# Adding a Simple Package Model to the Channel Response

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# Supporters

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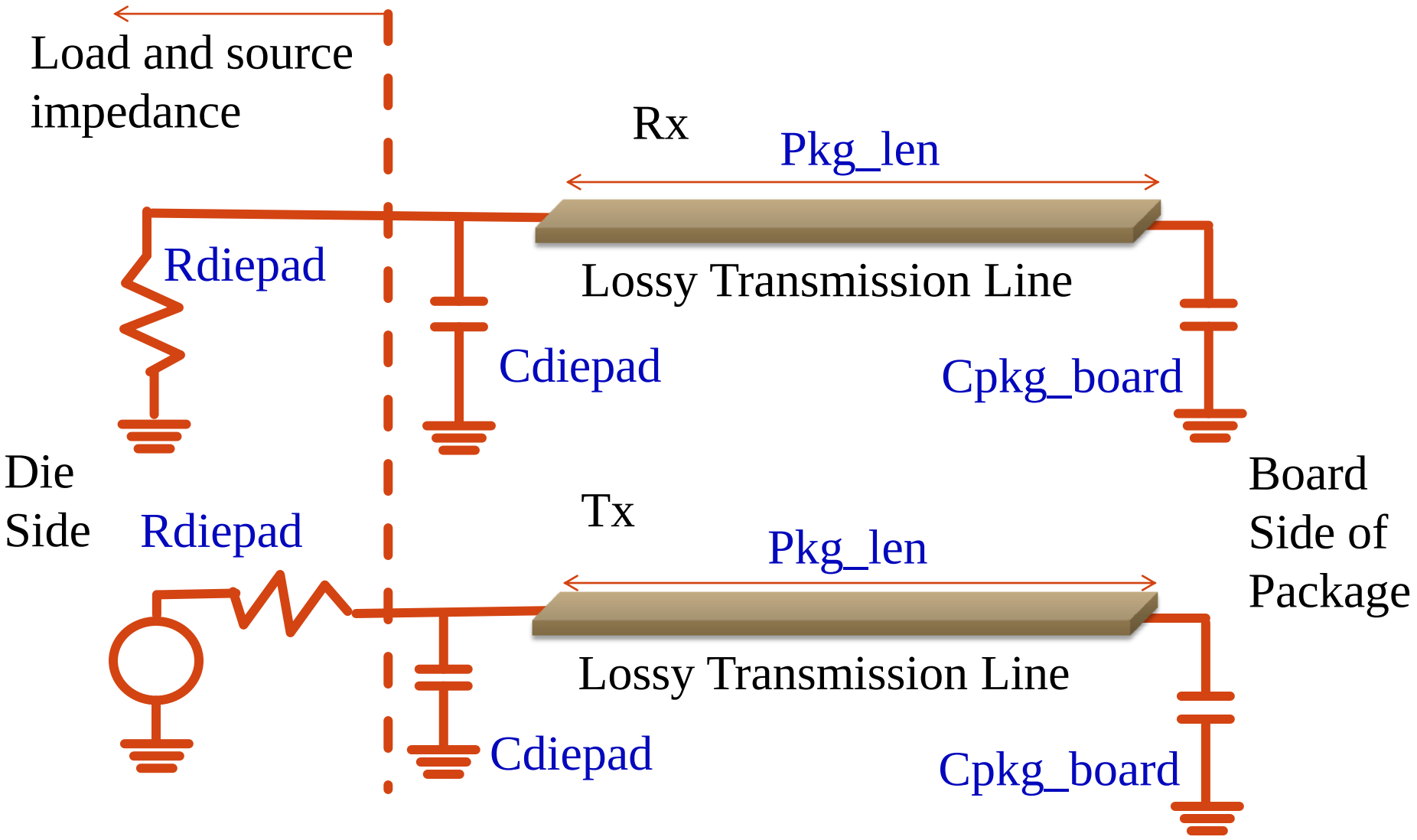
