A path forward following lack of complete consensus on COM package models

Liav Ben-Artsi – Marvell Technology

Contributor: Based on former work done by Richard Mellitz and jointly presented in benartsi_3df_01_2211

Agenda

- Recap on package model as presented Nov 2022
- What can we agree upon?! - Justifying model construction
- Package material loss consensus discussions ongoing, will be presented as part of consensus group presentation

Supporters

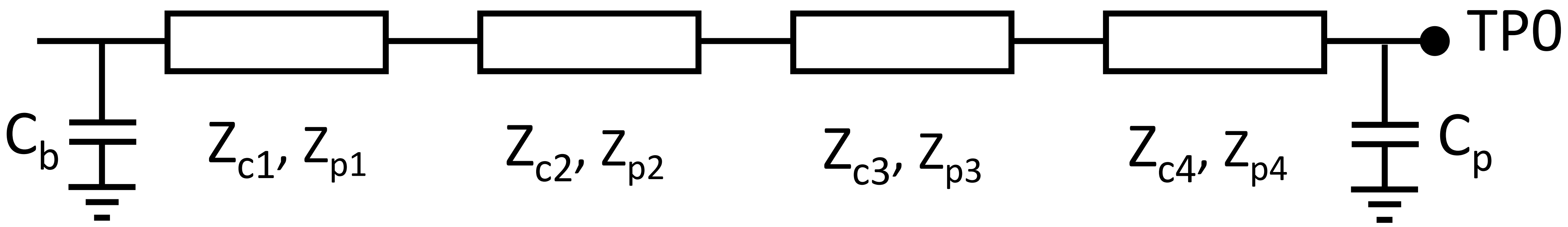
Recap on Assumptions/Former Work

- A realistic package loss/mm for 40µ dielectric height + 27µ-45µ-27µ trace geometry was given as 0.21dB/mm (we will discuss possible cases of lowering loss); Other parts of the package model were optimistic - ~800µ core, 7-2-7 stack-up, no impedance manufacturing tolerance, etc.
- Routing of Tx, or Rx lanes can easily be 40-45mm long, or even longer in congestion cases – Length in this stage to be TBD
- 3D extraction was matched with a four sections package model for COM much better correlation than with 802.3ck model
  - The 4 sections are required to match higher frequency characteristics compared to 802.3ck. – Resulting COM run consistently better than when concatenating to extracted model (~0.2dB – probably some fine details are still left out when using matched model) – Slide #12

802.3dj suggested COM Model - Iteratively adjust γ_0, a_1, a_2, τ

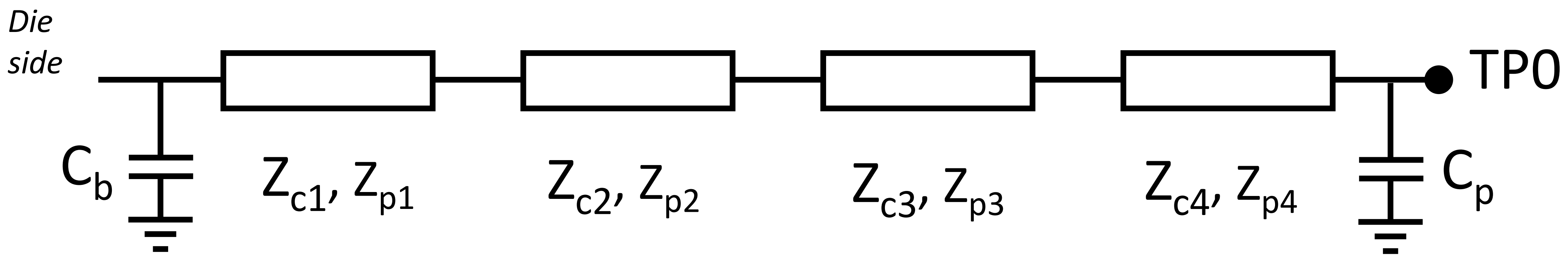
COM MODEL: IEEE802.3 ANNEX 93A.1.2.3

- Also tune
  - Z_p, Z_c, C_b, C_p



COM Model Results

COM MODEL: IEEE802.3 ANNEX 93A.1.2.3



30ff 92 Ω, 12/30/45 mm 70 Ω, 1.0 mm 80 Ω, 1.0 mm 100 Ω, 0.5 mm 50ff

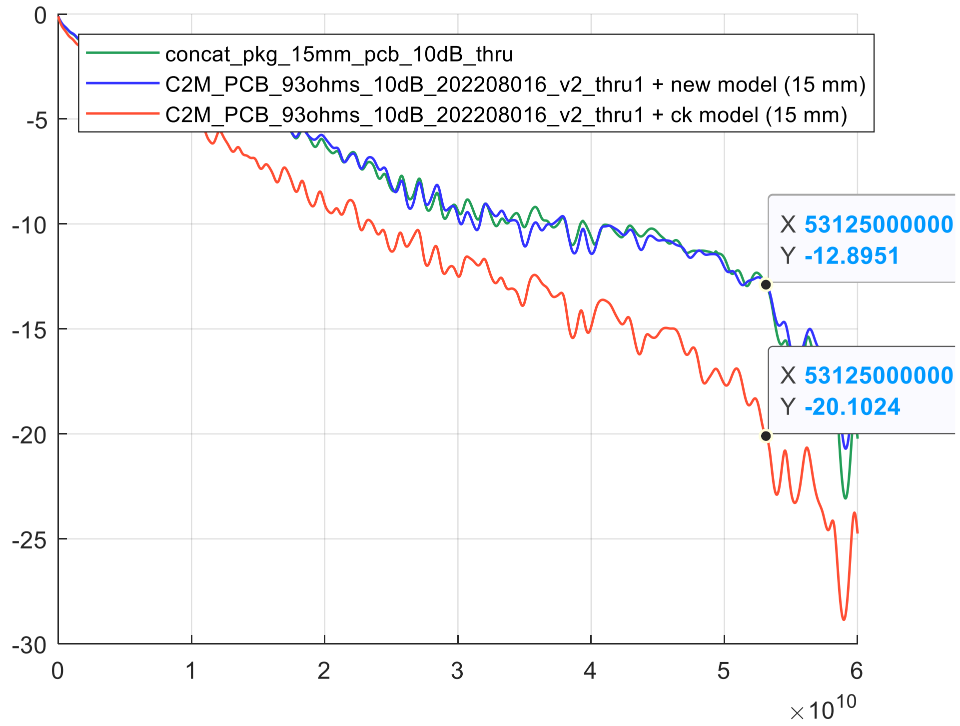
$\gamma_0 = 0,\ a_1 = 0.0008455,\ a_2 = 0.000340225,\ \tau = 0.00644805$

