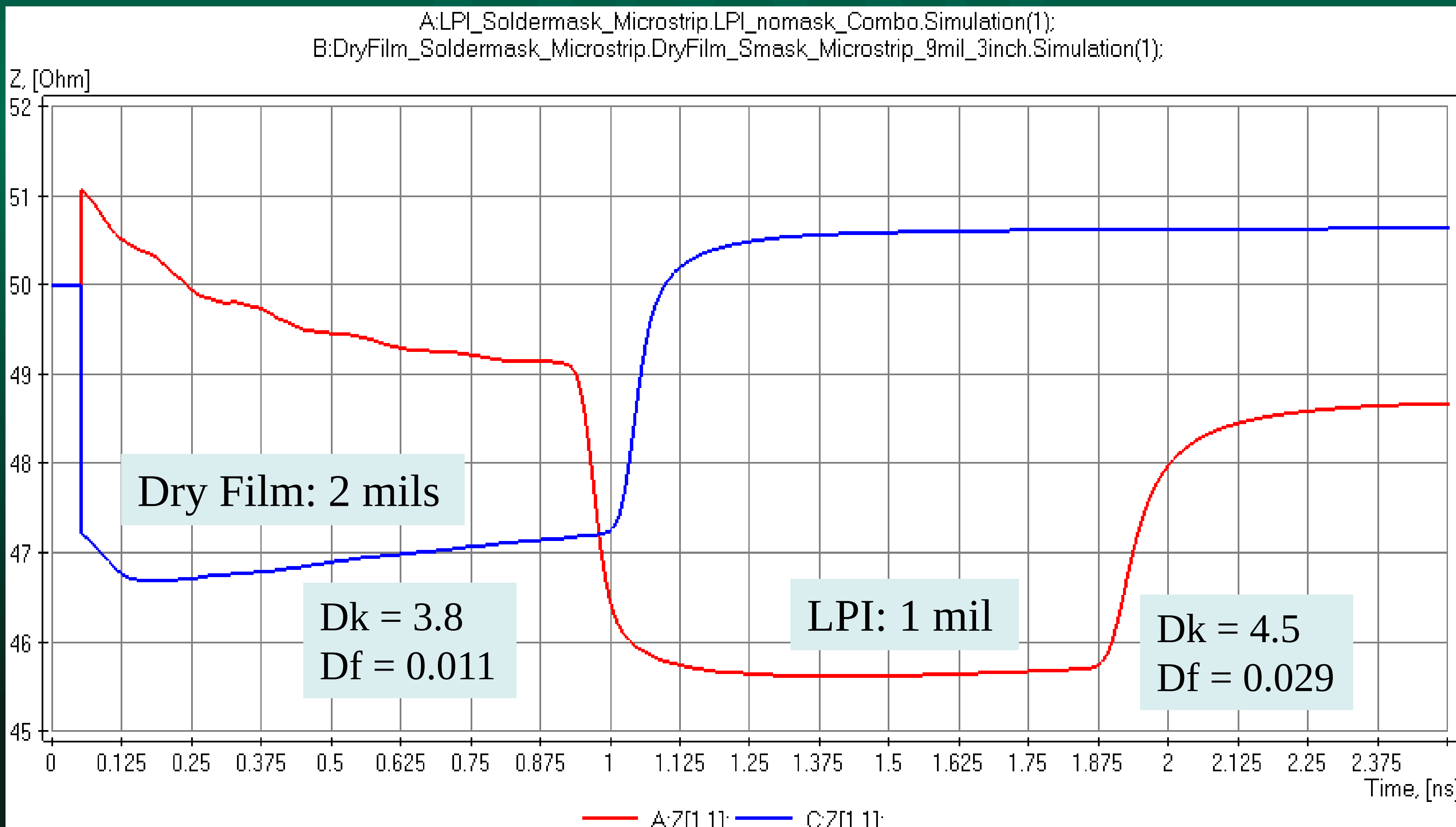




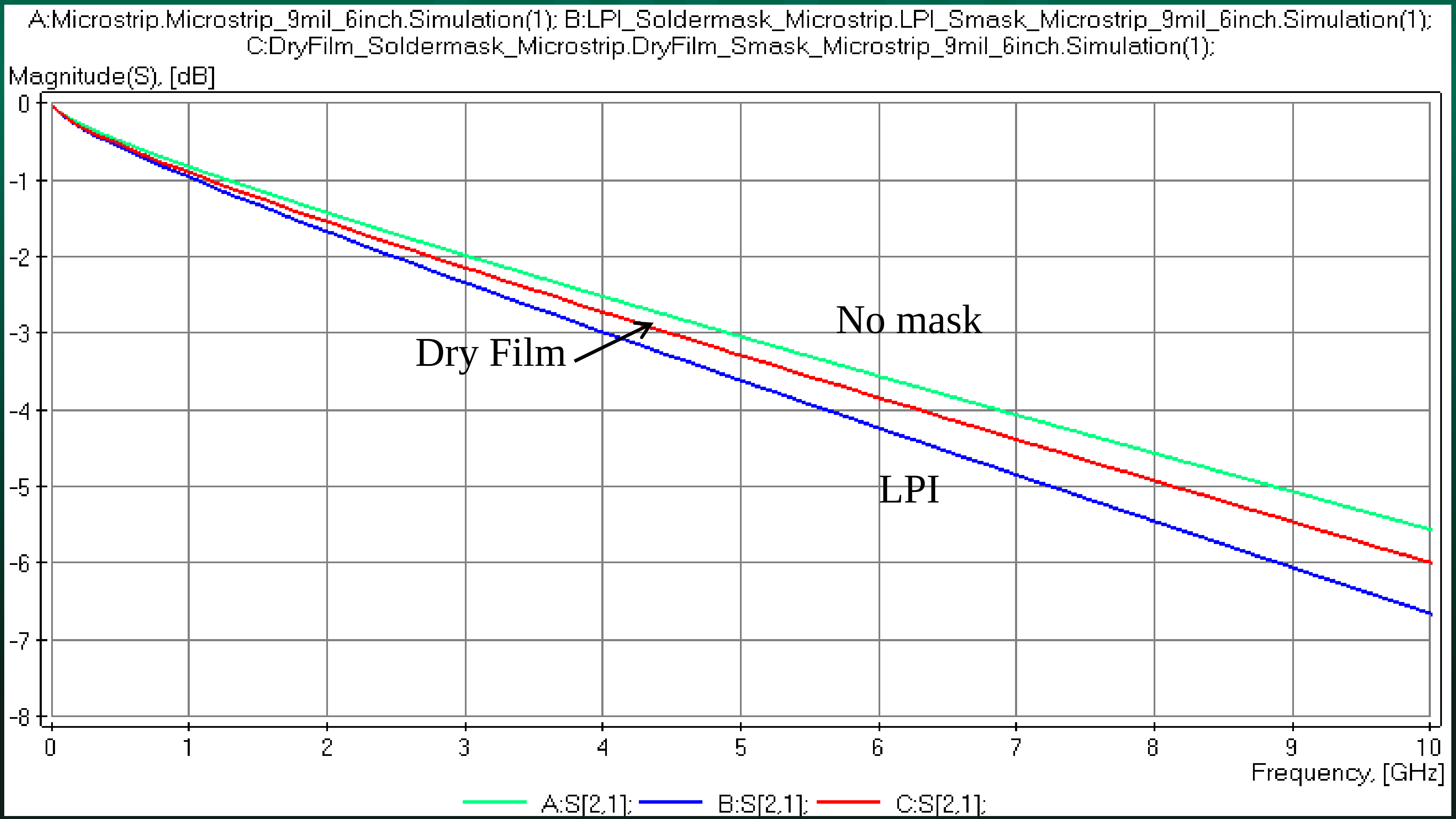
Embedded microstrip →



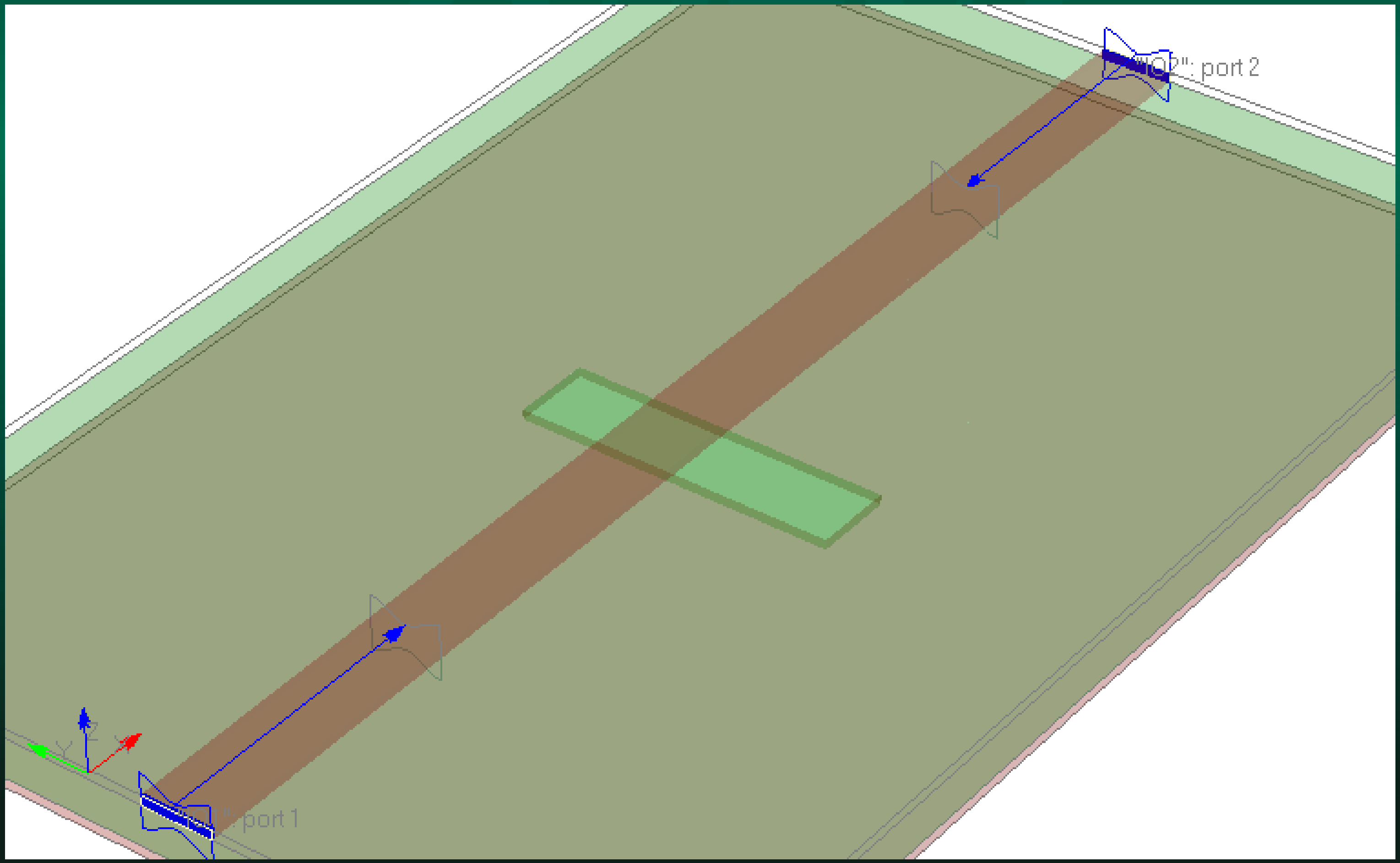
