Getting Ahead with...

# Broadband Macromodeling with IdEM

- Speaker: Michelangelo Bandinu
- Start time: 8 am PT, 11 am ET, 5 pm CET
- Audio will be broadcast through your computer speakers or headphones (no need to teleconference)
- In case of audio broadcast failure please use dial-in numbers from your registration email
- There will be no audio until the scheduled start time.
- A recording will be made available, you will be notified by email
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# Broadband Macromodeling with IdEM

Michelangelo Bandinu

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# Outline

- Introduction to Macromodeling
- Passivity and Causality
- IdEM flow
- Demo: building macromodels with IdEM
- An application

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# IdemWorks

- IdemWorks was born as SpinOff from Politecnico di Torino, Italy
- Founded in 2007

- **Mission**: IdemWorks provides modeling tools and services for electronic design automation flows, helping hardware manufacturers to produce better products with a reduced time to market.
- **Customers**: Leading worldwide companies in the computer, networking, communications, consumer electronics, and automotive markets.

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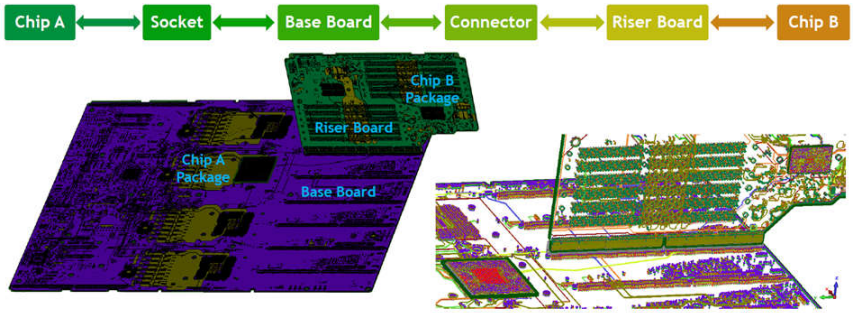
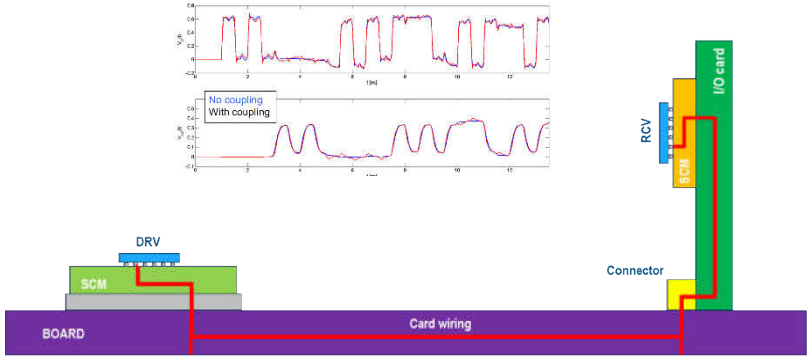
# Designing a complex high-speed link

- **Data transmission:** integrity of the signal through lines, bends, vias, connectors, transitions, …
- **Need modeling for:** coupling, dispersion, losses, delays, discontinuities, power/ground structures, nonlinear terminations, …

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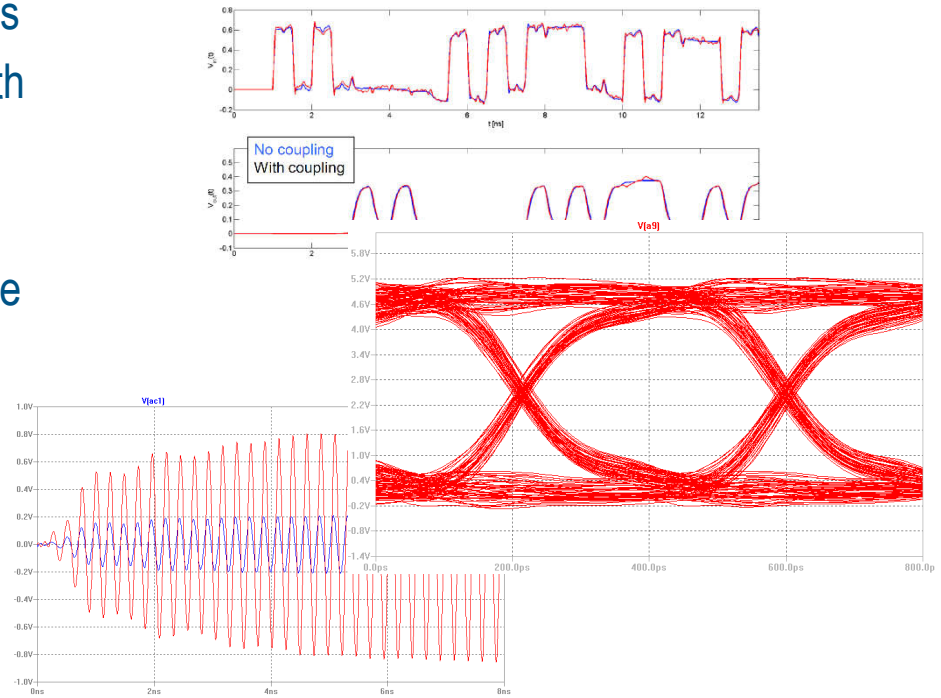
# The main objective

- Efficient Signal and Power integrity analysis requires **reliable** and **accurate** models both in pre-layout and post-layout phases.
- **Main Objective**: enabling fast and accurate circuit-level simulations.

