S-Parameter Based T-Connector for Consensus Model

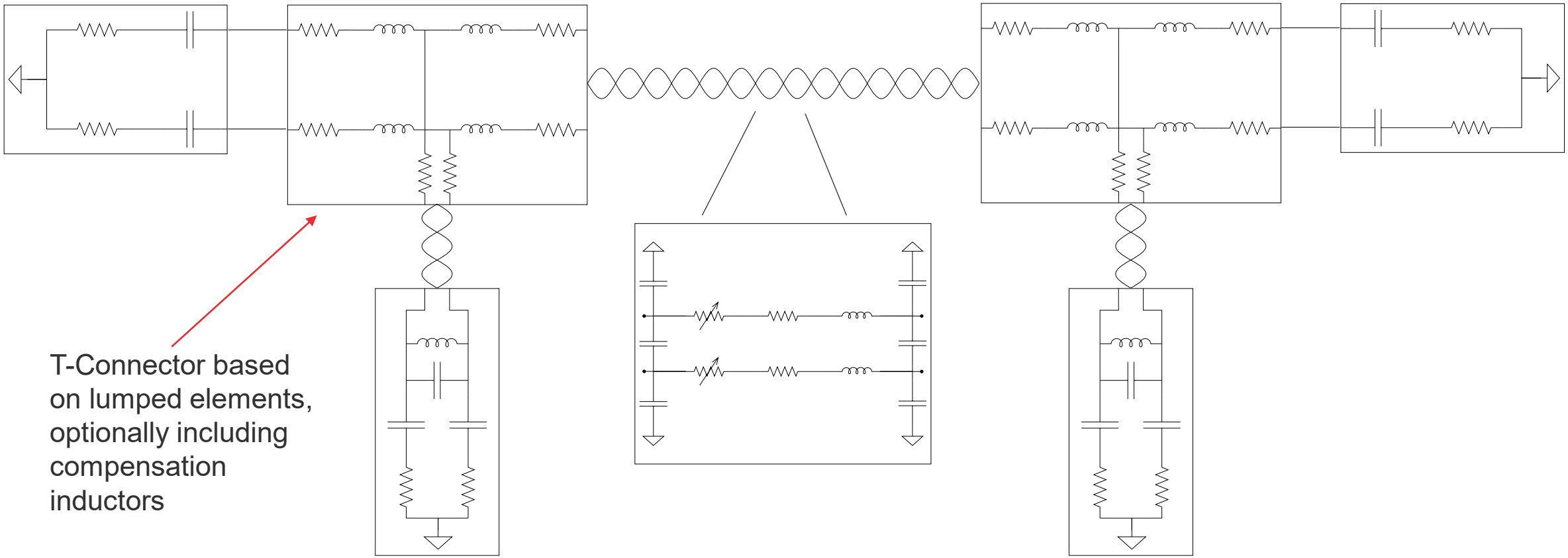
5th October 2022

Stephan Schreiner (Rosenberger)

Purpose

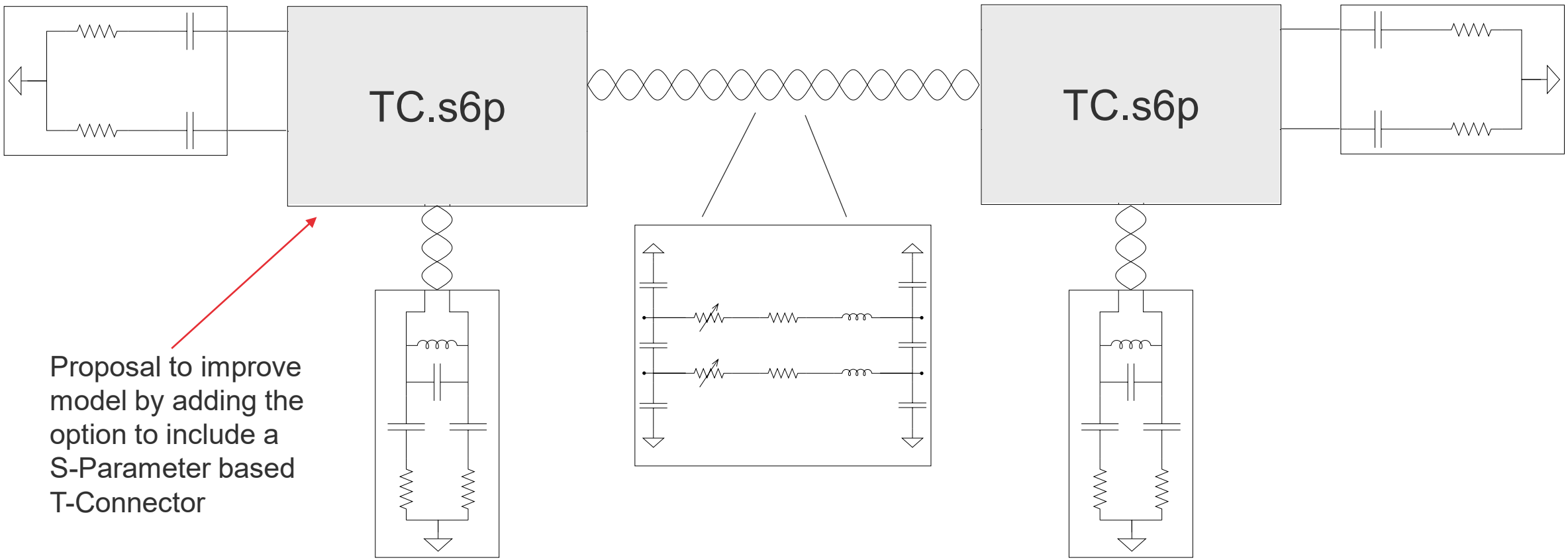
- New S-Parameter based T-Connector models based on EM-Simulation data or measurements for the consensus model
  - Add feature to optionally use S-Parameters (*.s6p) of the T-Connector within the consensus model
    - Import of S-Parameters within the consensus model
    - Vector fitting of S-Parameters to create the LT-Spice simulation model
    - Comparison of vector fitted model with original S-Parameters
    - Analysis of the effect within the consensus model

Elements of Consensus Model

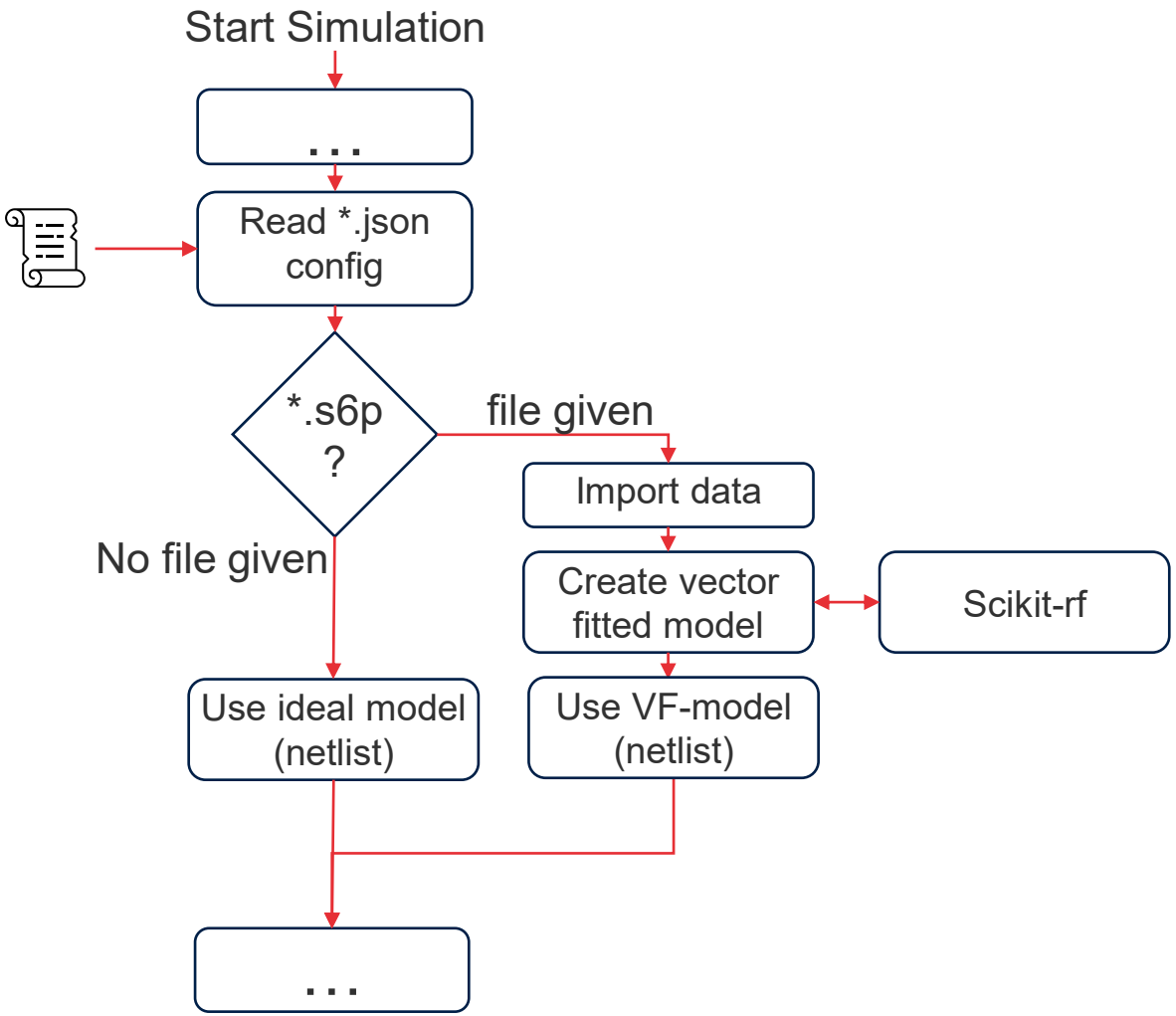


T-Connector based on lumped elements, optionally including compensation inductors

New Optional Element of the Consensus Model



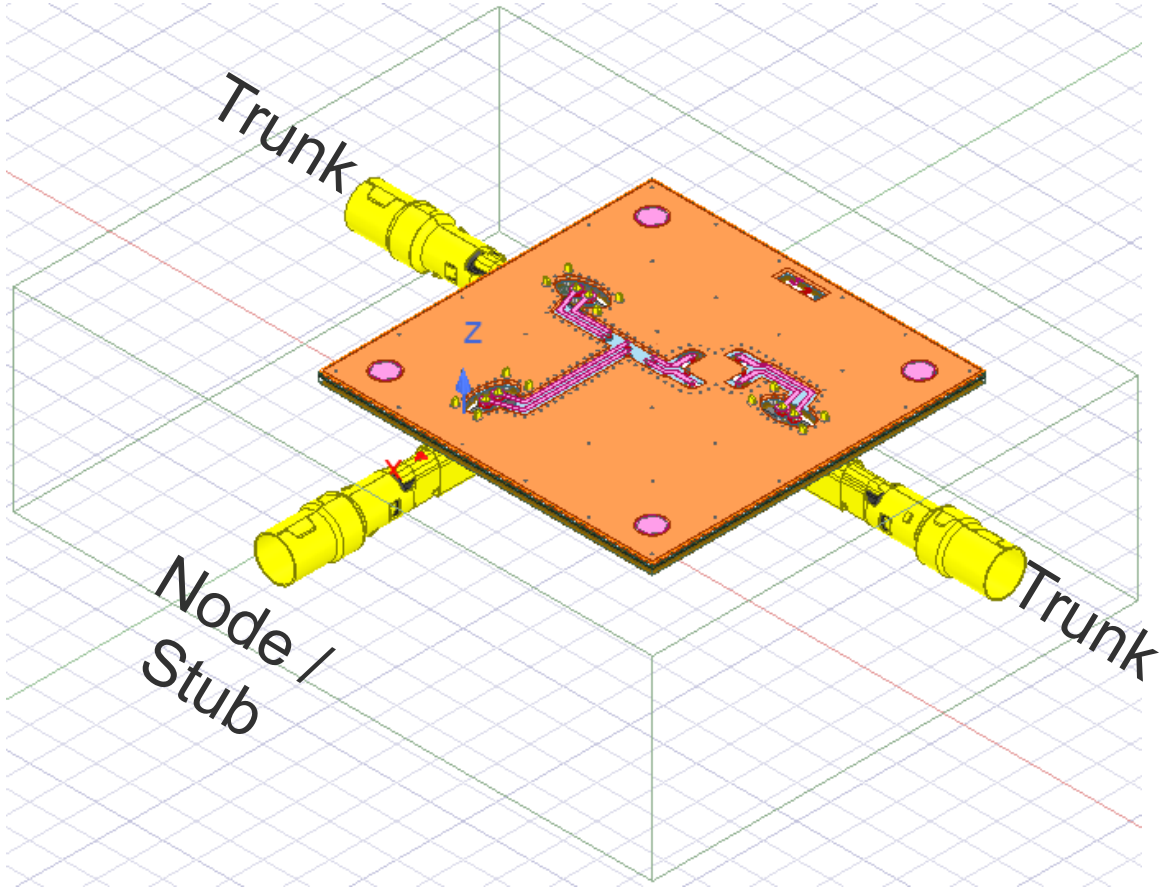
Proposed Changes



- Add an option in the *.json config to use a S-Parameter file for the T-Connector
  - If a S-Parameter file for the T is given, it is used
  - Otherwise the standard model for the T connector will be used
- Add an additional python class for vector fitting
  - If S-Parameter file is given
    - Import the data
    - Create a vector fitted model by the use of “scikit-rf” – python library
      - A small patch in scikit-rf is required to generate output which can be used in LT-Spice
    - Provide netlist of VF-model to consensus model

Test Model for vector fit

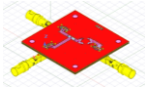
- Simple PCB based T-Connector
- Full 3D FEM Analysis
- Causal materials are used in simulation
- Two PCBs are simulated, one with matching impedance and one with a lower impedance
- Inductive compensation elements are included as ideal lumped elements
- ➢ Four different S-Parameter files (with and without compensation) for both PCBs (matching impedance [opt Tee] and lower impedance [Cap. Tee]) are generated