Frequency Domain Comparison

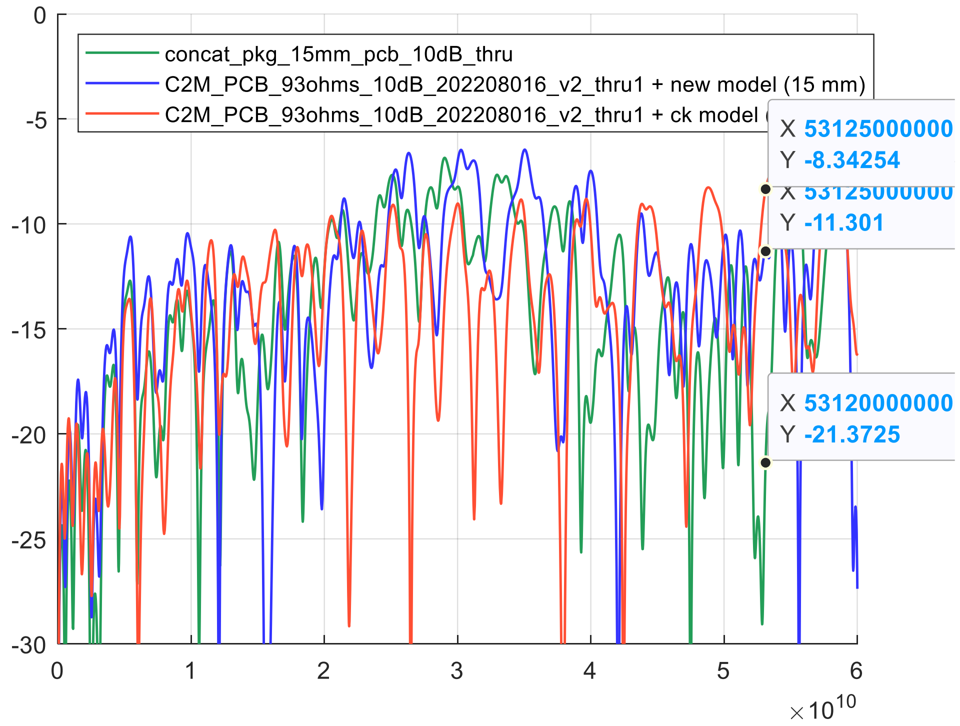
Example case: 15 mm + 10 dB

(After concatenation, how well does the “model” channel match “HFSS” channel?)

