
S-Parameter Based T-Connector for Consensus Model

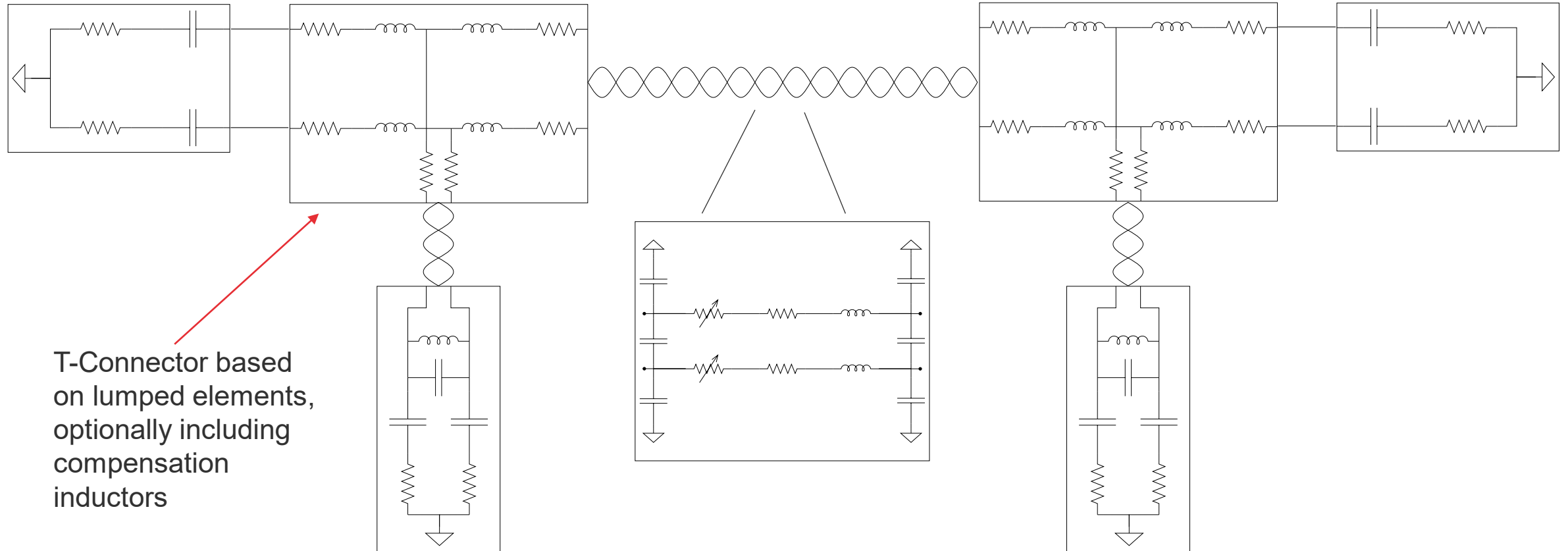
5th October 2022

Stephan Schreiner (Rosenberger)

Purpose

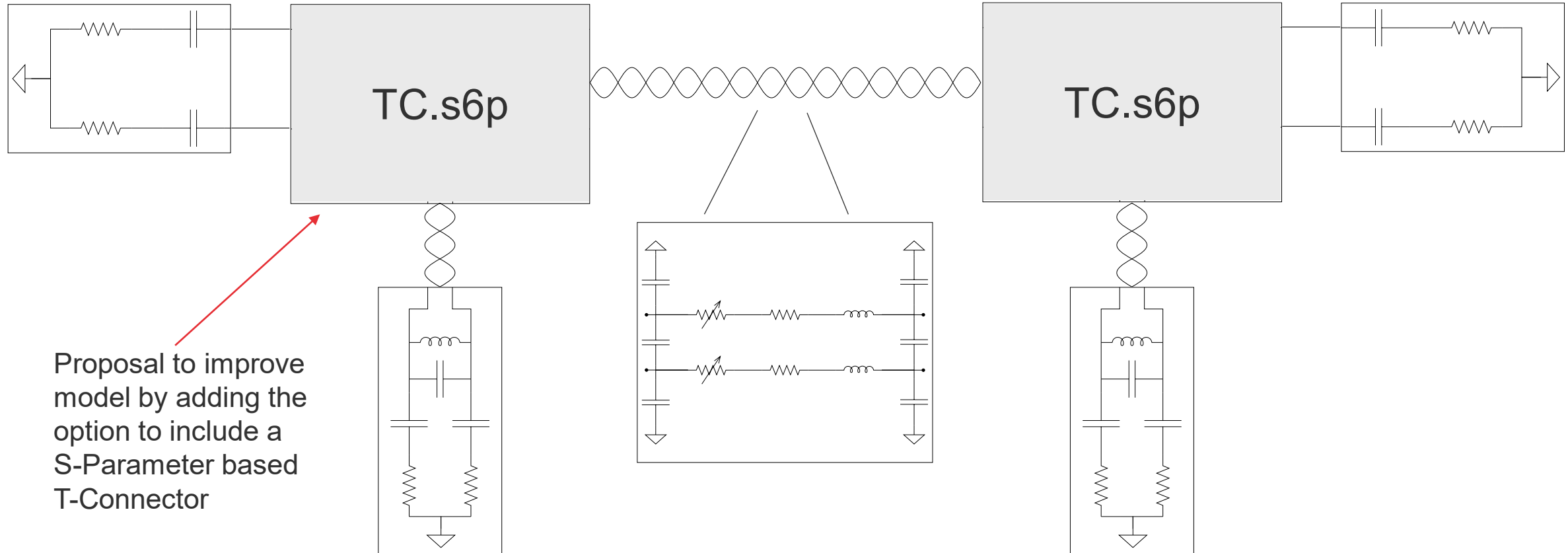
- New S-Parameter based T-Connector models based on EM-Simulation data or measurements for the consensus model
 - Add feature to optionally use S-Parameters (*.s6p) of the T-Connector within the consensus model
 - Import of S-Parameters within the consensus model
 - Vector fitting of S-Parameters to 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



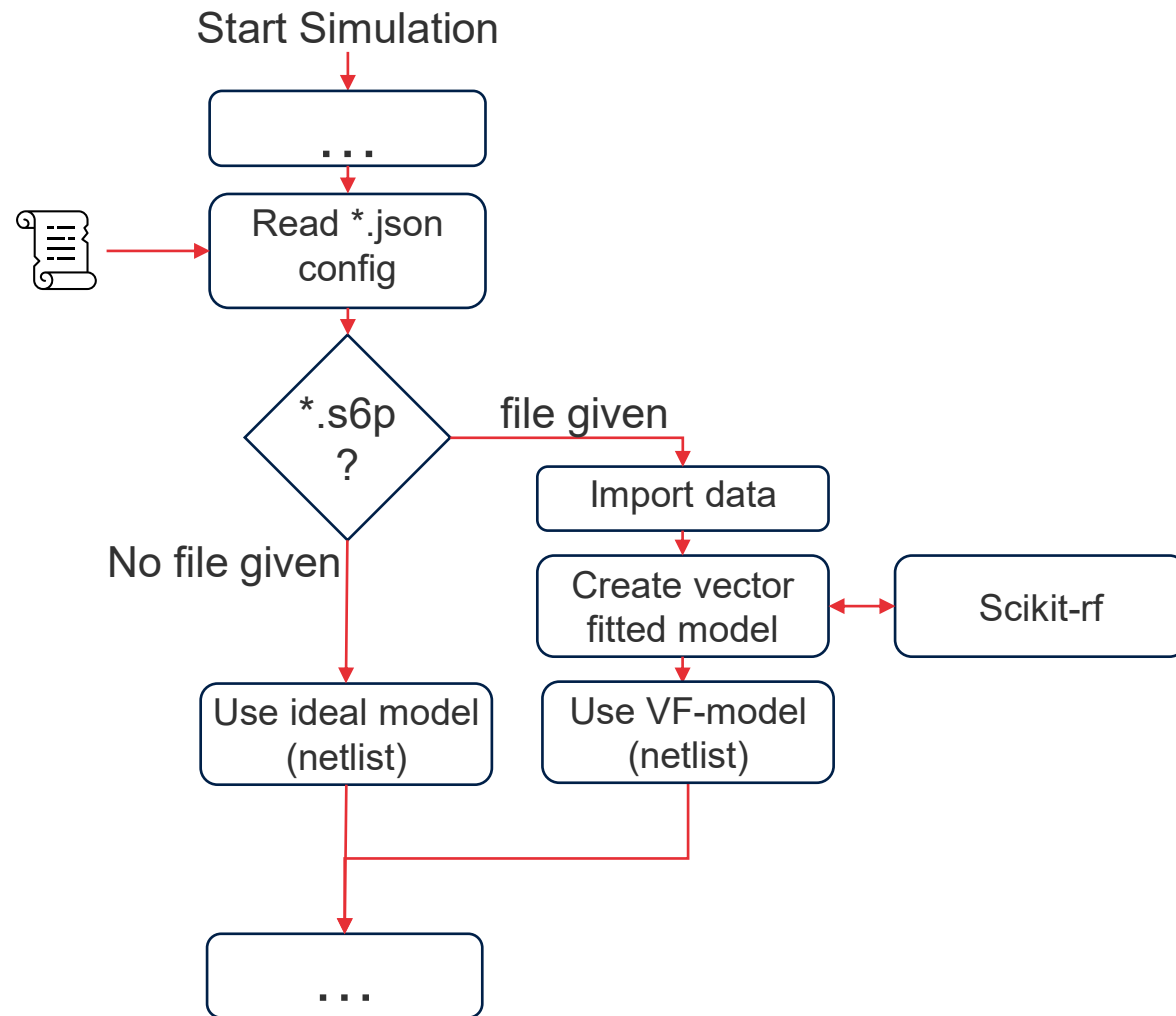
T-Connector based
on lumped elements,
optionally including
compensation
inductors