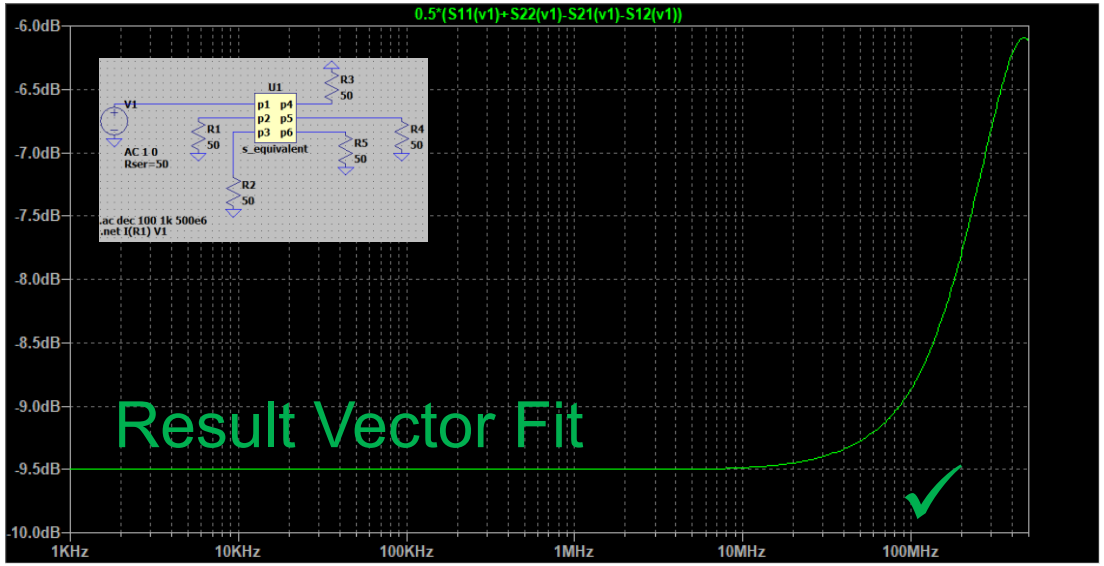


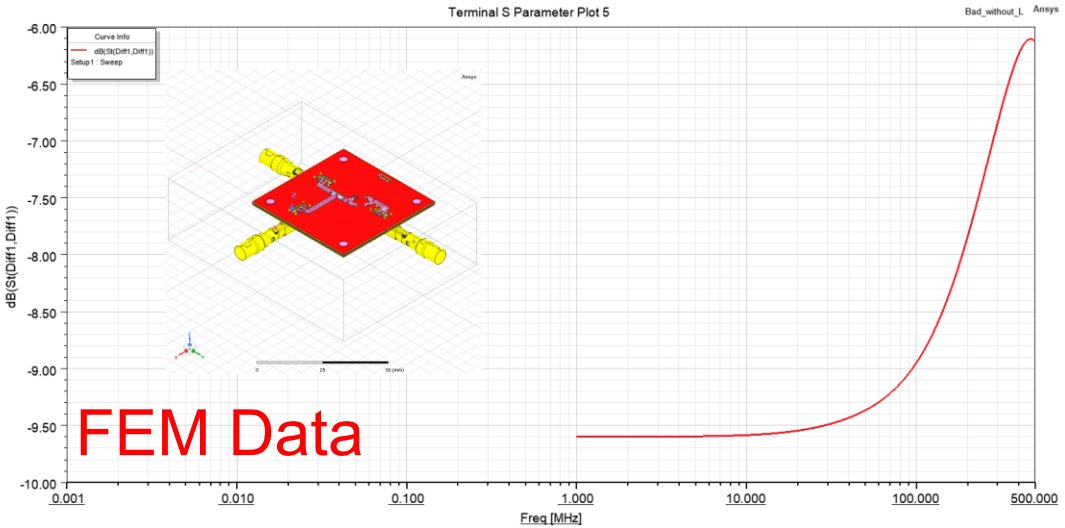
Vector Fit Results Sdd11

Without compensation inductor

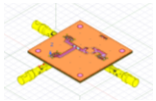
Cap. Tee

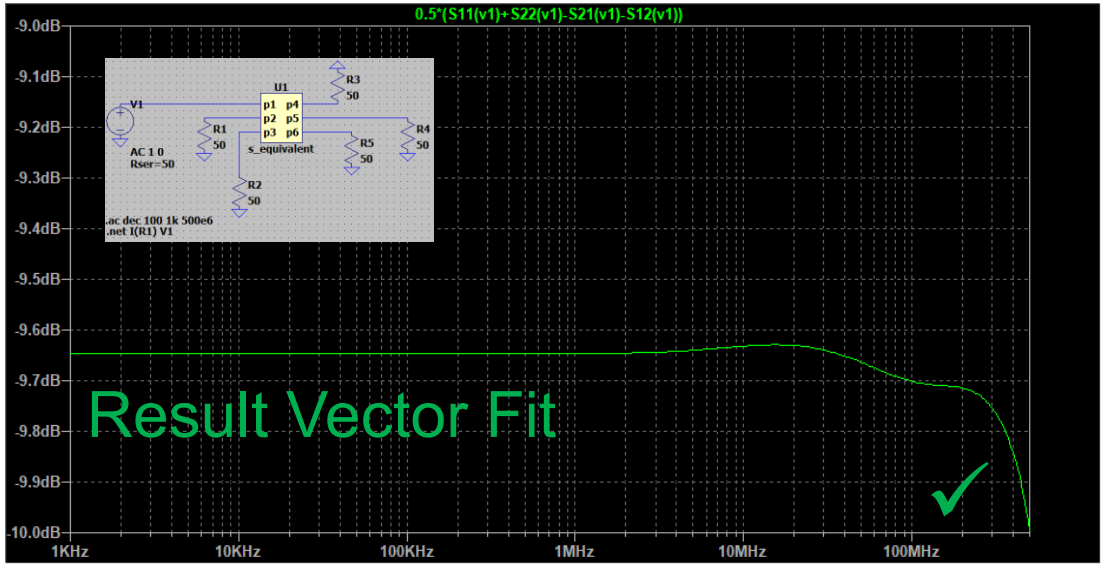


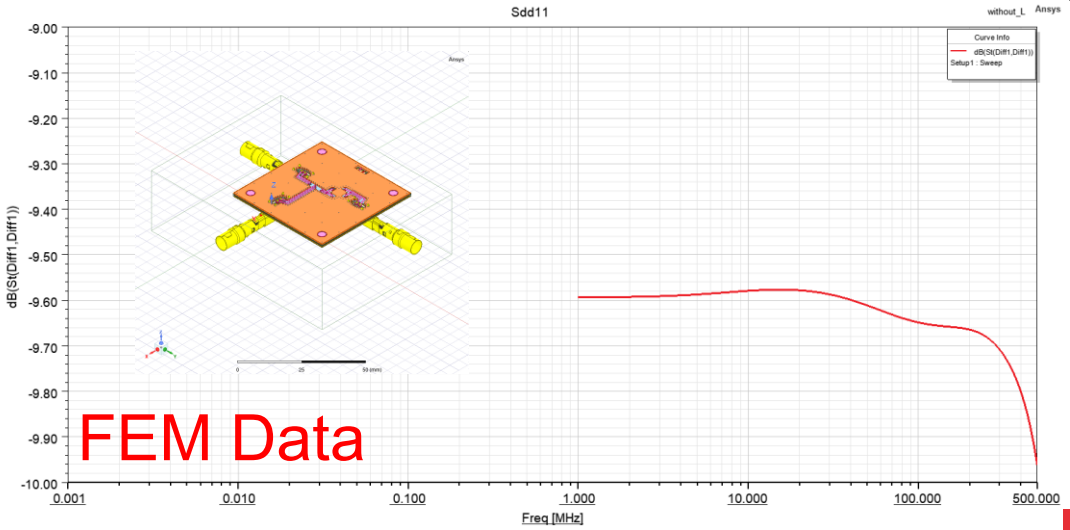




Opt. Tee



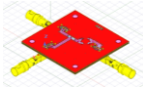


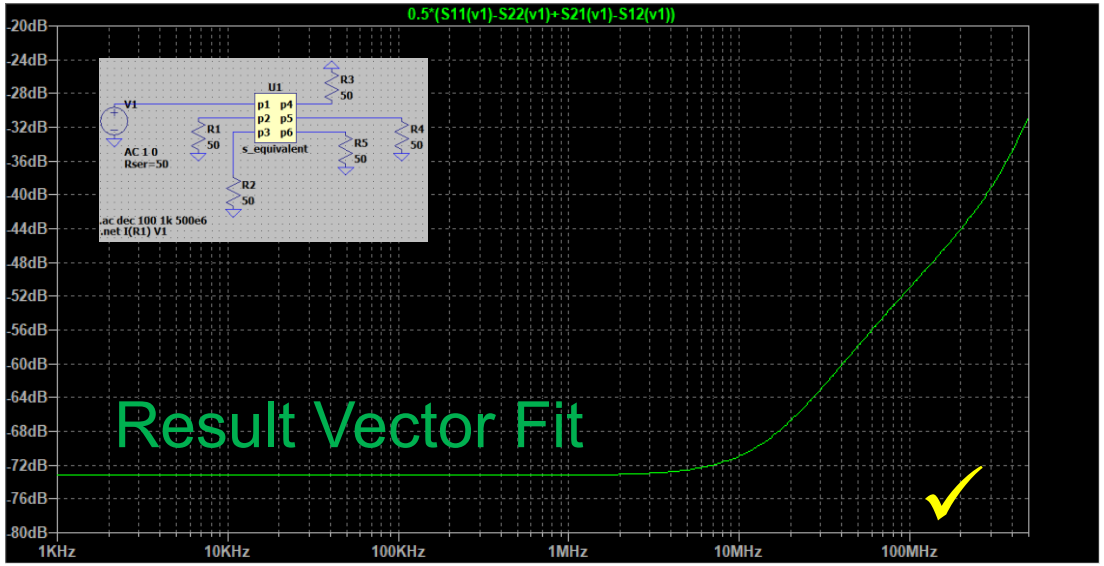


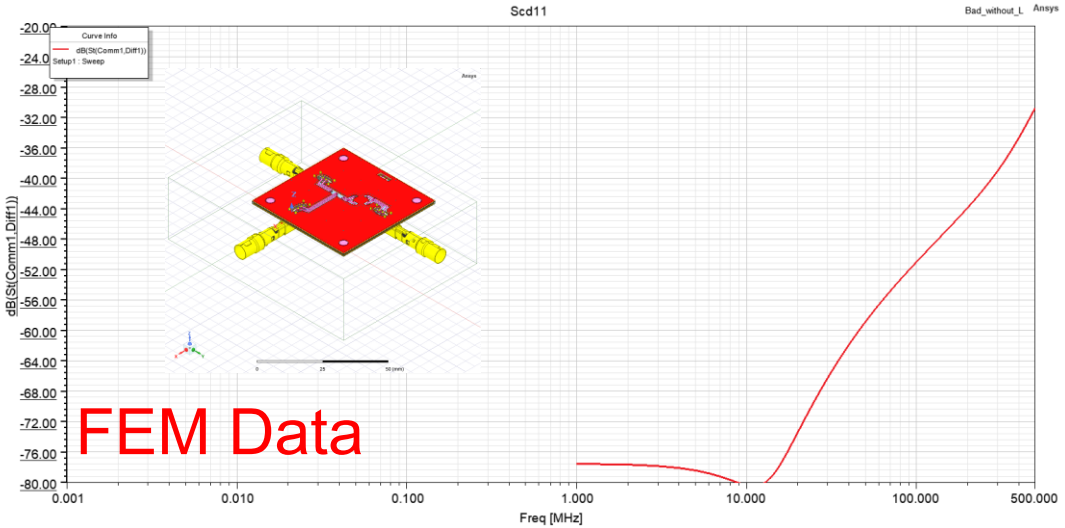
Vector Fit Results Scd11

Without compensation inductor

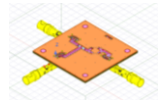
Cap. Tee

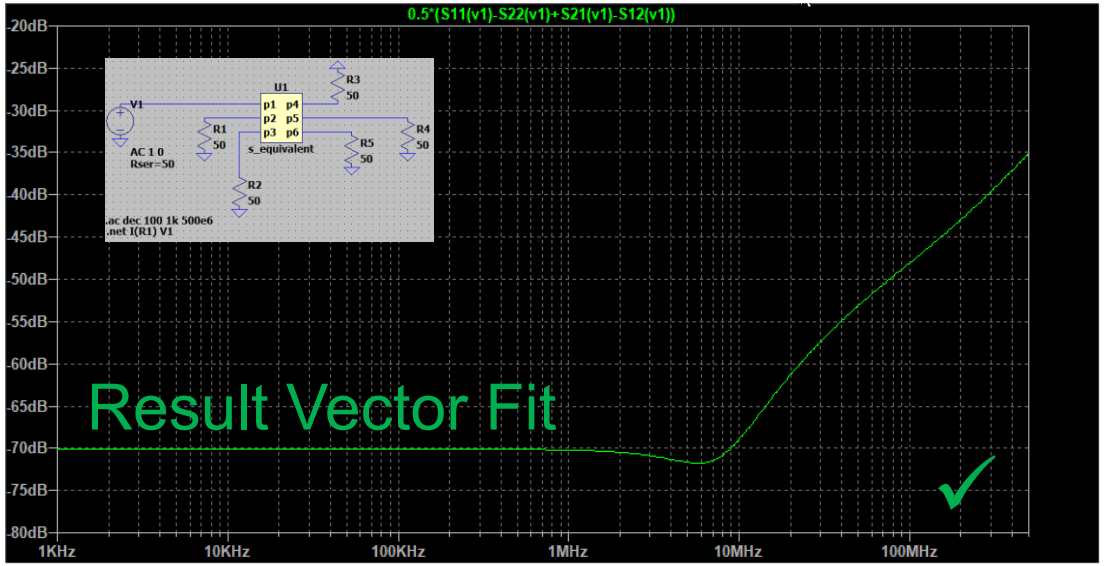


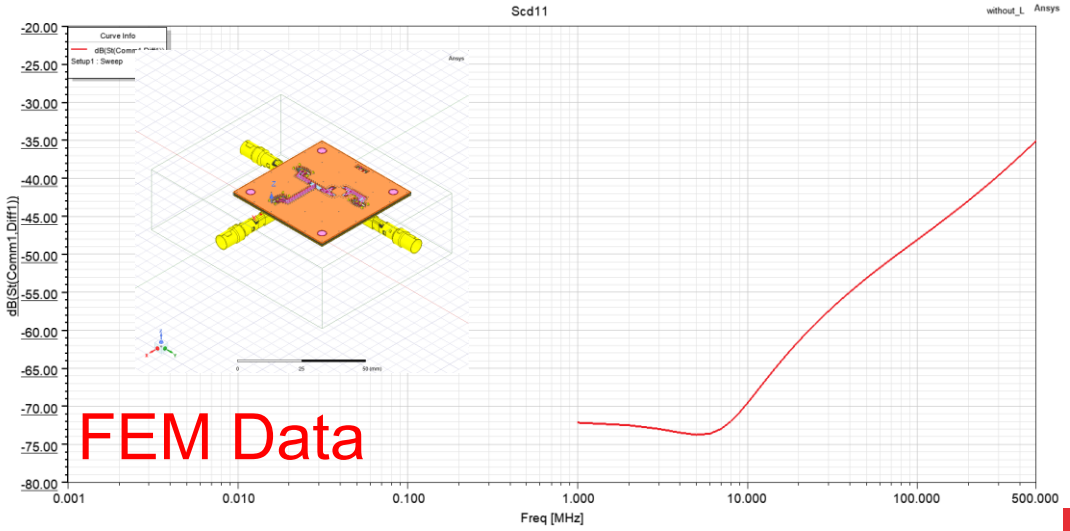




Opt. Tee



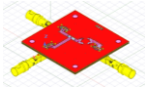


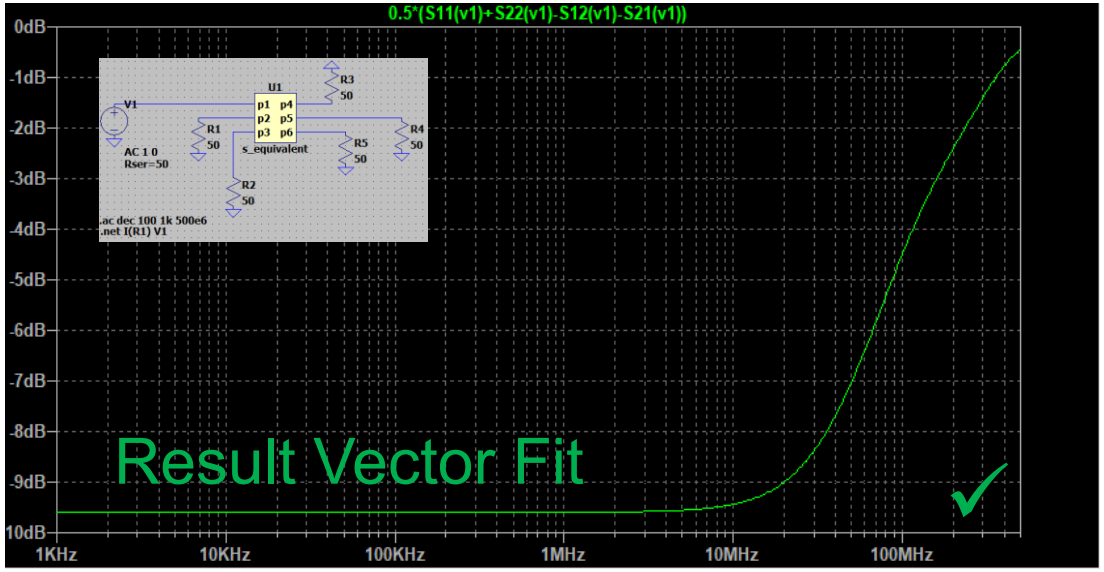


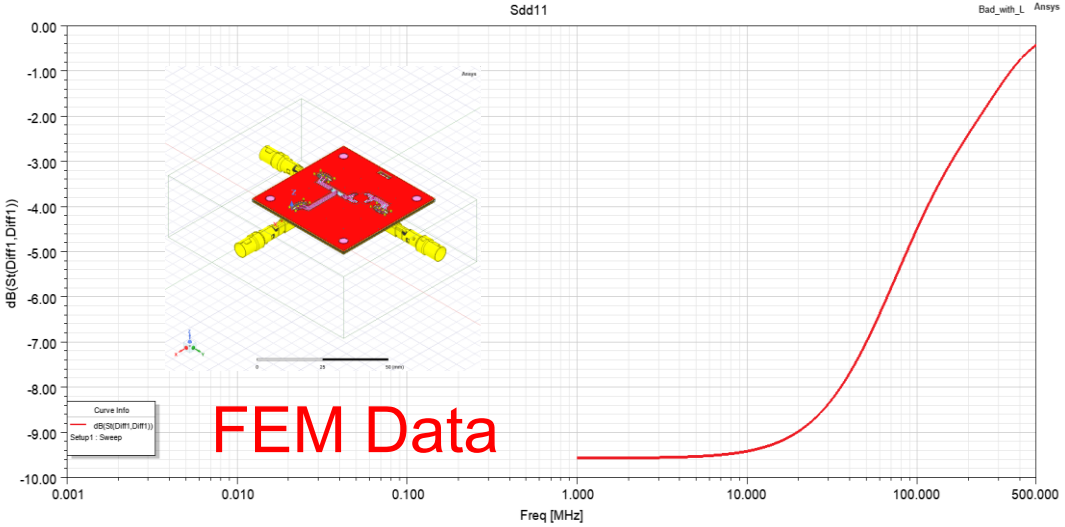
Vector Fit Results Sdd11

With compensation inductor

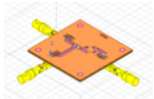
Cap. Tee

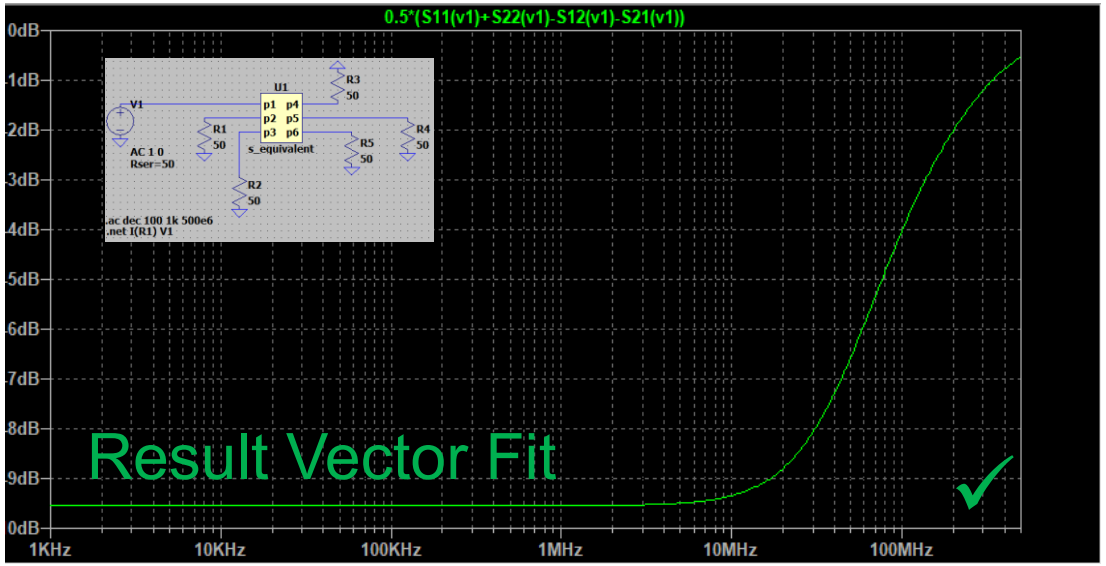


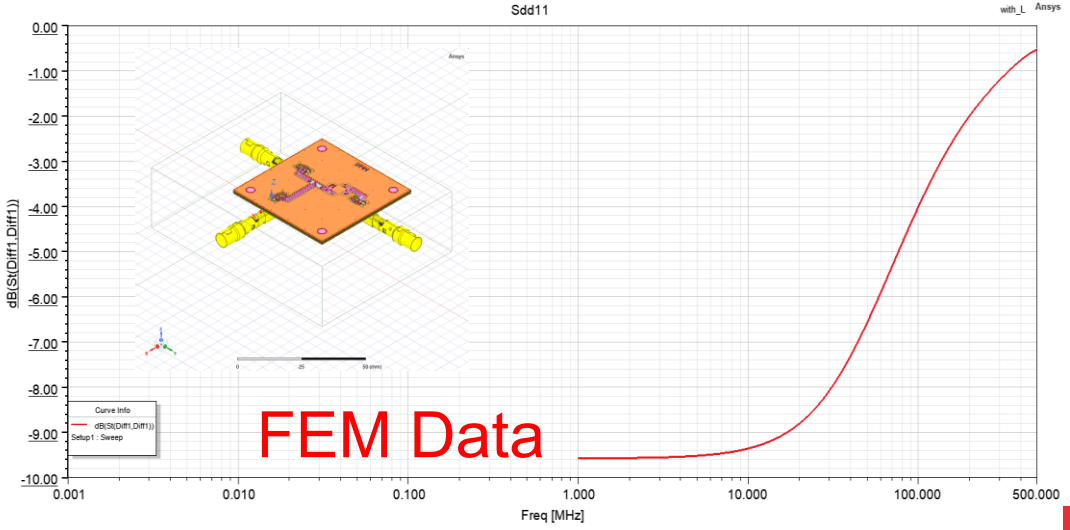




Opt. Tee



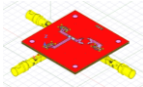


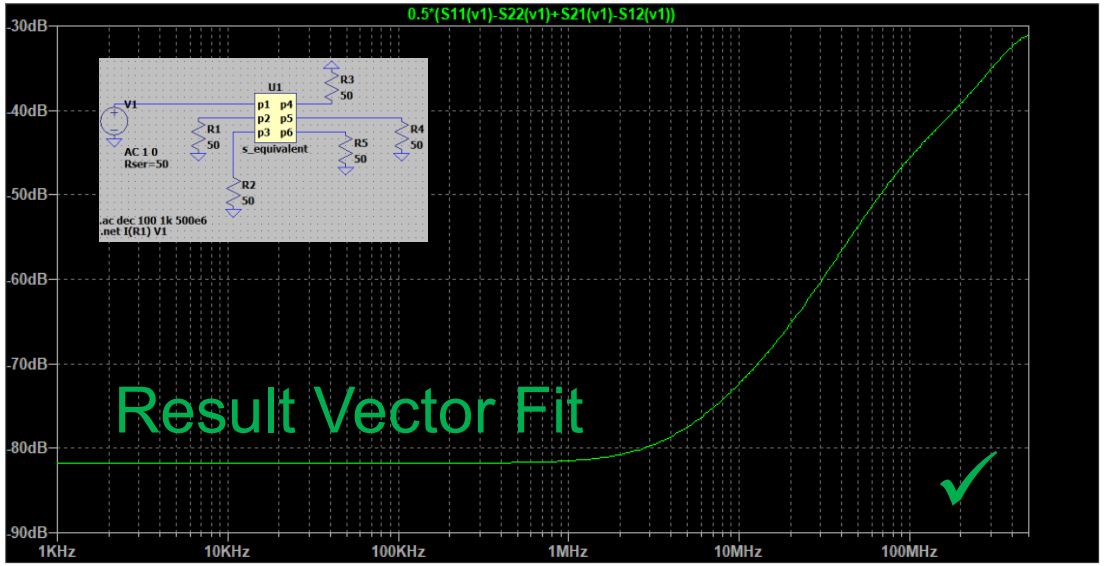