ILDD

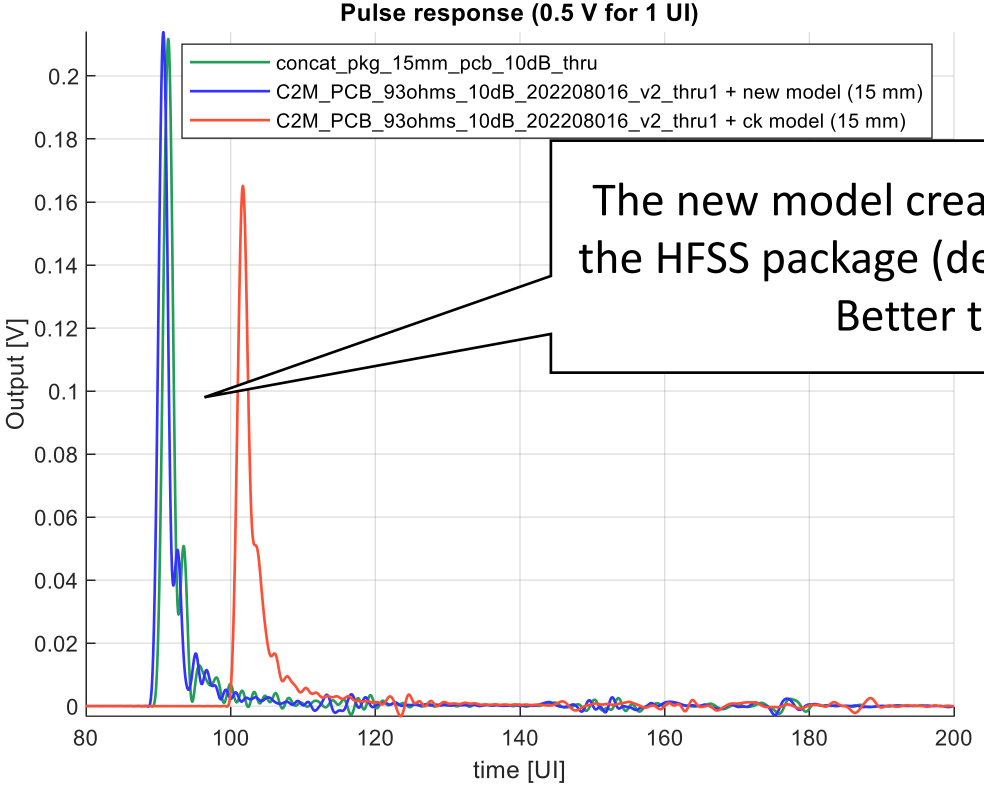


RLDD



Time domain SBR comparison

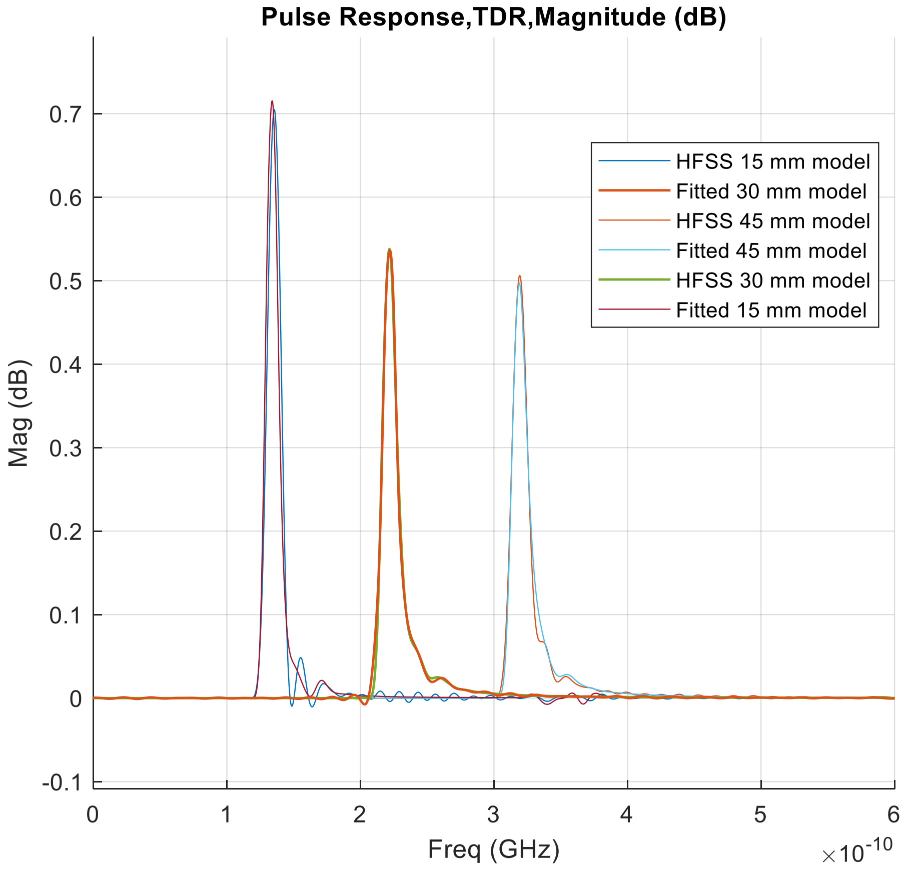
Example case: 15 mm + 10 dB

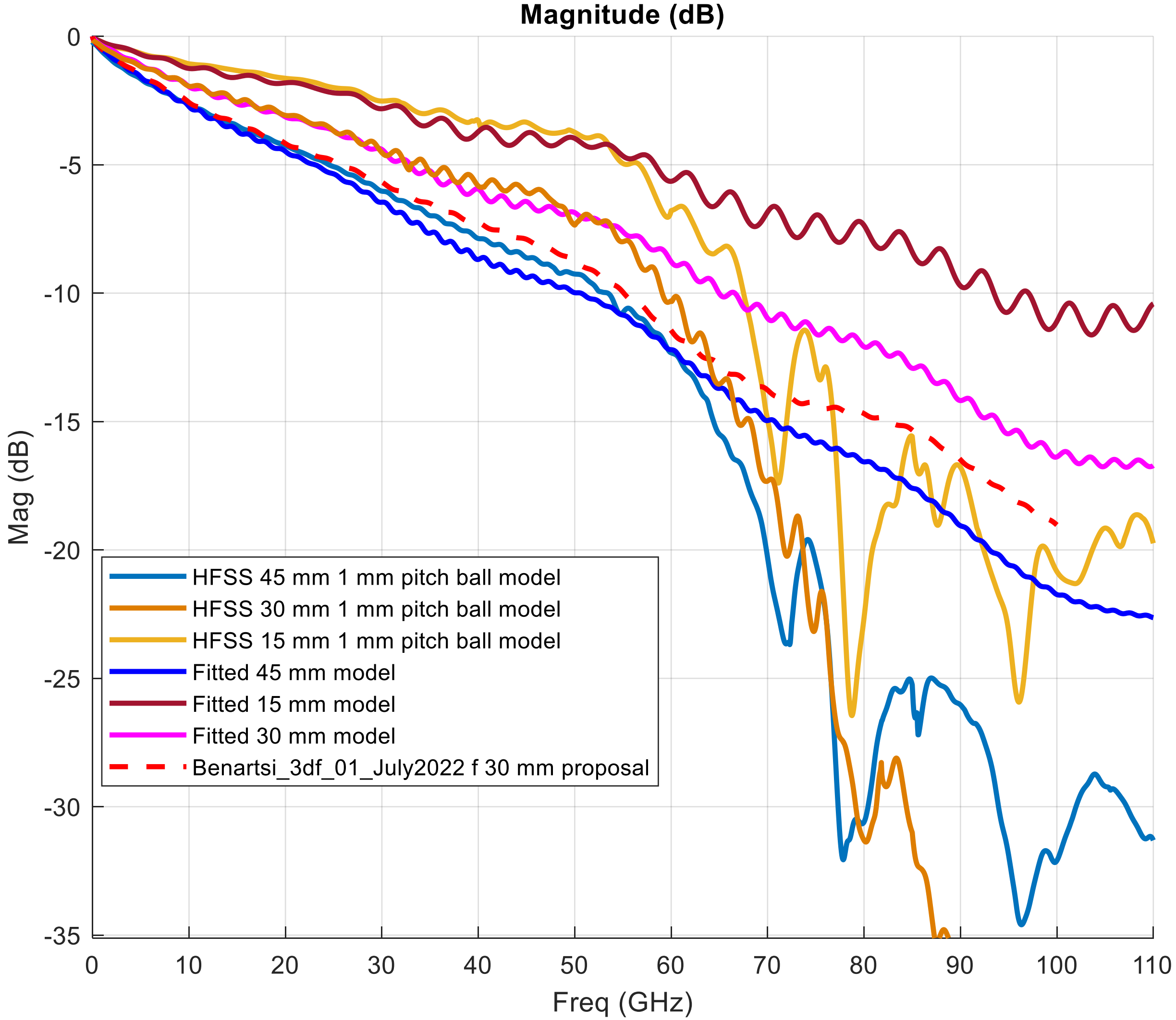


The new model creates a response that is close to the HFSS package (delay, pulse shape, pulse height)
Better than the ck model

Graphic View of Results

IF PACKAGE HAS A ROLL-OFF – NOT IN FITTED COM MODEL





COM Config Settings

C2M EXAMPLE

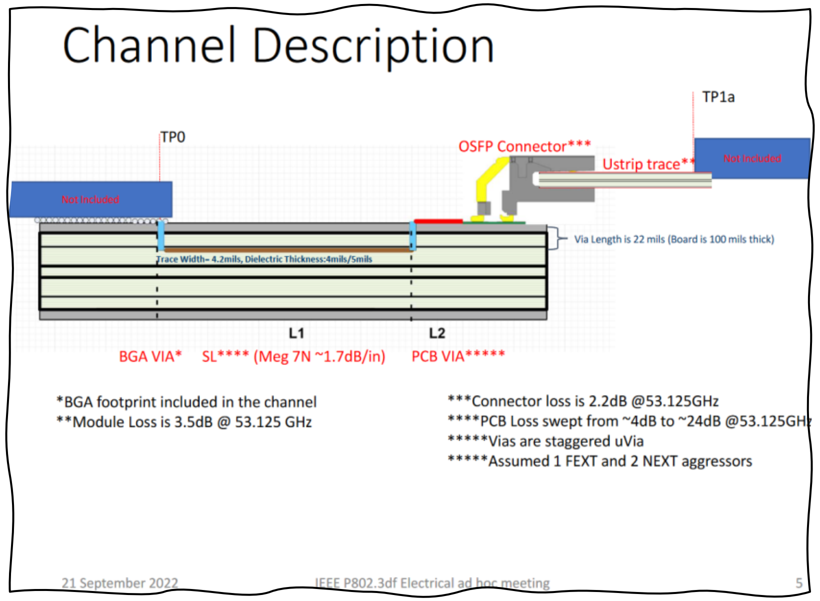
Table 93A–3 parameters		
Parameter	**Setting**	**Units**
package_tl_gamma0_a1_a2	[0 0.0008455 0.000340225]	
package_tl_tau	0.00644805	ns/mm
package_Z_c	[92 92 ; 70 70; 80 80; 100 100]	Ohm

C_d	[0.4e-4 0.9e-4 1.1e-4 ;0 0 0]
L_s	[.12 .15 .14; 0 0 0]
C_b	[.3e-4 0]
z_p select	[1 2 3]
z_p (TX)	[12 30 45 ; 1 1 1 ; 1 1 1 ; 0.5 0.5 0.5]
z_p (NEXT)	[0 0 0; 0 0 0;0 0 0 ;0 0 0]
z_p (FEXT)	[12 30 45 ; 1 1 1 ; 0.1 0.1 0.1 ; 0.58 0.58 0.58]
z_p (RX)	[0 0 0; 0 0 0;0 0 0 ;0 0 0]
C_p	[0.5e-4 0]