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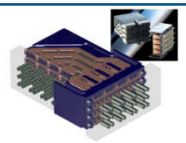
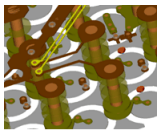
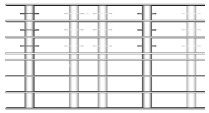
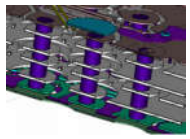
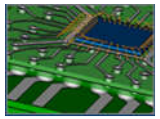
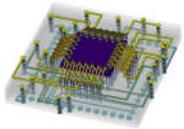
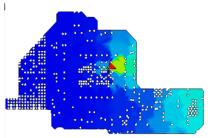
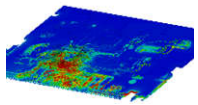
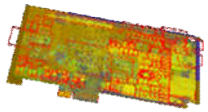
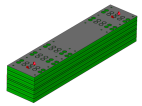
# Interconnects: showcase

| | |
|---|---|
| **Connectors** |  |
| **Vias, via fields** |    |
| **Packages** |   |
| **PDN** |    |
| **Backplane links** |  |

**EM SIMULATION**

S-parameter
(*tabulated*)

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{21} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{24} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix}$$

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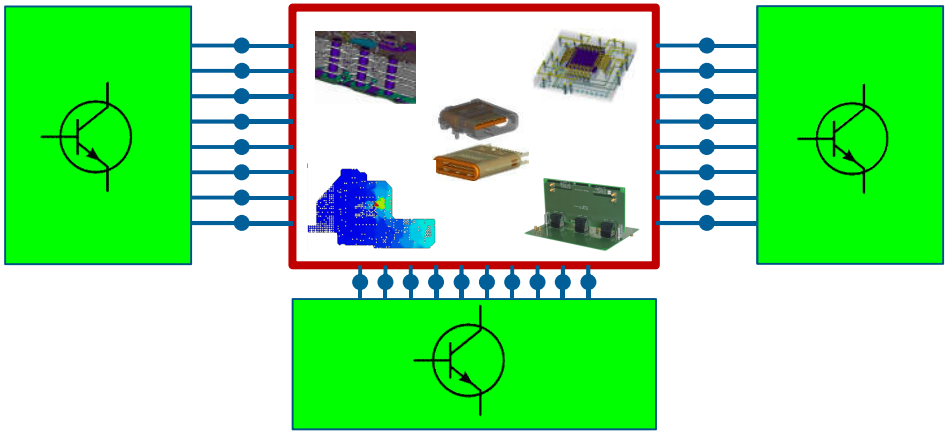
# Frequency and Time domain “interplay”

- Electrical interconnect characterizations are typically available in the **frequency- domain**, often in terms of scattering parameters. Conversely, system-level simulations require **time-domain** analysis due to the presence of nonlinear driver/receiver circuitry.



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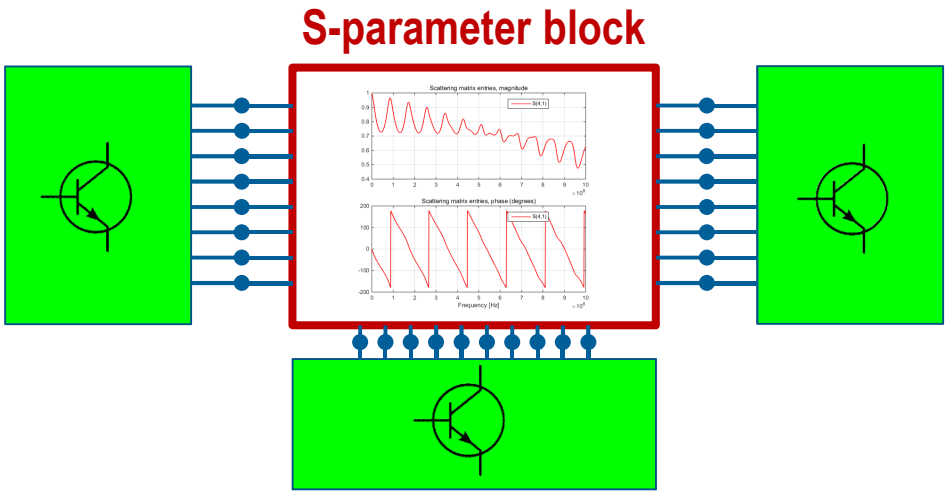


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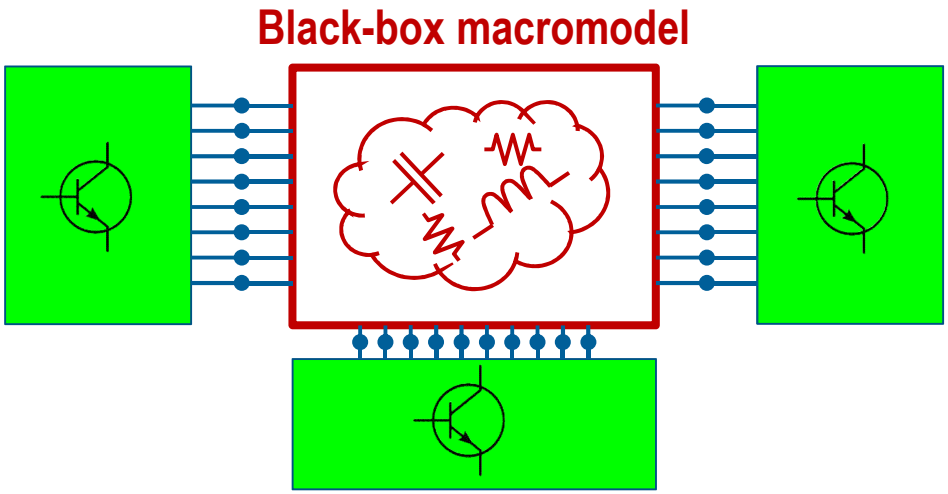


