Adding a Simple Package Model to the Channel Response

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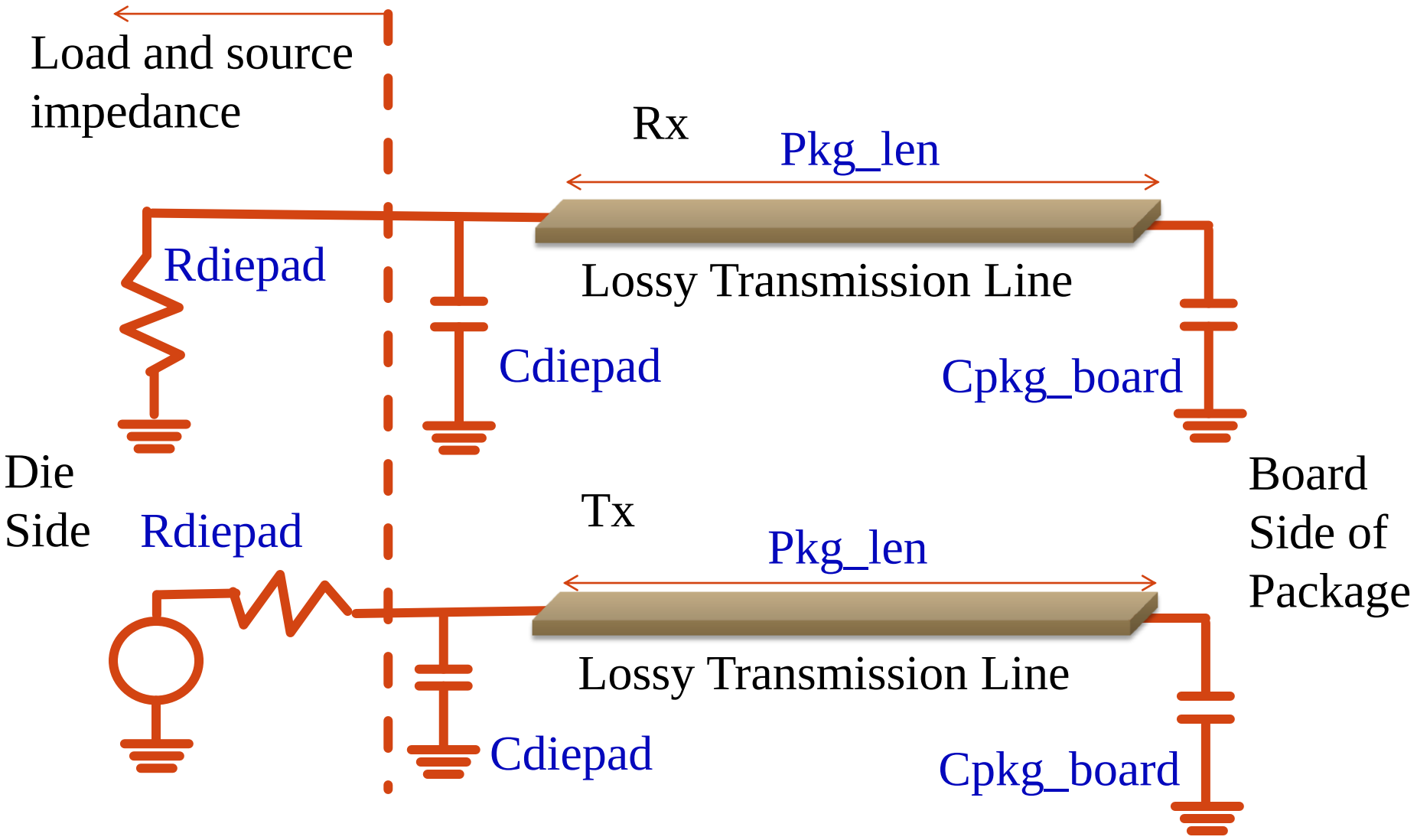
In support of comment 36, 129, 132 resolution