New Optional Element of the Consensus Model



Proposal to improve model by adding the option to include a S-Parameter based T-Connector

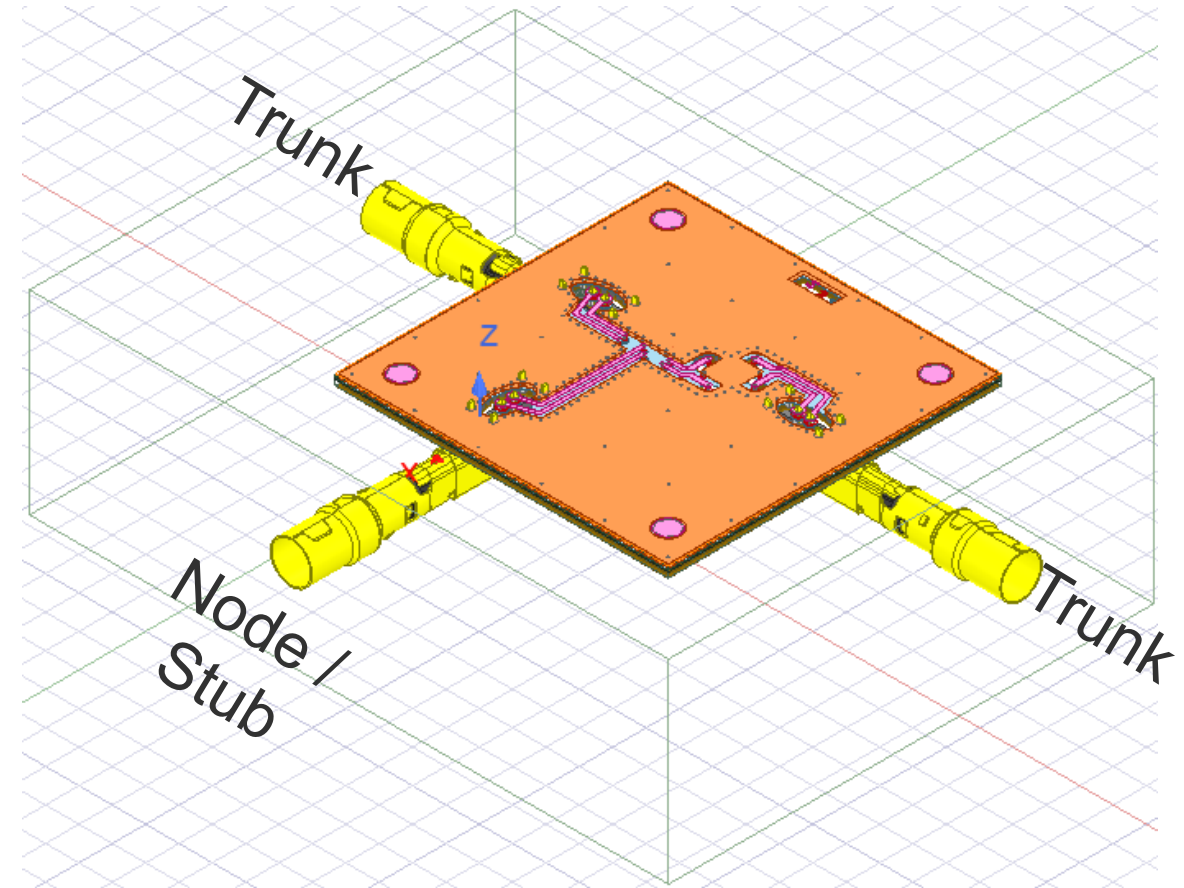
Proposed Changes



- 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

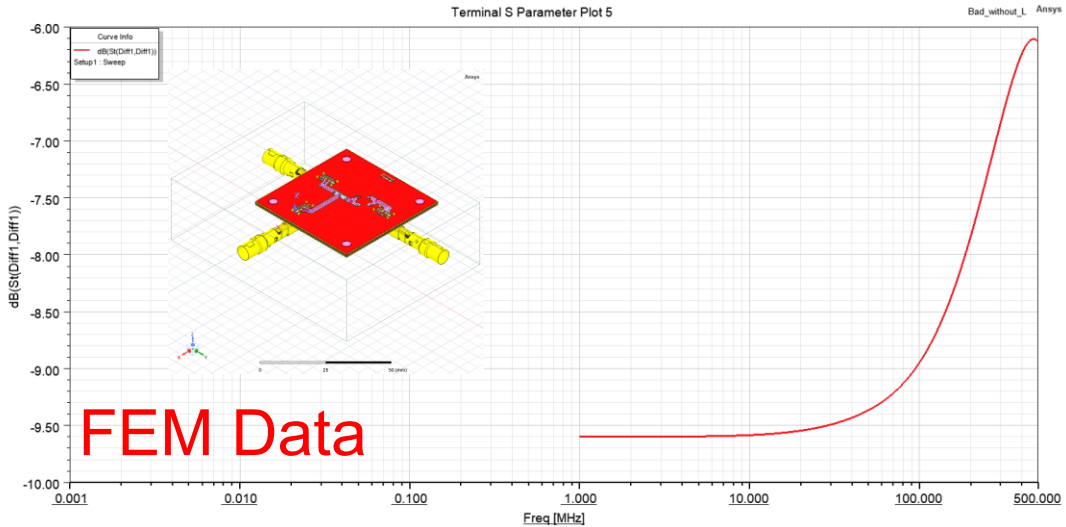
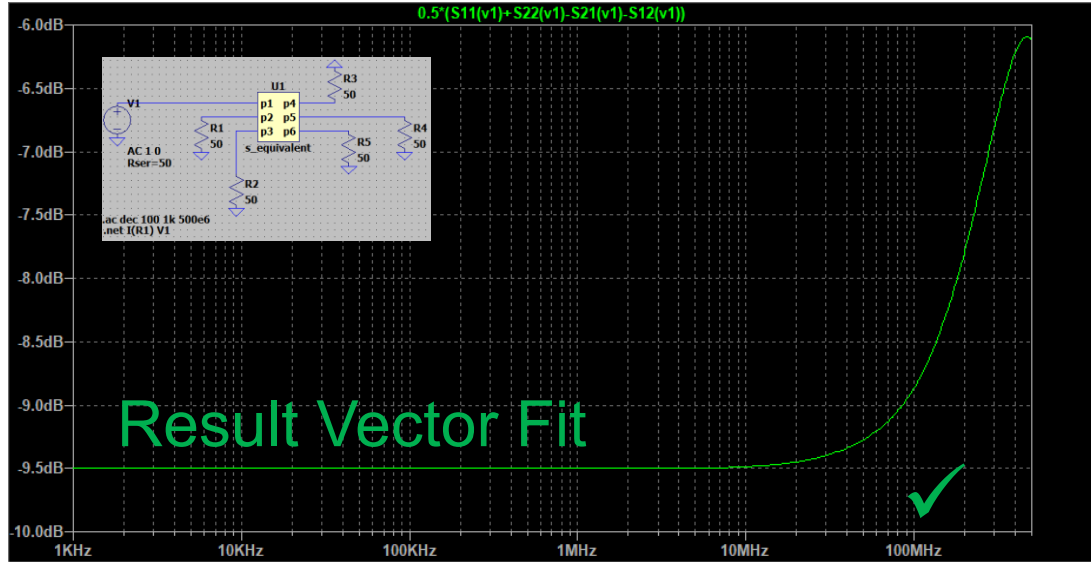
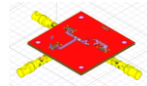
- Simple PCB based T-Connector
- Full 3D FEM Analysis
- Causal materials are used in simulation
- Two PCBs are simulated, one with matching impedance and one with a lower impedance
- Inductive compensation elements are included as ideal lumped elements
- Four different S-Parameter files (with and without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