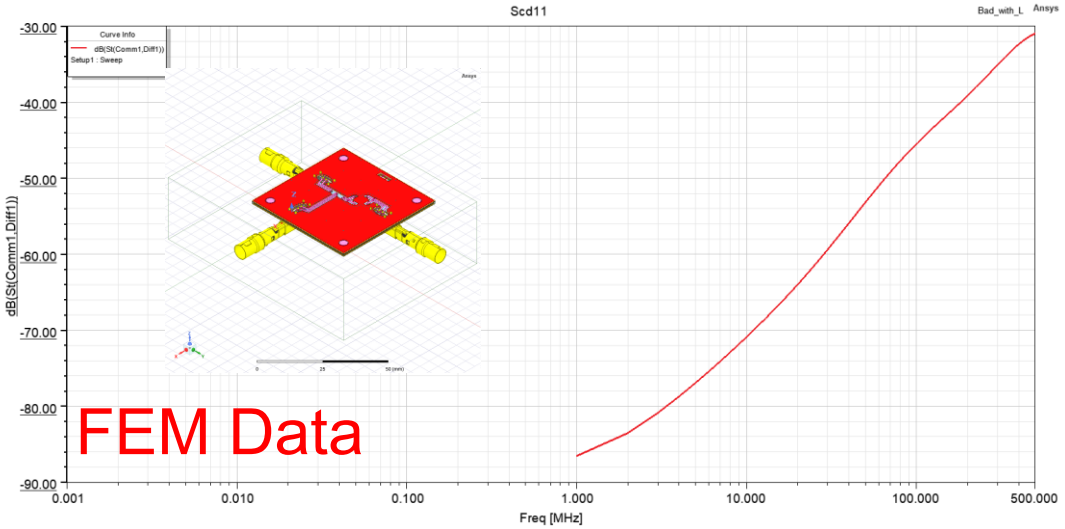
Vector Fit Results Scd11

With compensation inductor

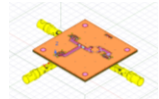
Cap. Tee

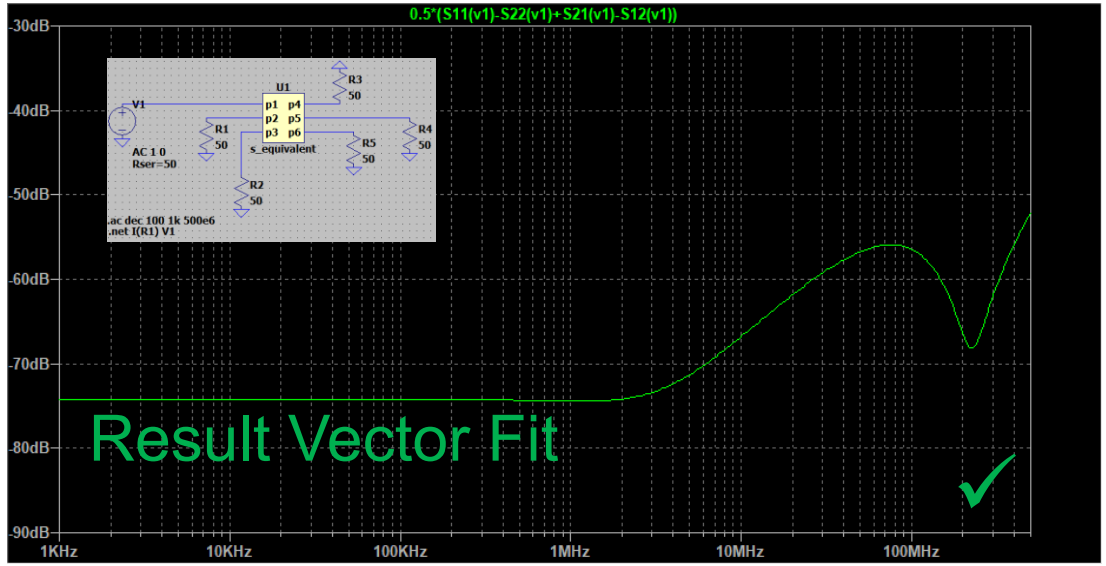


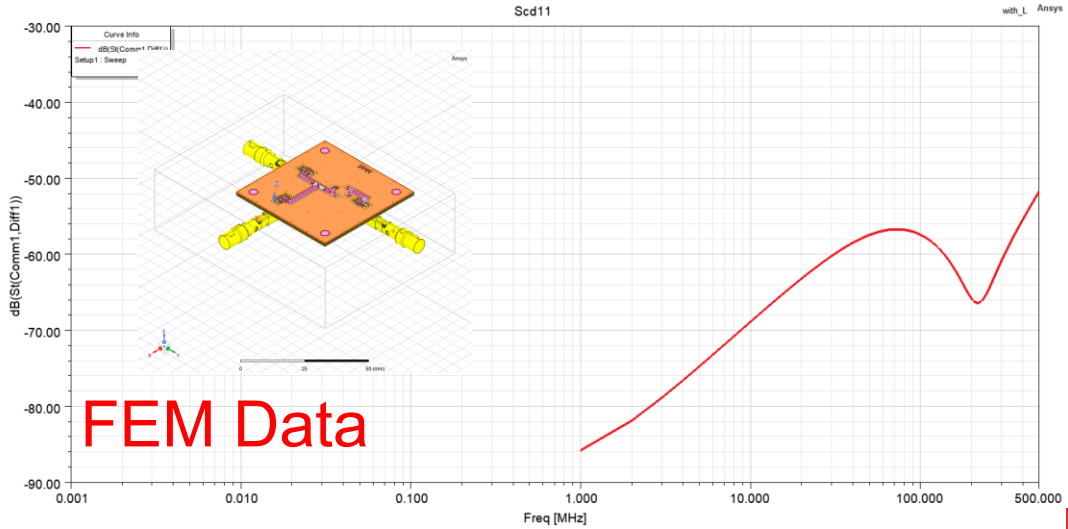




Opt. Tee

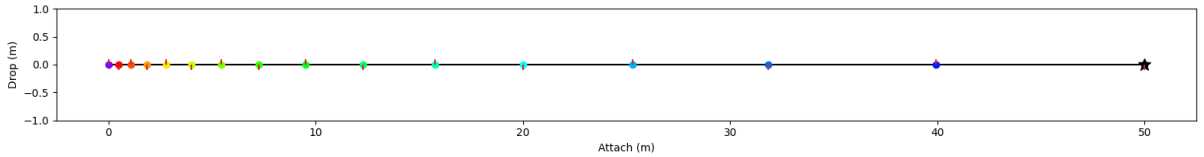






Test Channel for Comparison

- Channel with different segment length was chosen
- Channel Parameters
  - 16 Nodes
  - 50m
  - Exponentially spaced starting with 0.5m distance



  - TX Node permutations evaluated: 1; 8; 16
  - Drop length 10cm
  - Lpodl 80uH
  - Cnode 30pF

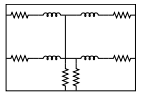
```
"attach_points": [
  0.0,
  0.5,
  1.1,
  1.85,
  2.8,
  4.0,
  5.45,
  7.25,
  9.5,
  12.3,
  15.75,
  20.0,
  25.3,
  31.85,
  39.95,
  50.0
],
```

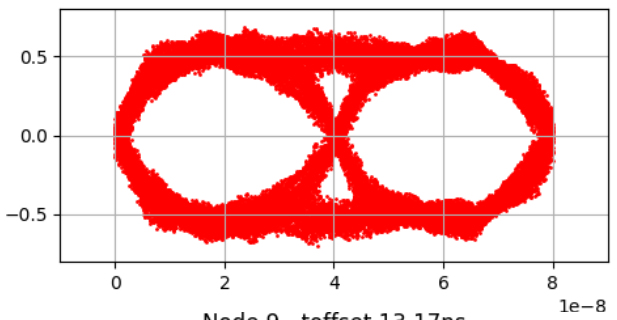
```
"tee": {
  "touchstone": "c:/data/Tee_with_L.s6p",
  "fitted_model_name": "FEM3d_Tee_Compensated",
  "fitting_error_rms": 0.00001,
  "port_order": [
    1,
    2,
    3,
    4,
    5,
    6
  ]
},
```