TDR data contrasts



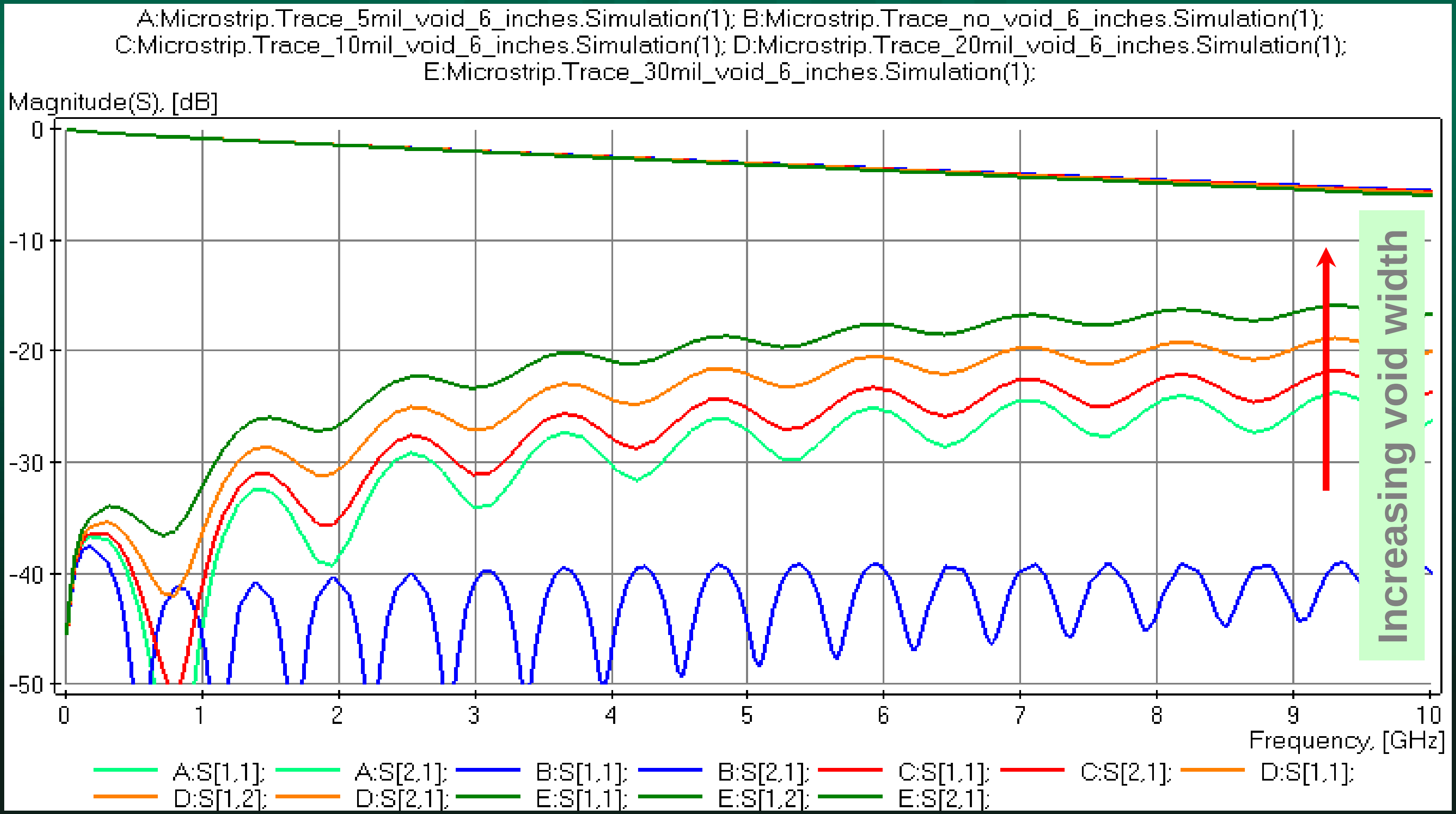
Insertion loss as a function of soldermask type