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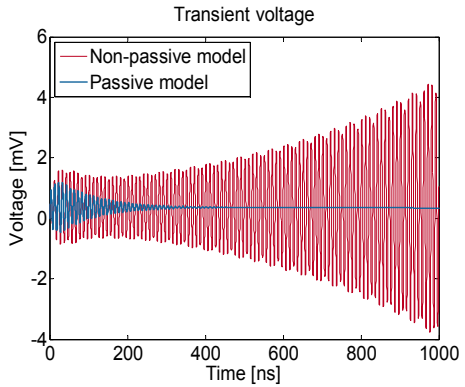
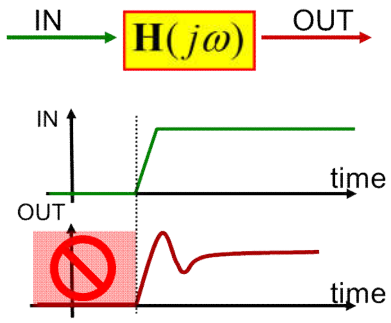
# Passivity and causality: requirements

- SI/PI analysis requires **PASSIVE** and **CAUSAL** models to enable reliable and fast system level simulations




- **PASSIVITY**: Electrical interconnects never amplify signals. Non-passive models lead to time-domain convergence problems and are non physical
- **CAUSALITY**: Electrical interconnects never provide a response that anticipates in time their excitations

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# Passivity and causality issues: why?

- When data come from **measurements** the passivity/causality violations may be due to:
  - improper calibration and de-embedding
  - human mistakes
  - measurement noise
- When data come from **simulations** the passivity/causality violations may be due to:
  - poor meshing
  - inaccurate solver
  - bad models or assumptions on material properties
    - (e.g. dielectrics with a tandelta which is constant in frequency)
  - human mistakes
  - improper use of data interpolation or extrapolation features of the solver
    - (often based on ill-defined and non-causal interpolation rules)
  - putting together results from two solvers

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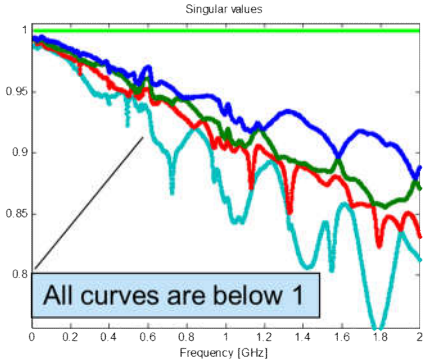
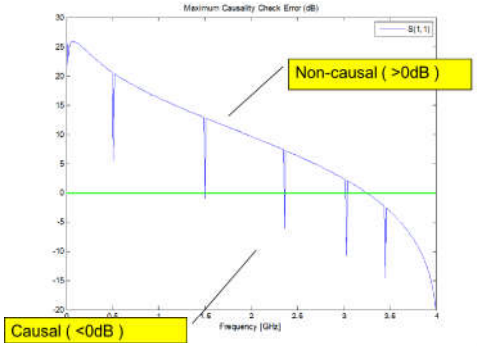
# Validation of S-parameter Data

- "***Energy gain***" is a necessary, but not sufficient condition for passivity.
- Causality is a prerequisite for Passivity.

**Passivity "Energy gain"**




**Causality "Hilbert-based check"**




- All the models generated by IdEM are **CAUSAL** by construction. The causality condition is enforced during the macromodel generation.
- The model is also **PASSIVE** if the passivity enforcement has been enforced by IdEM.

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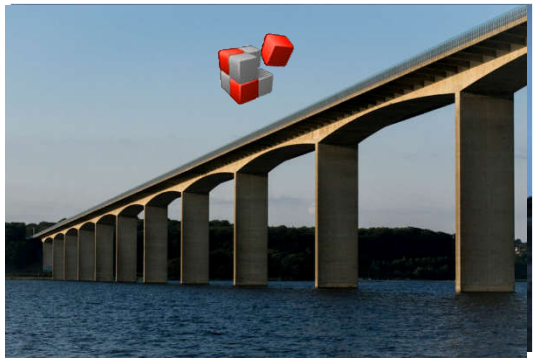
# IdEM: bridging the gap

***Frequency-domain***

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{21} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{24} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix}$$



***Time-domain***

**IdEM** validates S-parameters:

- ✓ **PASSIVITY** check
  - ✓ *Energy gain*
- ✓ **CAUSALITY** check

**IdEM** delivers reliable models:

- ✓ **Passive**
- ✓ **Causal**
- ✓ **Stable**
- ✓ **Accurate**
- ✓ **SPICE-ready**