- Eliminate the problem caused by looking at the signal the package/board interface (aka bga ball).
  - It causes a shelf on the SBR edge which is correct at the ball but not at the pad. It causes too much precursor equalization with reduces the available signal.
  - The caveat is that the Rx package loss is added back in because exact s-parameter concatenation replaces the VTF (voltage transfer function)
  - Such impairments cannot be addressed adequately with guard band.
- To help specify Tx and Rx Return loss using the test fixture
  - Enable changes for and review of COM code as these values may change through the ballot process as RL speciation evolve (comment 129 132)
- Provide potential applicability to other IEEE standards (like CAUI).
- Provide direct understandable physical implementation rational
  - This would suggest not how to build a package, but in the line of Tx/Rx architecture,
    - provide a package architecture to be use in COM with a clear relationship to the Tx/Rx RL spec
- Define a model for COM that is understandable and alterable with a table

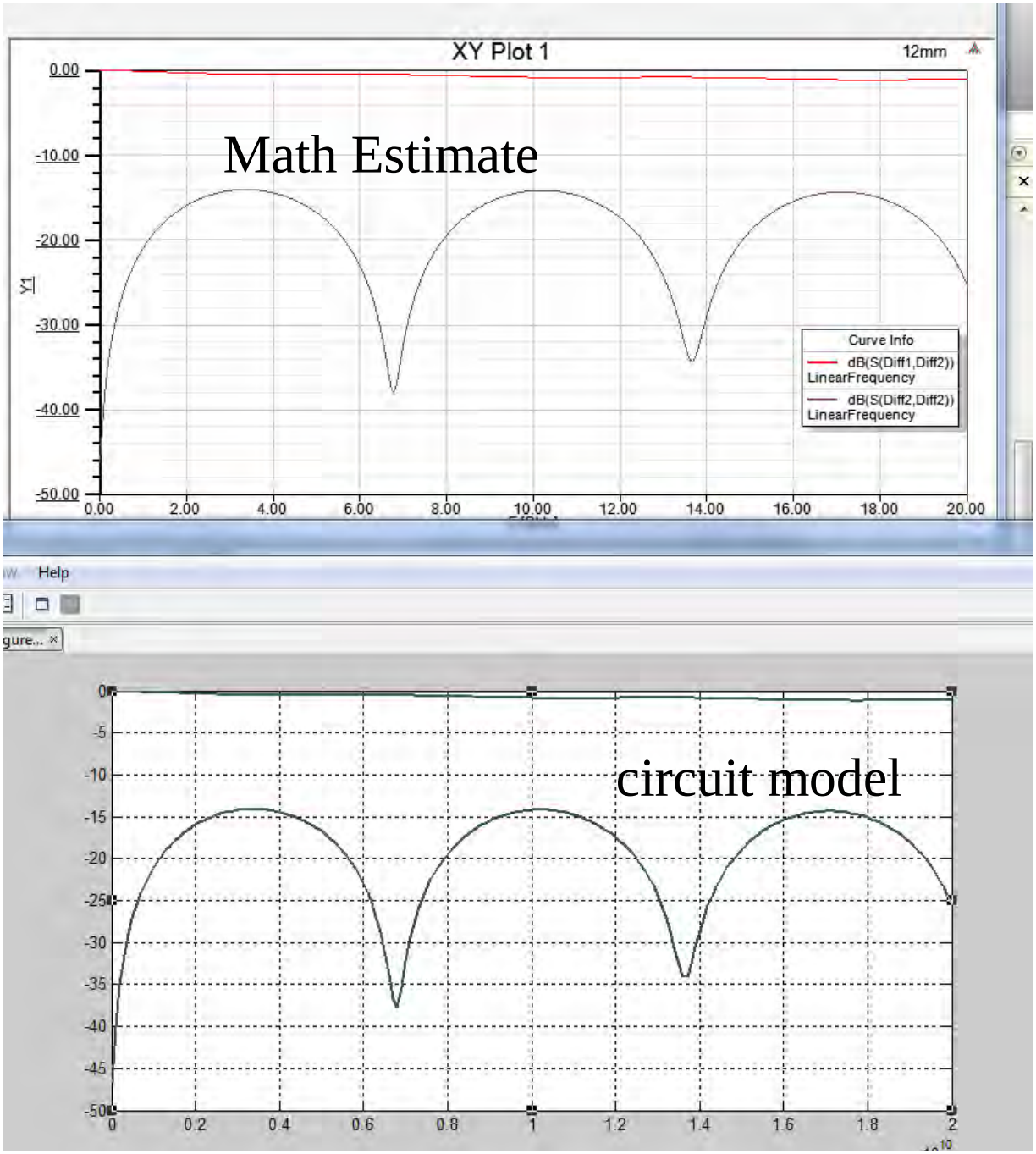
Simplest Useful Package Modeling



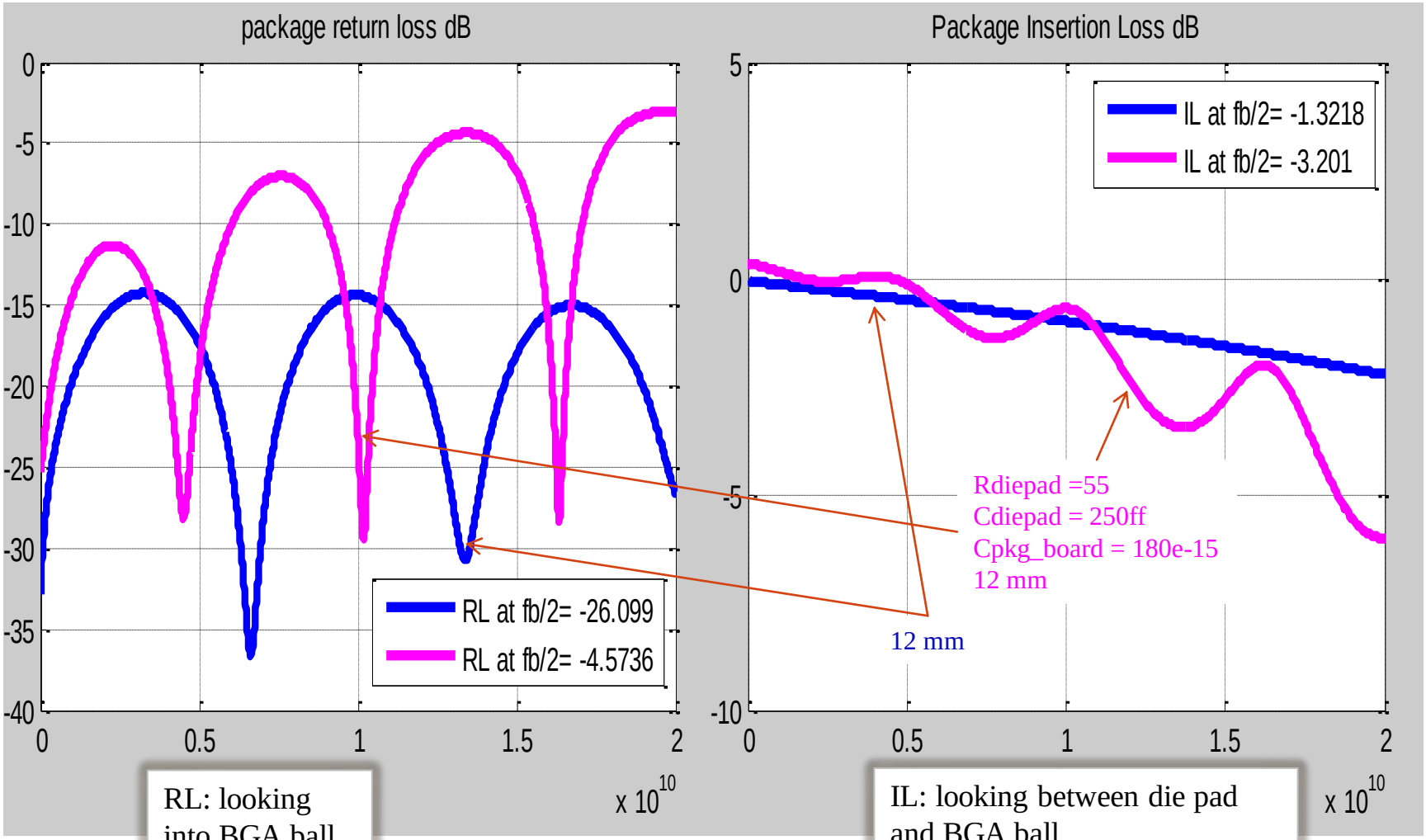
Estimate differential s-parameters for a small segment of uniform lossy transmission line (replaces 93A.1.2)