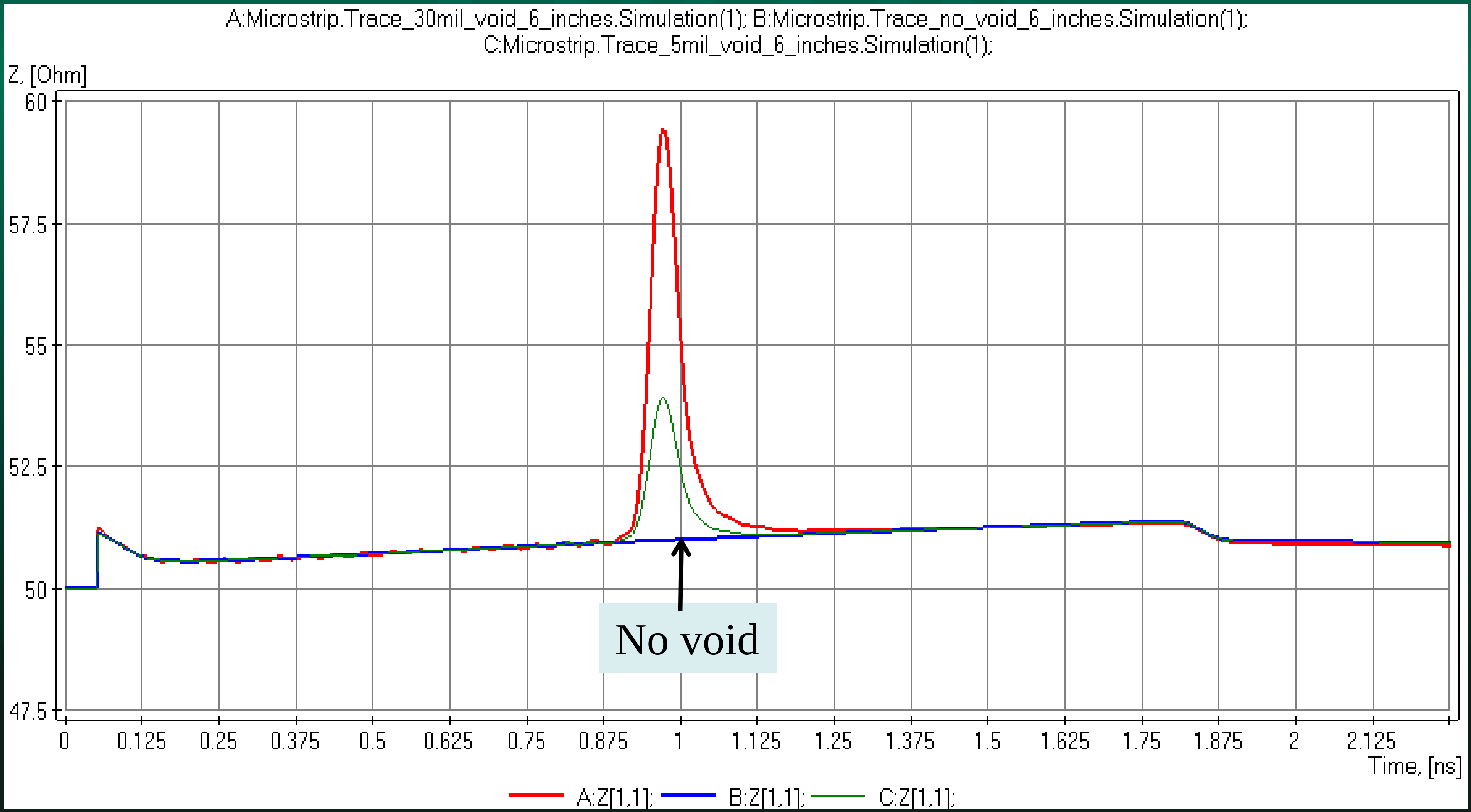
Void in reference plane



Insertion loss and return loss as a function of void in reference plane



TDR data as a function of void in reference plane

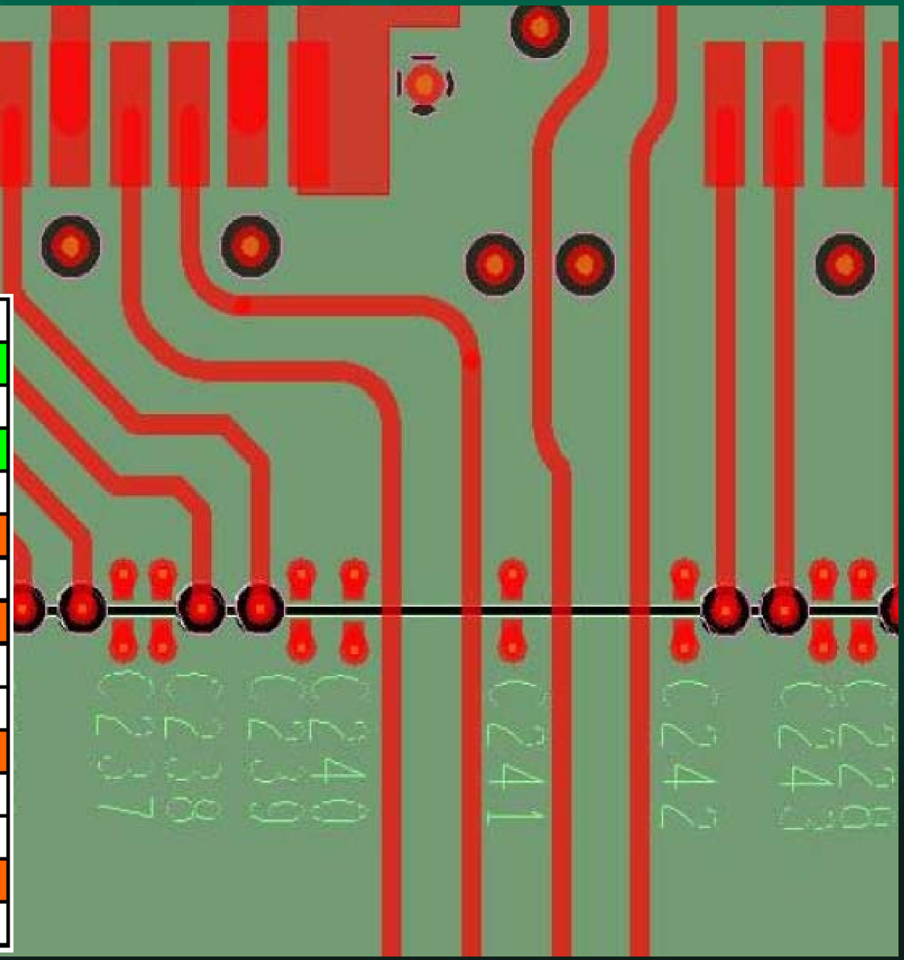


Application-mandated void in reference plane

DDR4 RDIMM

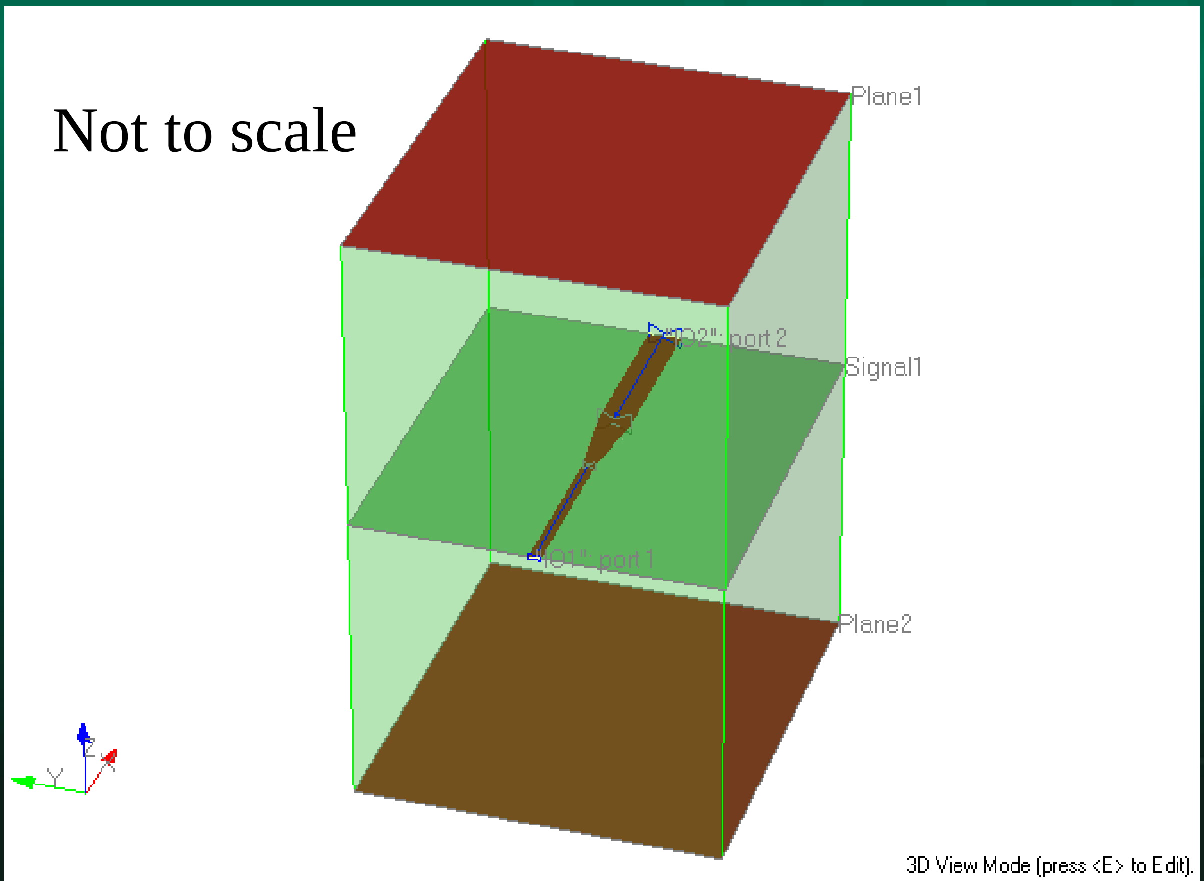
VSS	54
CB2	55
VSS	56
RESET#	57
VDD	58
CKE0	59
VDD	60
ACT#	61
BG0	62
VDD	63
A12	64
A9	65
VDD	66
A8	67
A6	68

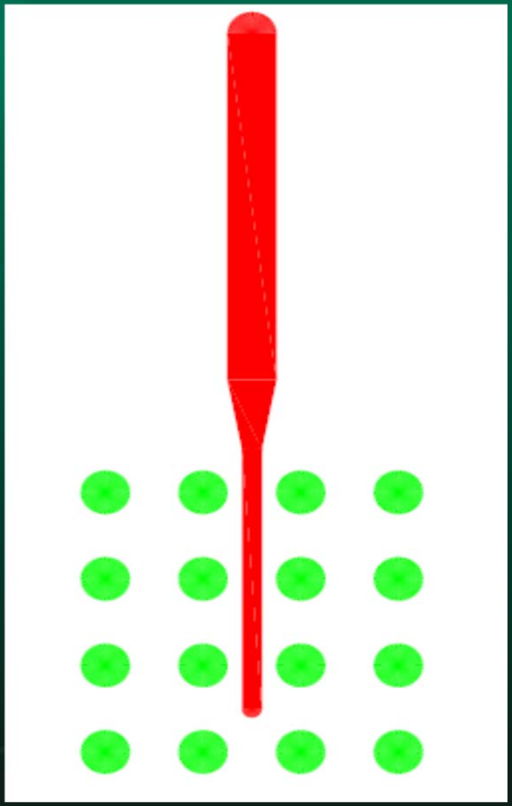
196	CB7
197	VSS
198	CB3
199	VSS
200	CKE1
201	VDD
202	RFU
203	VDD
204	BG1
205	ALERT#
206	VDD
207	A11
208	A7
209	VDD
210	A5