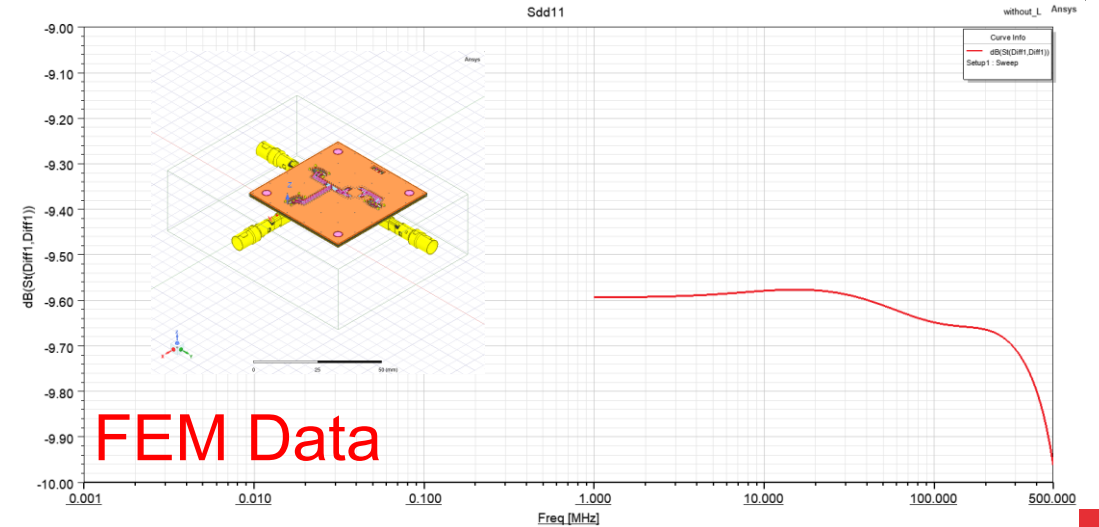
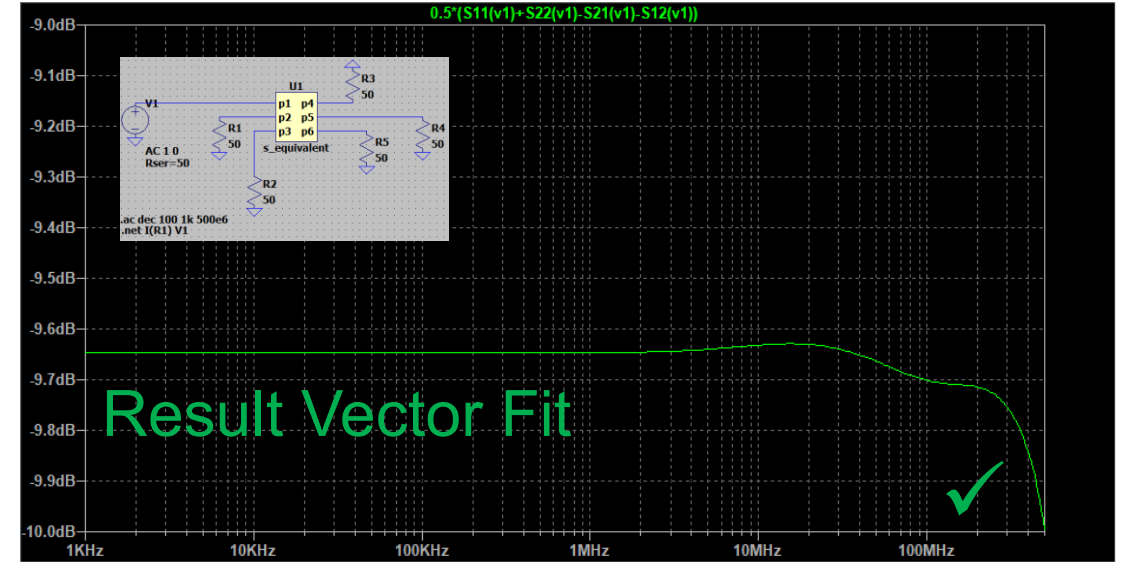
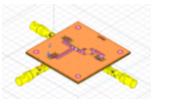
Vector Fit Results Sdd11

Without compensation inductor

Cap. Tee



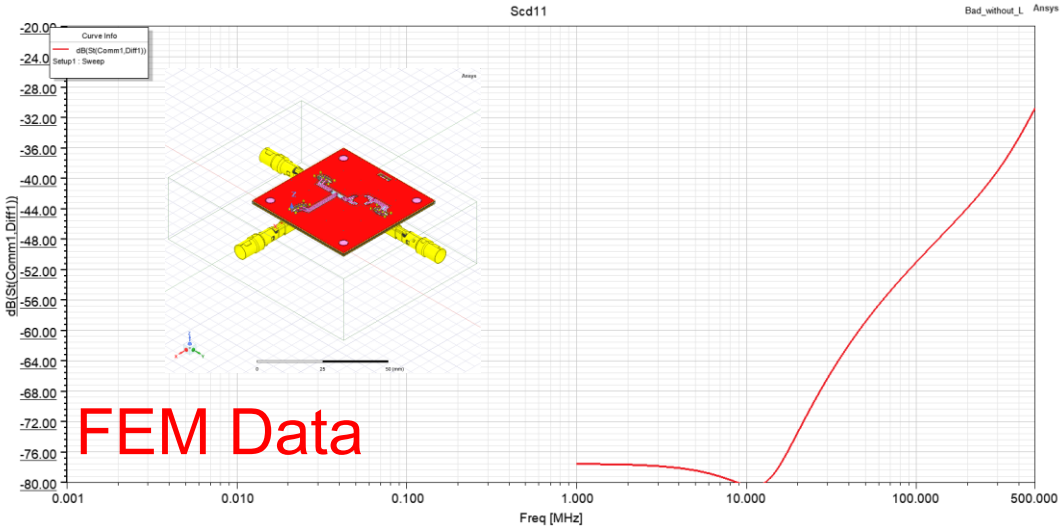
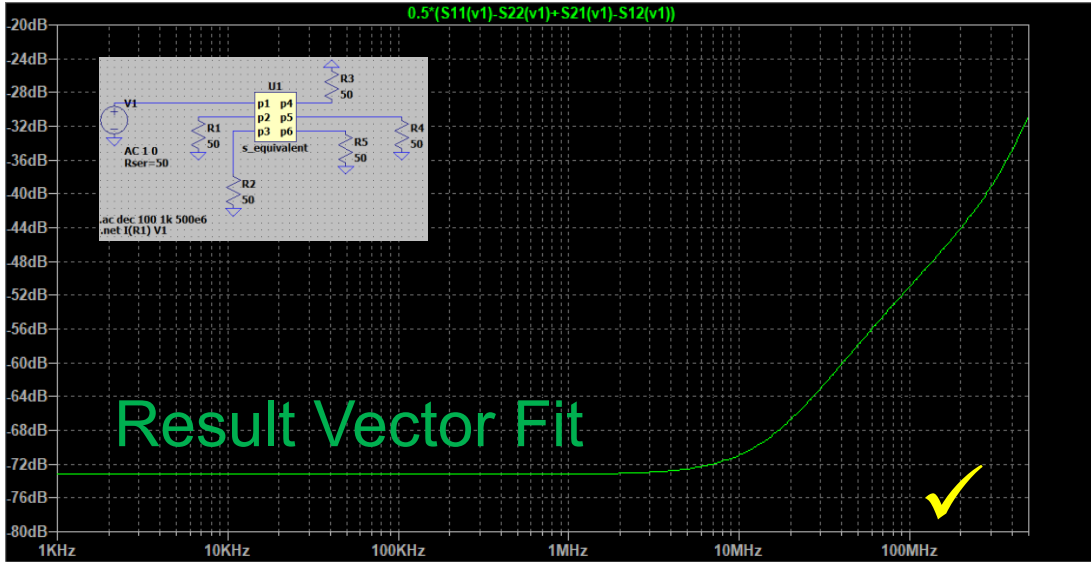
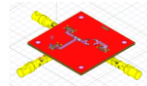
Opt. Tee



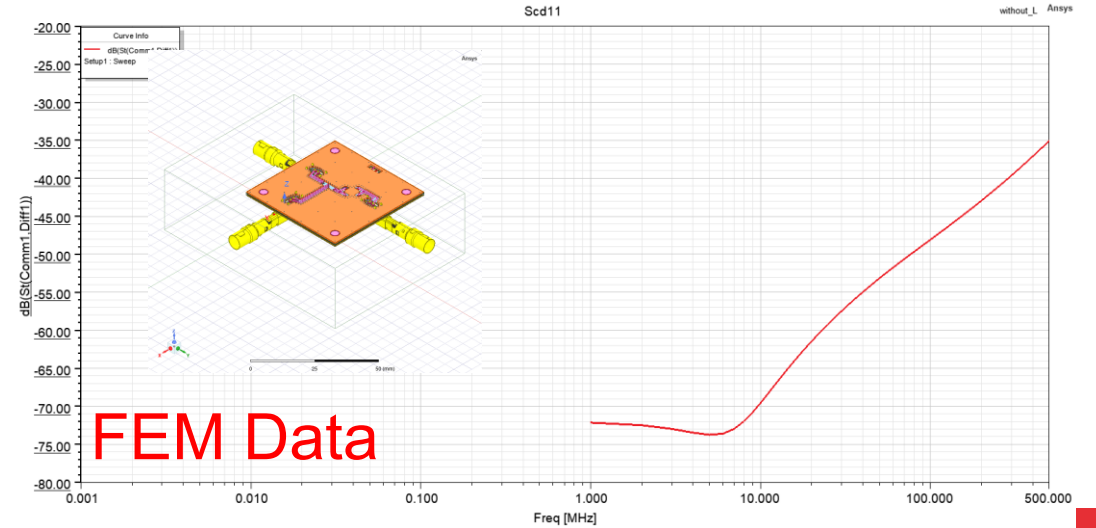
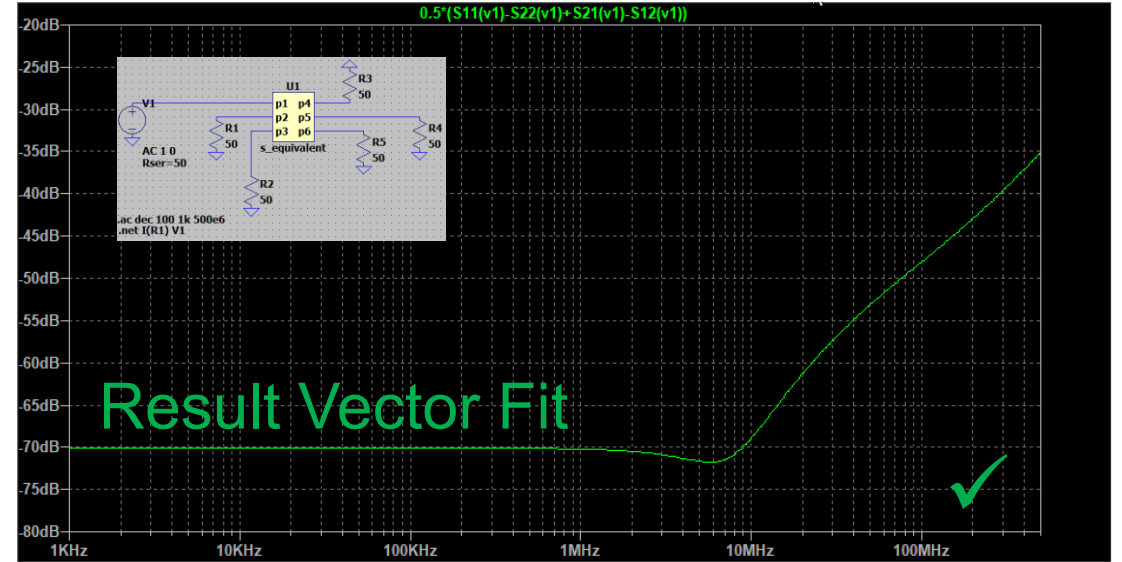
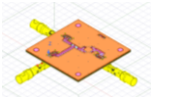
Vector Fit Results Scd11