# In support of comment 36, 129, 132 resolution

- 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

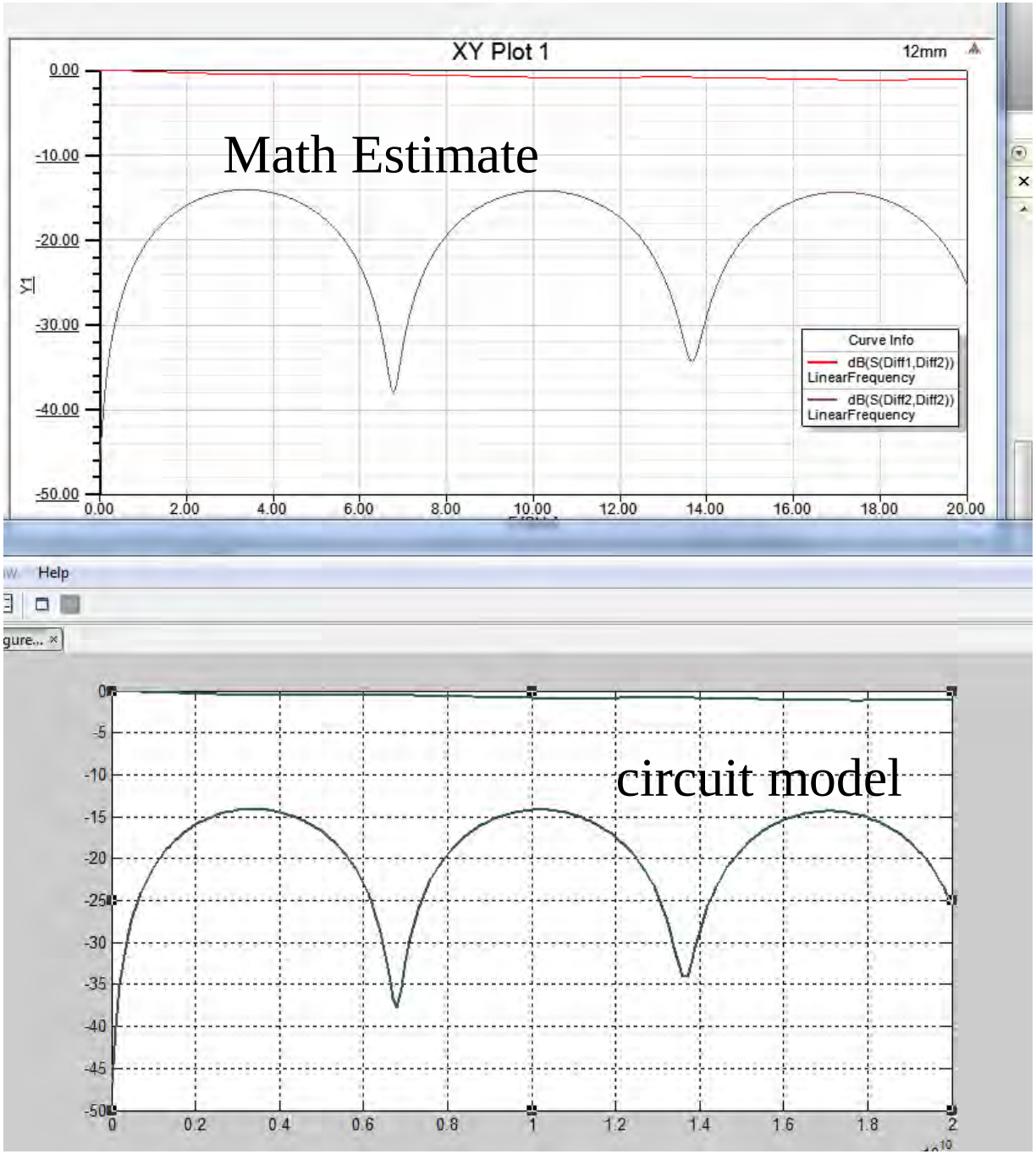
# Simplest Useful Package Modeling



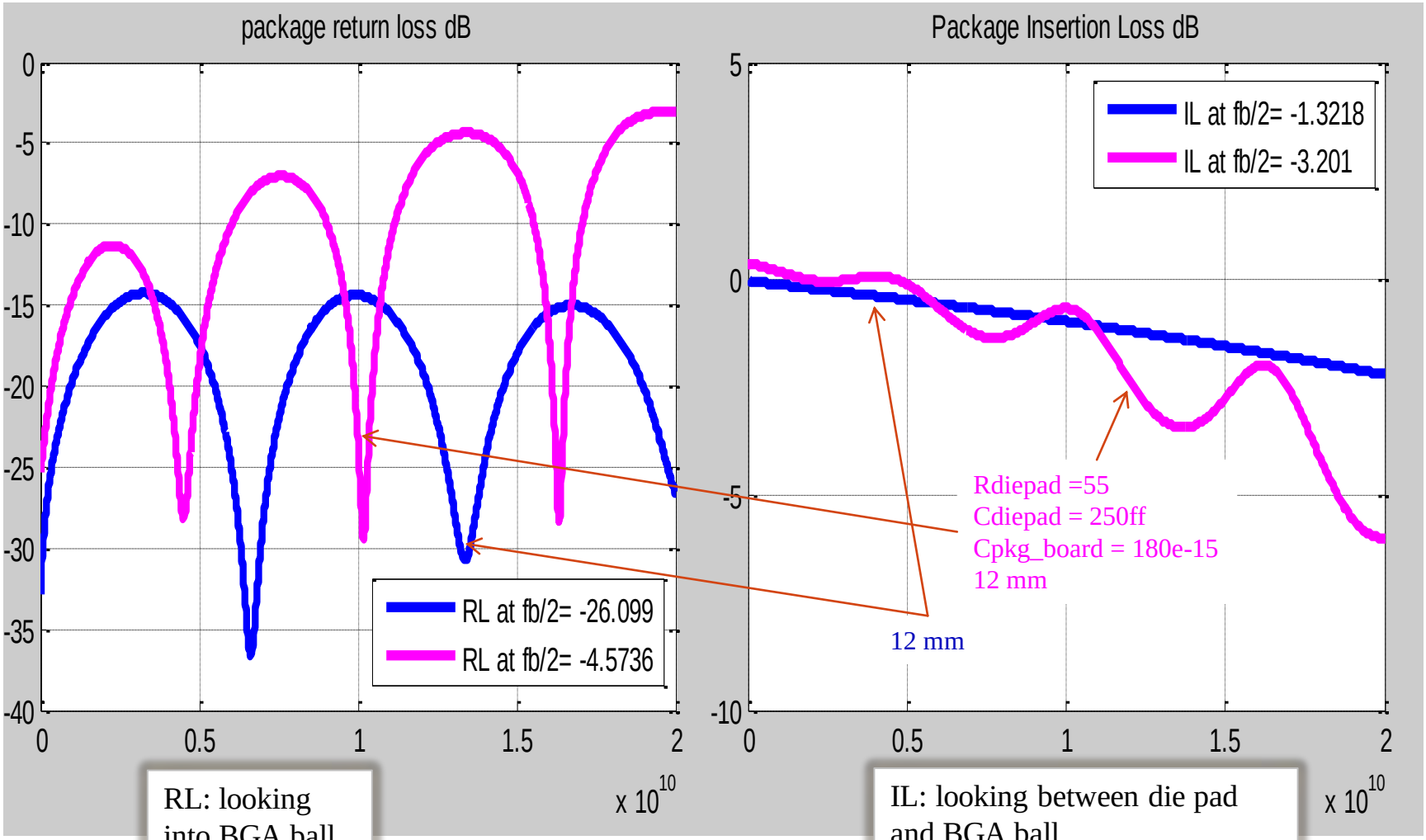