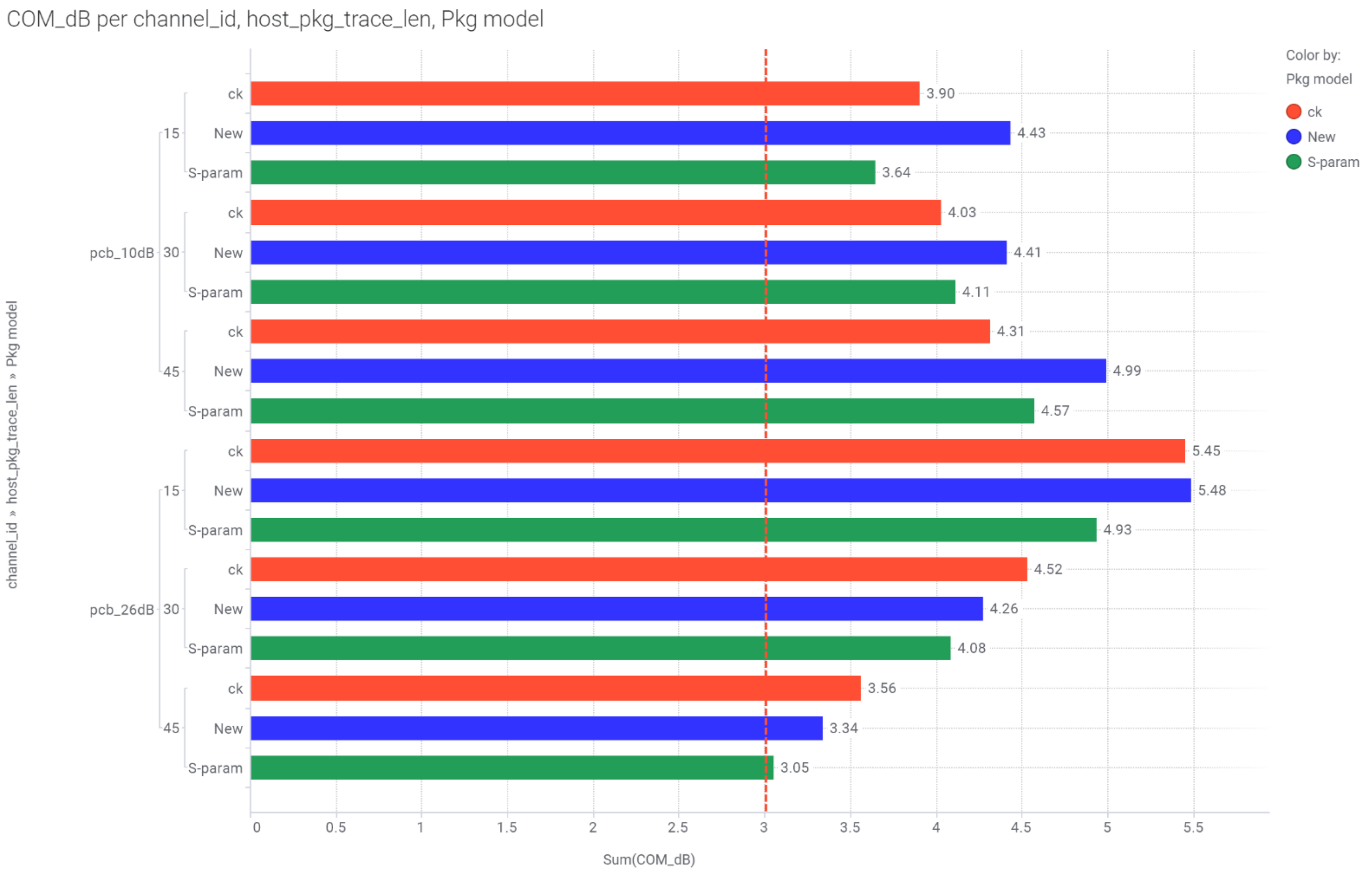
Test Cases

	z_p=15	z_p=30	z_p=45
C2M_PCB_93ohms_10dB_202208016_v2_thru1.s4p	concat_pkg_15mm_pcb_10dB	concat_pkg_30mm_pcb_10dB	concat_pkg_45mm_pcb_10dB
C2M_PCB_93ohms_26dB_202208016_v2_thru1.s4p	concat_pkg_15mm_pcb_26dB	concat_pkg_30mm_pcb_26dB	concat_pkg_45mm_pcb_26dB

Channels are from akinwale_3df_elec_01_220921



COM Results Comparison



- COM results with the updated fitted model (blue) are consistently higher than with HFSS S-parameter concatenation (green)
  - The difference is usually 0.2-0.5 dB
  - The “shortest” combination is an exception
- For the high loss channel, the new model is closer to the HFSS results than the ck model (red)
  - For the low loss channel, the ck model had worse COM in 2 cases!
- The fitted model is somewhat optimistic…?
  - but in a more consistent way than the old model

Conclusions & Recommendations

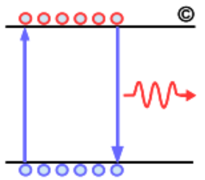
- ❑ Providing a package model for COM to account for 200Gbps PAM4 signaling requires "high amount of" details in higher frequency than before
- ❑ Former .ck package model failed to supply required accuracy
- ❑ A suggested higher details model showed relatively consistent results compared to concatenated 3D extracted model
- ❑ Recommend adopting new, 4 TL model as the COM model; parameters yet to be decided according to consensus group work

Backup

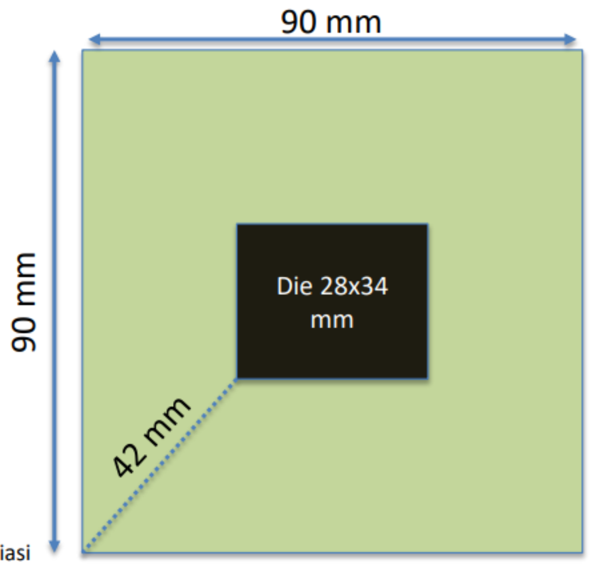
Ali Ghiasi's Suggested BGA Configuration