Without compensation inductor

Cap. Tee

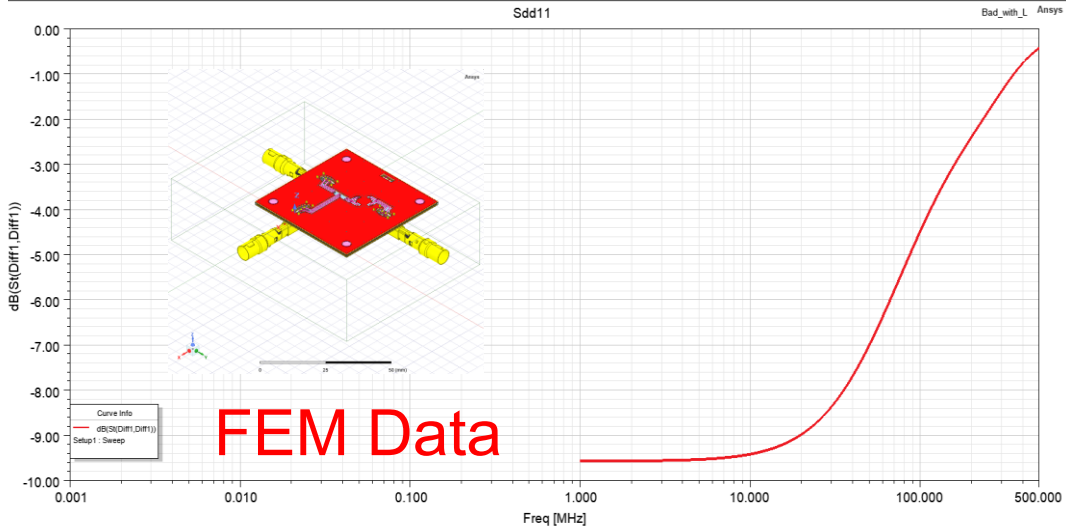
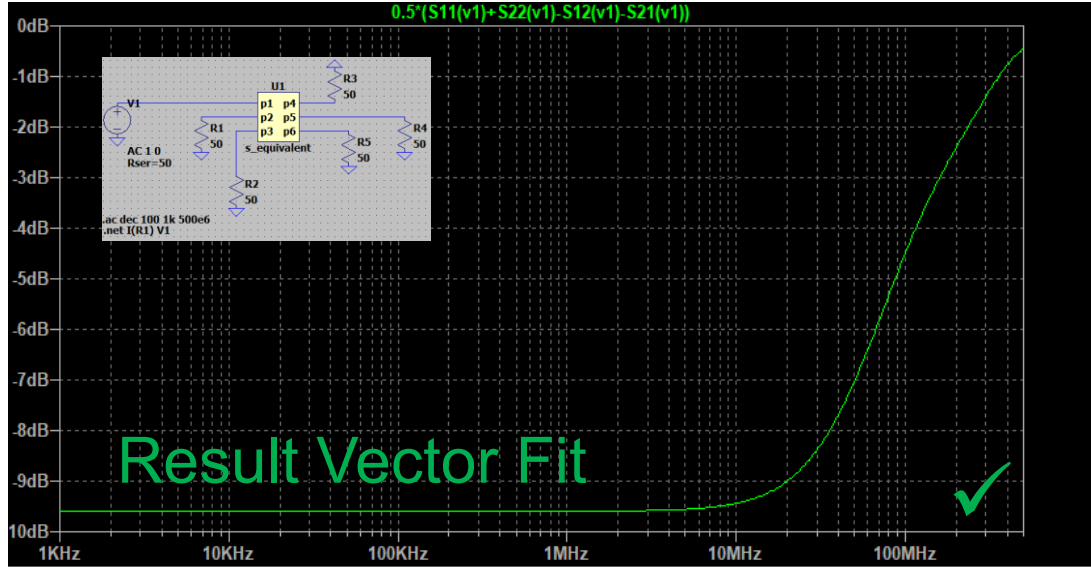
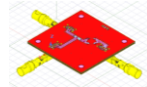


Opt. Tee

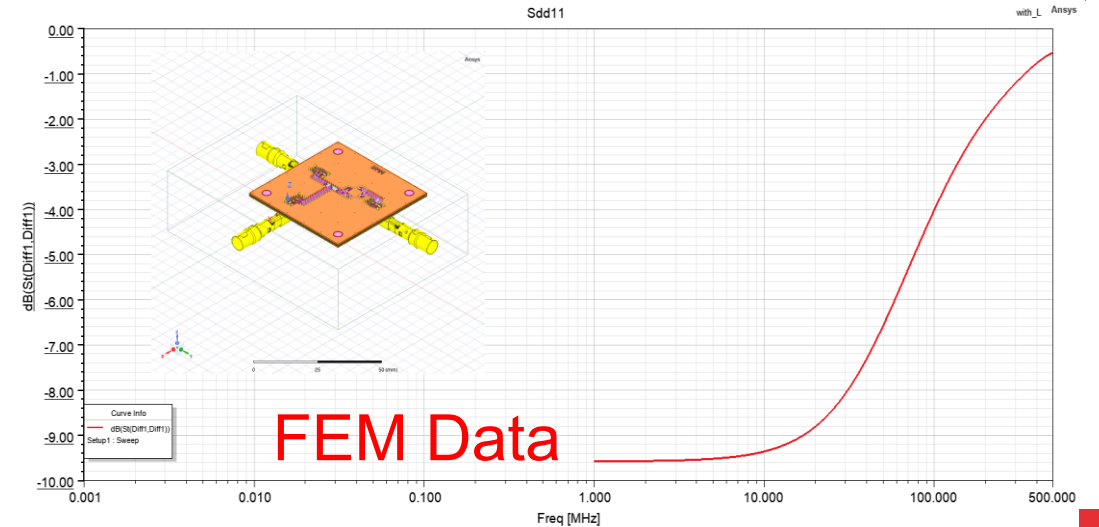
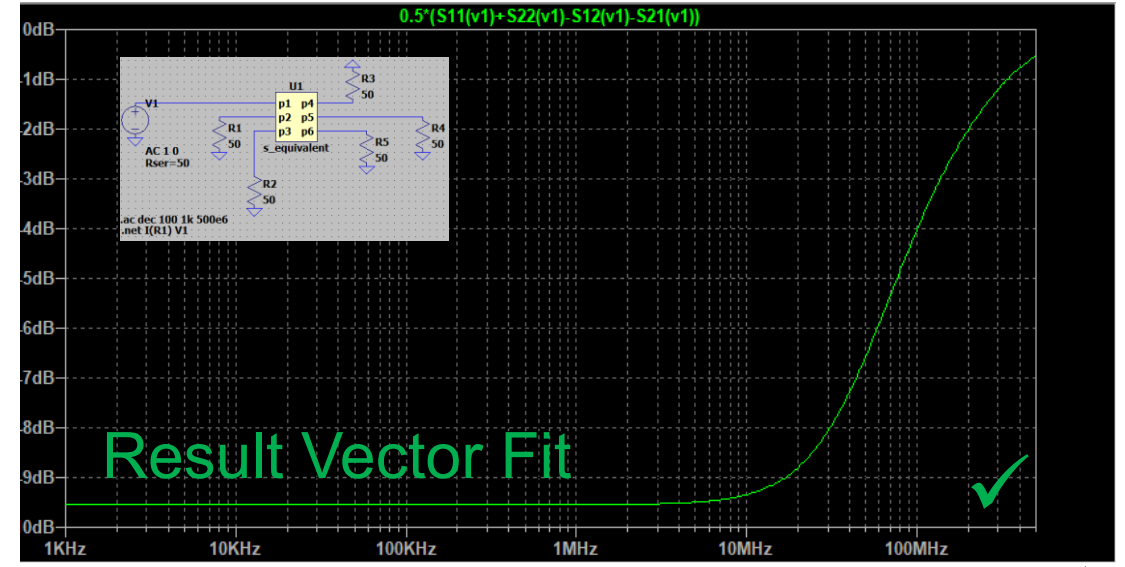
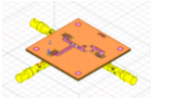