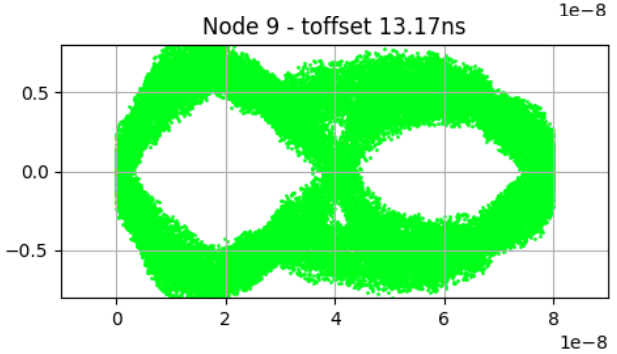
Eye Diagram Comparison TX Node 1

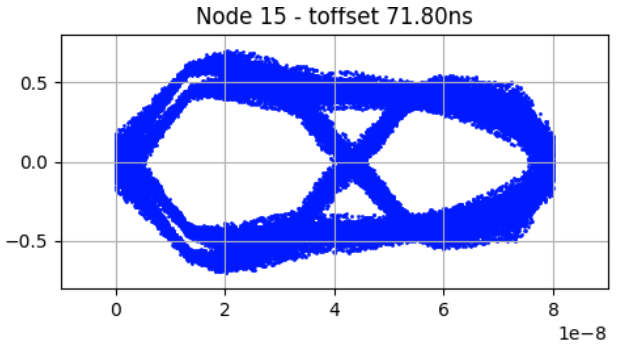
Without compensation inductors

Ideal Tee

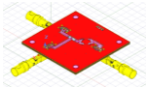


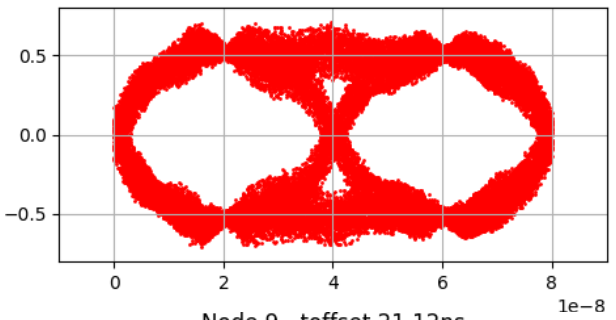


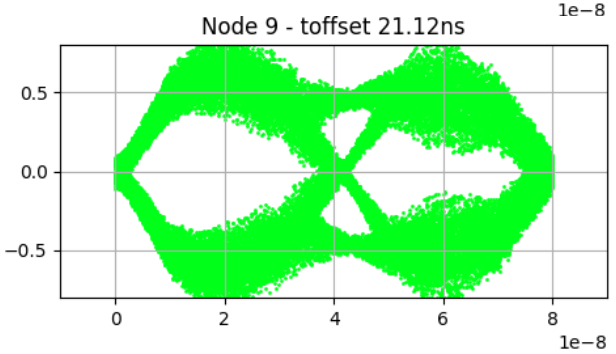


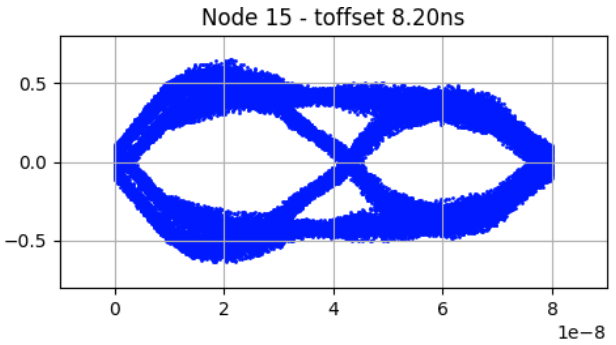


Cap. Tee

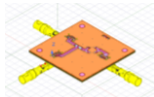


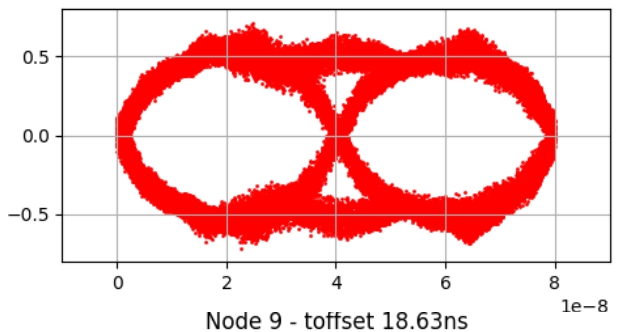


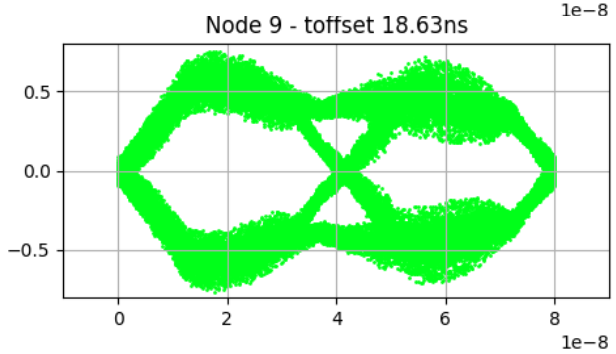


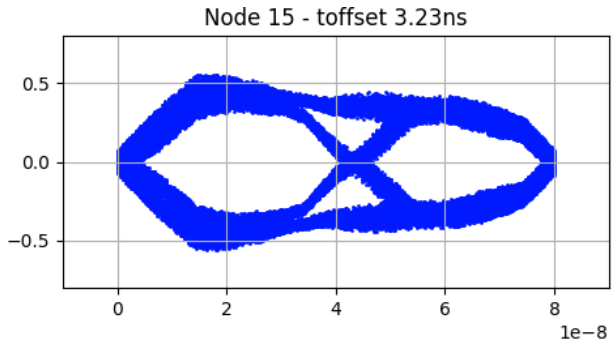


Opt. Tee





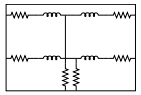


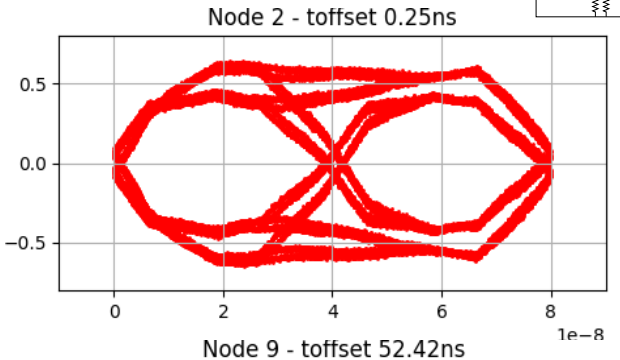


Eye Diagram Comparison TX Node 8

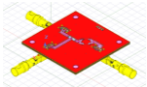
Without compensation inductors

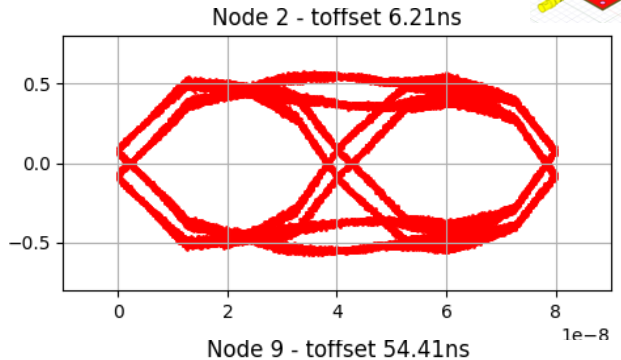
Ideal Tee



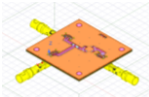


Cap. Tee





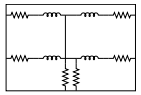
Opt. Tee

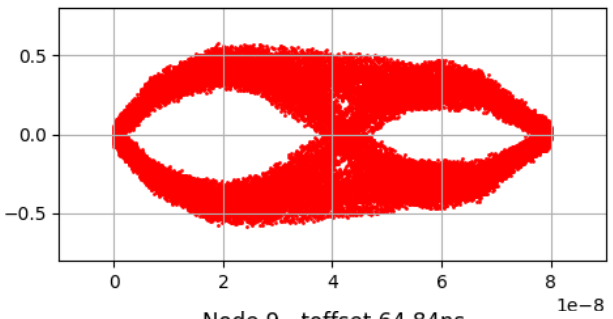


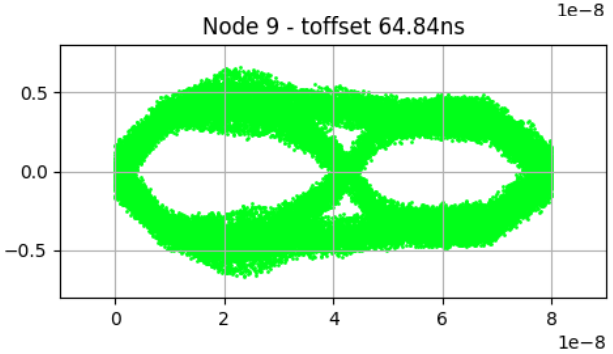
Eye Diagram Comparison TX Node 16

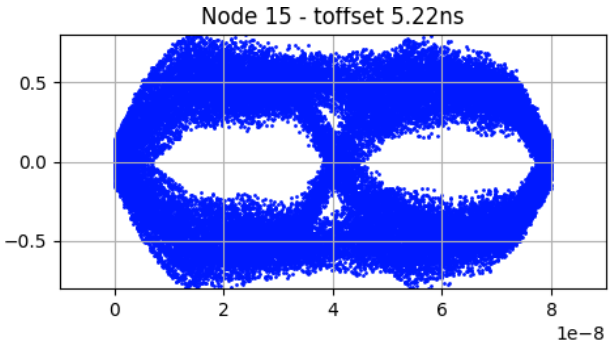
Without compensation inductors

Ideal Tee

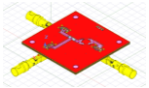


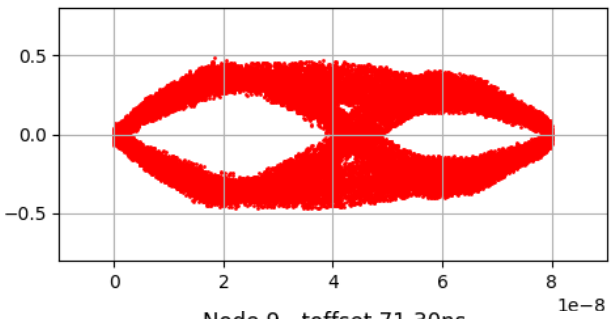


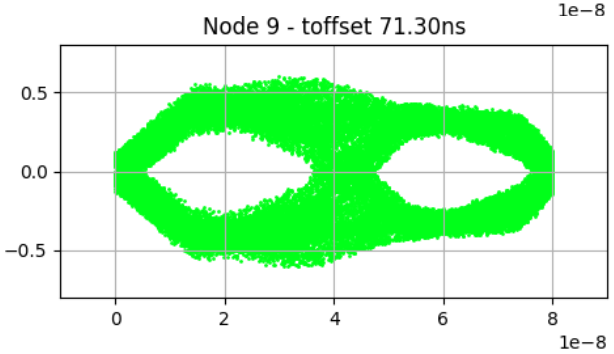


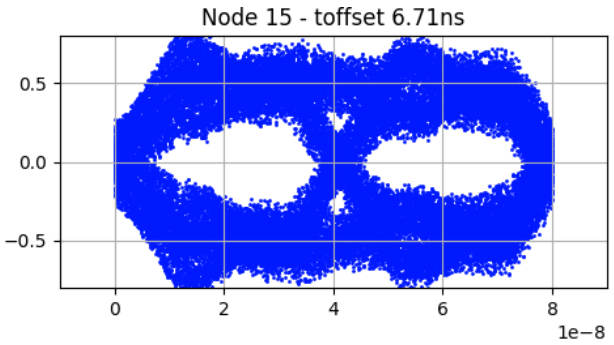


Cap. Tee

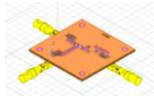


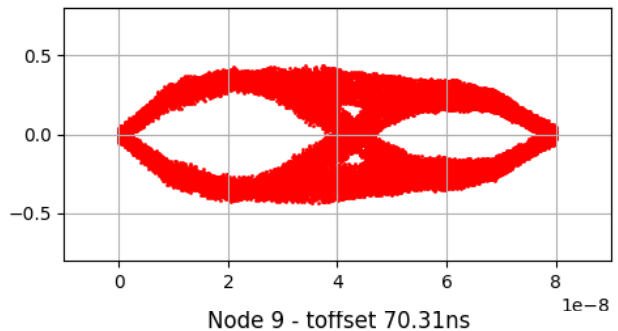


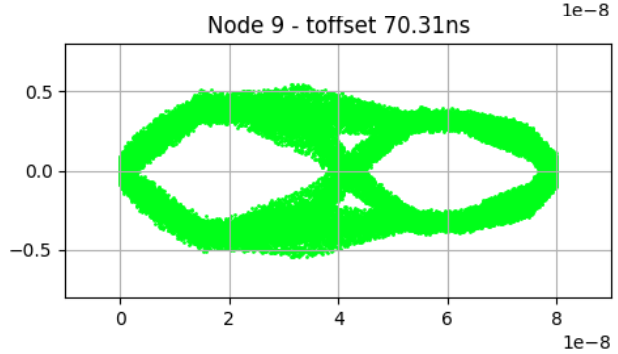


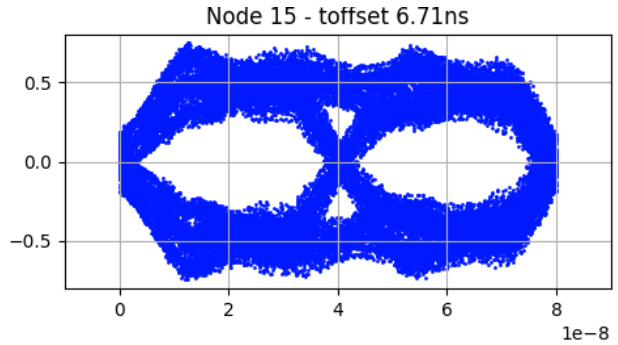


Opt. Tee





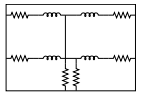


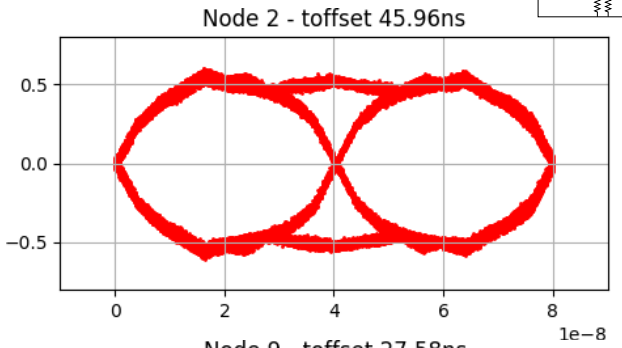


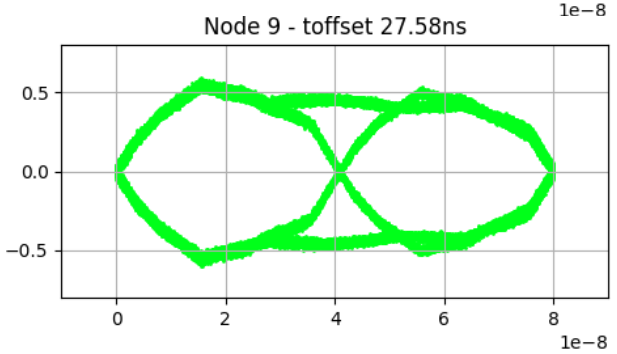
Eye Diagram Comparison TX Node 1

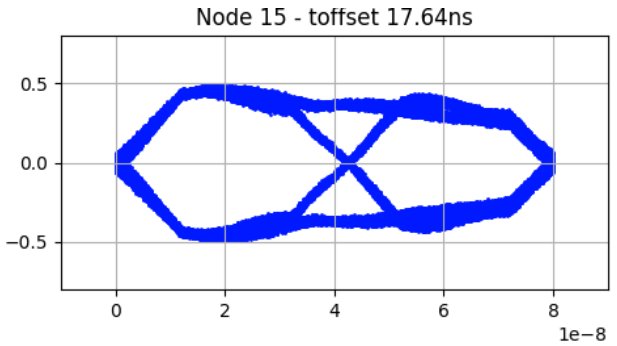
With compensation inductors

Ideal Tee

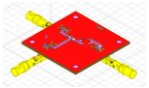


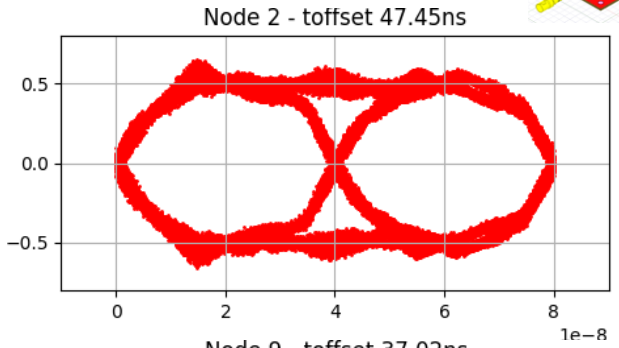


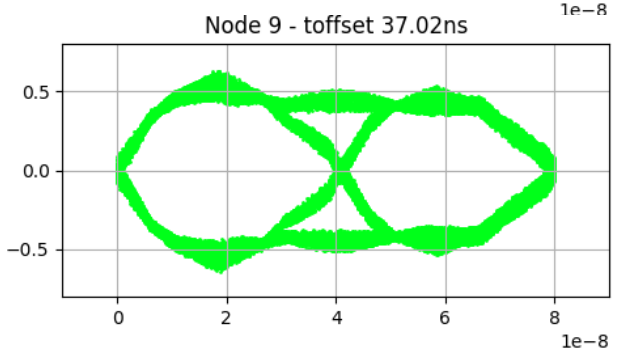


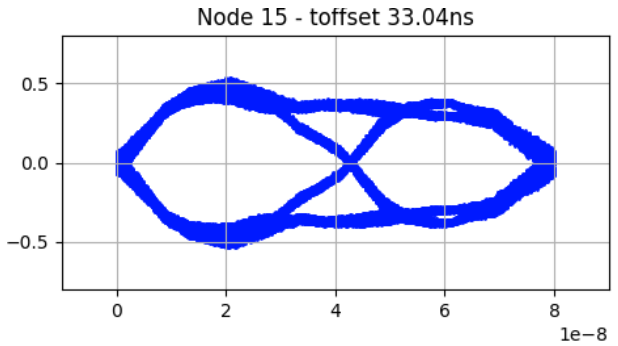


Cap. Tee

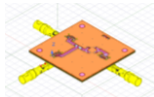


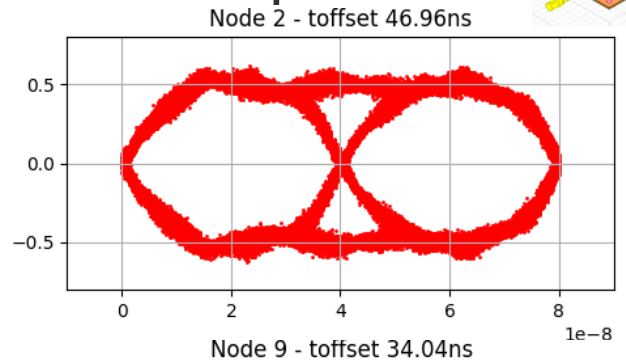


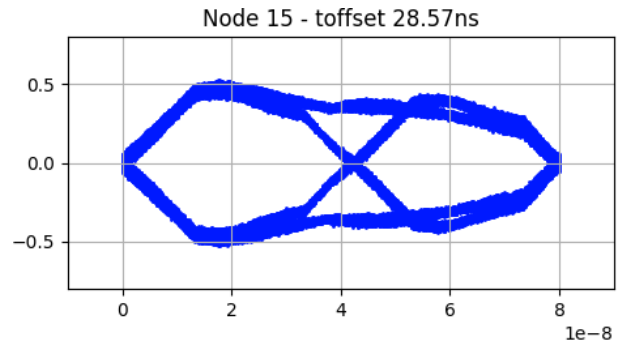




Opt. Tee



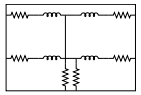


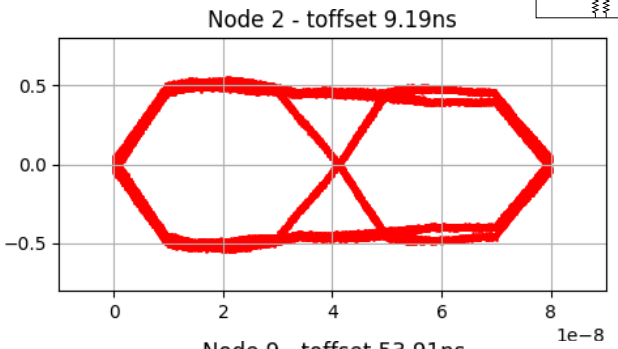


Eye Diagram Comparison TX Node 8

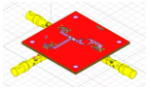
With compensation inductors

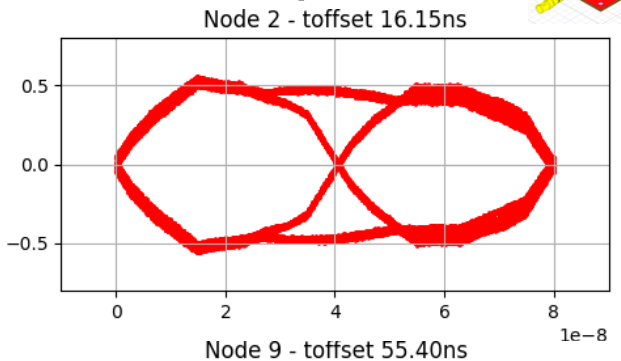
Ideal



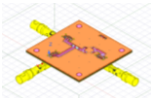


