Multi-200Gbps/lane Package Model Considerations

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Multi-lane Package Challenges – Introduction

- Multiple presentations were shared showing package modeling for 200Gbps/lane
- Packages had relatively short traces
- Packages had 400µ core layer, or coreless construction
- Ball pitch was 0.8mm max
- Multi-lane package routing congestion was not accounted for
- Multi-lane PCB implementation challenges will come on top of package challenges. But will not be addressed here – evaluate with COM
- Packages brought so forth were somewhat non-realistic to represent an actual multi-lane package
- We will suggest an <u>optimistic "best case"</u> intermediate representation of a multi-lane package

200Gbps/lane Package Related Contributions – Quoting: mli_3df_01a_220316.pdf

- ❑ Package loss minimized by usage of "skip layer" routing
- ❑ Package trace length related to smaller layer count packages
- ❑ Ball-out pitch was suggested to be 0.8mm or smaller

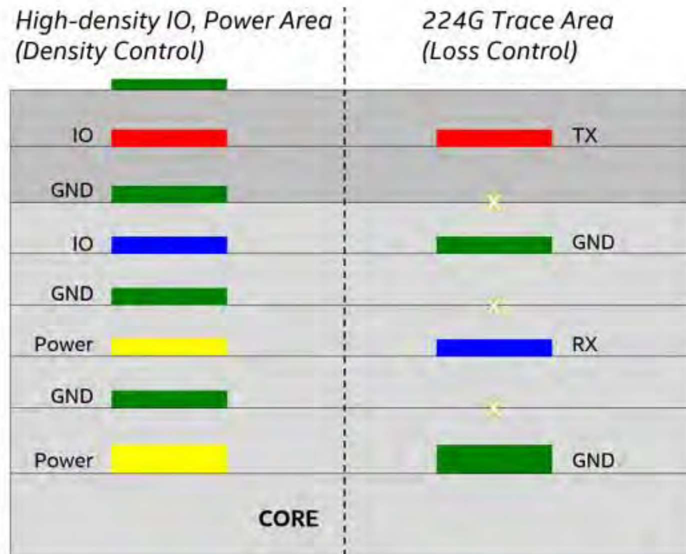
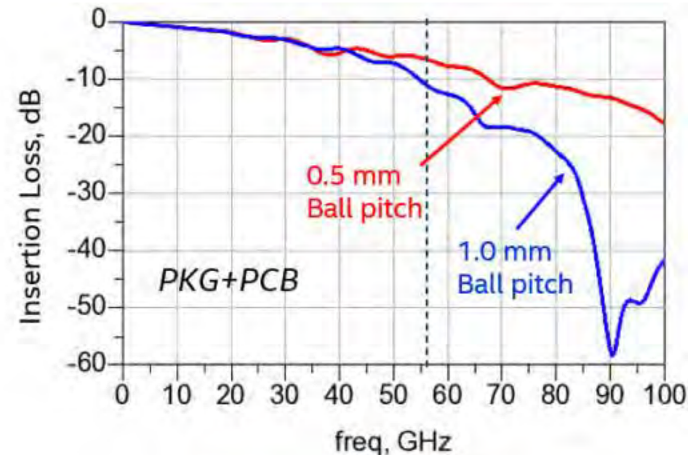