- Segment can be either solved or measured.
- Recommend: 1mm package transmission line s4p file
- Fit RL and IL using clause 93A.2
  - Find a_{il} and a_{fl} from S11 and s21
  - Determine γ_{IL} and γ_{RL}
  - Were $\gamma_x = a0 + a1 \cdot \sqrt{f} + a2 \cdot f + a4 \cdot f^2$
    - This form is from clause 93A.2, eq. (93A–31)
- For the transmission line
- $s11tline = e^{\gamma_{RL}}\left[\sum_{n=1}^{segments} e^{\gamma_{IL}\cdot(2\cdot n-2)}\right]$
- $s21tline = e^{\gamma_{iL}\cdot segements}$
- i.e. $[S_{tline}]$
- The package transmission line is defined by 9 parameters in a table in 93a.1.2
  - a_{il}(0, 1, 2, 4), a_{rl}(0, 1, 2, 4), number of segments (Pkg_length in mm)

Comparison for 12 mm line between math estimated and circuit model



Example of an estimated package and tline model



RL: looking into BGA ball

IL: looking between die pad and BGA ball

Create s parameters for pad and ball (more replacements for 93A.1.2)

- $Zpad = \frac{1}{2*\pi*i*f*Cdiepad}$
- $s11_{pad} = \frac{2*Z0}{Z_{pad}+2*Z0}$, $s21_{pad} = \frac{2*Zpad}{Z_{pad}+2*Z0}$ → [S_{pad}]
- $Z_{ball} = \frac{1}{2*\pi*i*f*Cpkg\_board}$
- $s11_{ball} = \frac{2*Z0}{Z_{ball}+2*Z0}$, $s21_{pad} = \frac{2*Zball}{Z_{ball}+2*Z0}$ → [Sball]

- $\Gamma_1 = \Gamma_2 = \frac{Z0-Rdiepad}{Z0+Rdiepad}$

- 3 parameters: Rdiepad, Cdiepad, Cpkg_board

Combining 2 port S parameters

Given $[S_1]$ and $[S_2]$

First convert to T matrixes

$$[T_1] = \begin{bmatrix} \frac{1}{s21_1} & \frac{s22_1}{s21_1} \\ \frac{s11_1}{s21_1} & \frac{s11_1 \cdot s22_1 - s12_1 \cdot s21_1}{s21_1} \end{bmatrix} \qquad [T_2] = \begin{bmatrix} \frac{1}{s21_2} & \frac{s22_2}{s21_2} \\ \frac{s11_2}{s21_2} & \frac{s11_2 \cdot s22_2 - s12_2 \cdot s21_2}{s21_2} \end{bmatrix}$$

Combine T matrixes

$$[T_3] = [T_1] * [T_2]$$

Determine $[S_3]$

$$[S_3] = \begin{bmatrix} \frac{t21_3}{t11_3} & \frac{t11_3 \cdot t22_3 - t12_3 \cdot t21_3}{t11_3} \\ \frac{1}{t11_3} & \frac{-t12_3}{t11_3} \end{bmatrix}$$

Combine parameters (replaces eq. 96a-5)

- $[S_{pkgtx}]$=combine([combine($[S_{pad}]$, ($[S_{tline}]$), $[S_{ball}]$])
  - Create $[T_{pkgtx}]$ → $[S_{pkgtx}]$
- $[S_{pkgrx}]$=combine([S_{ball}, combine([S_{tline}], $[S_{pad}]$])
  - Create $[T_{pkgrx}]$
- Channel response:
  - $[T] = [T_{pkgtx}] * [T_{channel}] * [T_{pkgrx}] \rightarrow [S]$

- $$H_{21} = \frac{S_{21}(1-\Gamma_1)(1+\Gamma_2)}{1-S_{11}\Gamma_1-S_{22}\Gamma_2-S_{21}S_{12}\Gamma_1\Gamma_2+S_{11}\Gamma_1S_{22}\Gamma_2}$$