The necessity of line neckdown

Space constraints lead to the use of neckdown

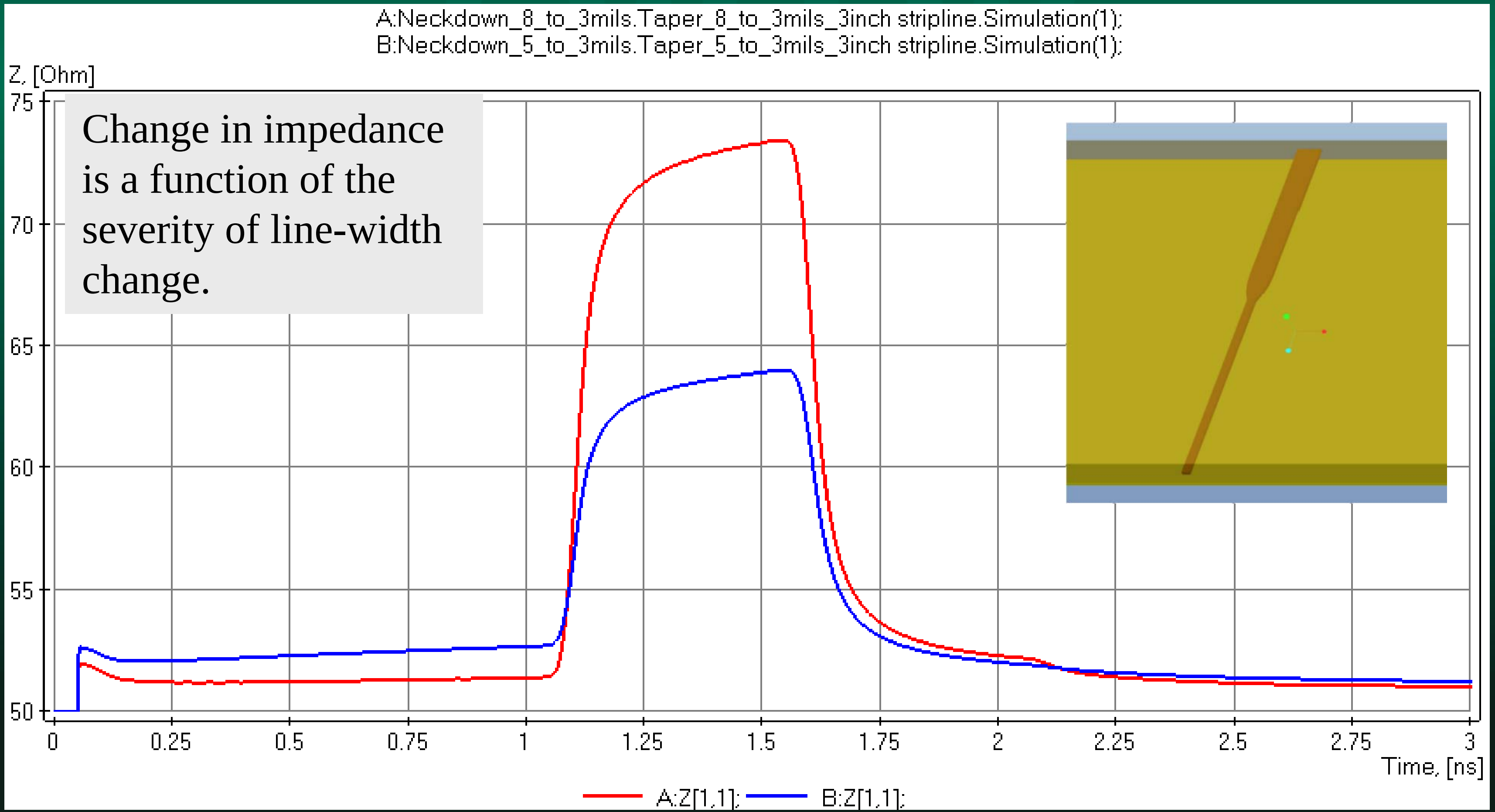




Ball-grid array

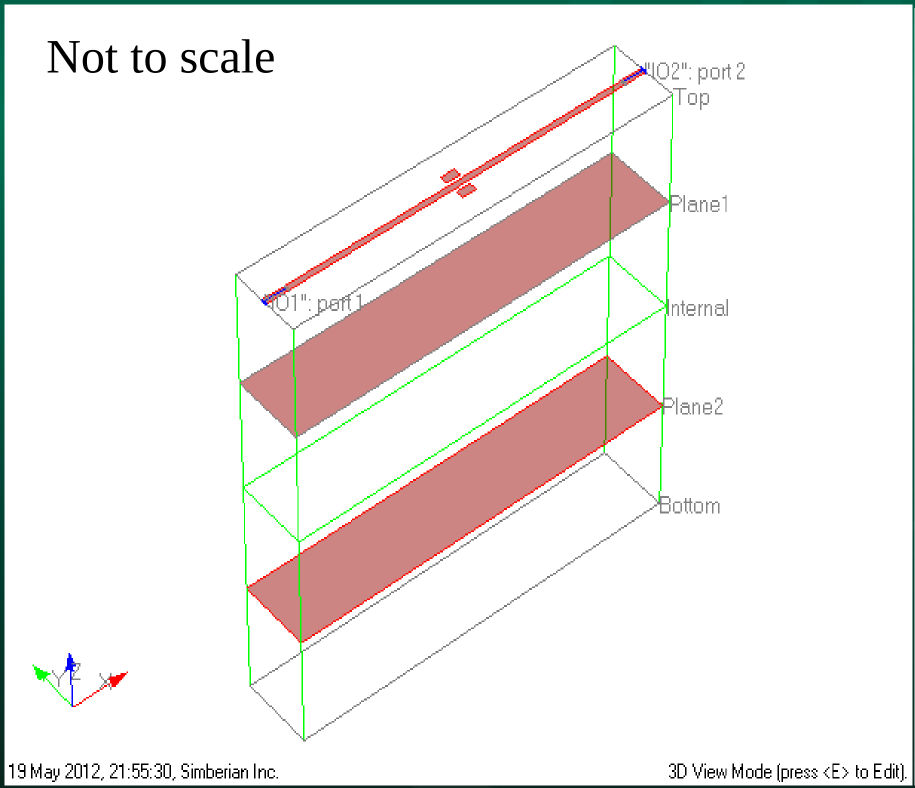
TDR data for necked down lines