Illustration of a localized skip-layer configuration for 224G trace routing



Package+PCB with 1mm vs. 0.5mm BGA ball pitch

Multi-lane package - ran_3df_elec_01a_220418.pdf

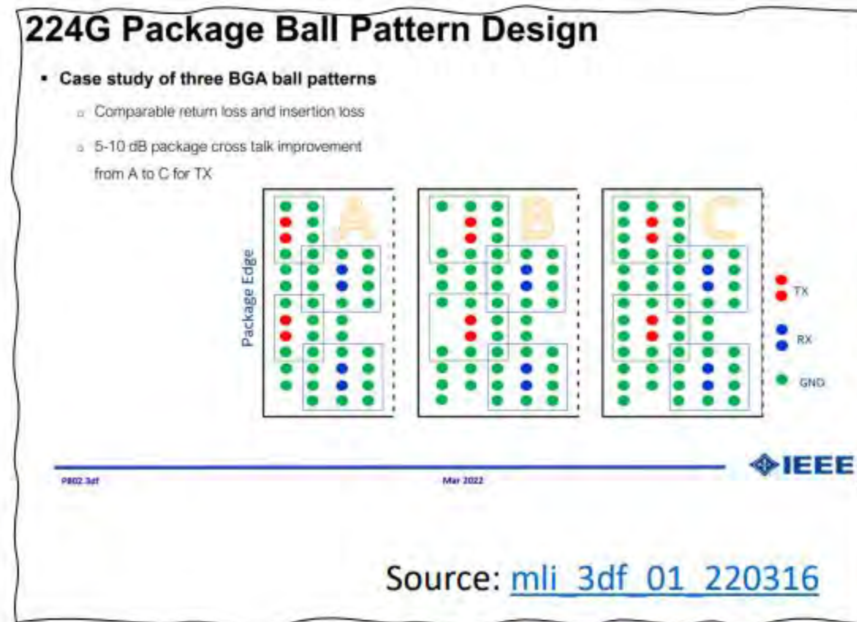
- ❑ High (FarEnd) crosstalk lane organization results in PKG size of ~75x75 or (realistically) bigger

➔ Will have traces of up to at least 30mm, most likely longer

Ball pattern of a high-speed radix switch

Thought exercise:

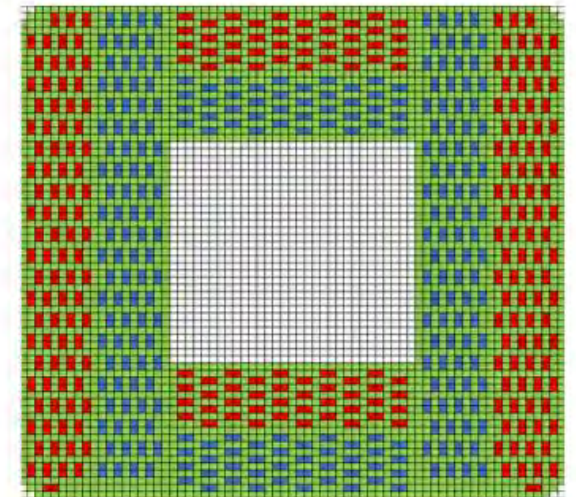
Assume the minimum presented Tx/Rx separation, populate 256 lanes…



Just the AUI signals require a 69x69 grid (in practice, more are needed)

⇒ larger package than previously assumed (>75 mm square?)

⇒ longer traces



Package Trace optimized for COM model fitting

Parameters used for creating a model for extraction:

- 6-2-6 package stack-up with best “next gen” dielectric properties (May go up to 9-2-9)
- Multi-lane packages routing density ➔challenging, if not impossible to use skip-layer
  ➔40µ dielectric height on each side to lower loss WO skip-layer
- ~90Ω target impedance
- Trace geometry: 27-45-27
- Best “next gen” surface roughness correlated and modeled in a Huray model
- 800µ core layer thickness – bigger packages – 1200?! (what will be the impact?)
- 1mm ball size – Ball area was carefully adjusted to mitigate roll-off
  - Should examine assembly and manufacturing tolerances and their impact on the model
- 30mm used intermediately, longer traces around 40mm are very realistic to be encountered