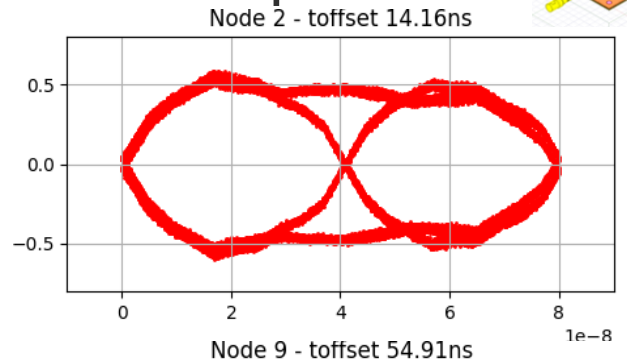
Cap. Tee





Opt. Tee

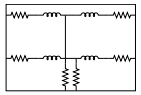


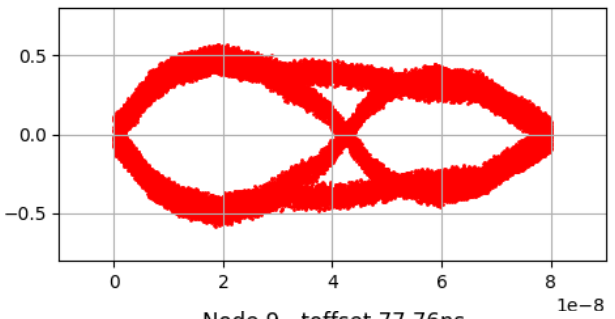


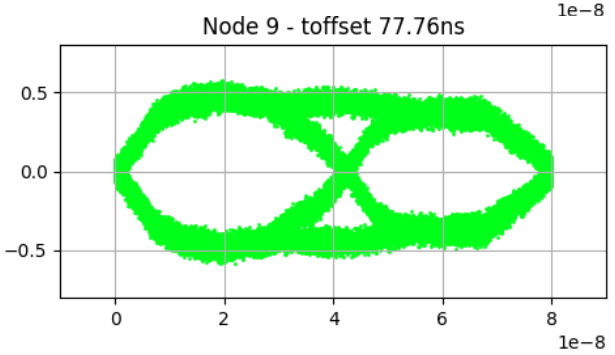
Eye Diagram Comparison TX Node 16

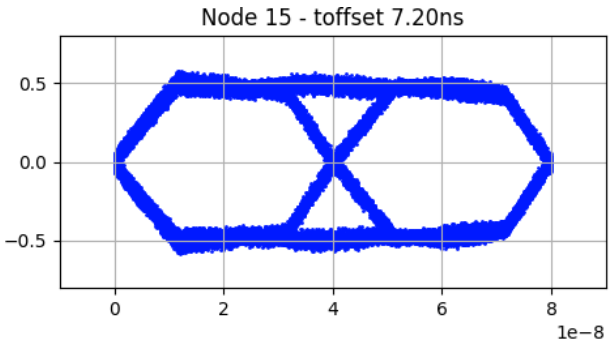
With compensation inductors

Ideal

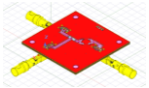


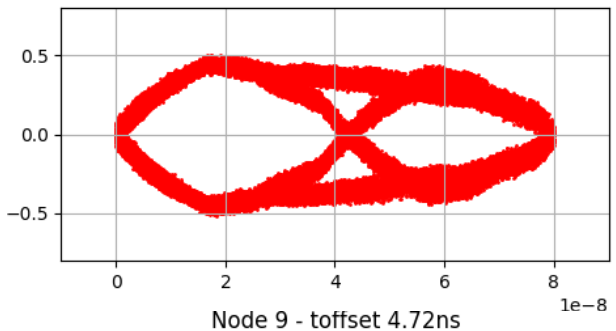


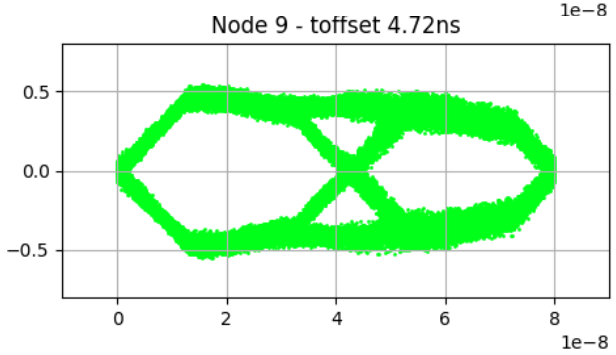


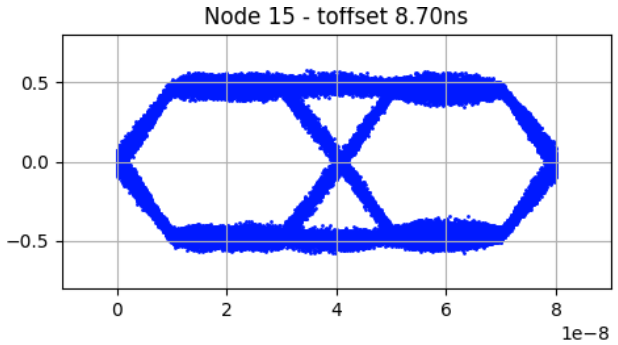


Cap. Tee

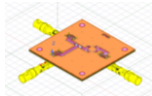


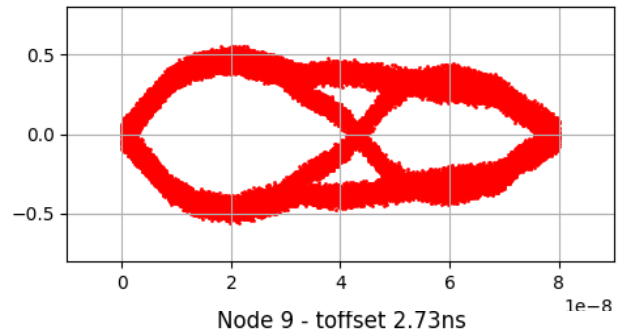


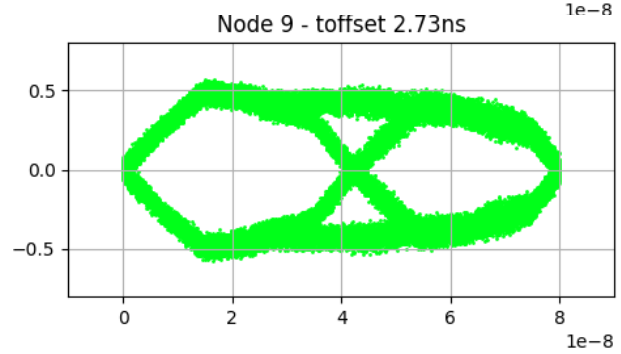


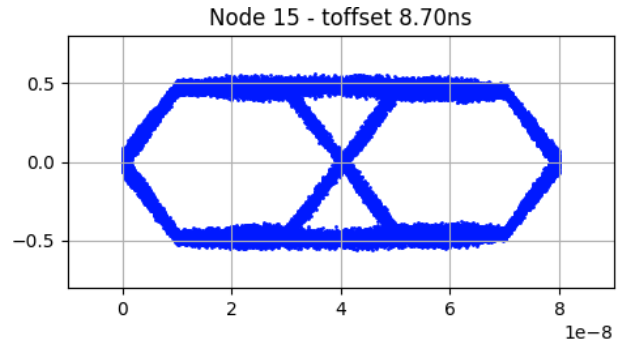


Opt. Tee









Pros and Cons of vector fitting approach

- Pros
  - S-Parameter data of Tee-Connector can be generated from simulation or measurement
  - Parasitic elements of the model are handled
  - Comfortable to bring in data
  - Convenient way to take a look on the channel with imperfections
  - Approach of using S-Parameters could be adapted for the use with nodes or end termination with minor changes
- Cons
  - Simulation time is slightly increased
  - Vector fitting is an iterative process which can fail
  - Complexity of simulation increases

Summary

- Use vector fitting to improve Tee-Simulation-Model within the consensus model to take into account reflections and other parasitic behaviour
- Proposal:
  Integrate the S-Parameter Tee-Model feature as option within the consensus model

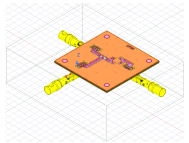
Thanks for Listening!

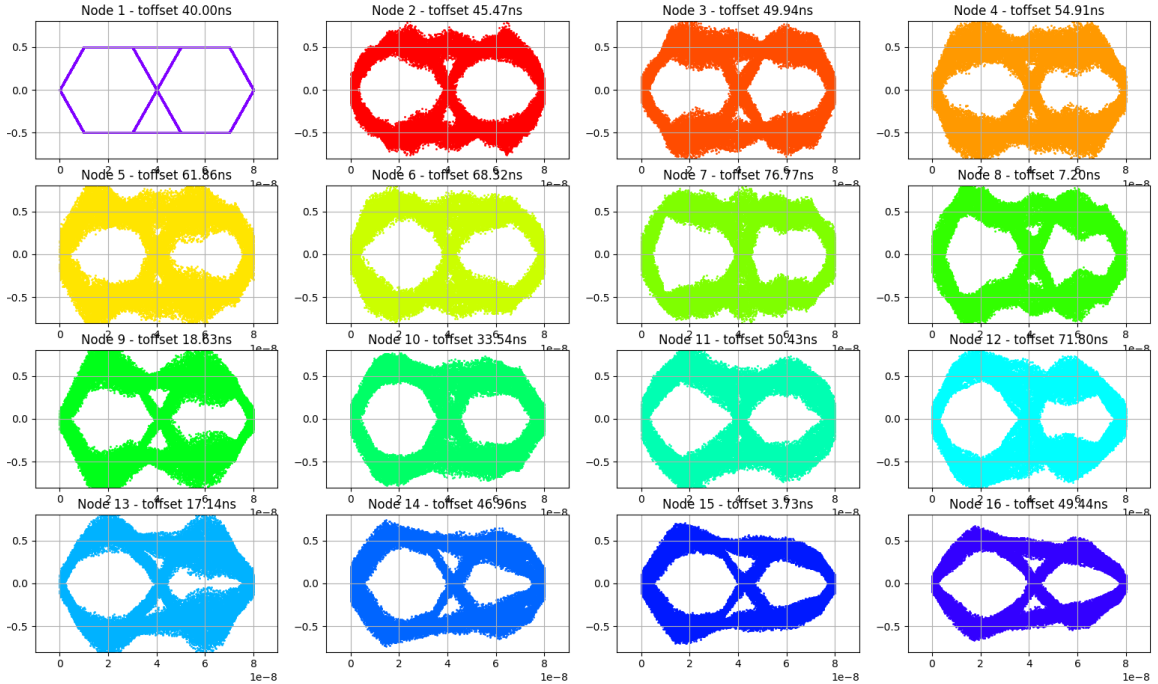
Questions

Appendix: Eye Diagram Comparison

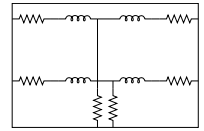
Without compensation inductors, TX Node 1

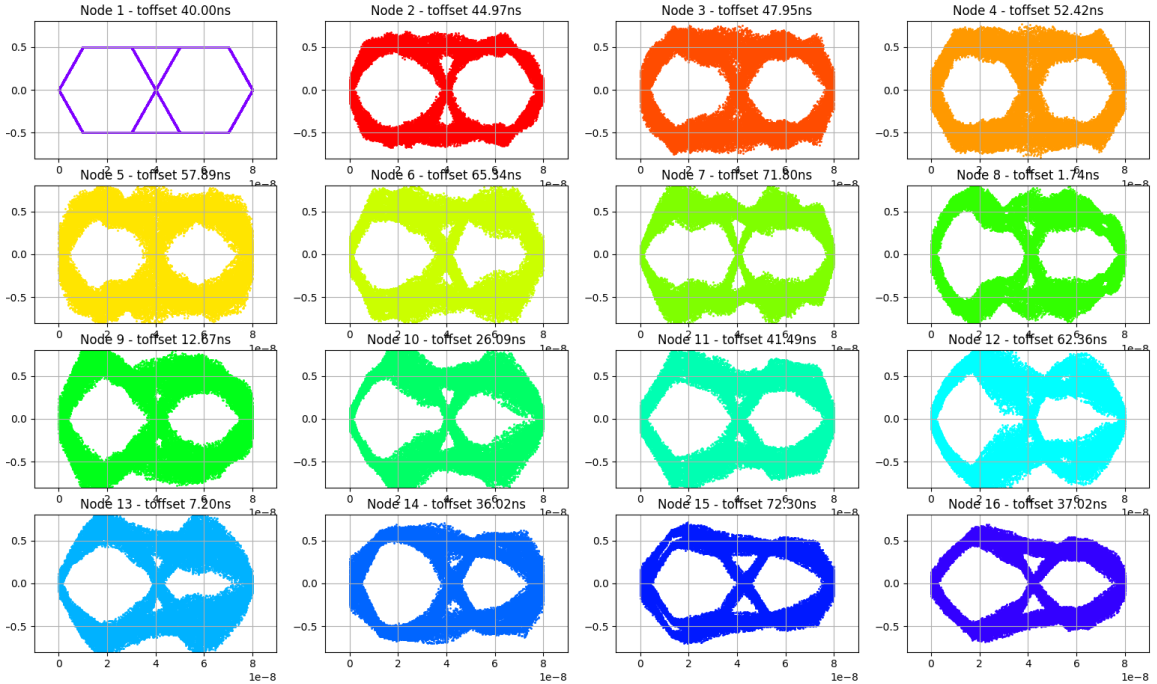
S-Parameter based Tee





Ideal Tee

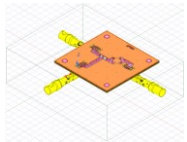


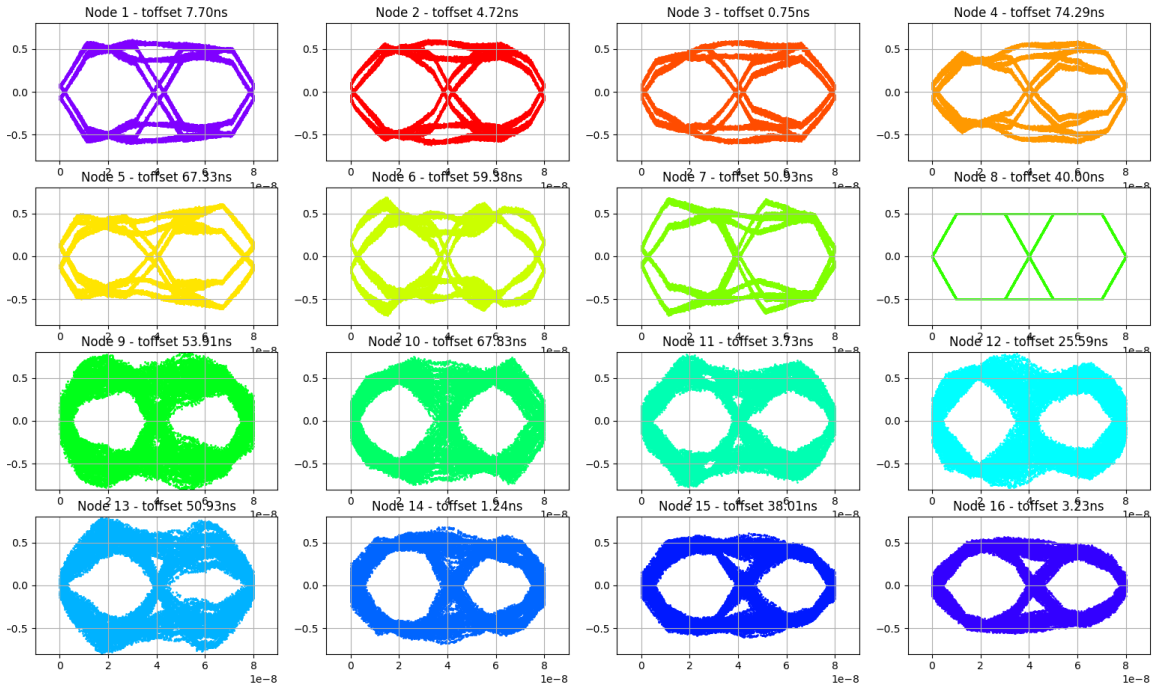


Appendix: Eye Diagram Comparison

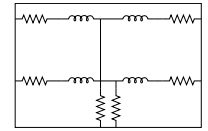
Without compensation inductors, TX Node 8

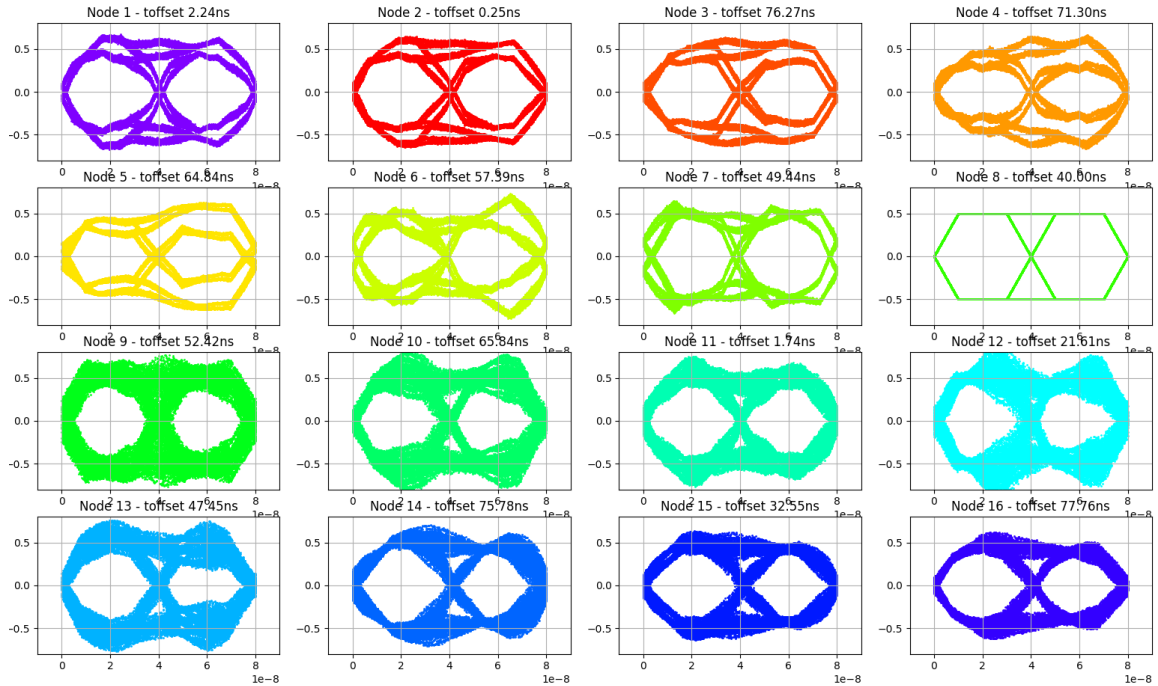
S-Parameter base Tee





Ideal Tee

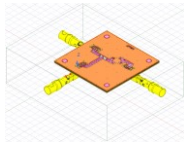


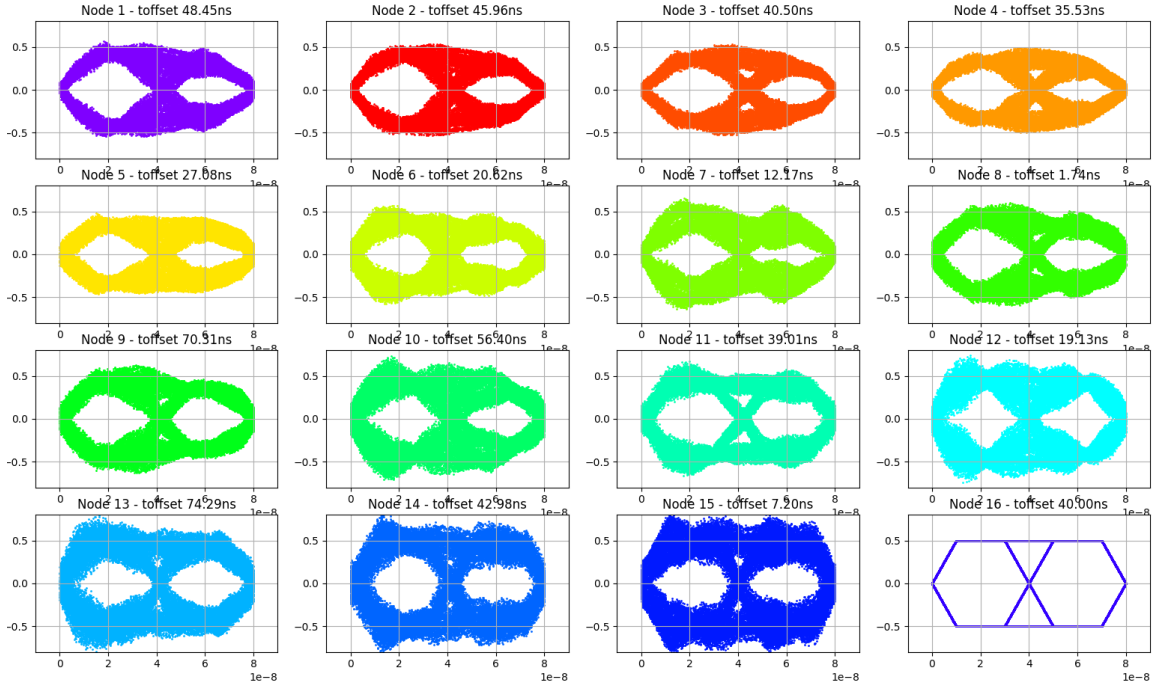


Appendix: Eye Diagram Comparison

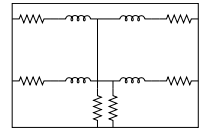
Without compensation inductors, TX Node 16