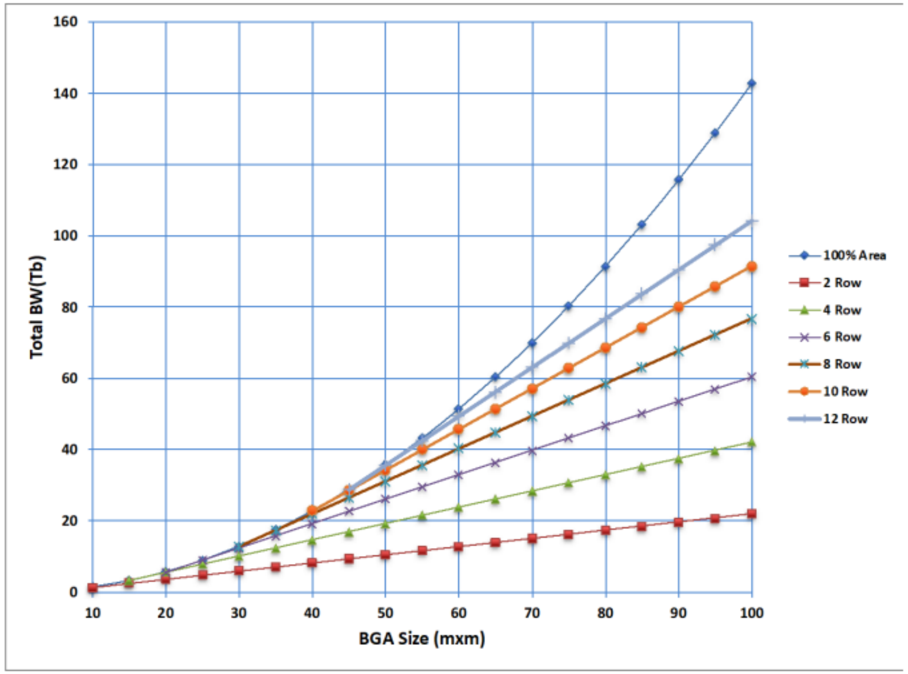
WWW.IEEE802.ORG/3/DF/PUBLIC/22_10/22_0927/GHIASI_3DF_01_220927.PDF

Hypothetical 512x200G Switch



- **Likely will require 90x90 BGA**
  - Provides √2 for FEXT pairs
  - Provides 2 balls separations for NEXT
  - For the hypothetical switch with 28x34 mm die results in 42 mm long substrate trace!





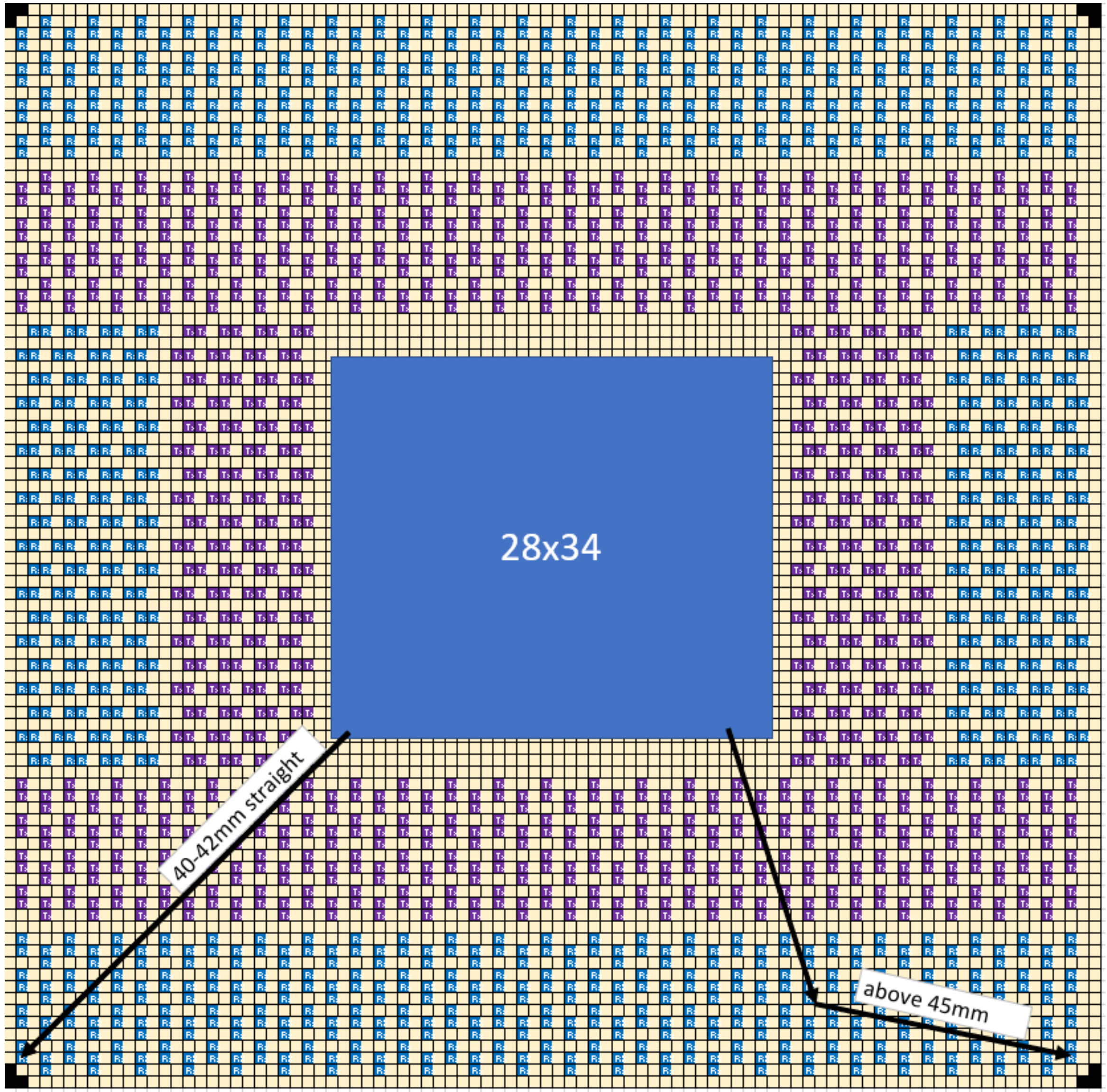
For the BGA ball grid assumed, see https://opg.optica.org/oe/fulltext.cfm?uri=oe-23-3-2085&id=310831

A. Ghiasi 802.3df Task Force 10

Full Population of 512 Tx Lanes & 512 Rx Lanes

92X92 BALL-OUT MATRIX ACCORDING

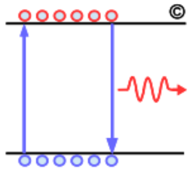
- No overhead was taken for CMOS, PCIe, or any addition signals
- Routing of Tx, or Rx lanes can easily be 40-45mm long, or even longer in congestion cases