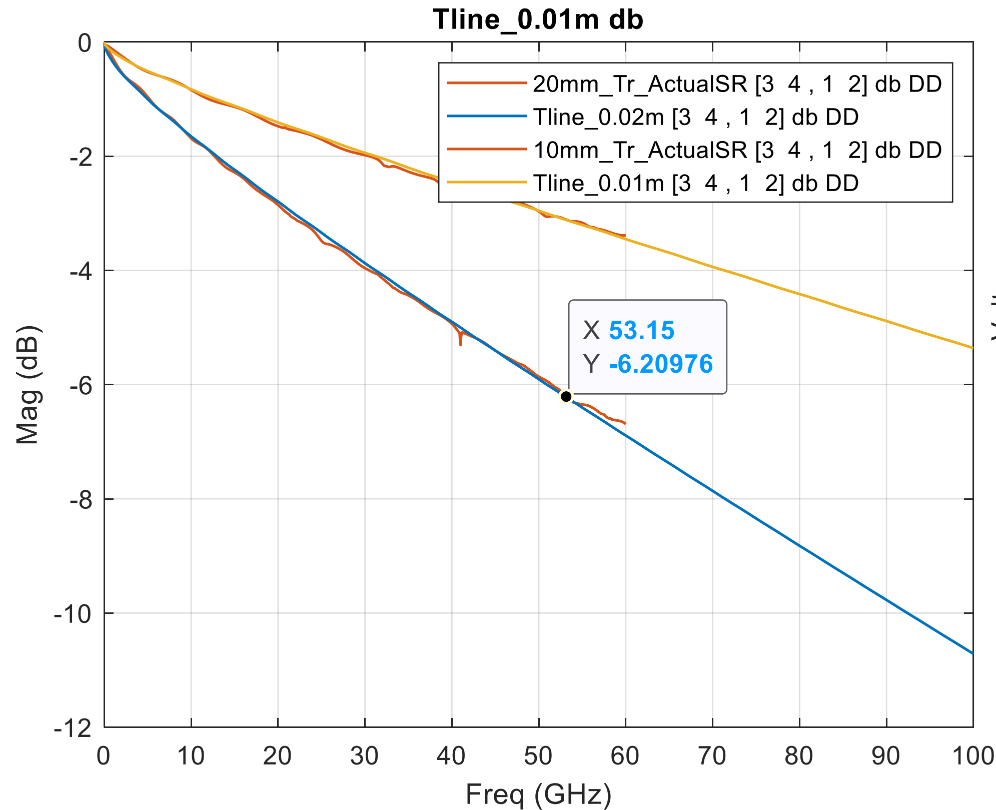
Procedure

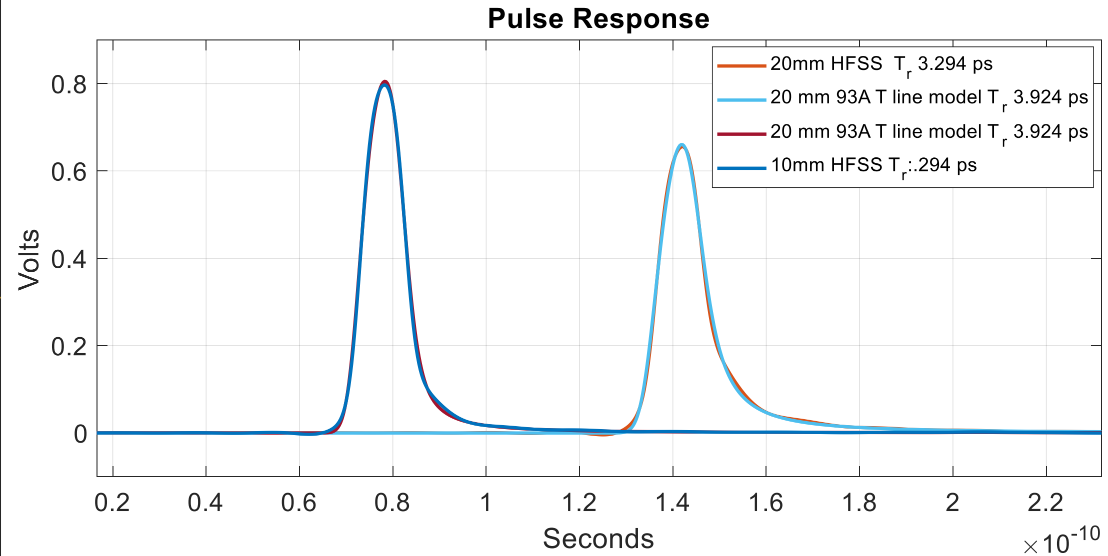
COM model fitting

- ❑ Extract HFSS package models s parameters for traces
- ❑ Adjust/fit COM trace model to emulate 3-D extracted transmission line model s-parameters.
- ❑ Extract HFSS package models s parameters
- ❑ Adjust/fit COM package model to emulate 3-D extracted package model s-parameters.
- ❑ Compare a channel in COM by cascading the fitted COM models and the 3-D extracted package model.