Vector Fit Results Sdd11

With compensation inductor
Cap. Tee

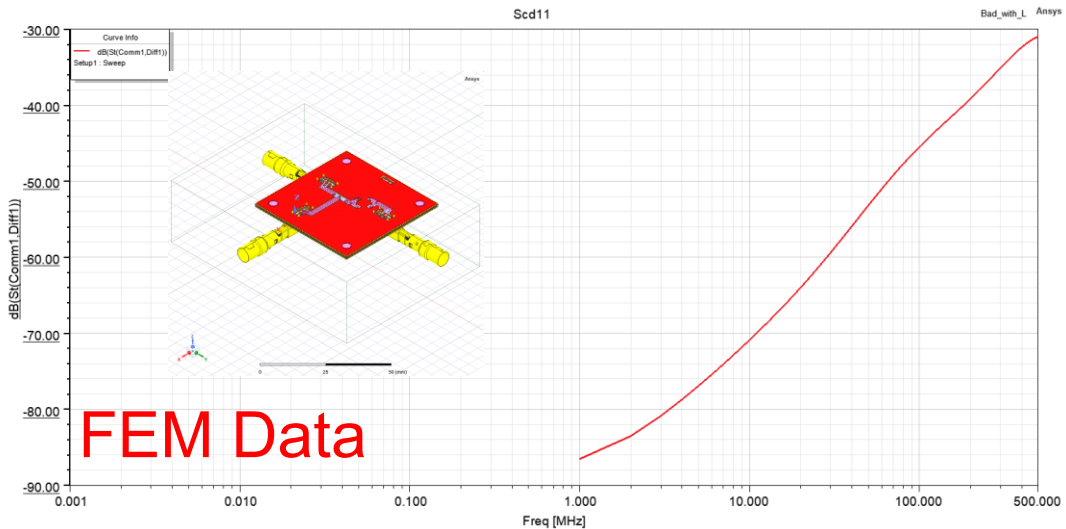
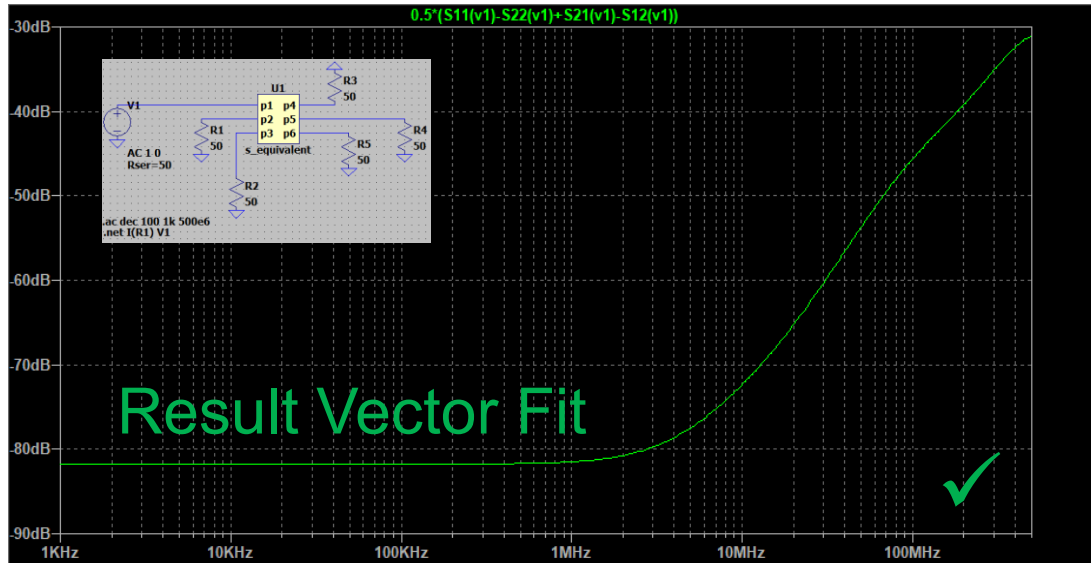
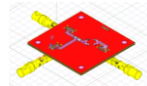


Opt. Tee

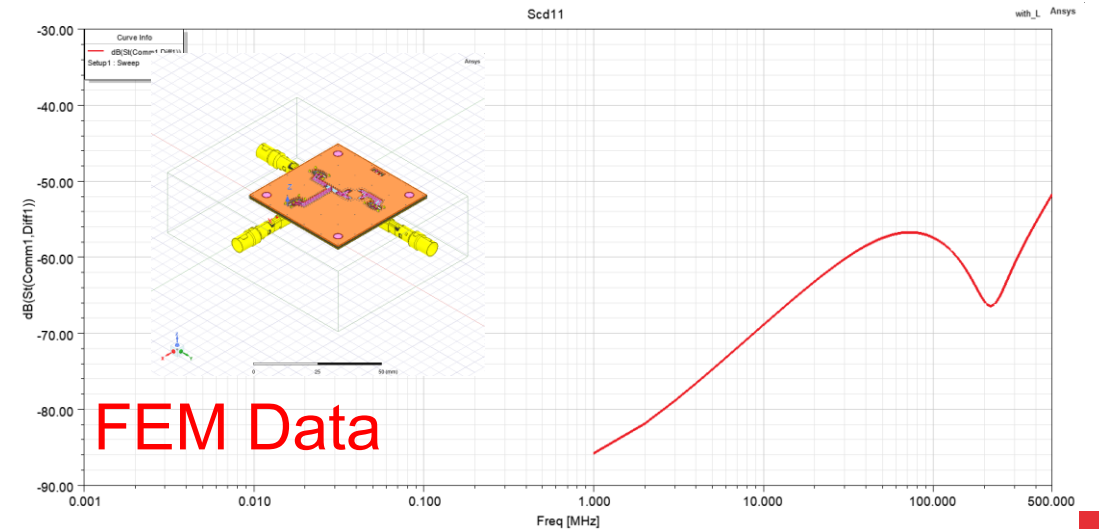
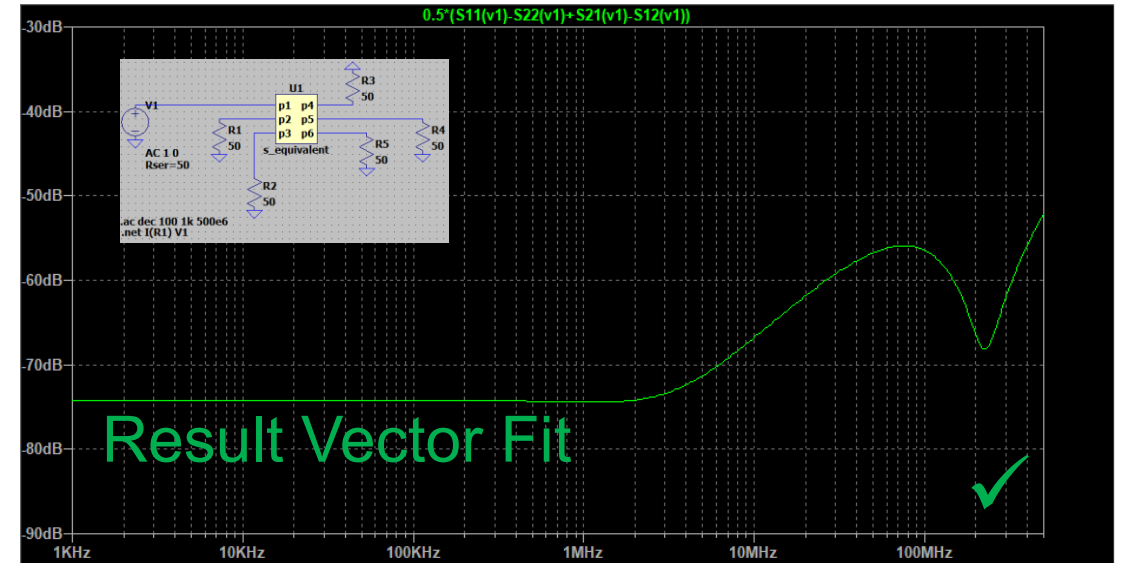
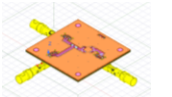