# Estimate differential s-parameters for a small segment of uniform lossy transmission line (replaces 93A.1.2)

- 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 $\gamma_{IL}$ and $\gamma_{RL}$
  - 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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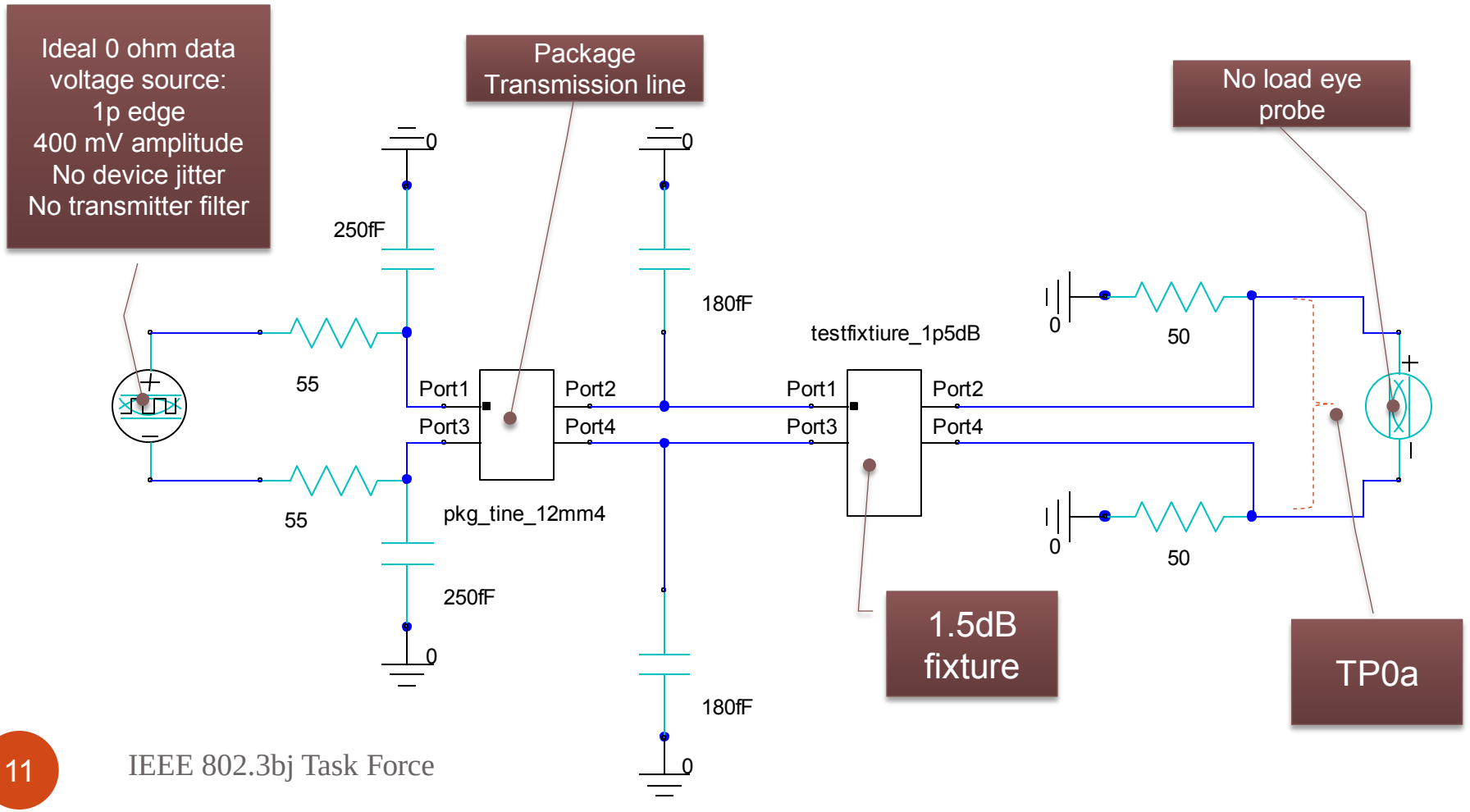
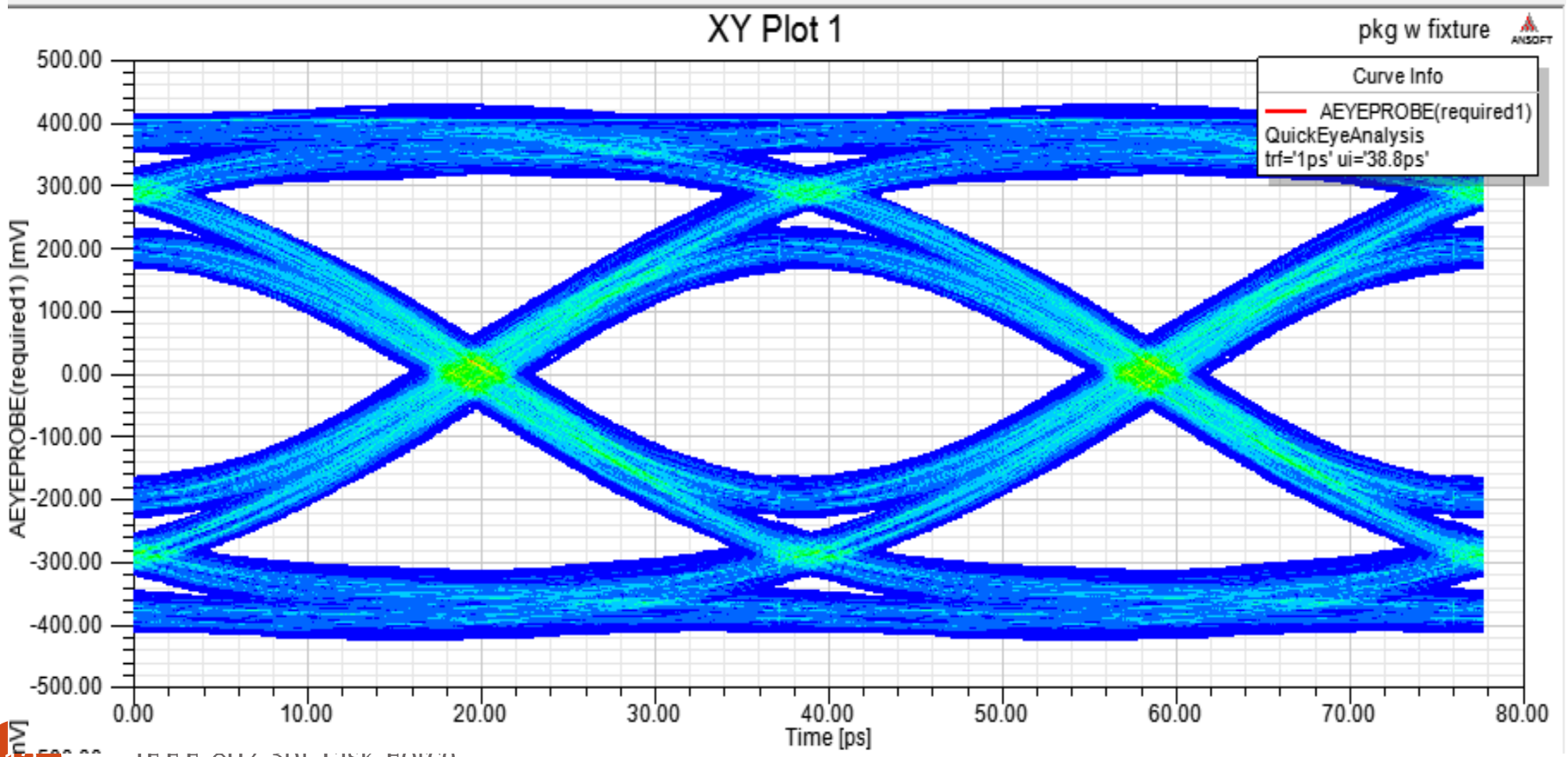
# Commercial simulation circuit used to examine response with proposed COM package at tp0a



# 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 | 240 |
| 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.