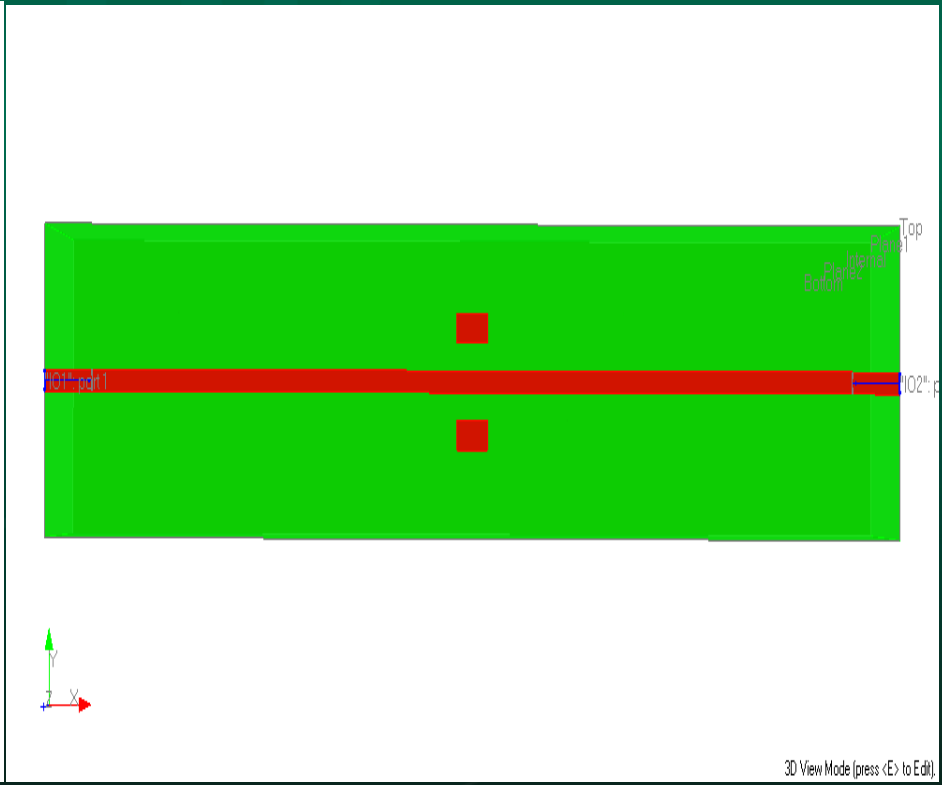
Change in impedance is a function of the severity of line-width change.



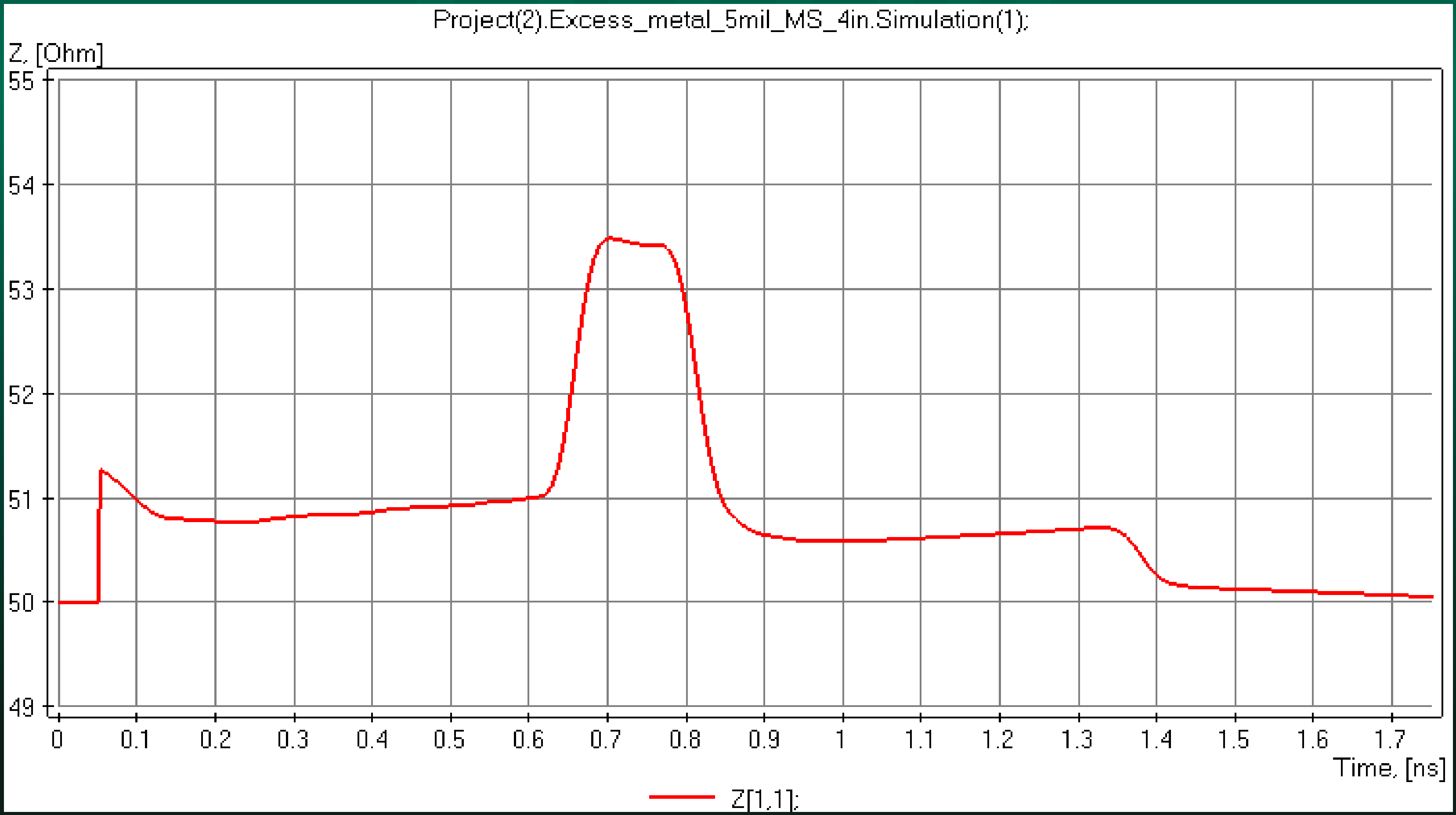
Stray floating conductor in the vicinity