Fitting COM PKG model to the extraction Starting point: Main Trace routes

93A transmission line parameters



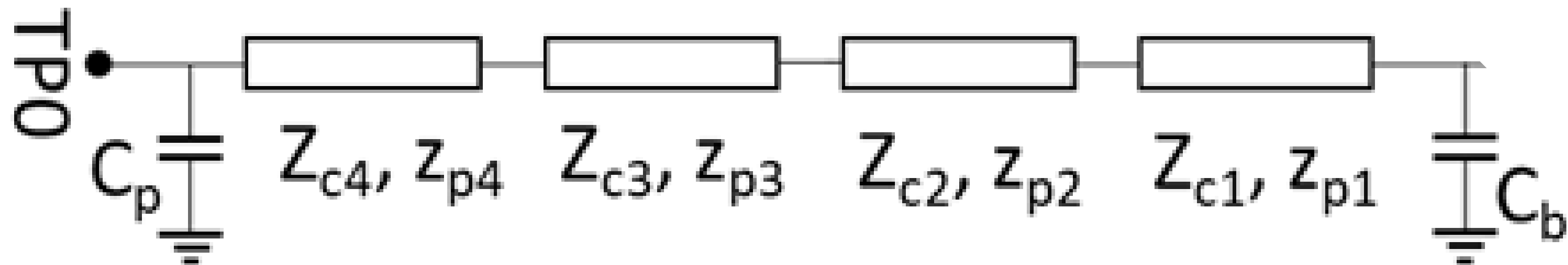


- Use IL and Pulse Response

Iteratively adjust γ_0, a_1, a_2, τ

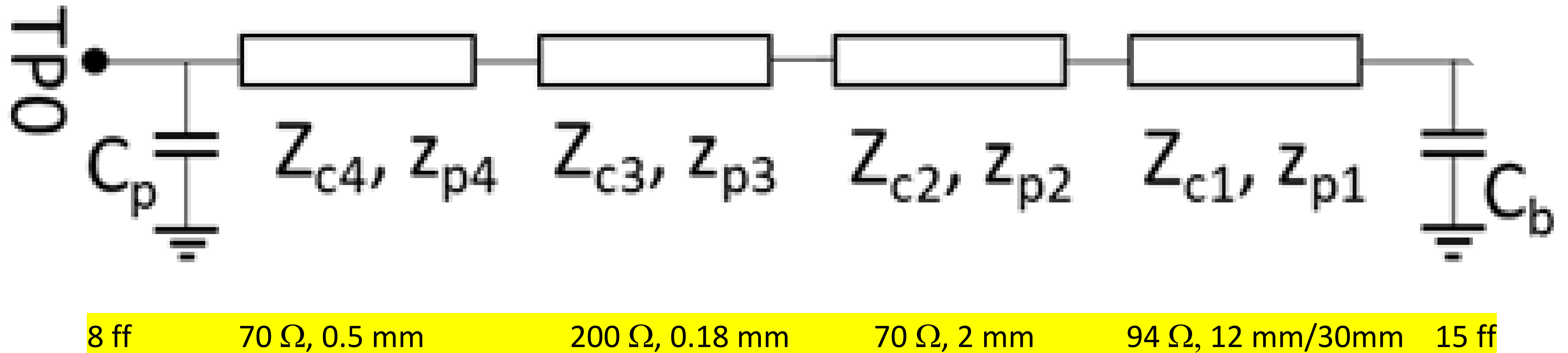
93A.1.2.3

- And
  - Z_p, Z_c, C_b, C_p



- Match HFSS package model for 12 mm and 30 mm extraction to COM Package model

Matched COM model

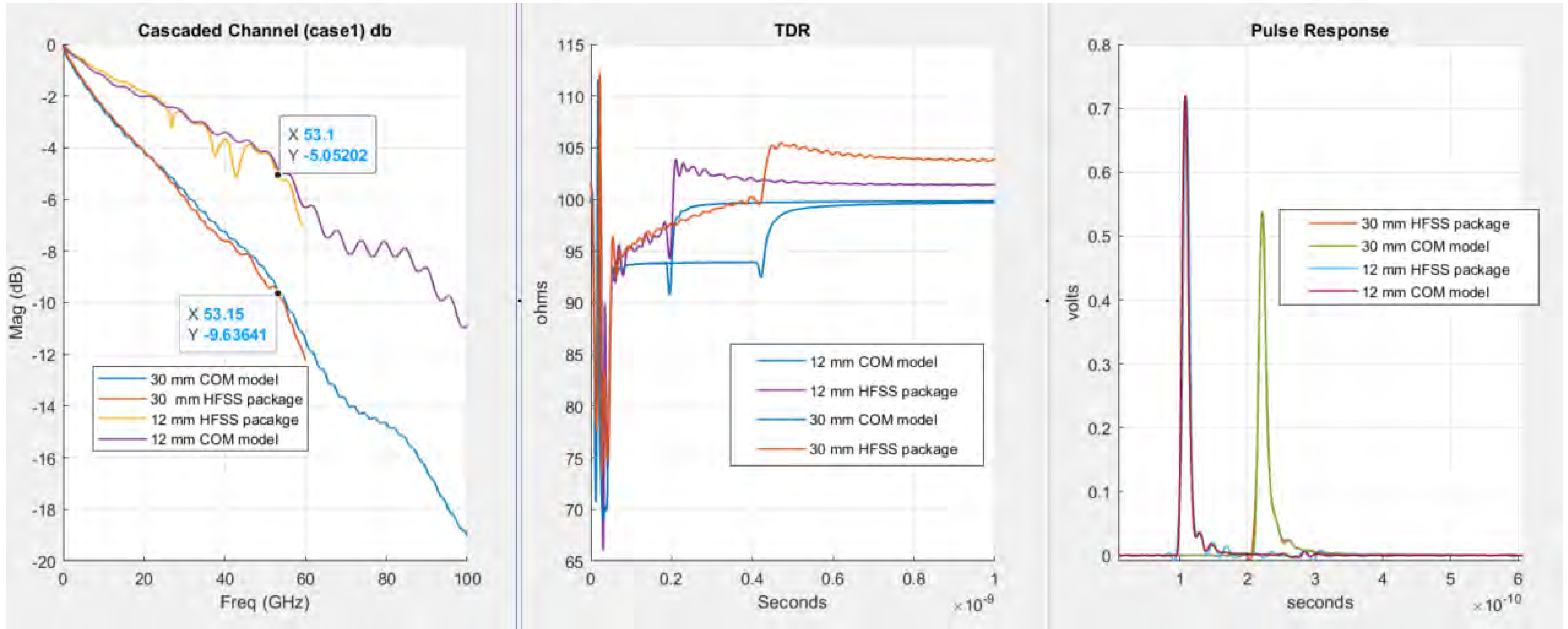