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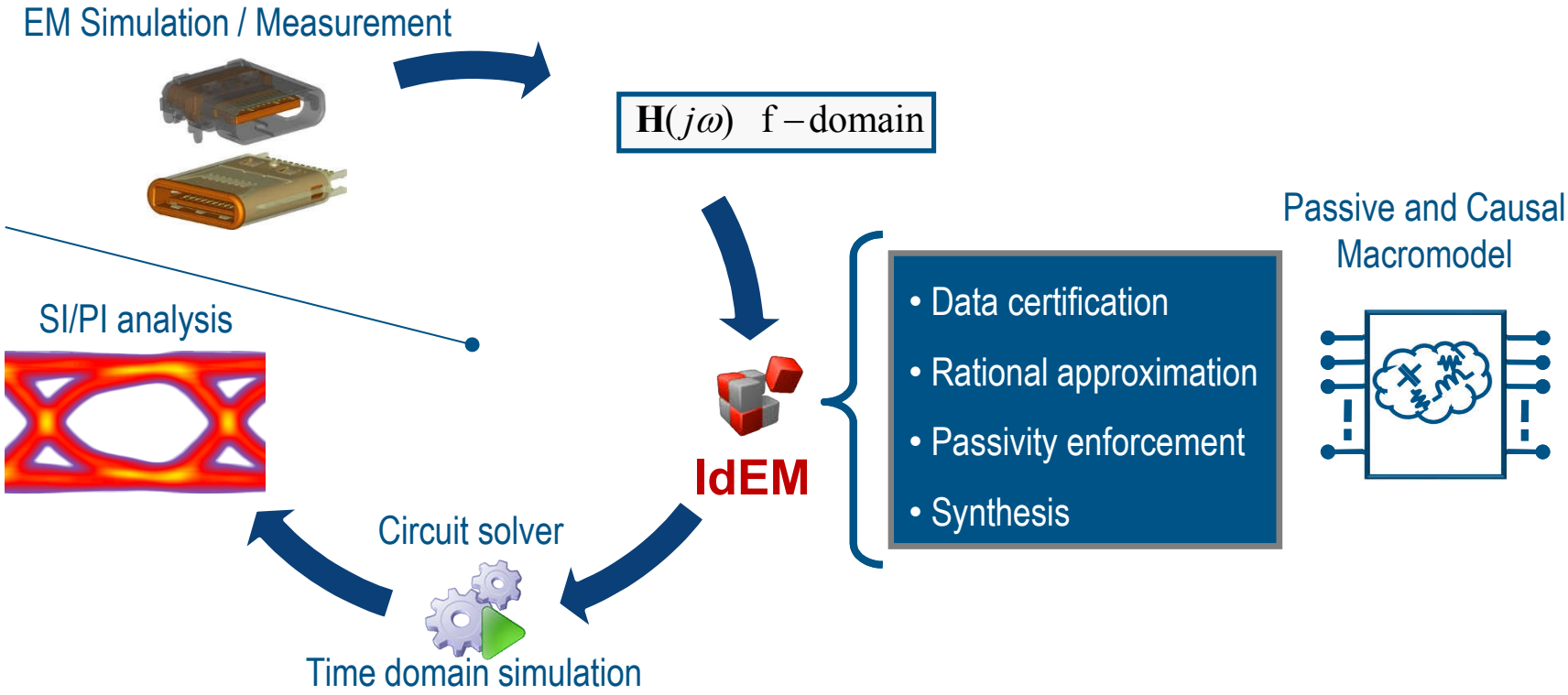
# IdEM-based simulation flow

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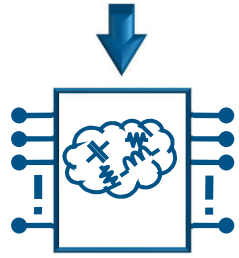
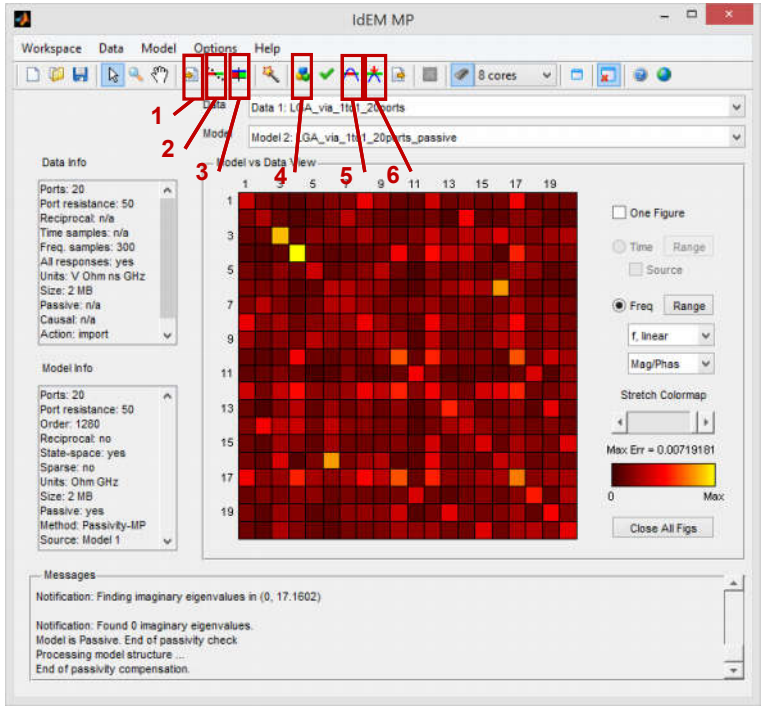
# The IdEM flow

## IdEM work-flow

1. Import Touchstone file
2. Check data passivity
3. Check data causality
4. Model build
5. Check model passivity
6. Enforce model passivity



**SPICE netlist**

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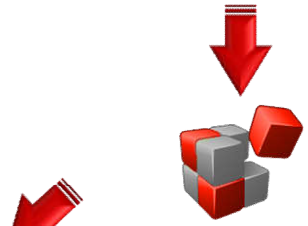
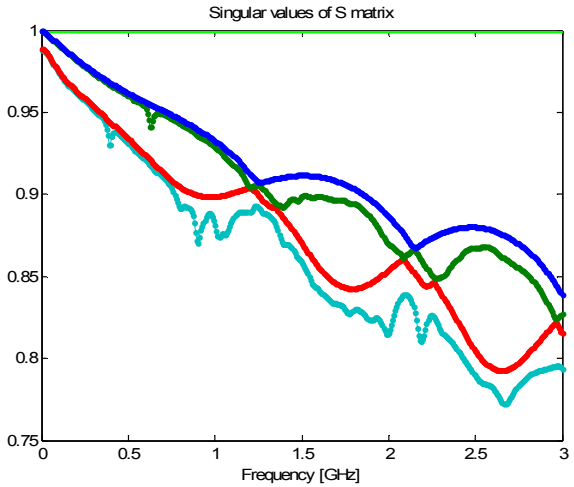
# IdEM: unique data certification engine