Vector Fit Results Scd11

With compensation inductor
Cap. Tee

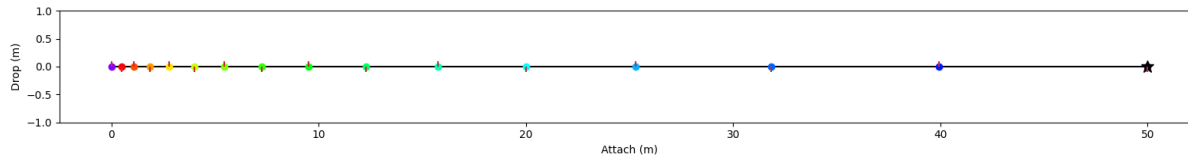


Opt. Tee



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.sóp",  
  "fitted_model_name": "FEM3d_Tee_Compensated",  
  "fitting_error_rms": 0.00001,  
  "port_order": [  
    1,  
    2,  
    3,  
    4,  
    5,  
    6  
  ]  
},
```

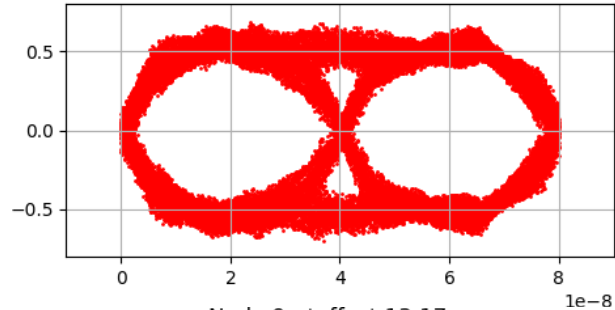
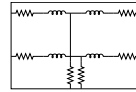
Eye Diagram Comparison TX Node 1

Without compensation inductors

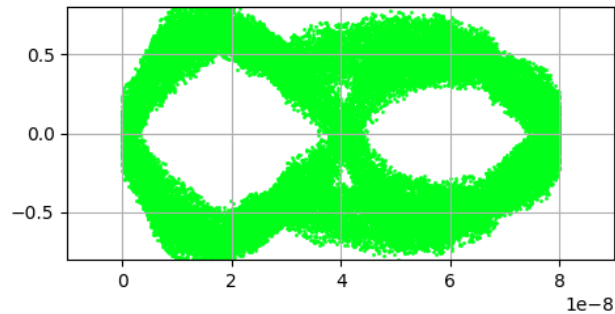


Ideal Tee

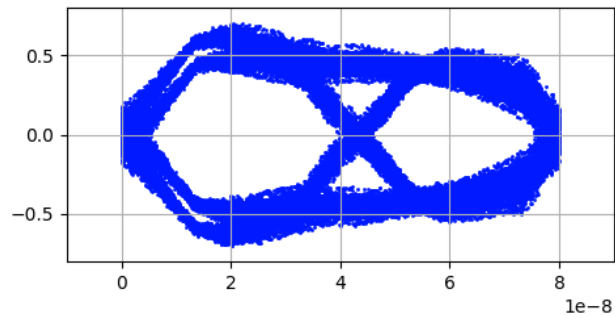
Node 2 - toffset 44.47ns



Node 9 - toffset 13.17ns

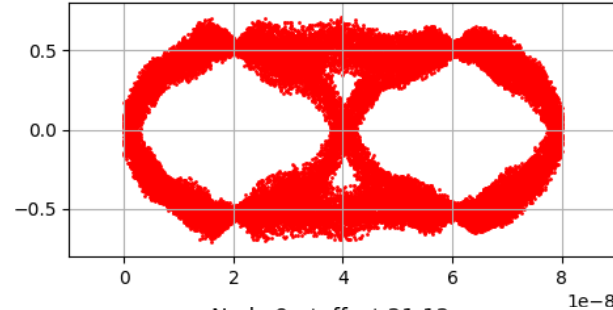
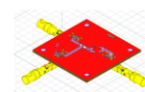


Node 15 - toffset 71.80ns

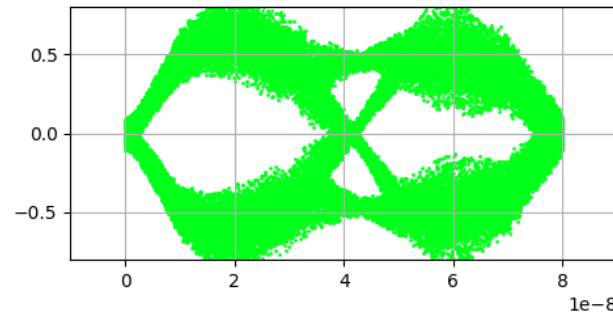


Cap. Tee

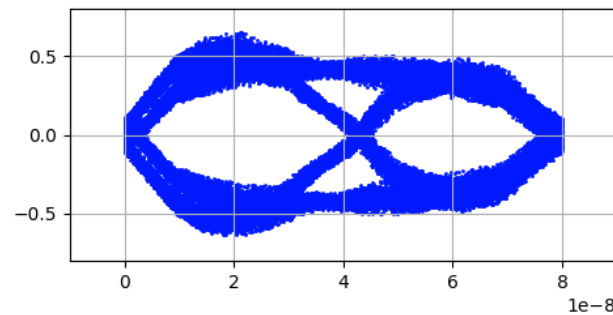
Node 2 - toffset 45.96ns



Node 9 - toffset 21.12ns

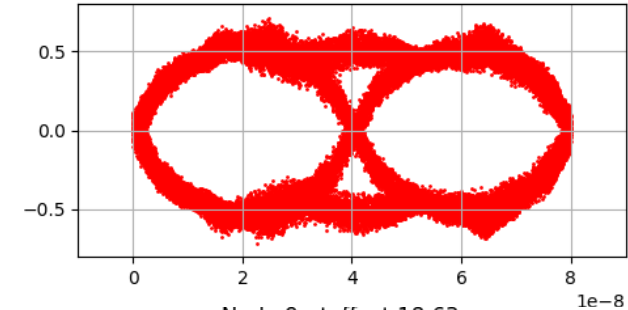
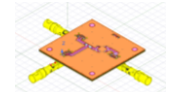


Node 15 - toffset 8.20ns

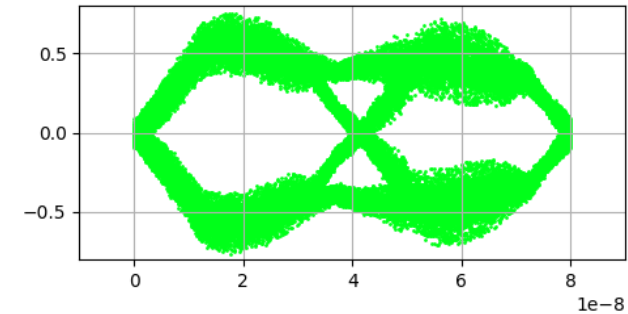


Opt. Tee

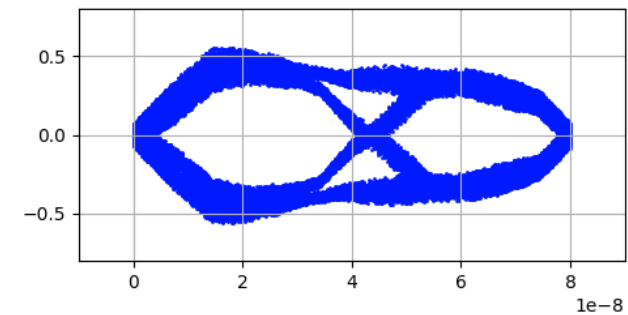
Node 2 - toffset 45.47ns



Node 9 - toffset 18.63ns



Node 15 - toffset 3.23ns



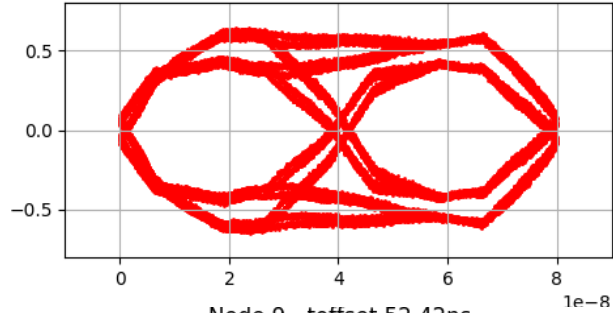
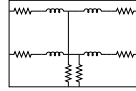
Eye Diagram Comparison TX Node 8

Without compensation inductors

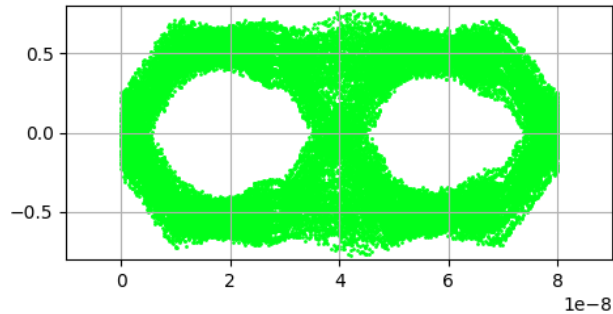