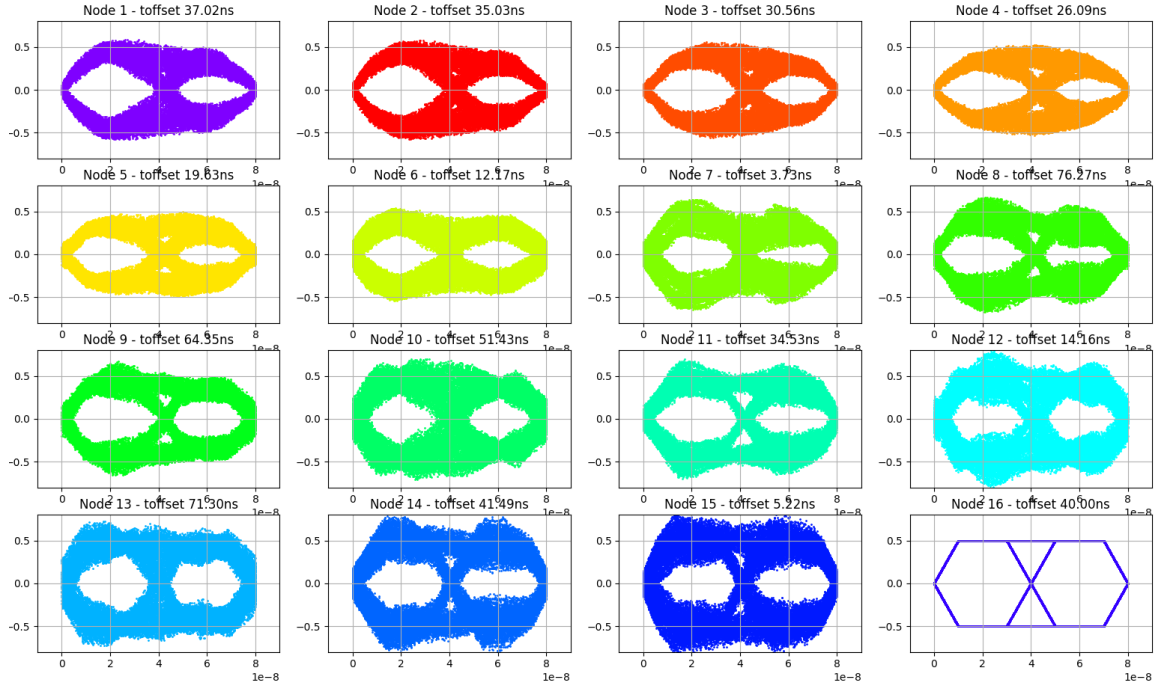
S-Parameter base Tee





Ideal Tee

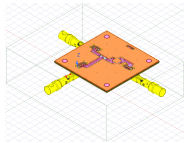


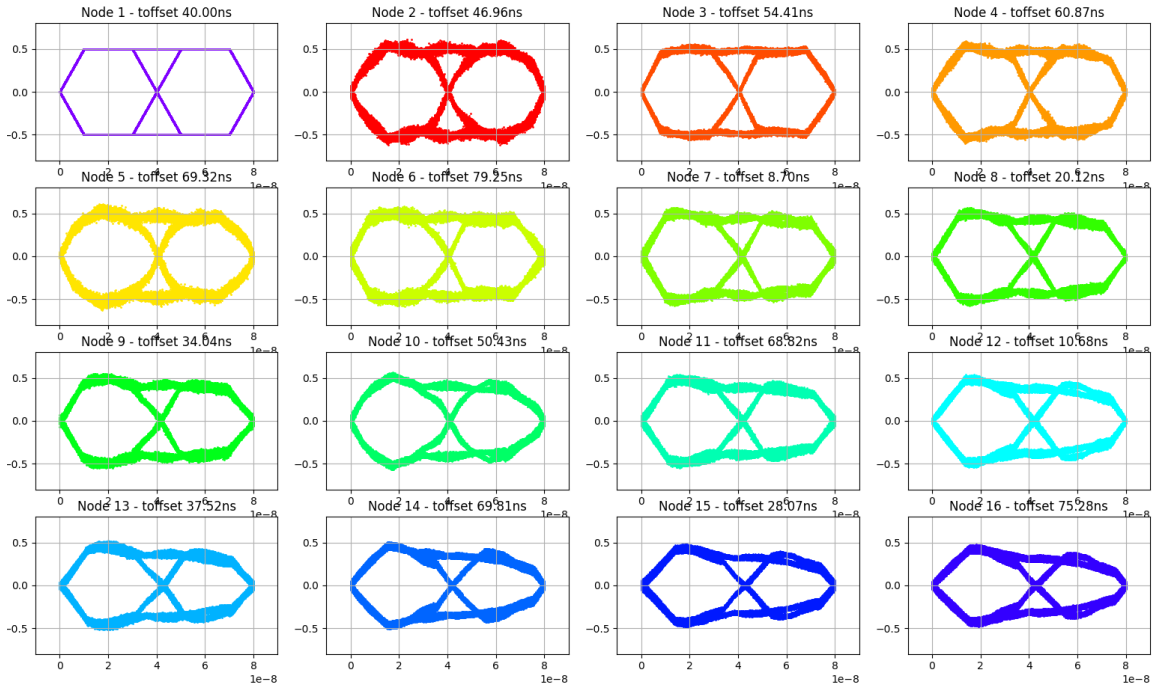


Appendix: Eye Diagram Comparison

With compensation inductors, TX Node 1

S-Parameter based Tee





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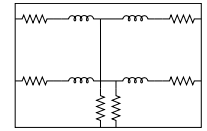
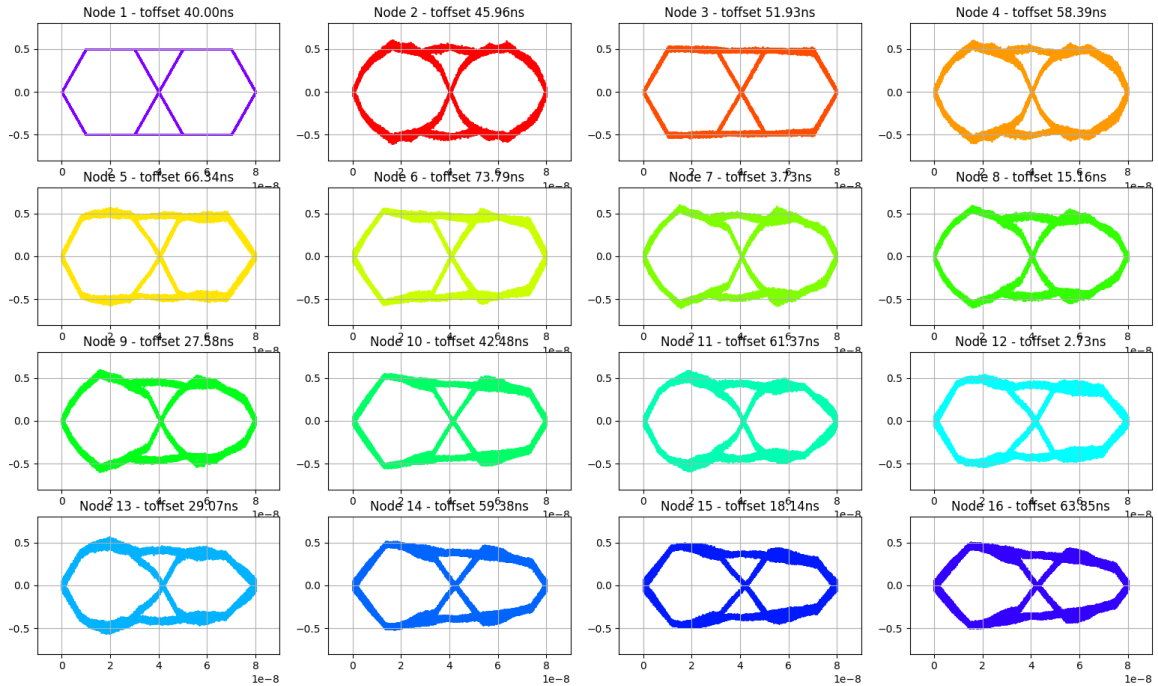
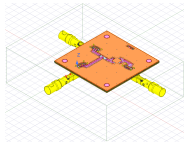


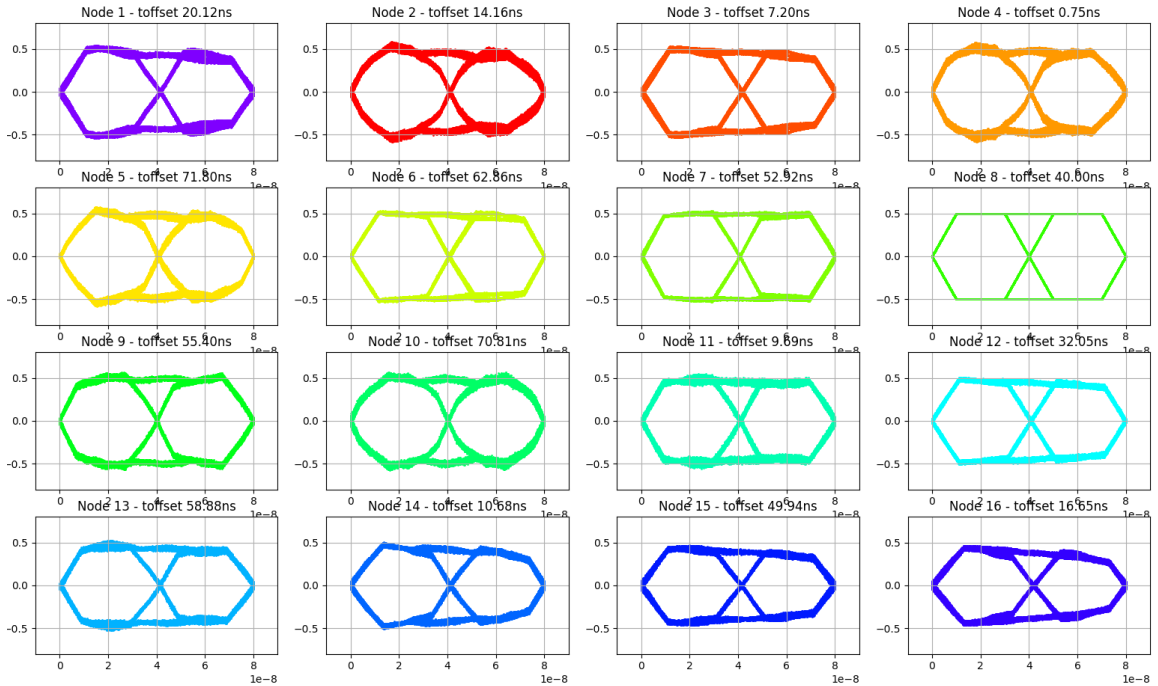


Appendix: Eye Diagram Comparison

With compensation inductors, TX Node 8

S-Parameter based Tee





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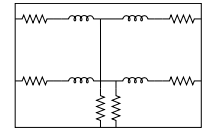
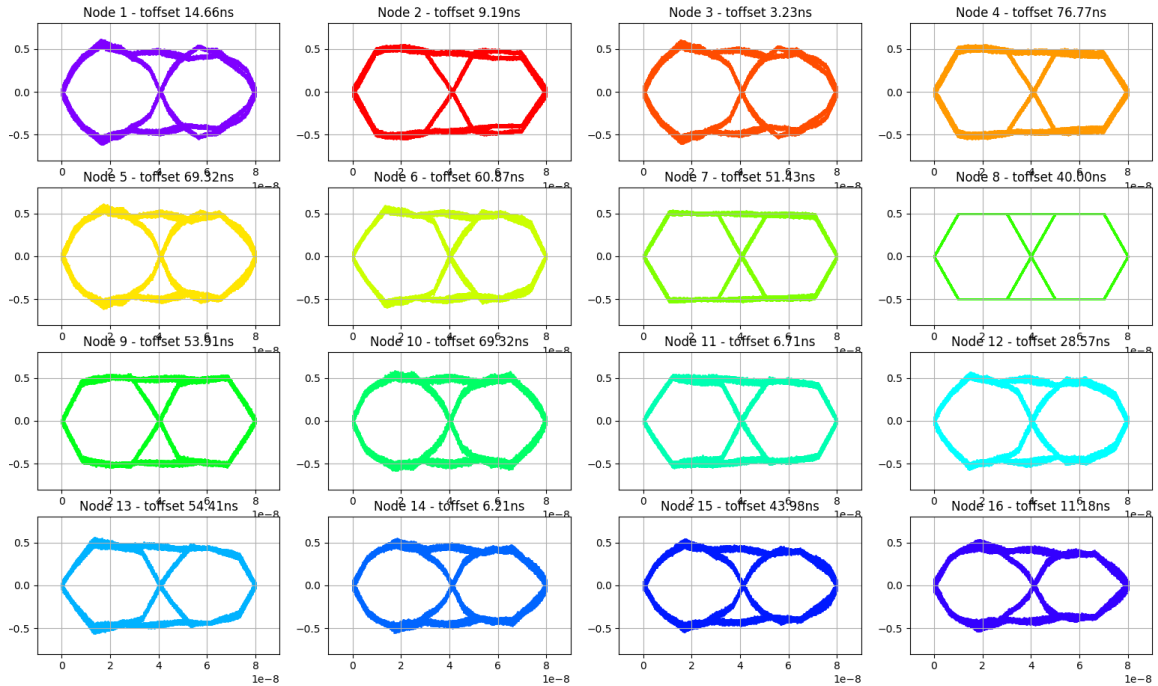
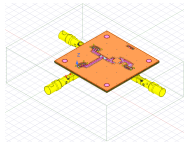


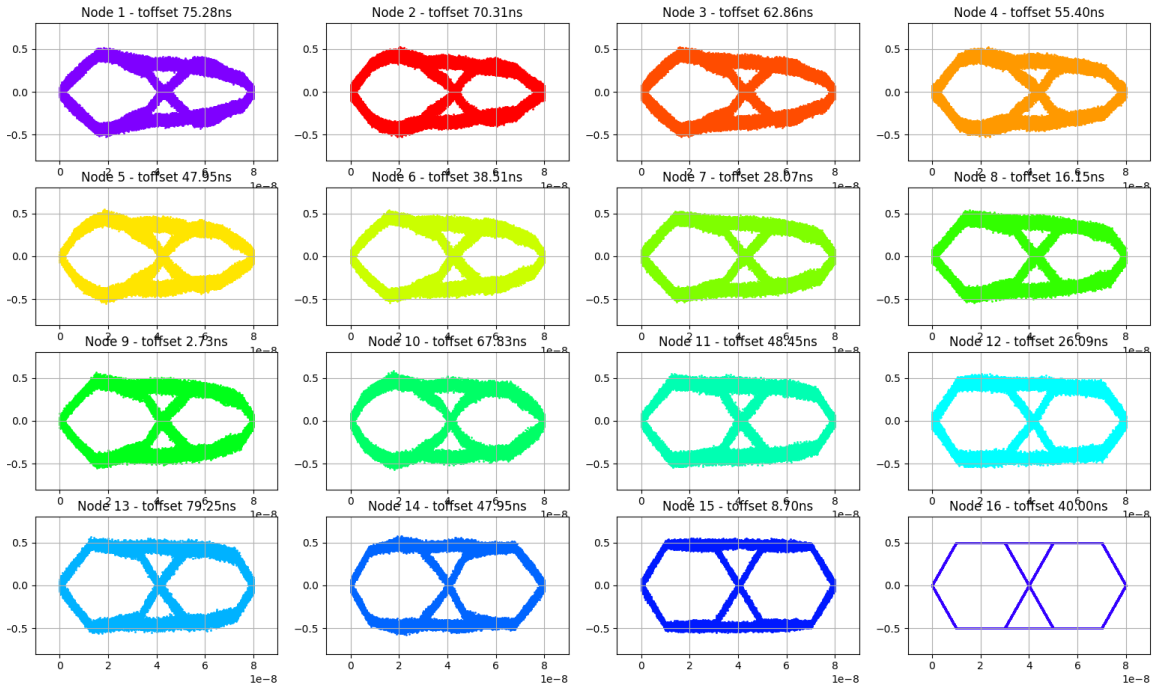


Appendix: Eye Diagram Comparison

With compensation inductors, TX Node 16

S-Parameter based Tee





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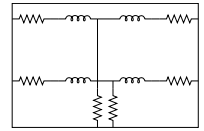
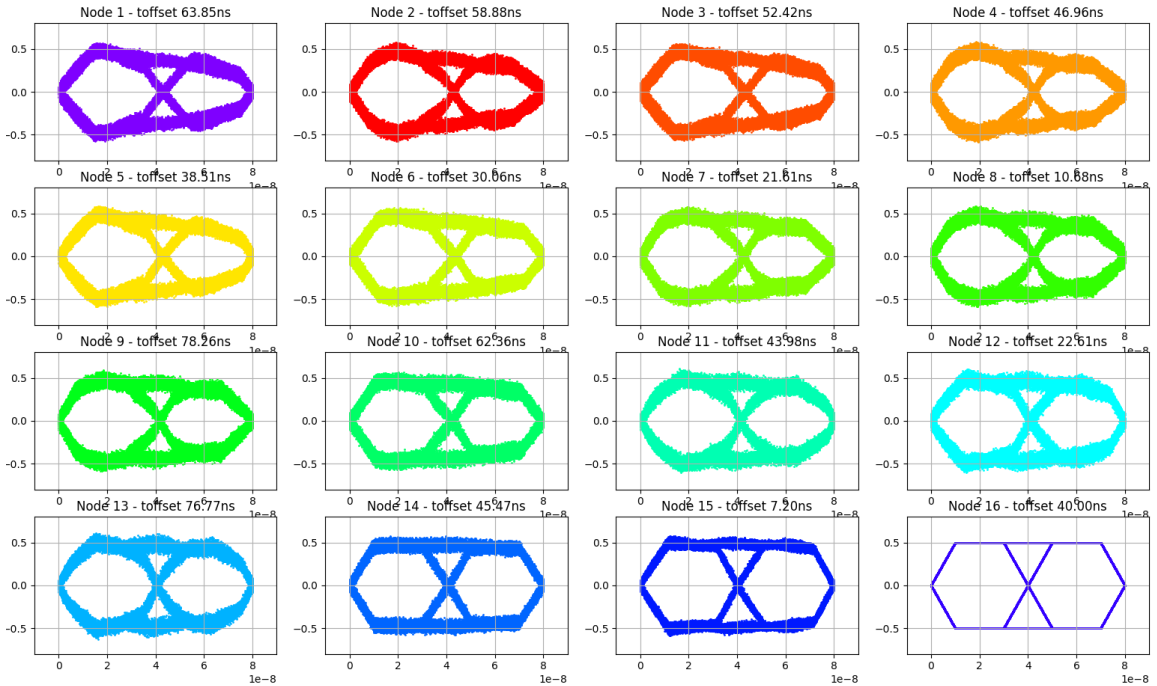
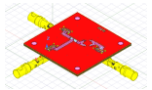