Touchstone file

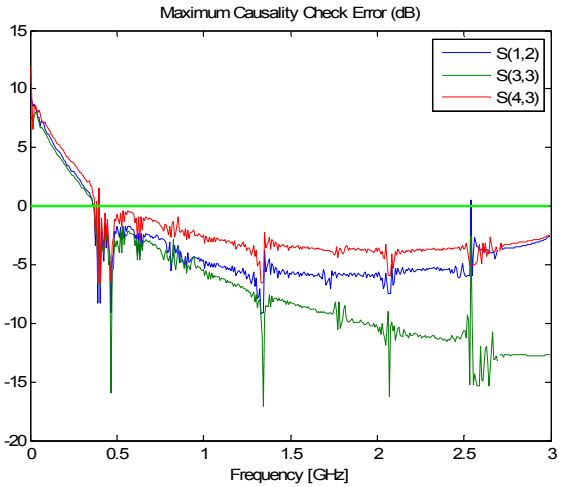


IdEM

Data **Passivity Check**




Data **Causality Check**

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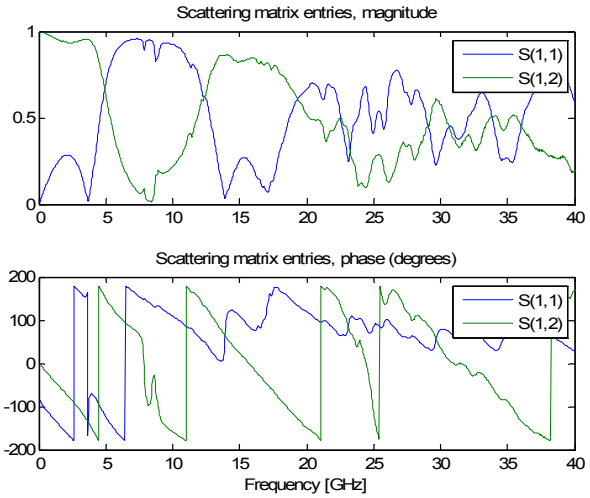
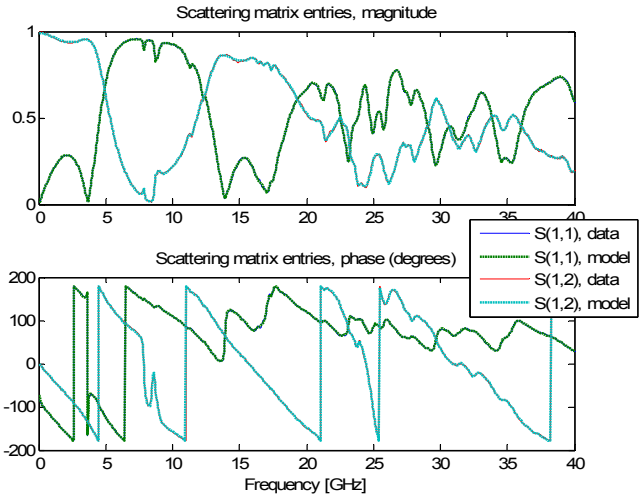
# IdEM: model generation

Data responses

IdEM

Model responses




**Accurate – Stable – Causal – Passive**

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# IdEM: model synthesis

## IdEM spice subcircuit

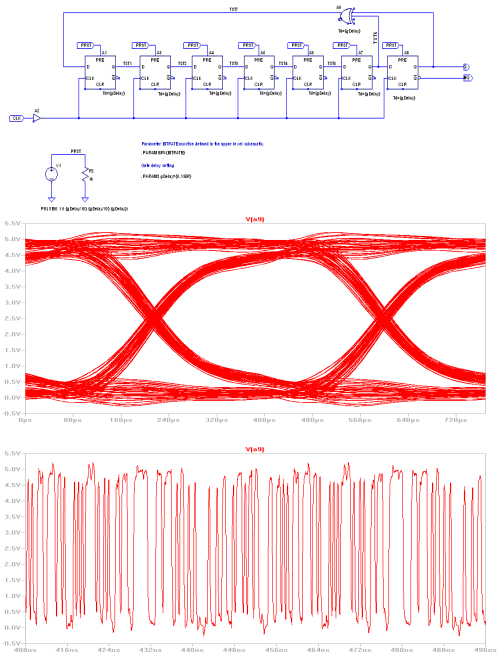
```
****************************************
* STATE-SPACE REALIZATION              *
* This file is automatically generated *
****************************************
* Created by IdEM
****************************************

**********************************
* Interface (ports specification) *
**********************************
.subckt passive_circuit
+  a_1 a_2 a_3 a_4 ref

****************************************
* Main circuit connected to output nodes *
****************************************
* Port 1
VI_1 a_1 NI_1 0
RI_1 NI_1 b_1 5.0000000000000000e+001
GC_1_1 b_1 NI_1 NS_1 0 2.5693083123524896e-001
GC_1_2 b_1 NI_1 NS_2 0 -5.6469170068284752e-002
GC_1_3 b_1 NI_1 NS_3 0 4.8926190008399095e-002
GC_1_4 b_1 NI_1 NS_4 0 -5.2083718292784568e-002
GC_1_5 b_1 NI_1 NS_5 0 1.4574389378577475e-005
GC_1_6 b_1 NI_1 NS_6 0 -2.1775247527891126e-005
```