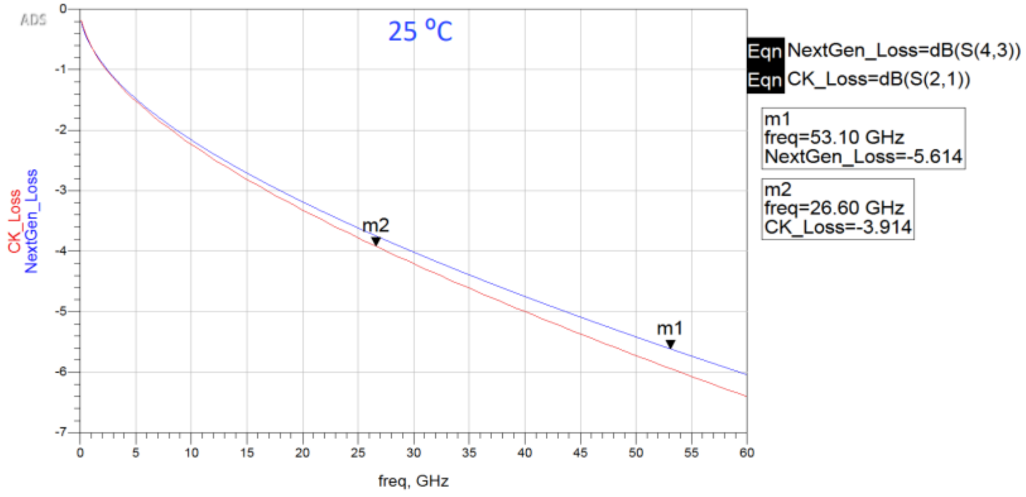
Expected Losses of Next Gen Material

- ghiasi_3df_01_220927.pdf: “benartsi_3df_01b_2207 uses best ABF conventional 27-45-27 µm construction and reports trace loss of 0.31 dB/mm @53 GHz (loss include transition via/BGA) • Benartsi loss expect to be lower ~0.22 dB/mm after accounting for improved surface roughness”

CK and Next Gen Package Losses for Reduced Trace Width



- **Adjust trace width to 27 µm as suggested by benartsi_3df_01b_2207**
  - Use the same Hurray surface roughness model that was previously matched best ABF film in 2018/2019
  - Reduced trace width may be required for some high radix switches implementations
  - Losses for **27 µm** wide 92.5 Ω stripline traces
    - For best ABF film from 2018/2019 the CK 30 mm package trace loss is 3.94 dB or 0.13 dB/mm instead of assumed 0.109 dB/mm assumed loss @26.56 GHz
    - Next Gen 2022 ABF film the 30 mm package trace loss would be 5.6 dB or 0.19 dB/mm @53.1 GHz (6.75 dB or ~0.225 dB/mm 90°C).



Loss Reported is only for the trace and does not include transition Via/BGA

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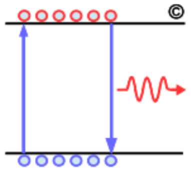

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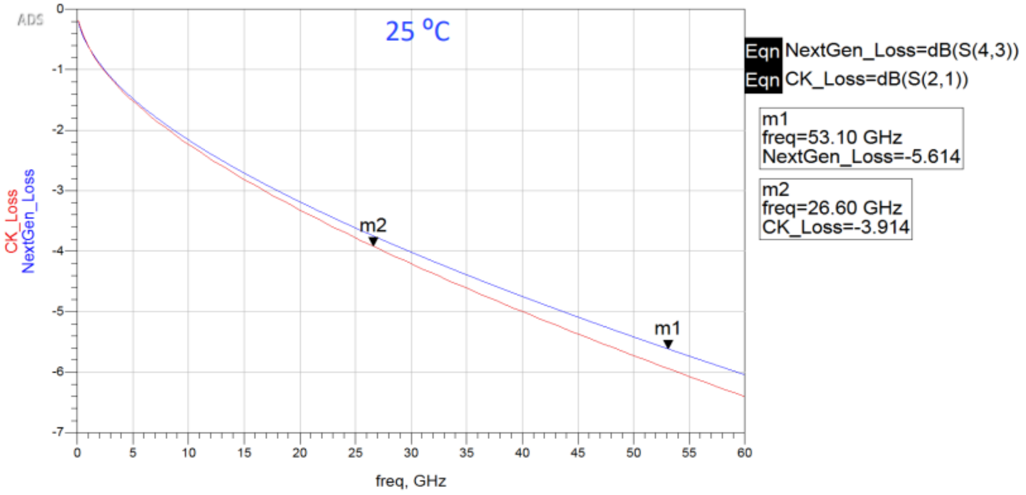

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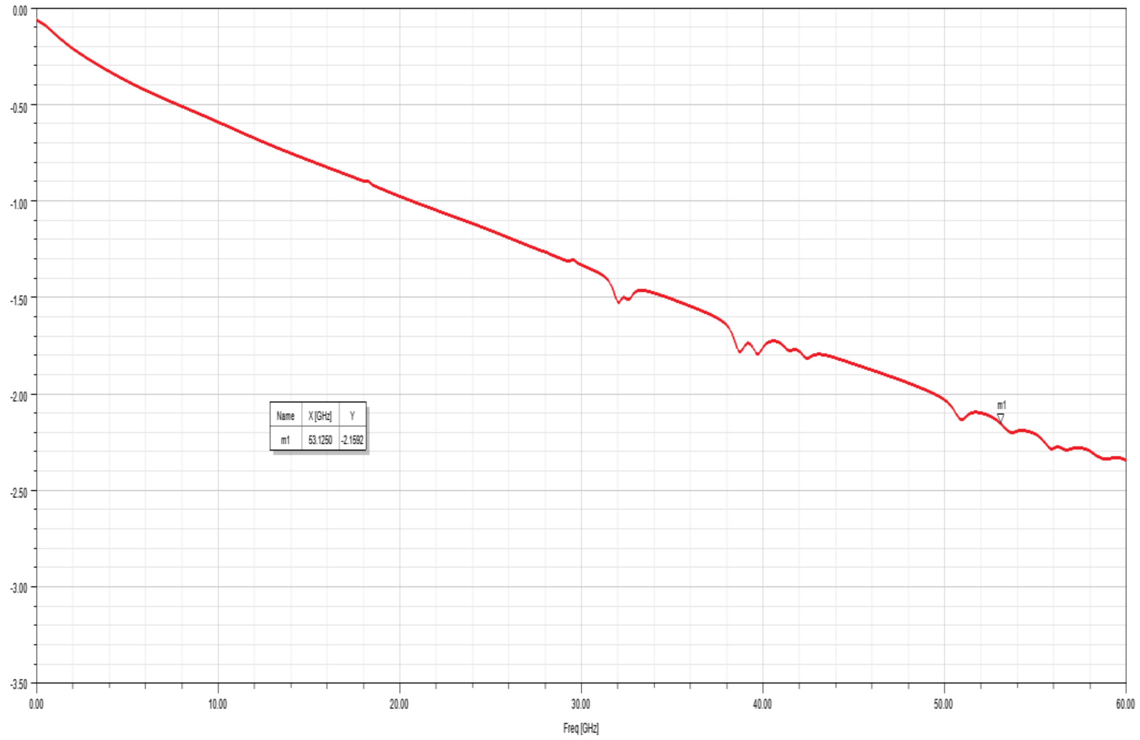
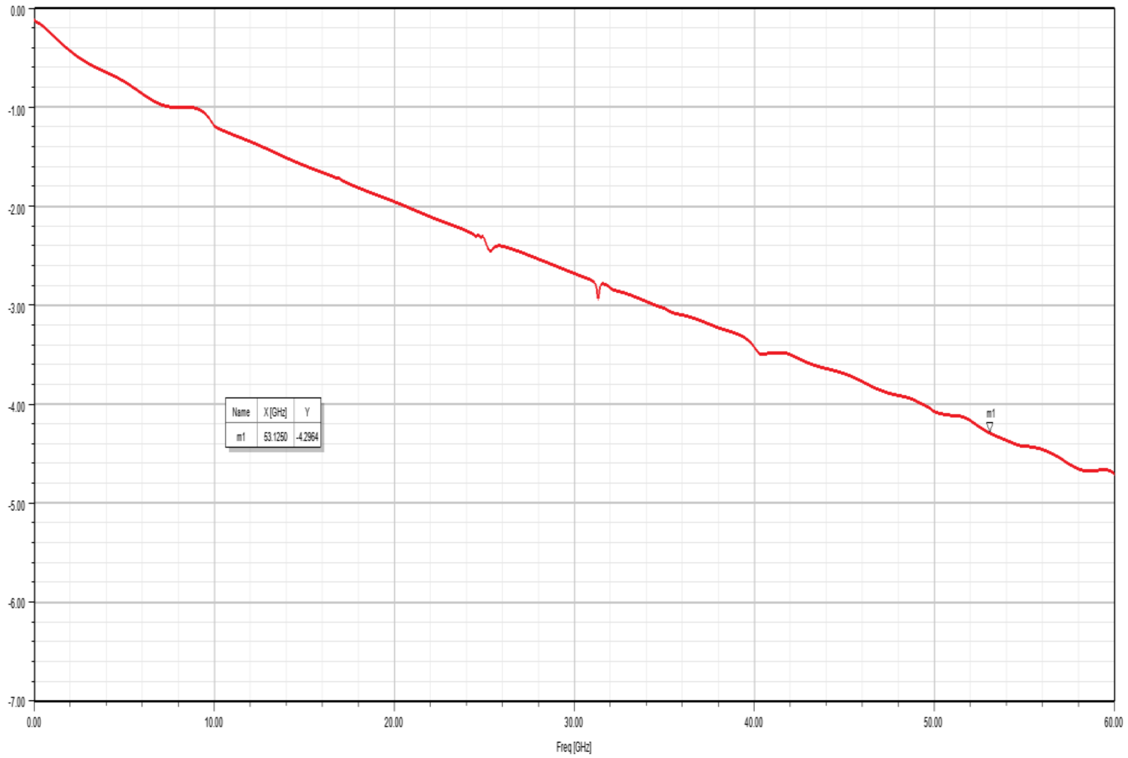
Adjusted Extraction of Loss/mm