Not to scale

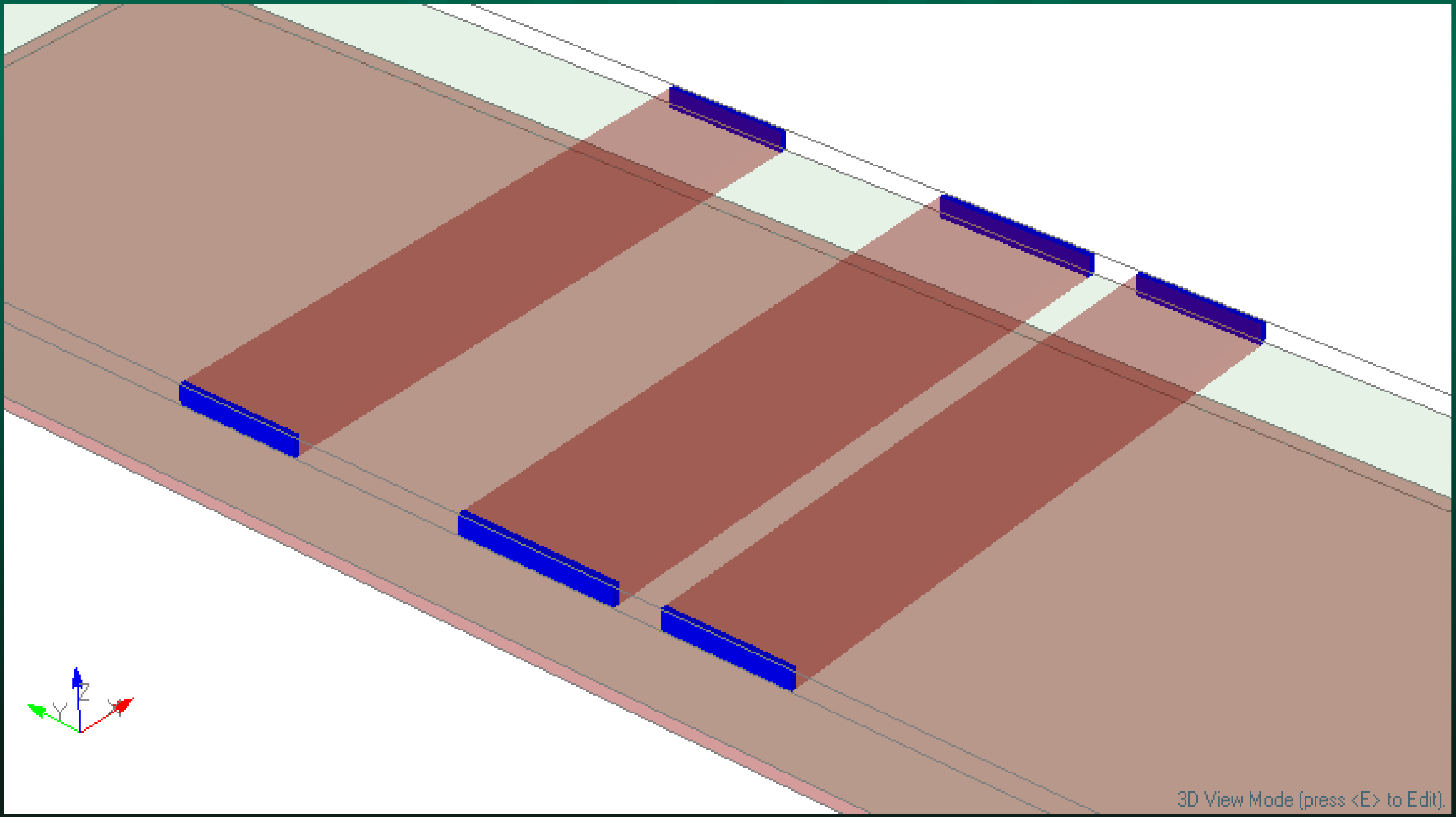




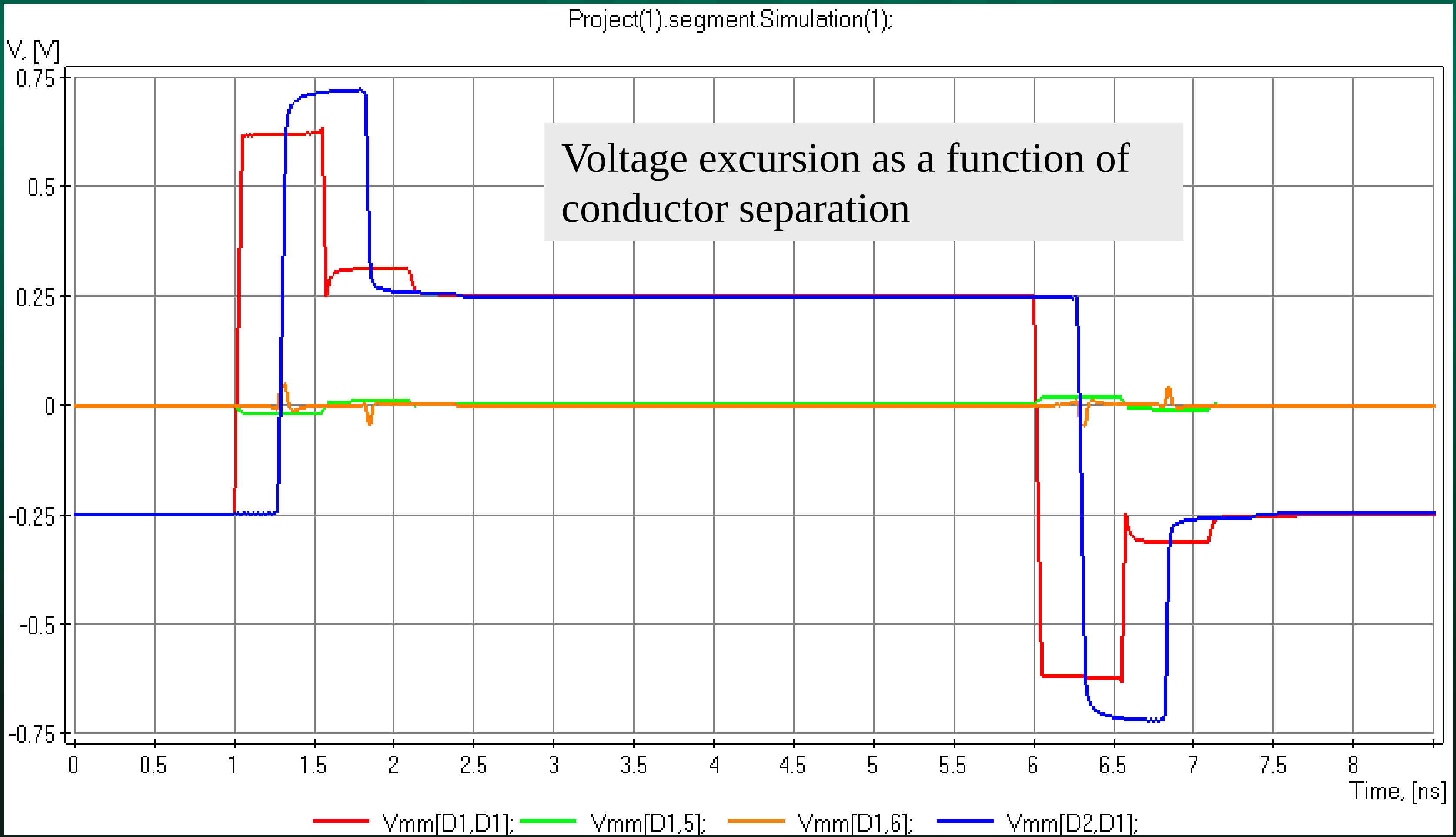
Impact of floating conductor by TDR



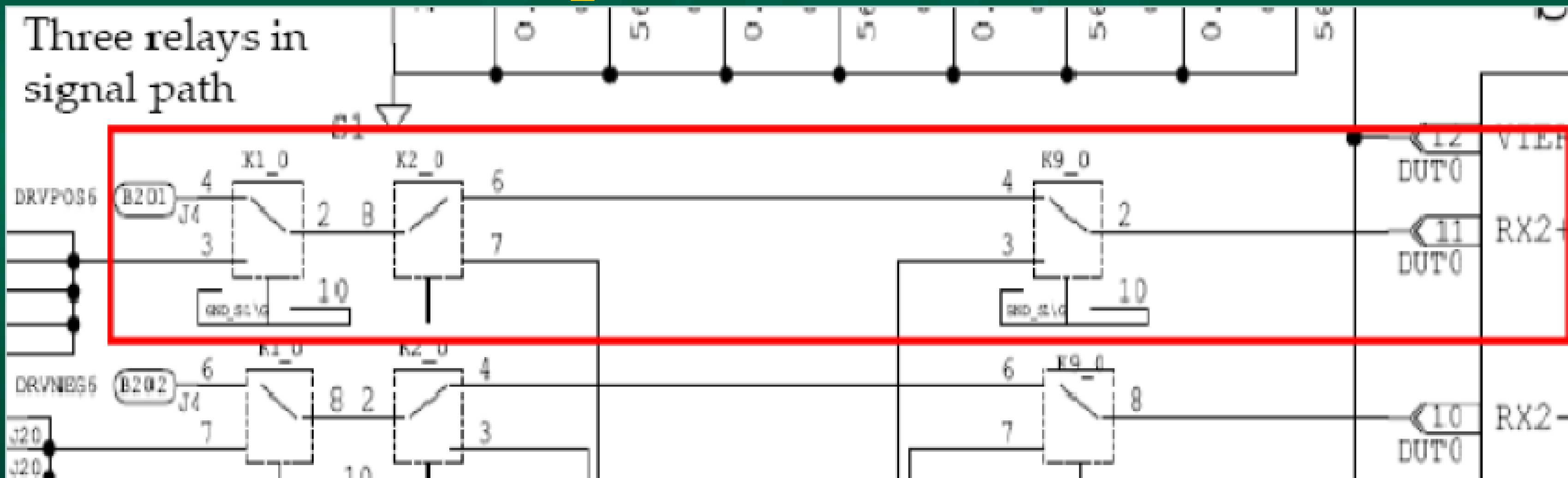
Parallel conductor crosstalk



Time-domain data for parallel conductors



Full signal path assessment for a 2-port network




```
!      GWN       .S2P       test        data            output    file    G-S-G    configuration
!      S11       S21        S12         S22
!      symbol    freq-unit  parameter-  data-format     keyword   impedance-ohms
#      GHz       S          MA          R               50
```

1.99E-01	2.39E-02	-9.73E+00	9.94E-01	-1.71E+00	0.99449	-1.713867	0.01954	-8.47E+00
3.99E-01	2.46E-02	-1.42E+01	9.94E-01	-2.56E+00	0.994156	-2.562622	0.019885	-1.25E+01
5.98E-01	2.58E-02	-2.08E+01	9.94E-01	-3.83E+00	0.99374	-3.8302	0.020508	-1.84E+01
7.97E-01	2.75E-02	-2.68E+01	9.93E-01	-5.09E+00	0.993225	-5.0896	0.021345	-2.41E+01