**SPICE**

## Time domain simulation



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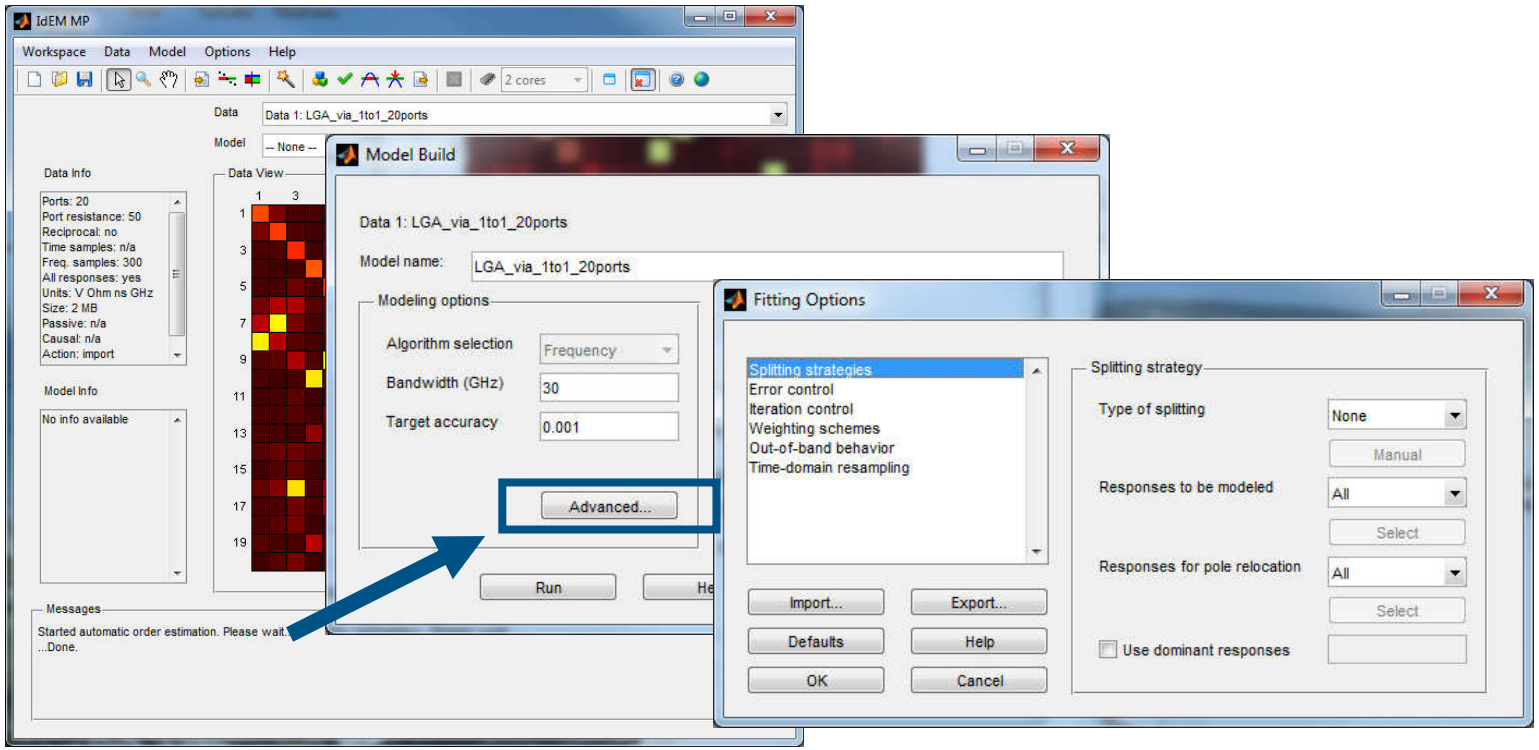
# Building macromodels with IdEM

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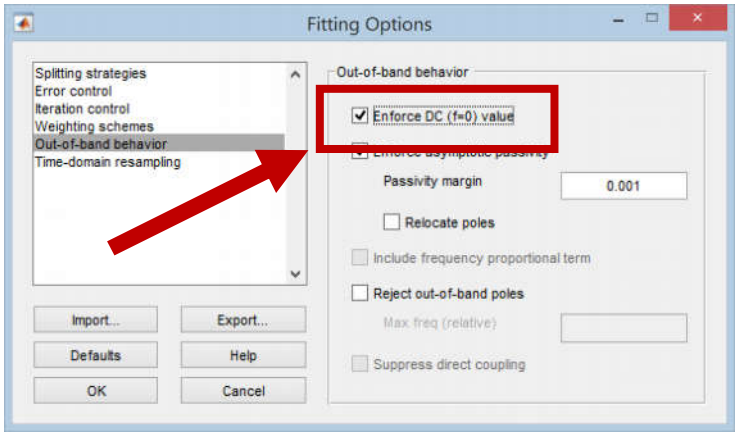
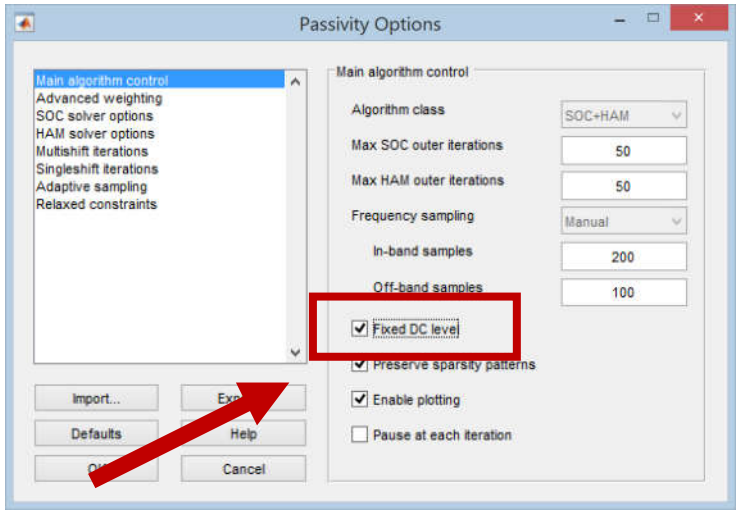
# Model generation with DC point constraints

**Advanced feature:** the DC response of a model can be constrained to the data DC point value. The DC point can be preserved both during fitting and passivity enforcement.