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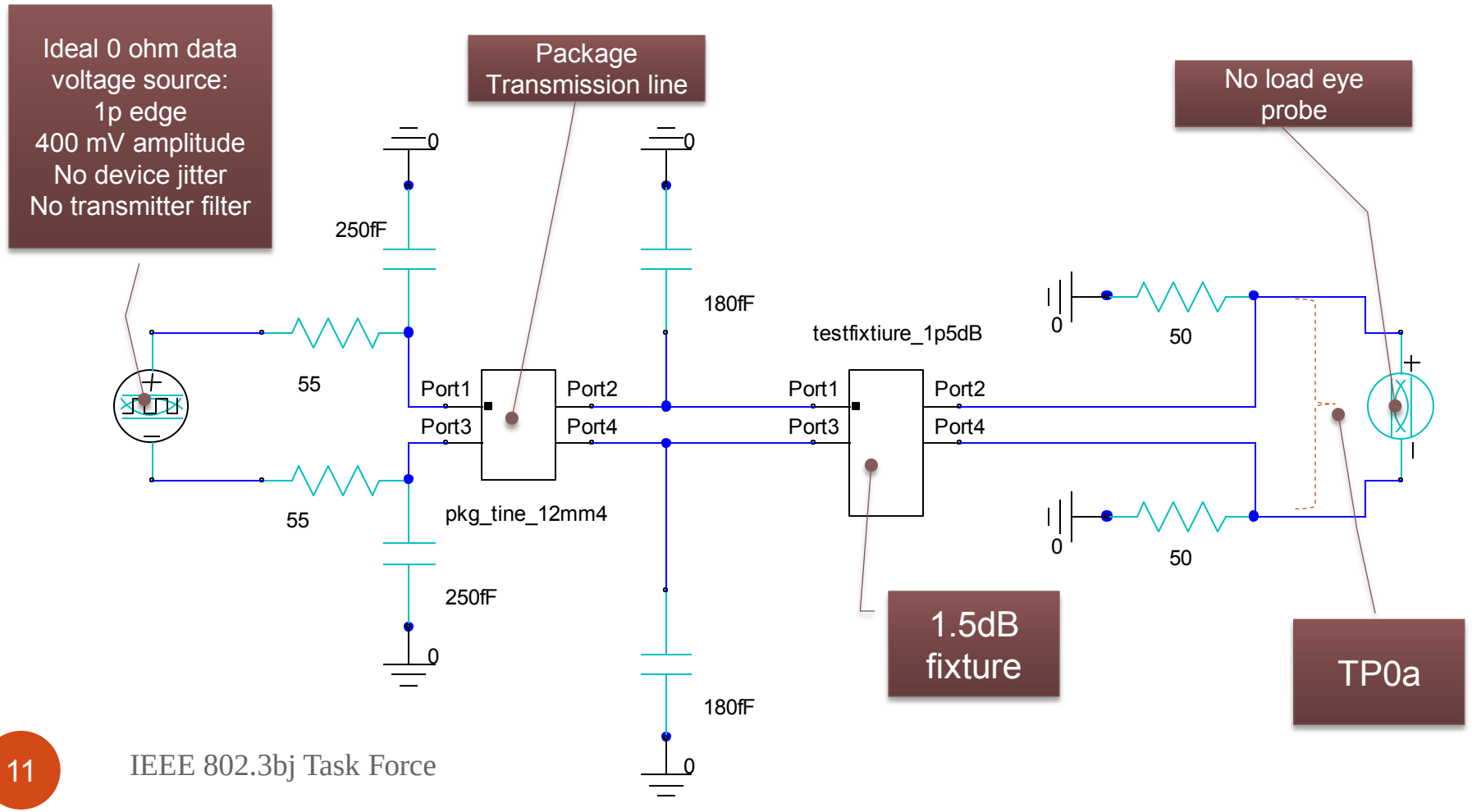
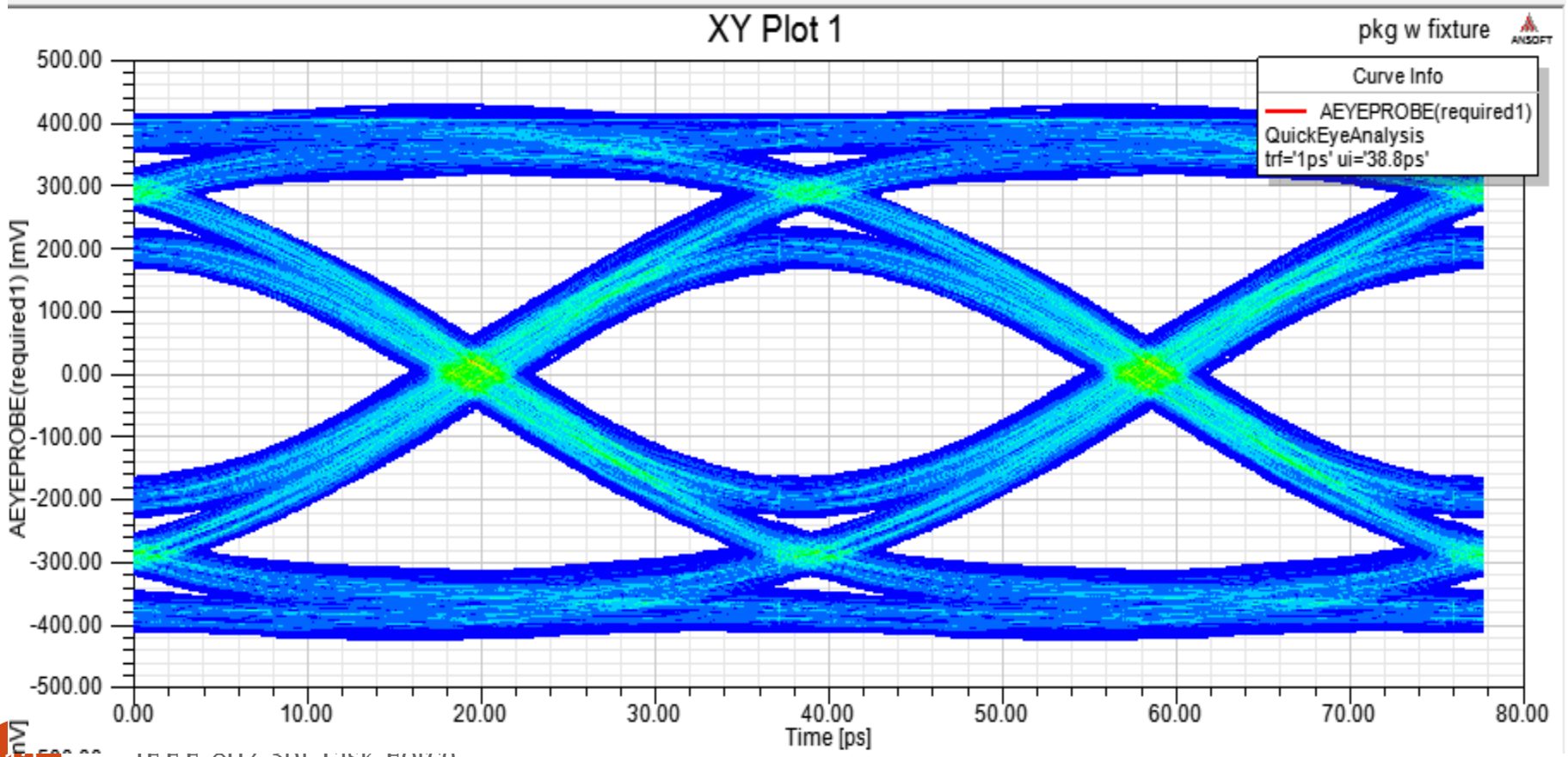
Commercial simulation circuit used to examine response with proposed COM package at tp0a



25Gbps NRZ eye diagram at tp0a suggests removing transmitter filter from COM is OK because the package and die load limits transition time



Parameters (Table 93A–2)

a_il_0	-4.453e-4 + 4.467e-05i
a_il_1	-1.049e-08 - 4.568e-08i
a_il_2	-6.409e-13-3.914e-11i
a_il_4	-1.669e-23 + 3.134e-23i
a_rl_0	-6.473 - 1.51i
a_rl_1	6.451e-05 + 3.351e-07i
a_rl_2	-2.712e-10 - 4.903e-11i
a_rl_4	2.167e-21 + 2.765e-22i
Cdiepad	250
Rdiepad	55
Cpkg_board	180
Pkg_len	12

- a_il_0, 1, 2 and 4 are insertion loss fit coefficients for $a_{il}(0, 1, 2, 4)$ on slide 5
- a_rl_0, 1, 2 and 4 are return loss fit coefficients for $a_{rl}(0, 1, 2, 4)$ on slide 5
- Cdiepad, Rdiepad, Cpkg_board, and Pkg_len are the package parameter on slide 4
- Remove parameter f_v f_f amd f_n and associated clauses.