8 ff | 70 Ω, 0.5 mm | 200 Ω, 0.18 mm | 70 Ω, 2 mm | 94 Ω, 12 mm/30mm | 15 ff

- $\gamma_0 = 0$, $a_1 = 0.00133$, $a_2 = 3.9525e\text{-}04$, $\tau = 0.00642$

Graphic view of results

Observation: 30 mm package has 9.6 dB loss at 53.1 GHz



Now Tune package loss using COM

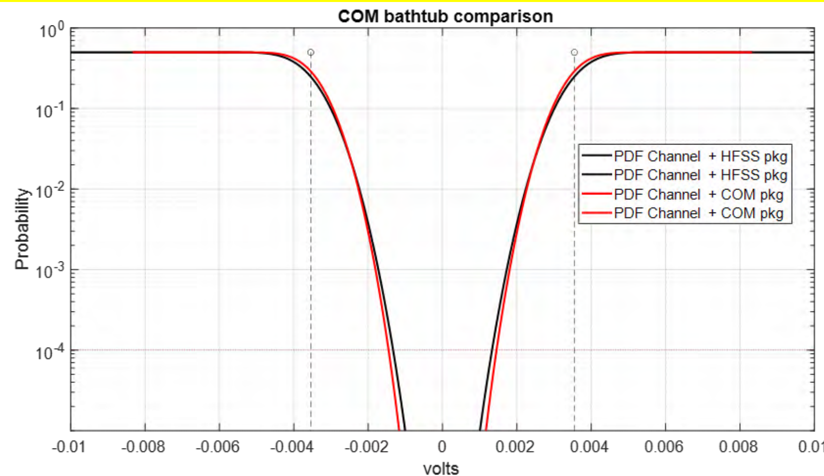
- Channel Plus COM package (parameters shown)
  - COM = 3.622 dB
- Channel Plus HFSS package
  - C_b reduced by 15 ff (slide 10)
  - All Z_p ʹand C_p set to 0
  - COM = 3.675 dB