## Advanced fitting options




## Advanced passivity options

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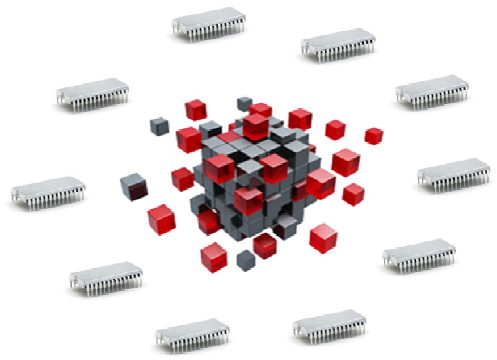
# Multi-processing

IdEM enables multi-processing capabilities that allows handling even large structures with an extraordinary speed-up in simulation runtime.



| Benchmark | N. ports | N. samples | State-space | CPU time | IdEM MP |
|---|---|---|---|---|---|
| Benchmark 1 | 48 | 690 | 1248 | Fitting | 21s |
| | | | | Passivity | 6s |
| | | | | Total | **27s** |
| Benchmark 2 | 98 | 189 | 6664 | Fitting | 1m 50s |
| | | | | Passivity | 6m 45s |
| | | | | Total | **8m 35s** |
| Benchmark 3 | 83 | 1228 | 1826 | Fitting | 48s |
| | | | | Passivity | 55s |
| | | | | Total | **1m 43s** |
| Benchmark 4 | 148 | 364 | 4440 | Fitting | 43s |
| | | | | Passivity | 3m 8s |
| | | | | Total | **3m 51s** |
| Benchmark 5 | 165 | 348 | 8250 | Fitting | 2m 12s |
| | | | | Passivity | 2m 22s |
| | | | | Total | **4m 34s** |

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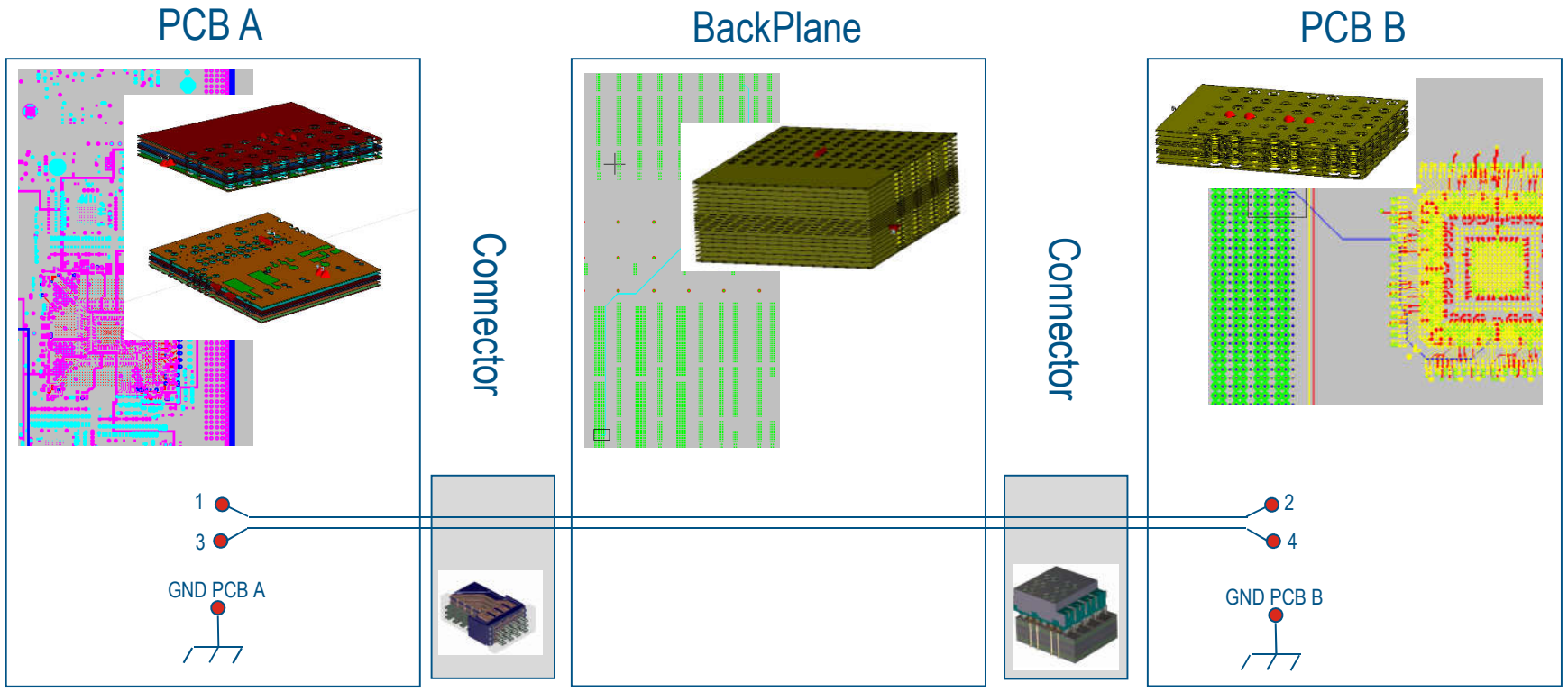
# Application: interconnect link