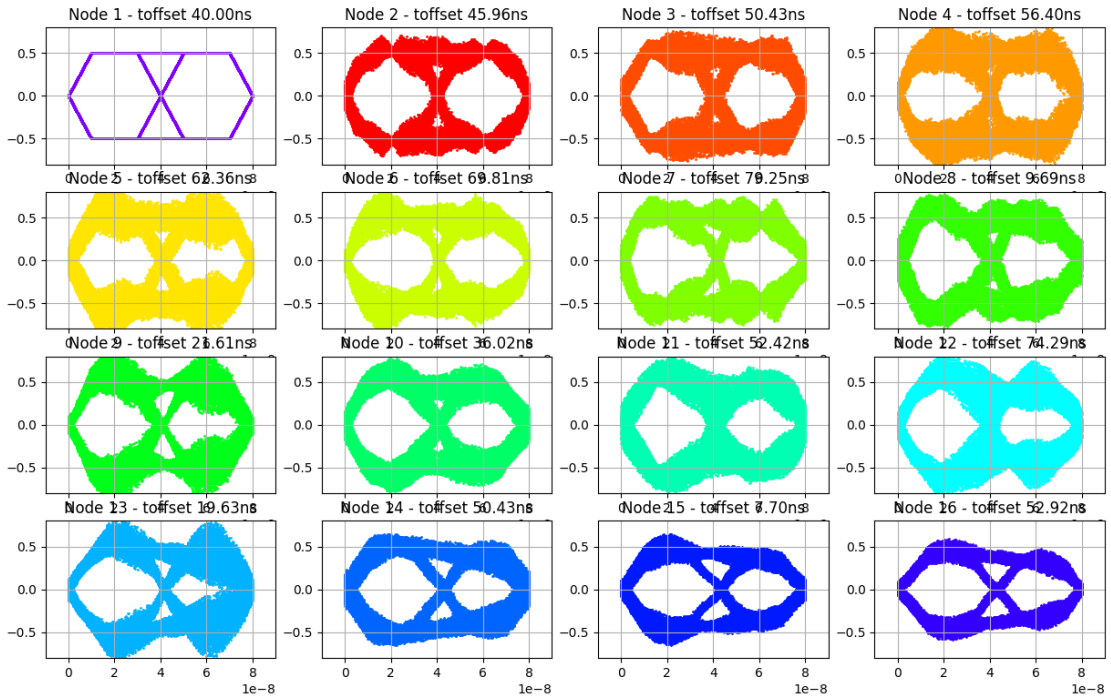


Appendix: Eye Diagram Comparison

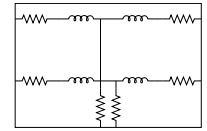
Without compensation inductors, TX Node 1

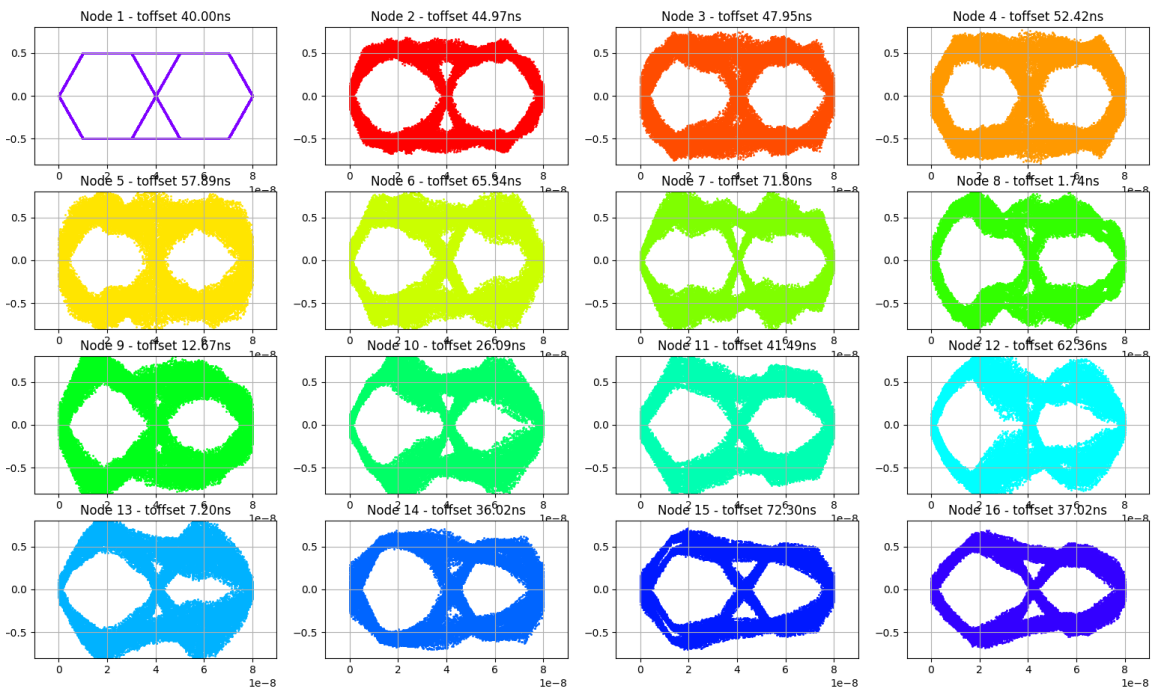
S-Parameter based cap. Tee





Ideal Tee

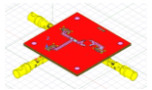


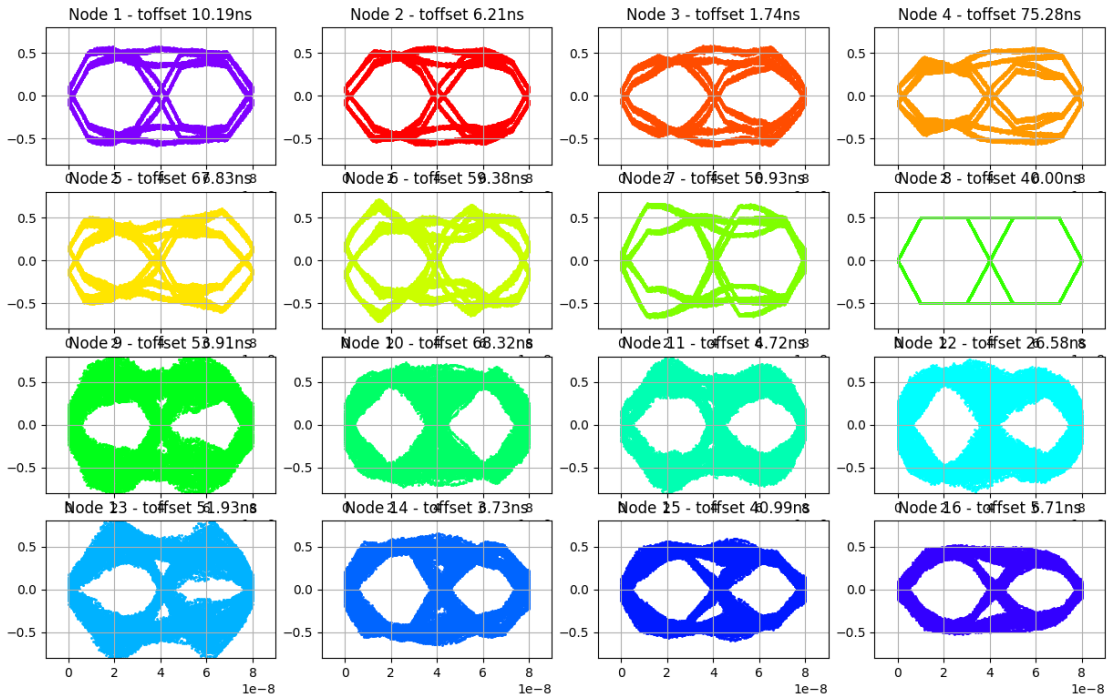


Appendix: Eye Diagram Comparison

Without compensation inductors, TX Node 8

S-Parameter base cap. Tee





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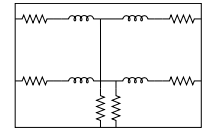
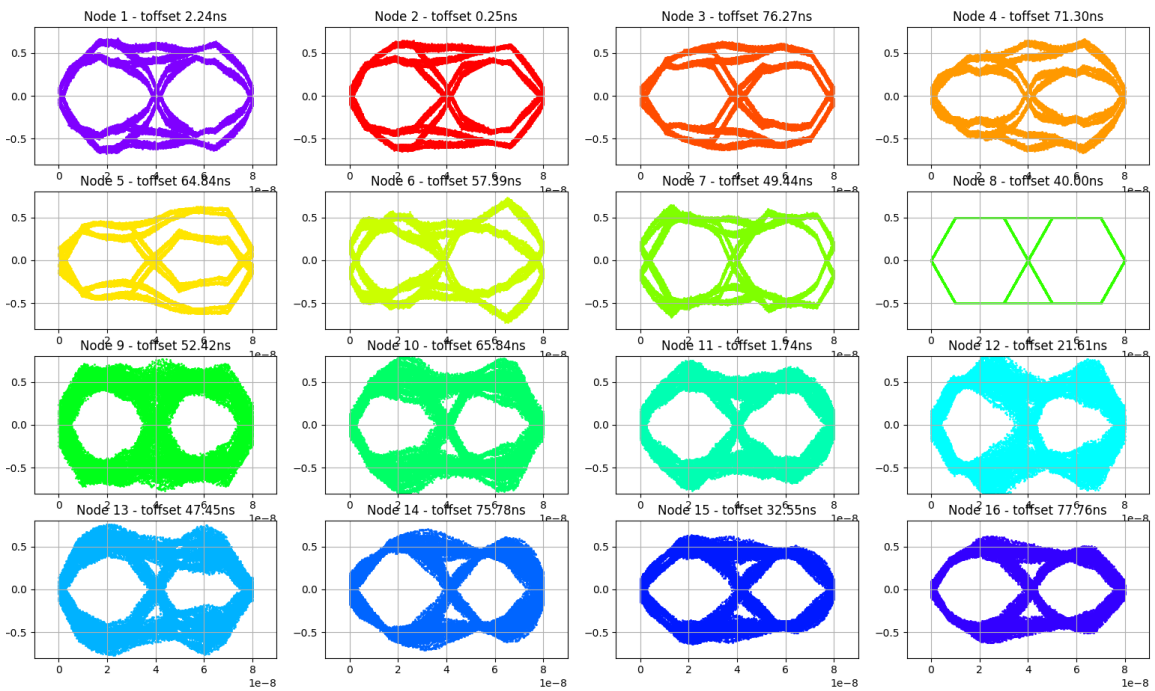
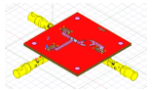


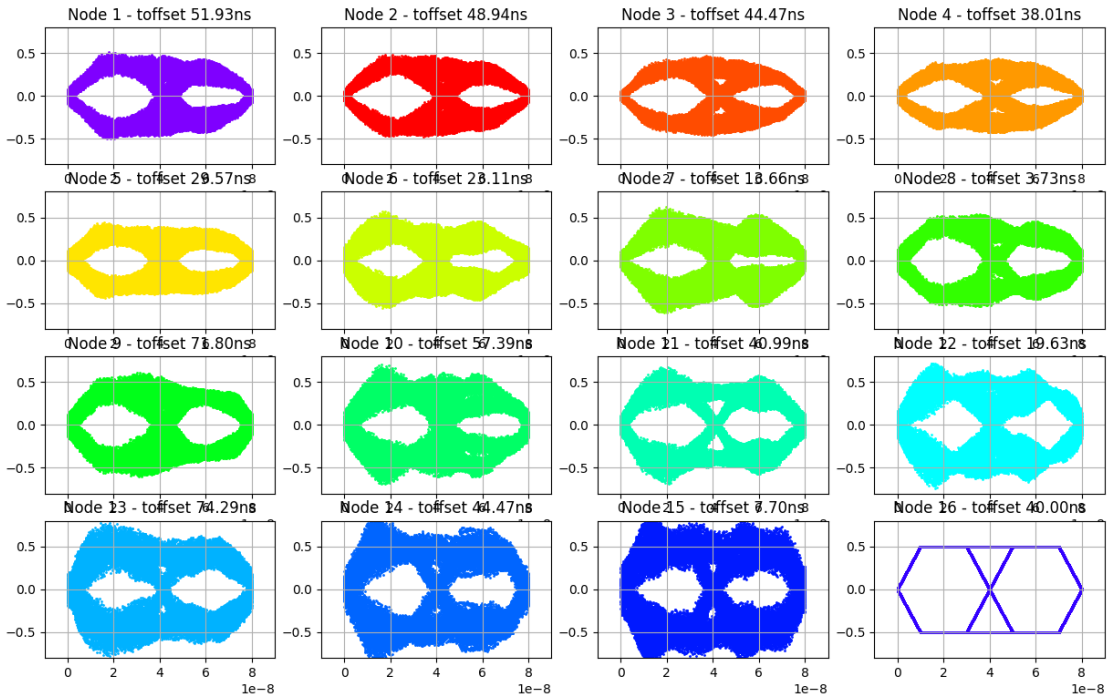


Appendix: Eye Diagram Comparison

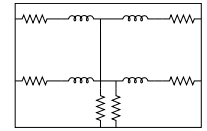
Without compensation inductors, TX Node 16