9.96E-01	2.96E-02	-3.22E+01	9.93E-01	-6.33E+00	0.992561	-6.33374	0.022397	-2.94E+01
1.20E+00	3.21E-02	-3.71E+01	9.92E-01	-7.57E+00	0.991837	-7.565674	0.023666	-3.45E+01
1.39E+00	3.50E-02	-4.15E+01	9.91E-01	-8.78E+00	0.990954	-8.779785	0.025139	-3.92E+01
1.59E+00	3.82E-02	-4.55E+01	9.90E-01	-9.98E+00	0.990062	-9.978516	0.026817	-4.37E+01
1.79E+00	4.17E-02	-4.91E+01	9.89E-01	-1.12E+01	0.989025	-11.16113	0.028683	-4.78E+01
1.99E+00	4.56E-02	-5.25E+01	9.88E-01	-1.23E+01	0.988004	-12.32568	0.030732	-5.17E+01
2.19E+00	4.96E-02	-5.57E+01	9.87E-01	-1.35E+01	0.986935	-13.46826	0.032922	-5.53E+01
2.39E+00	5.40E-02	-5.87E+01	9.86E-01	-1.46E+01	0.985919	-14.58301	0.035251	-5.87E+01
2.59E+00	5.86E-02	-6.15E+01	9.85E-01	-1.57E+01	0.984903	-15.67383	0.037702	-6.20E+01

Courtesy Johnstech International

Relays in signal path

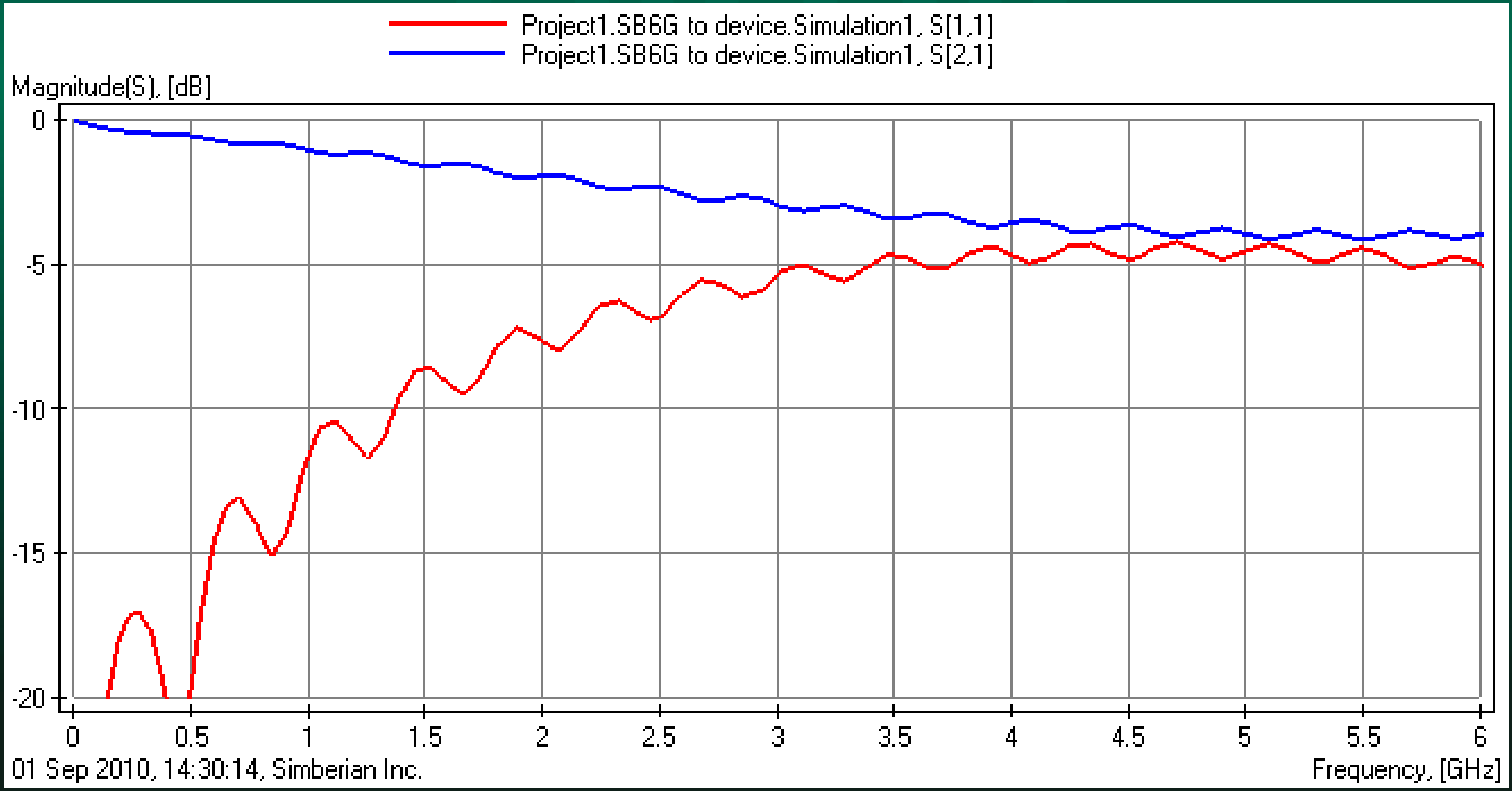
6.5 GHz bandwidth for RF and Pulse switching (fast rise time pulses)