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CST joins SIMULIA
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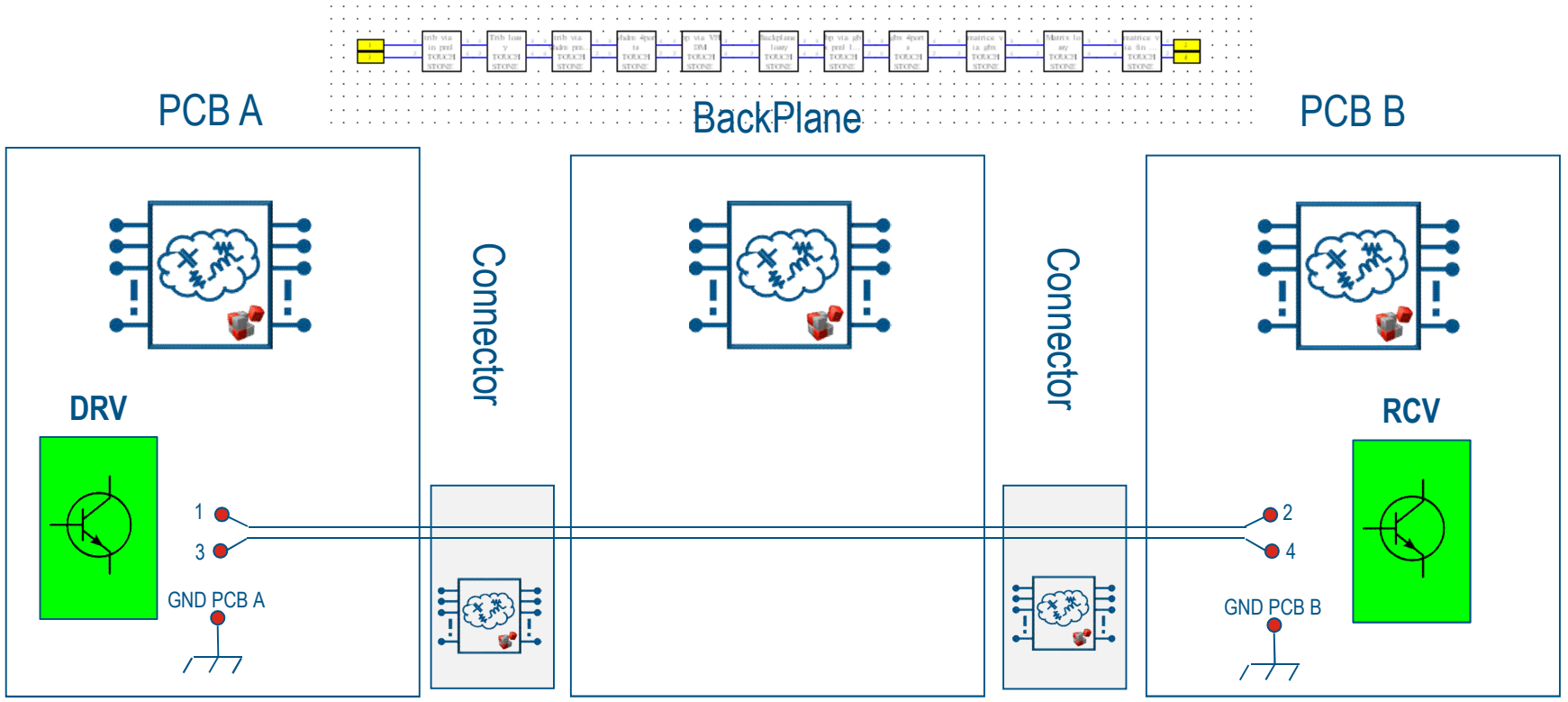
# Application: interconnect link

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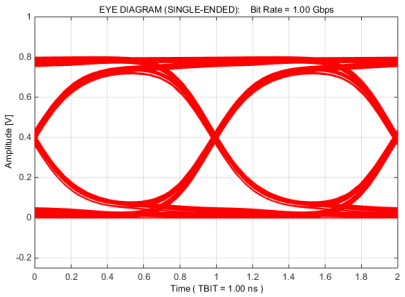
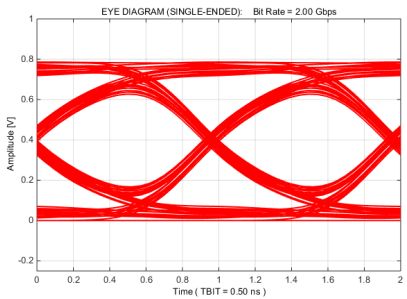
# Application: interconnect link

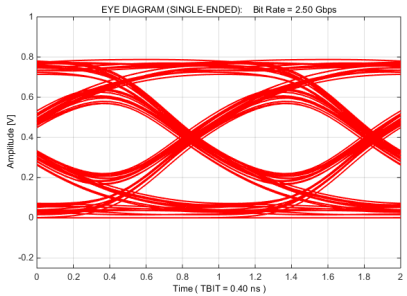
## 1 GBps



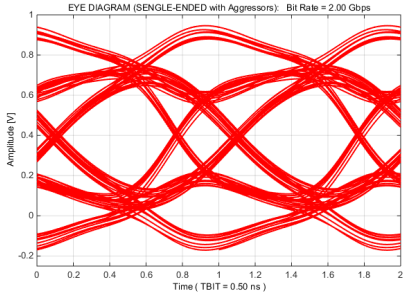

## 2 GBps



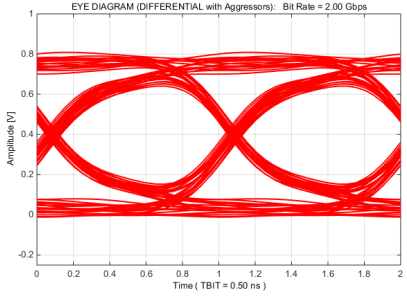

## 2.5 GBps




## 2 GBps + aggressors




## 2 GBps + differential + aggressors

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