Ideal Tee

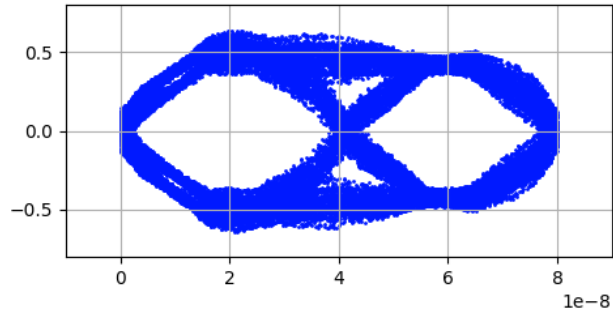
Node 2 - toffset 0.25ns



Node 9 - toffset 52.42ns

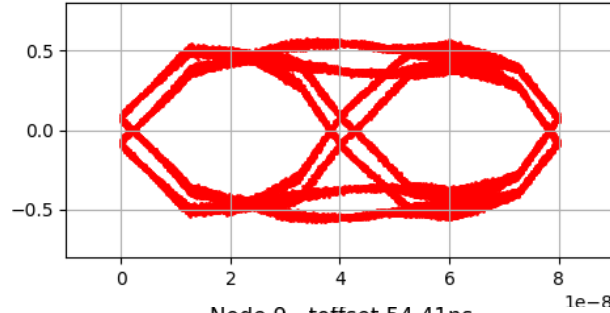
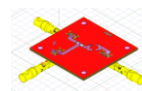


Node 15 - toffset 32.55ns

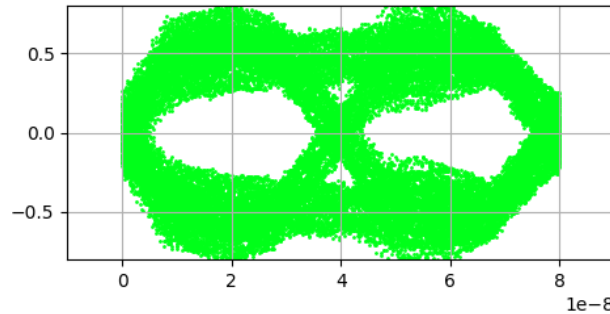


Cap. Tee

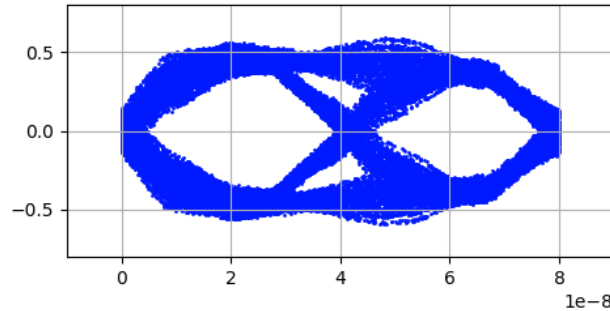
Node 2 - toffset 6.21ns



Node 9 - toffset 54.41ns

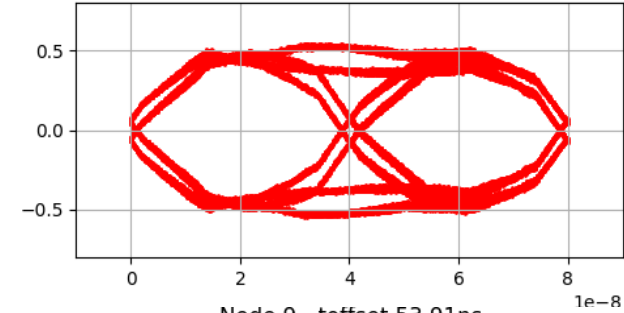
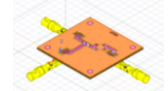


Node 15 - toffset 40.99ns

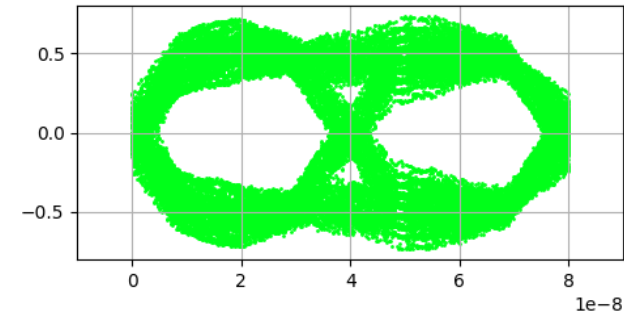


Opt. Tee

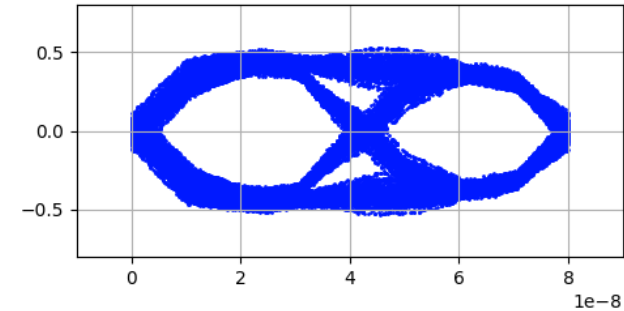
Node 2 - toffset 4.72ns



Node 9 - toffset 53.91ns



Node 15 - toffset 38.01ns



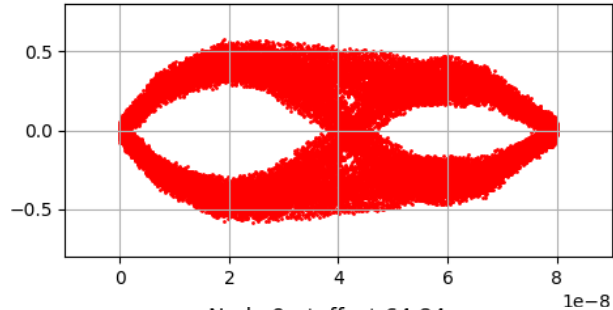
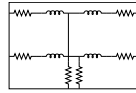
Eye Diagram Comparison TX Node 16

Without compensation inductors

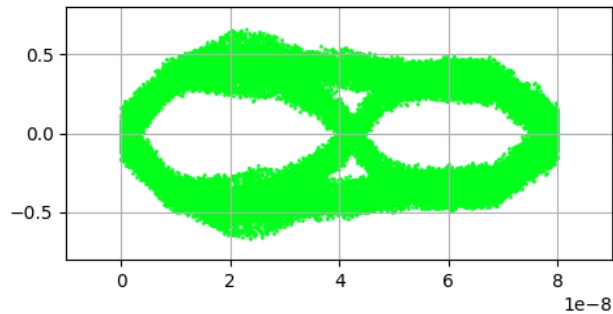


Ideal Tee

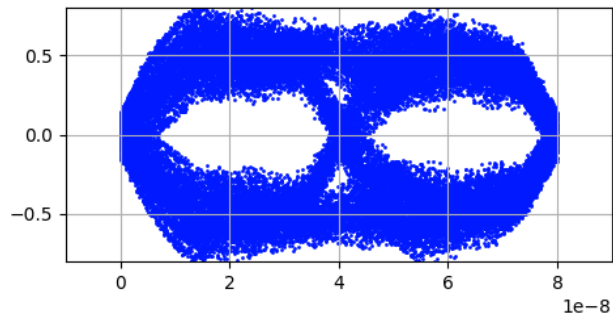
Node 2 - toffset 35.03ns



Node 9 - toffset 64.84ns

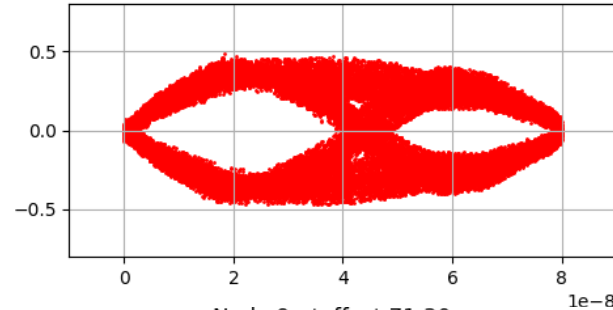
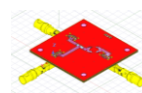


Node 15 - toffset 5.22ns

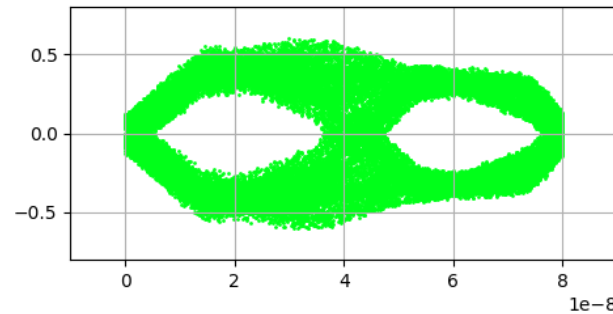


Cap. Tee

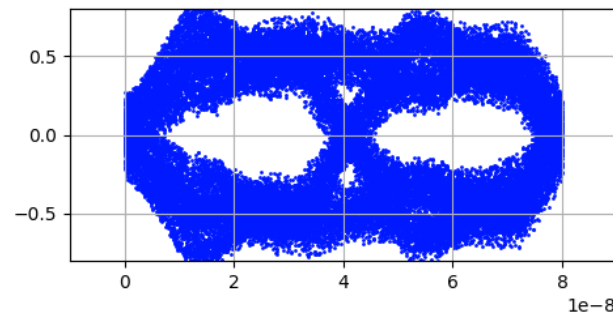
Node 2 - toffset 48.45ns



Node 9 - toffset 71.30ns

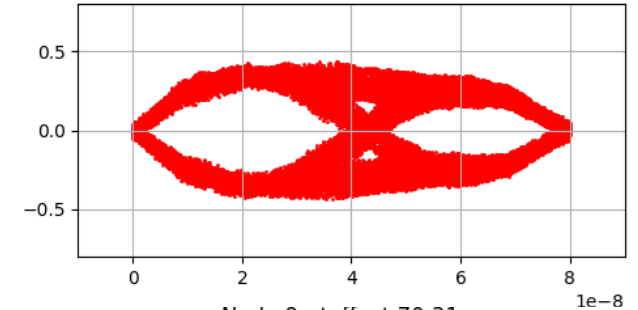
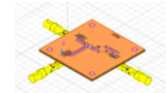


Node 15 - toffset 6.71ns

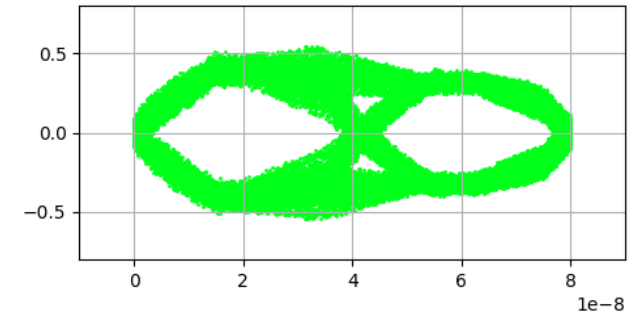


Opt. Tee