Option 1:
No S-parameters available

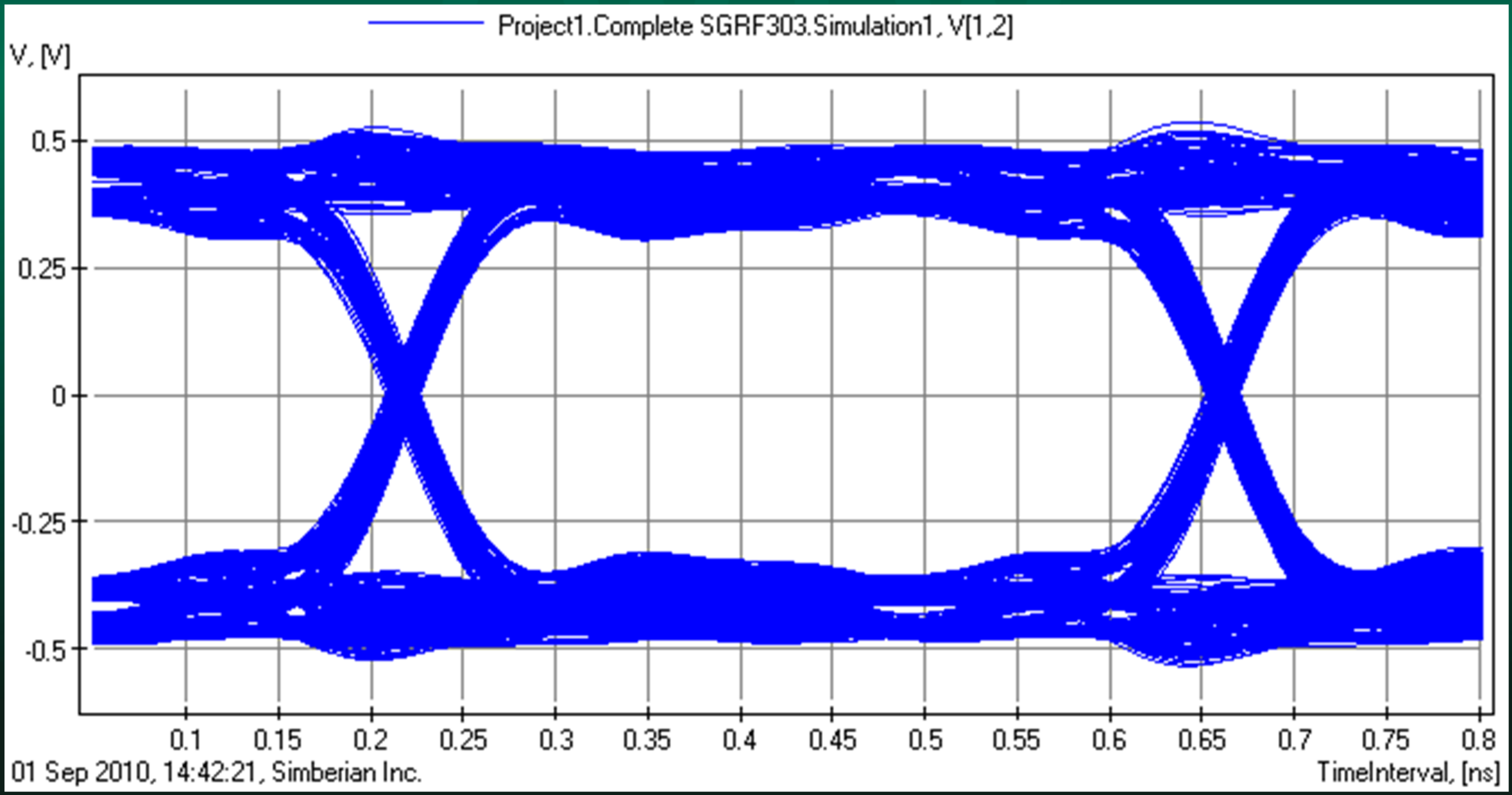
```
! Network Analyzer HP8722D.07.74: Oct 30, 2002 Serial No. US36140486
! Hewlett-Packard
! 20 May 2008  16:43:04
! Frequency       S11                 S21                 S12                 S22
# HZ   S   DB R  50
50000000   -40.412   -53.089   -.0296   -.8280   -.0579   -.9118   -42.16   -29.09
99750000   -39.6   -54.597   -.0546   -1.4639   -.0587   -1.4543   -38.359   -61.581
149500000   -35.172   -79.238   -.0537   -2.0517   -.0682   -1.9968   -35.655   -78.249
199250000   -33.698   -87.789   -.0702   -2.623   -.0621   -2.5612   -33.479   -89.824
249000000   -31.612   -100.55   -.0718   -3.1805   -.0845   -3.1421   -31.722   -99.451
298750000   -30.461   -108.37   -.0924   -3.6626   -.0722   -3.5829   -30.352   -108.51
348500000   -28.954   -118.87   -.0550   -4.3327   -.0685   -4.3643   -29.031   -117.2
398250000   -27.926   -126.49   -.1118   -4.8093   -.1133   -4.7749   -27.805   -124.88
448000000   -26.797   -135.42   -.0569   -5.4108   -.0555   -5.2652   -26.808   -132.38
497750000   -26.092   -141.87   -.0903   -5.9203   -.1151   -6.14   -26.037   -139.73
547500000   -25.089   -149.09   -.0456   -6.6975   -.0776   -6.2073   -25.056   -147.08
597250000   -24.503   -155.9   -.1358   -7.0601   -.0350   -7.2084   -24.52   -153.75
647000000   -23.853   -163.6   -.0212   -7.744   -.1133   -7.8662   -23.969   -160.74
696750000   -23.359   -170.09   -.1264   -8.3922   -.0556   -8.0516   -23.467   -167.6
746500000   -22.792   -177.47   -.0465   -9.1296   -.0729   -9.4263   -22.947   -174.93
796250000   -22.518   176.28   -.1304   -9.337   -.1542   -9.3672   -22.525   179.3
846000000   -22.175   169.62   -.0188   -10.418   -.0317   -9.9646   -22.266   172.22
895750000   -22.191   164.78   -.1633   -10.808   -.1200   -11.041   -22.291   165.51
945500000   -21.882   158.81   -.0738   -11.324   -.0944   -11.076   -22.042   158.85
```

Option 2:
Courtesy Teledyne

Frequency-domain results for signal path



Time-domain results for signal path



Concluding remarks

It is informative to quantify the effects of individual isolated elements in the environment on the signal path. Ultimately, one would still need to characterize the entire signal path with all factors taken into account before deciding if a particular design will satisfy the stated objectives and thus move forward to manufacturing. Fortunately, there are tools to help us make such decisions whether they concern signal integrity or power integrity.