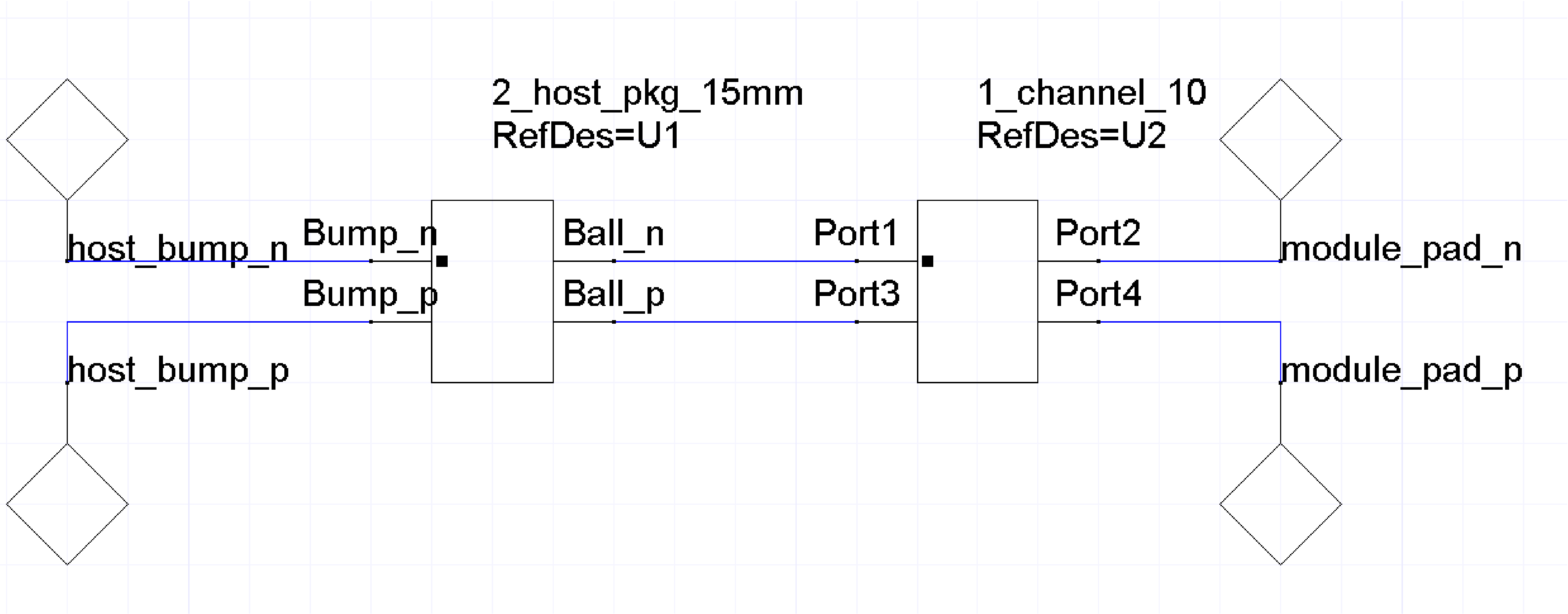
- ❑ 40µ dielectric height ; 15µ copper thickness ; 27µ-45µ-27µ trace geometry
- ❑ The resulting loss/mm ≈ 0.21dB
- ❑ Conductivity was updated to correlate and account for high temperature
- ❑ Correlates to the expected and measured loss/mm





S-parameter Concatenation (HFSS model)