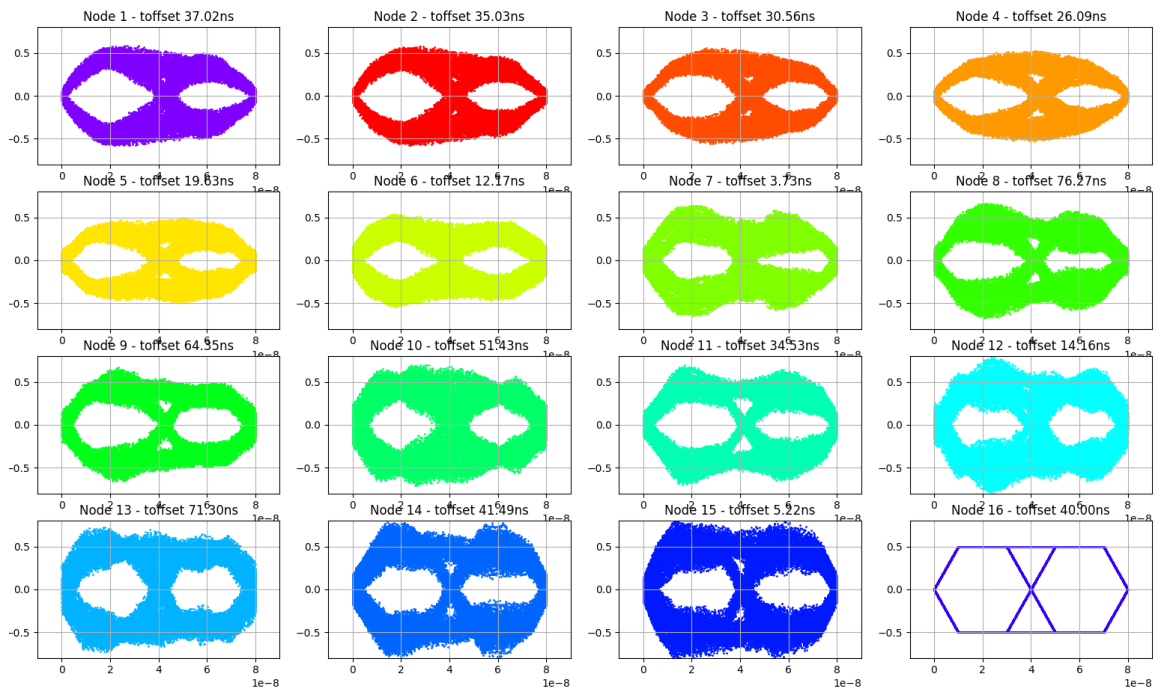
S-Parameter based Tee





Ideal Tee

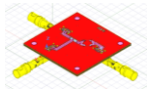


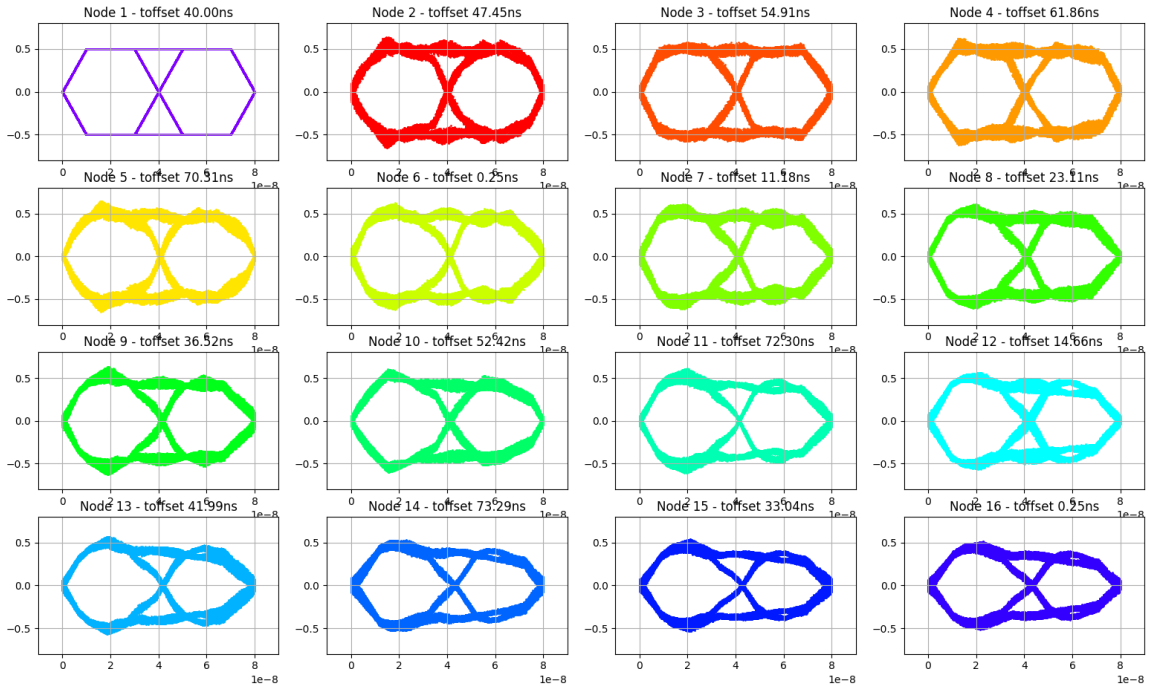


Appendix: Eye Diagram Comparison

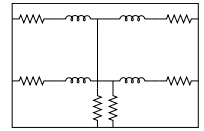
With compensation inductors, TX Node 1

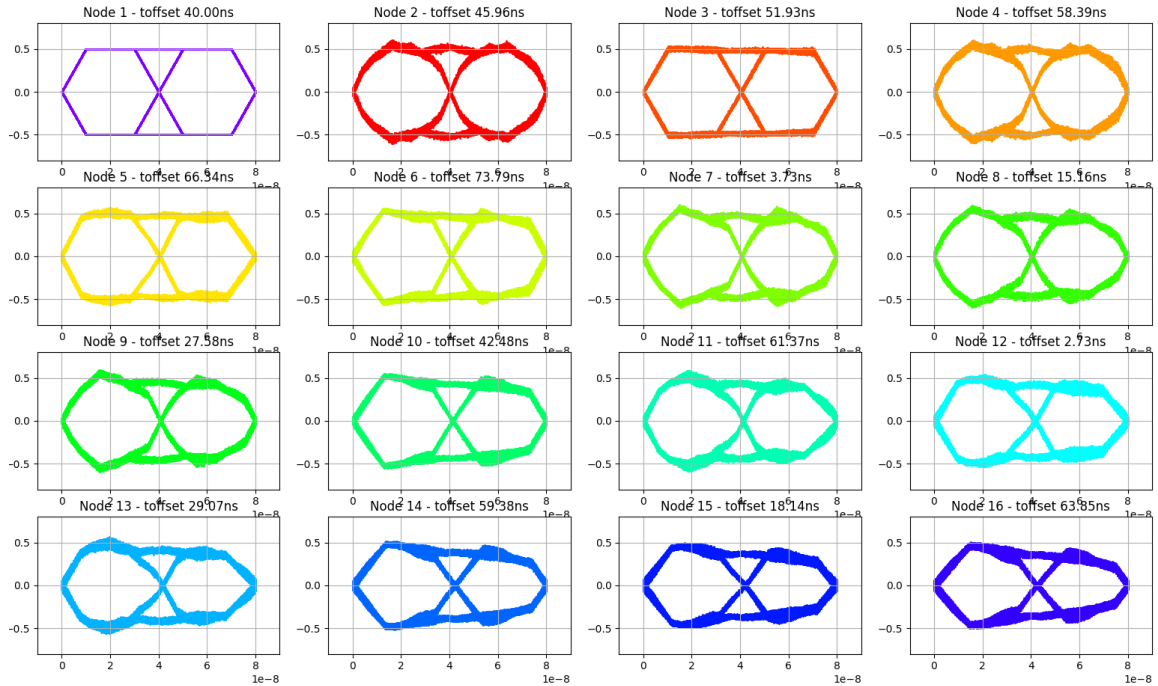
S-Parameter based bad Tee





Ideal Tee

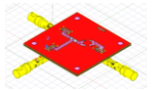


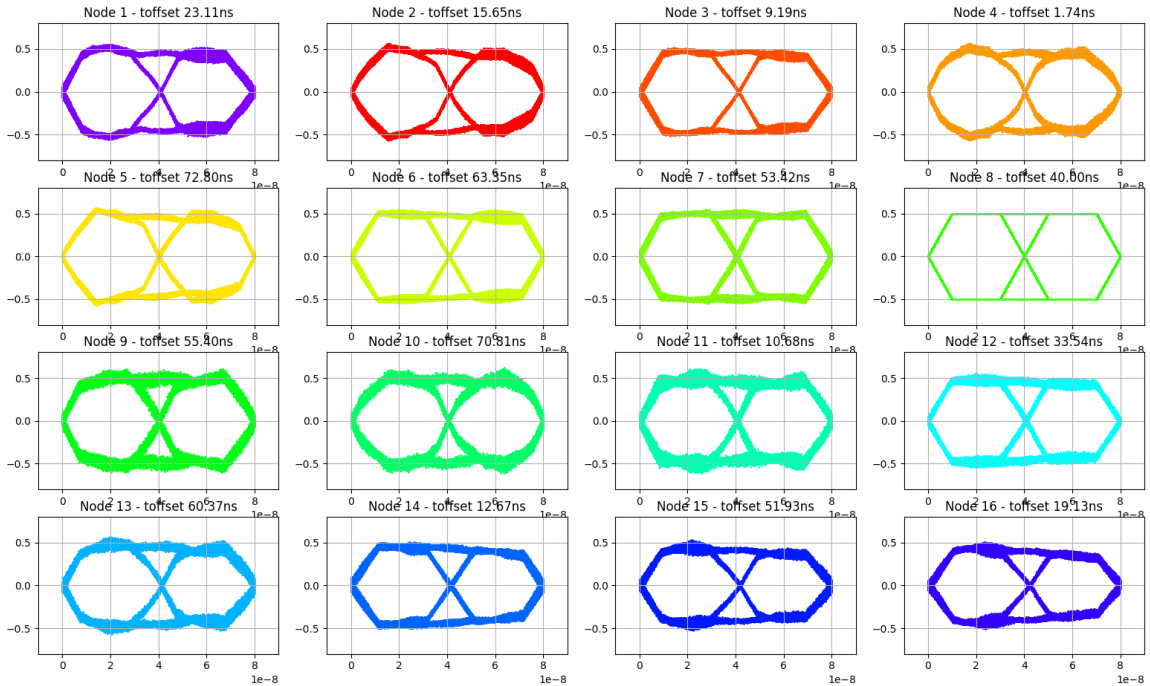


Appendix: Eye Diagram Comparison

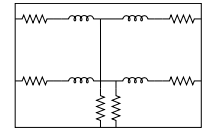
With compensation inductors, TX Node 8

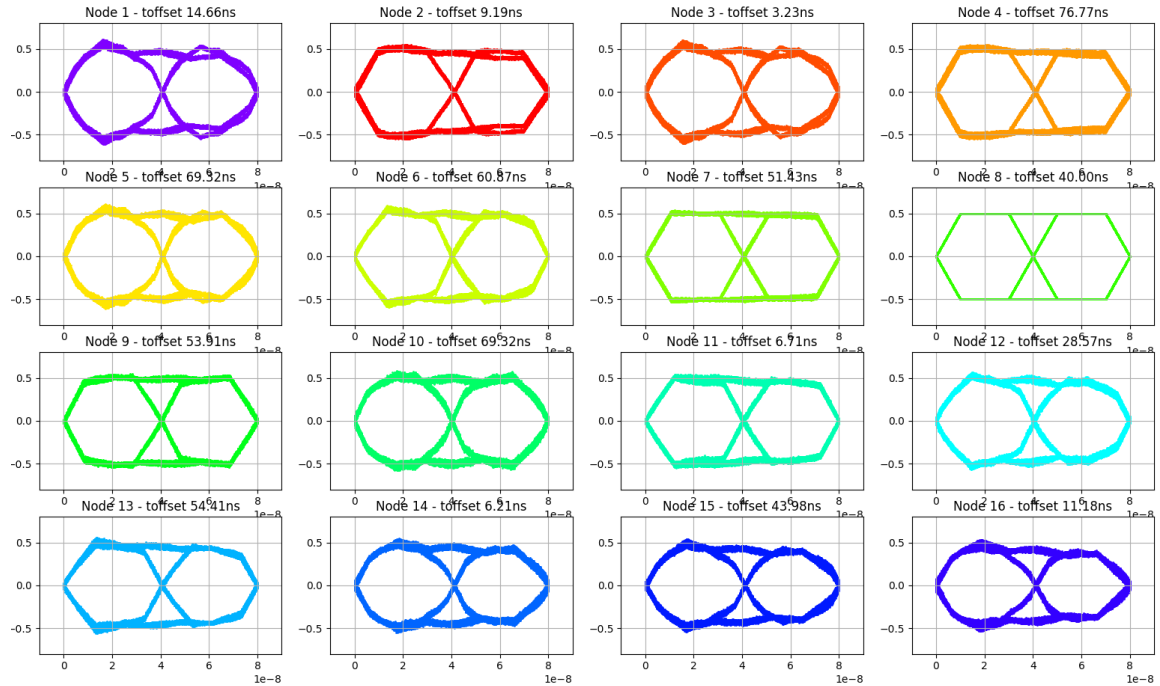
S-Parameter based bad Tee





Ideal Tee

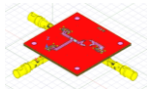


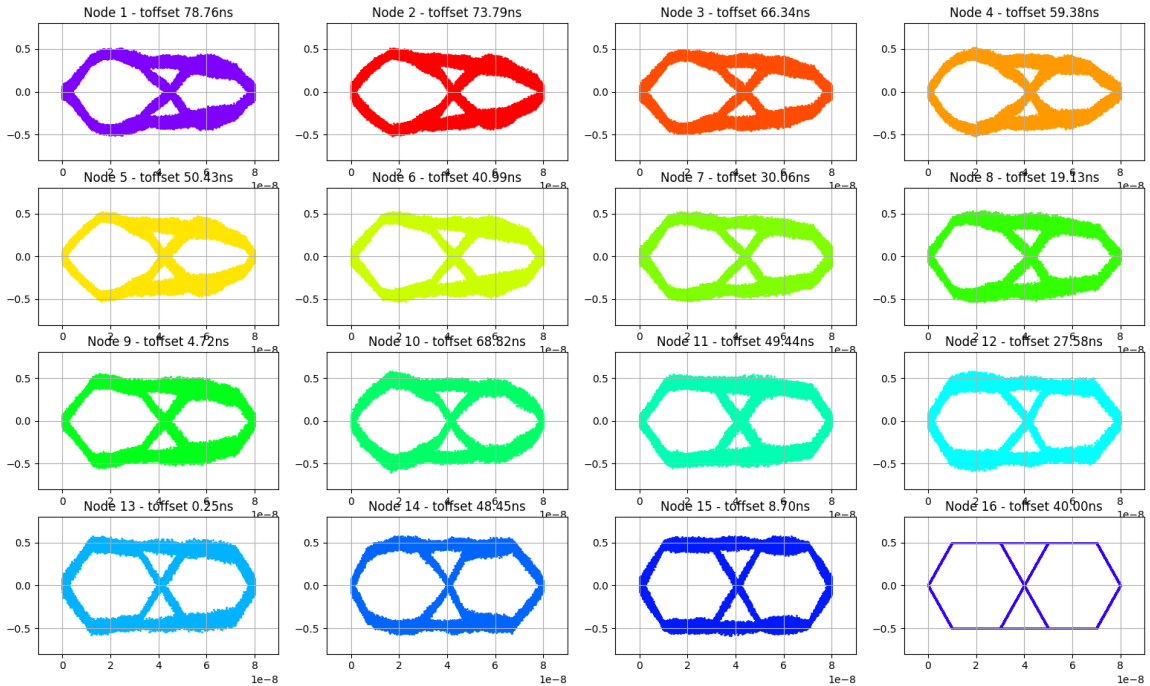


Appendix: Eye Diagram Comparison

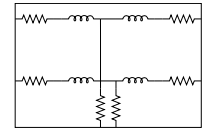
With compensation inductors, TX Node 16

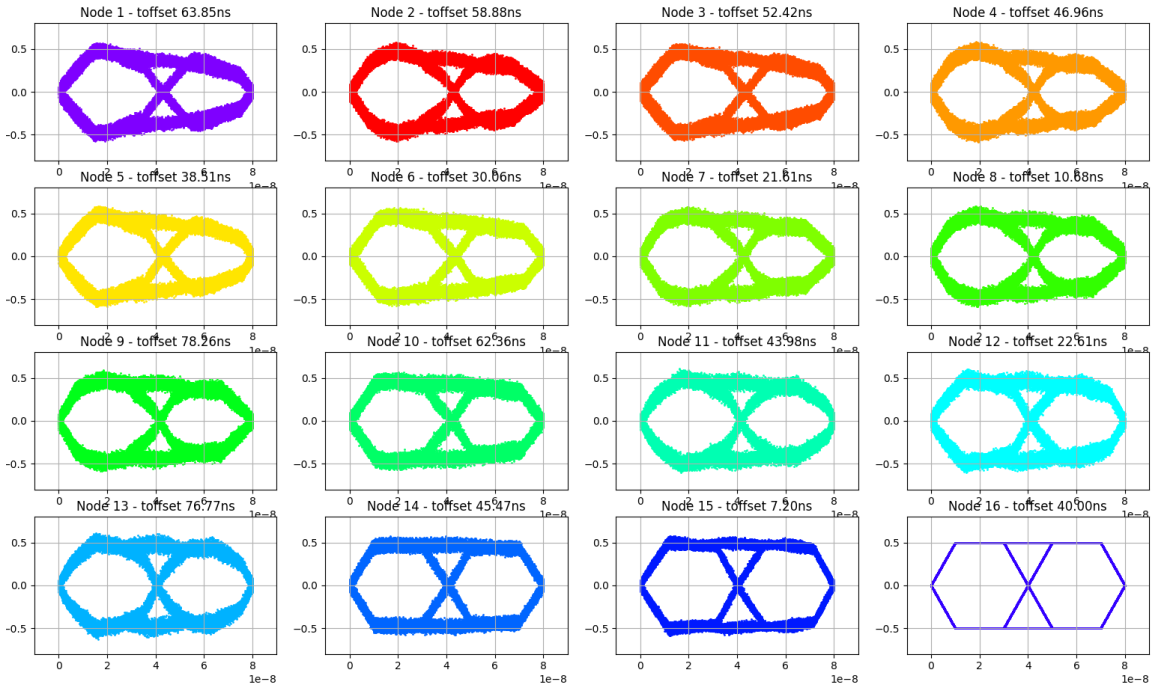
S-Parameter based bad Tee





Ideal Tee

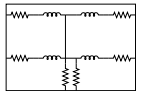


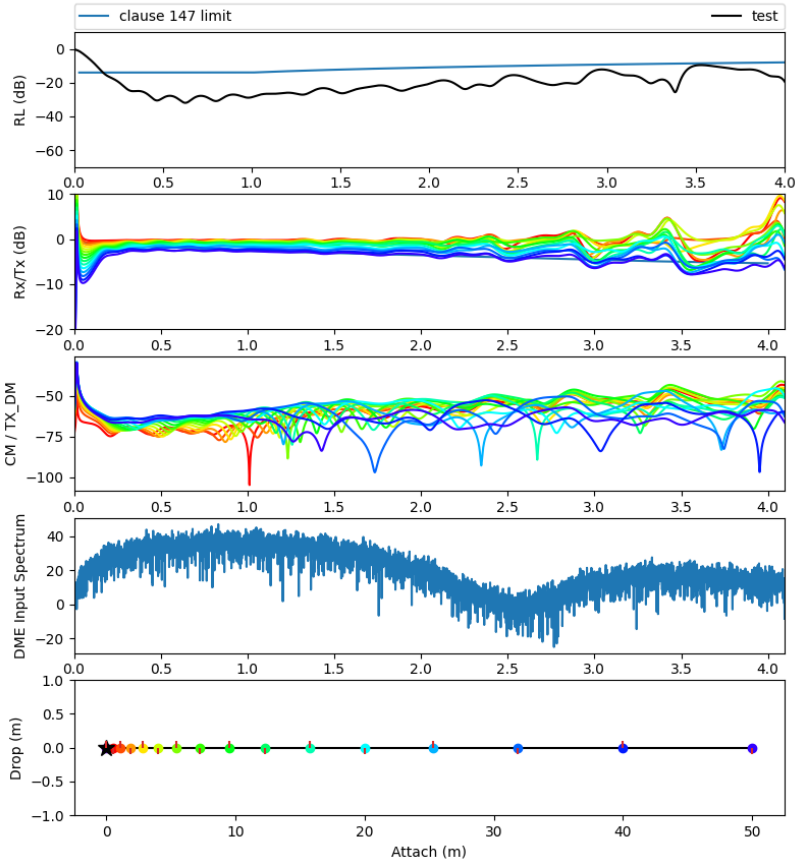


Appendix: Channel Simulation

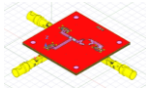
Comparison with compensation Inductors

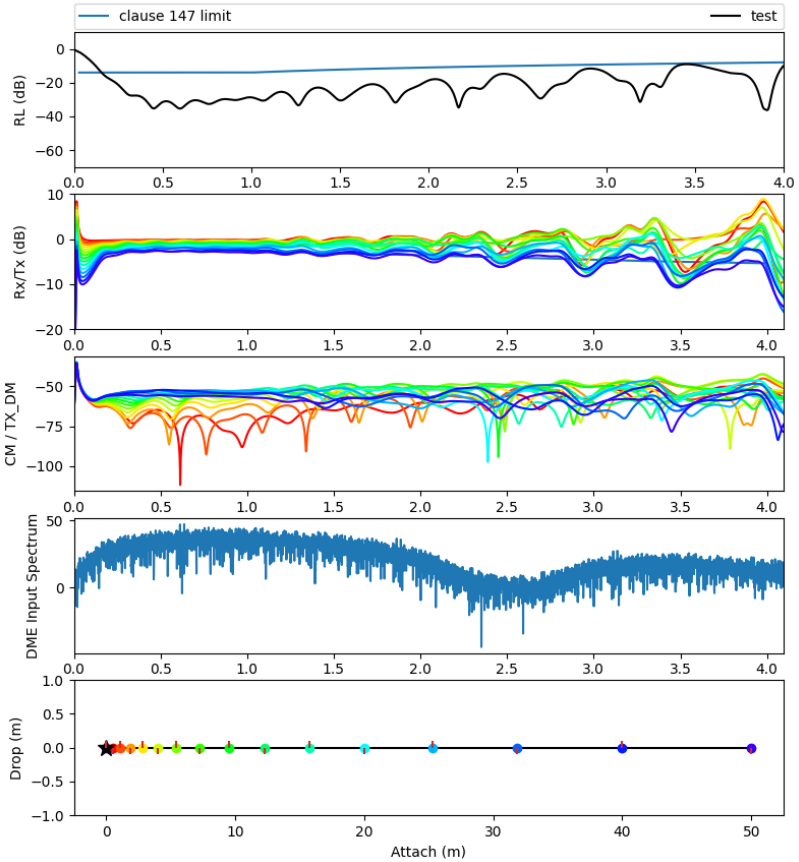
Ideal





Cap. Tee





Opt. Tee