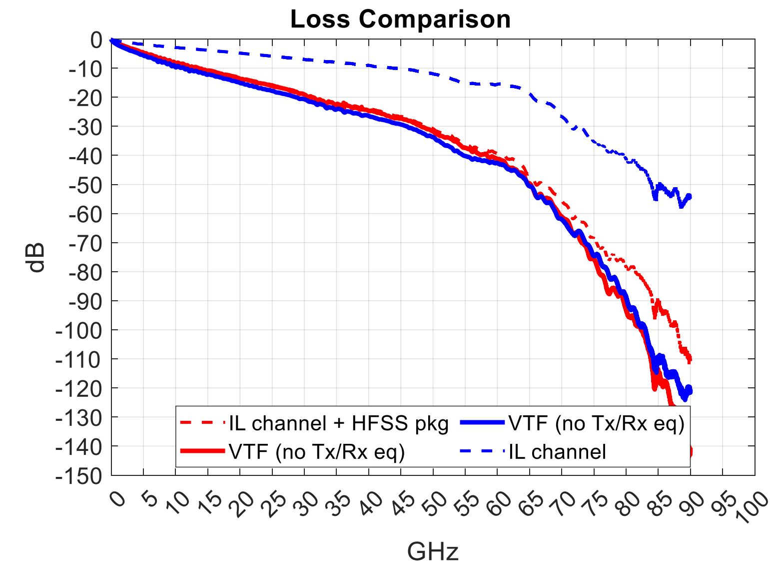
C_d	[0.4e-4 0.9e-4 1.1e-4 ; 0.4e-4 0.9e-4 1.1e-4]	nF	[TX RX]
L_s	[.13 .15 .14; .13 .15 .14]	nH	[TX RX]
C_b	[.3e-4 .3e-4]	nF	[TX RX]
z_p select	[2]		[test cases to run]
z_p (TX)	[12 30 ; 2 2 ; 0.18 0.18 ; 0.5 0.5]	mm	[test cases]
z_p (NEXT)	[12 30 ; 2 2 ; 0.18 0.18 ; 0.5 0.5]	mm	[test cases]
z_p (FEXT)	[12 30 ; 2 2 ; 0.18 0.18 ; 0.5 0.5]	mm	[test cases]
z_p (RX)	[12 30 ; 2 2 ; 0.18 0.18 ; 0.5 0.5]	mm	[test cases]
C_p	[.08e-4 .08e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[45 45]	Ohm	[TX RX]

Table 93A–3 parameters		
Parameter	Setting	Units
package_tl_gamma0_a1_a2	[0 0.0017423 0.000517778]	
package_tl_tau	6.42E-03	ns/mm
package_Z_c	[94 94 ; 76 76; 200 200; 70 70]	Ohm

Adjusted to Z_{c2} 76 Ω, 2 mm and a1/a2

70 Ω, 0.5 mm … (slide 10) 200 Ω, 0.18 mm 70 Ω, 2 mm 94 Ω, 12 mm/30mm





Summary; Work Yet to be Done; observations and Recommendations

- ❑ Package loss is by far higher than formerly discussed (>9dB at 53.1GHz) +
- ❑ No manufacturing tolerances analysis was done – examine stability and COM influence
- ❑ Need to examine actual package routing length influence ➔ length recommendation for COM
- ❑ Verify correlation of surface roughness in HFSS with actual best next generation material properties – Update model accordingly
- ❑ Extend model frequency to 100GHz – Examine if there is any requirement for better ball modeling (Ladder?!) and/or a more elaborated model to match
- ❑ Improve 12mm PKG optimization – wasn't fully optimized best due to lack of time
- ❑ Examine the ball mechanically – void around ball and ball-pad was optimized - Is the capacitance really achievable mechanically and while taking tolerances into account?
- ❑ Is it still justified not having package crosstalk?

➔ intermediately:

- ❑ Use the 30mm COM package model cautiously for initial big package analysis – take into account the above observations which WILL influence future model to be better&worse