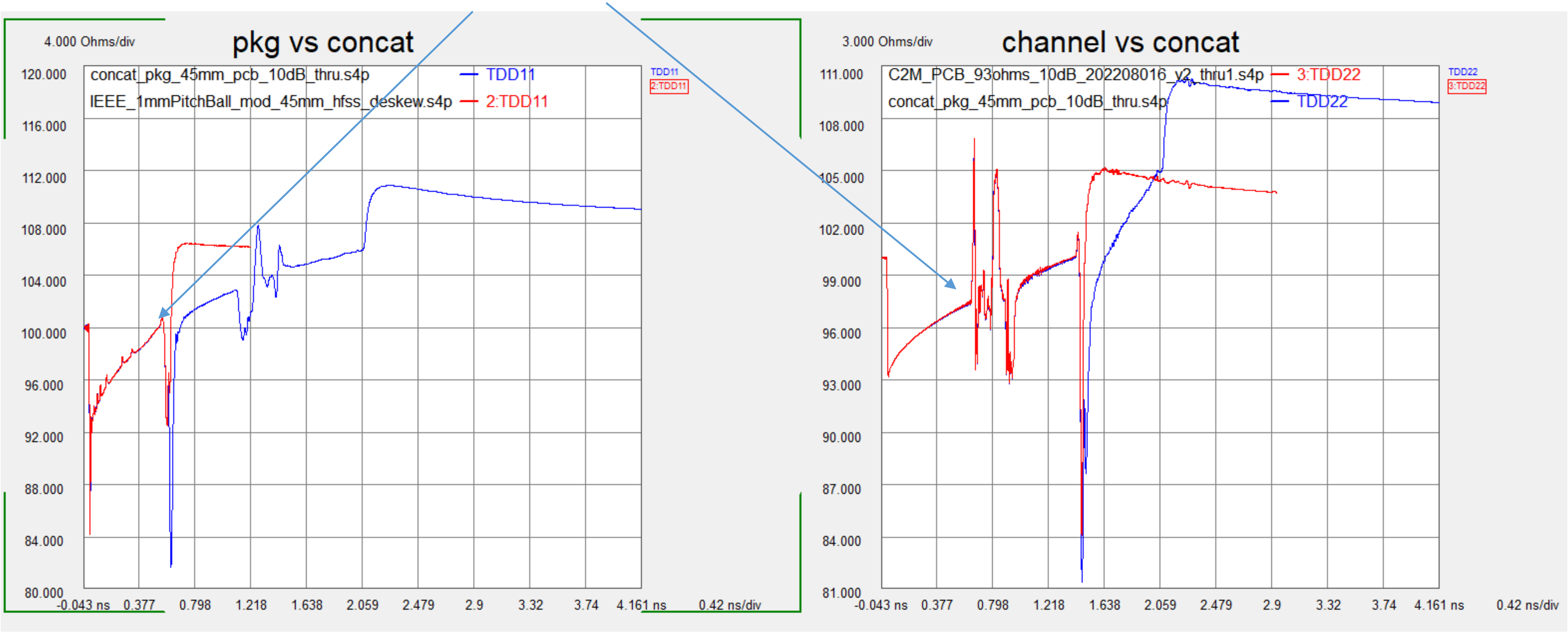
Example case: 15 mm + 10 dB



TDR Verification of the Concatenation

Example case: 15 mm + 10 dB

Good match on both sides



COM model parameters
(pkg model added only at Tx/TP0 side)

Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	106.25	GBd	
f_min	0.02	GHz	
Delta_f	0.02	GHz	
C_d	[40 90 110; 40 90 110]*1e-6	nF	[TX RX]
L_s	[0.13 0.15 0.14; 0.13 0.15 0.14]	nH	[TX RX]
C_b	[30e-6 30e-6]	nF	[TX RX]
z_p select	1		[test cases to run]
z_p (TX)	[15 30 45; 1 1 1; 1 1 1; 0.5 0.5 0.5]	mm	[test cases]
z_p (NEXT)	[0 0 0; 0 0 0; 0 0 0; 0 0 0]	mm	[test cases]
z_p (FEXT)	[15 30 45; 1 1 1; 1 1 1; 0.5 0.5 0.5]	mm	[test cases]
z_p (RX)	[0 0 0; 0 0 0; 0 0 0; 0 0 0]	mm	[test cases]
C_p	[50e-6 0]	nF	[TX RX]
R_0	50	Ohm	
R_d	[50 50]	Ohm	[TX RX]
A_v	0.413	V	
A_fe	0.413	V	
A_ne	0.608	V	
L	4		
M	32	Samp/UI	
samples_for_C2M	100	Samp/UI	
T_O	50	mUI	
AC_CM_RMS	0	V	[test cases]
filter and Eq			
f_r	0.55	*fb	
c(0)	0.5		min
c(-1)	[-0.34:0.02:0]		[min:step:max]
c(-2)	[0:0.02:0.14]		[min:step:max]
c(-3)	[-0.06:0.02:0]		[min:step:max]
c(-4)	[0:0.01:0.03]		[min:step:max]
c(1)	[-0.1:0.02:0]		[min:step:max]
N_b	24	UI	
b_max(1)	1		As/dffe1
b_max(2..N_b)	0.3		As/dfe2..N_b
b_min(1)	0.3		As/dffe1
b_min(2..N_b)	-0.15		As/dfe2..N_b
g_DC	[-18:1:-8]	dB	[min:step:max]
f_z	42.5	GHz	
f_p1	42.5	GHz	
f_p2	106.25	GHz	
g_DC_HP	[-3:0.5:0]		[min:step:max]
f_HP_PZ	0.6	GHz	

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	0	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\200GEL_C2M_host_{date}\	Path
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	C2M_eval_	
COM_CONTRIBUTION	0	logical
Local Search	2	
Operational		
COM Pass threshold	3	dB
ERL Pass threshold	7.3	dB
DER_0	1.00E-04	
T_r	6.00E-03	ns
FORCE_TR	1	5
PMD_type	C2C	
BREAD_CRUMBS	0	logical
SAVE_CONFIG2MAT	1	logical
PLOT_CM	0	logical
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	logical
TR_TDR	0.01	ns
N	1200	
beta_x	0	
rho_x	0.618	
fixture delay time	[0 0]	[port1 port2]
TDR_W_TXPKG	0	
N_bx	0	UI
Tukey_Window	1	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
Noise, jitter		
sigma_RJ	0.01	UI
A_DD	0.02	UI
eta_0	4.00E-09	V^2/GHz
SNR_TX	32.5	dB
R_LM	0.95	

Table 93A–3 parameters		
Parameter	**Setting**	**Units**
package_tl_gamma0_a1_a2	[0 8.455e-4 3.40225e-4]	
package_tl_tau	6.448E-03	ns/mm
package_Z_c	[92 92; 70 70; 80 80; 100 100]	Ohm
ICN & FOM_ILD parameters		
f_v	0.371	*Fb
f_f	0.371	GHz f_r specified in first column
f_n	0.371	GHz
f_2	58.4375	GHz
A_ft	0.600	V
A_nt	0.600	V

Histogram_Window_Weight	Gaussian	gaussian. triangle, rectangle
sigma_r	0.02	sigma in UI fo or gaus.. Wind

Table 92–12 parameters		
Parameter	**Setting**	
board_tl_gamma0_a1_a2	[0 3.8206e-04 9.5909e-05]	
board_tl_tau	0.00579	ns/mm
board_Z_c	100	Ohm
z_bp (TX)	407	mm
z_bp (NEXT)	407	mm
z_bp (FEXT)	407	mm
z_bp (RX)	407	mm
C_0	0	nF
C_1	0	nF
Include PCB	0	logical

different for each test fixture

updated for 802.3df/dj C2M

Floating Tap Control		
N_bg	3	0 1 2 or 3 groups
N_bf	3	taps per group
N_f	80	UI span for floating taps
bmaxg	0.2	max DFE value for floating taps
N_tail_start	24	
B_float_RSS_MAX	0.1	

Thank You!