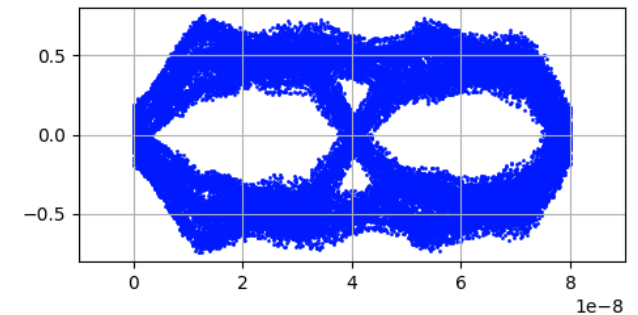
Node 2 - toffset 45.47ns



Node 9 - toffset 70.31ns



Node 15 - toffset 6.71ns



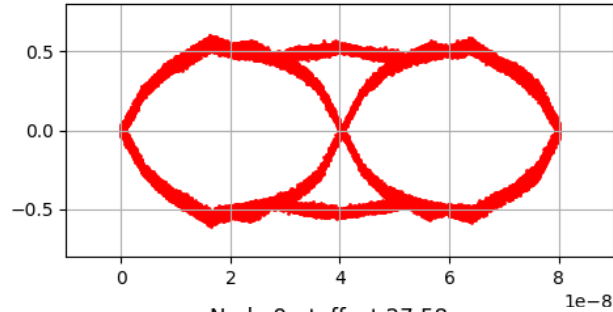
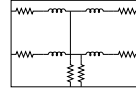
Eye Diagram Comparison TX Node 1

With compensation inductors

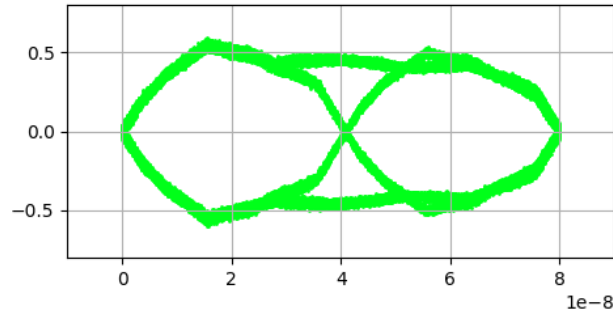


Ideal Tee

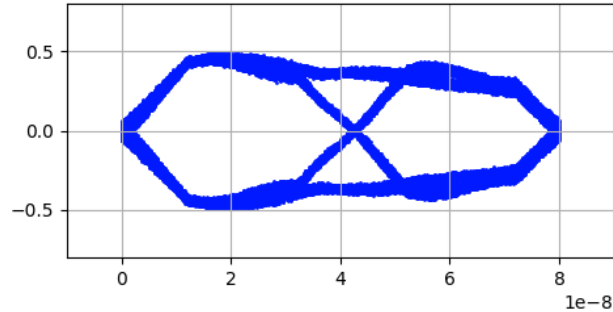
Node 2 - toffset 45.96ns



Node 9 - toffset 27.58ns

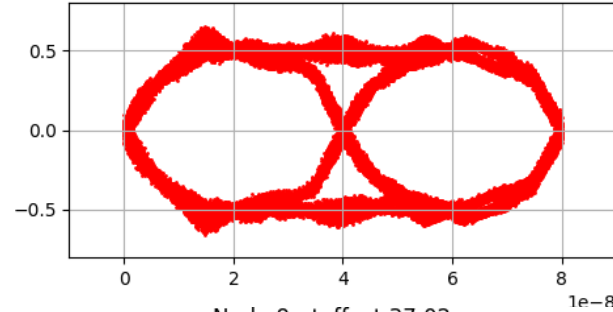
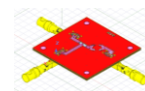


Node 15 - toffset 17.64ns

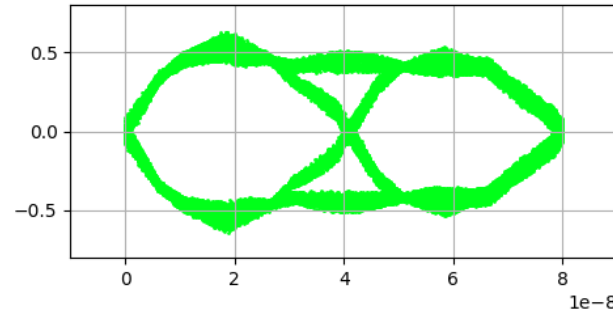


Cap. Tee

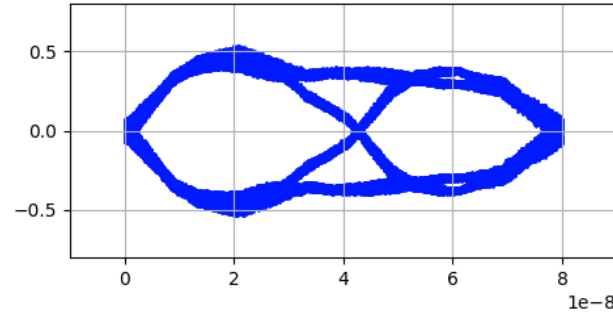
Node 2 - toffset 47.45ns



Node 9 - toffset 37.02ns

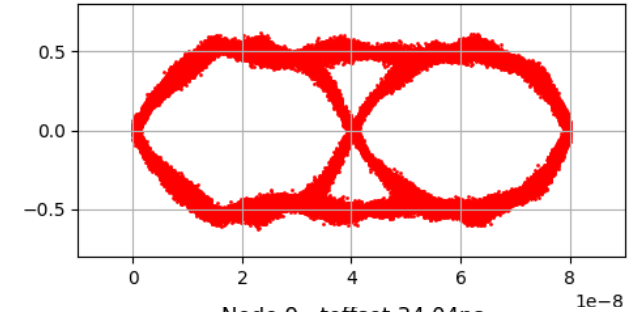
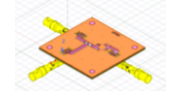


Node 15 - toffset 33.04ns

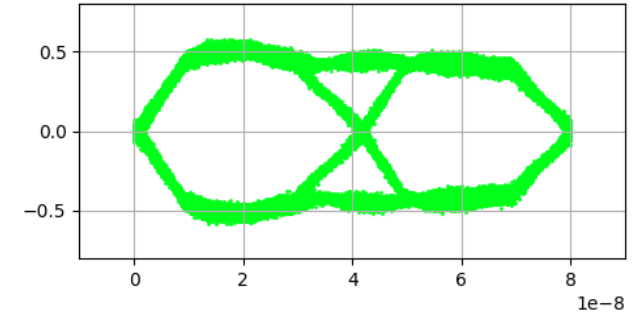


Opt. Tee

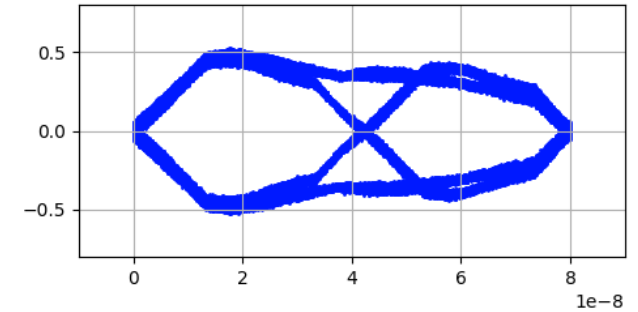
Node 2 - toffset 46.96ns



Node 9 - toffset 34.04ns



Node 15 - toffset 28.57ns

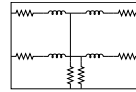


Eye Diagram Comparison TX Node 8

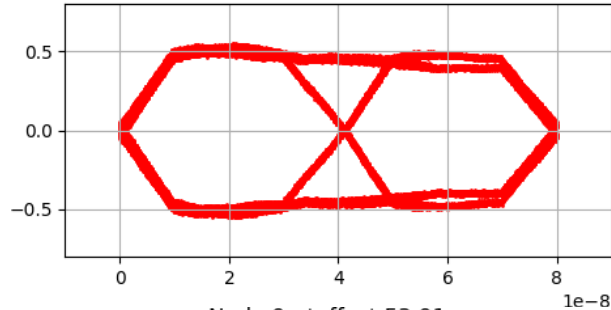
With compensation inductors



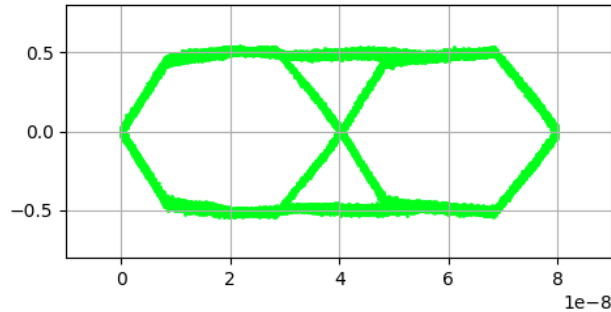
Ideal



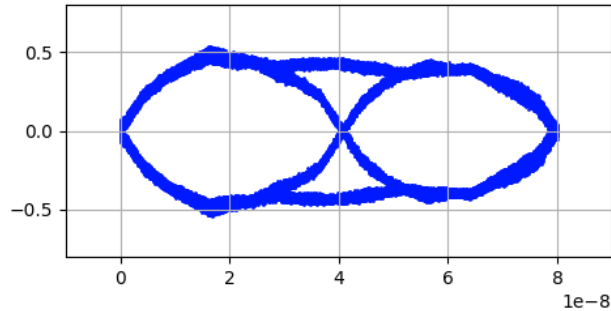
Node 2 - toffset 9.19ns



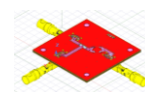
Node 9 - toffset 53.91ns



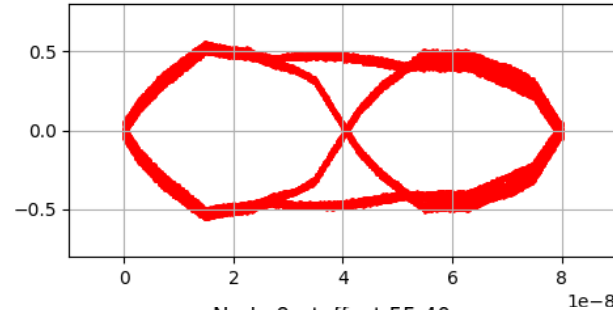
Node 15 - toffset 44.47ns



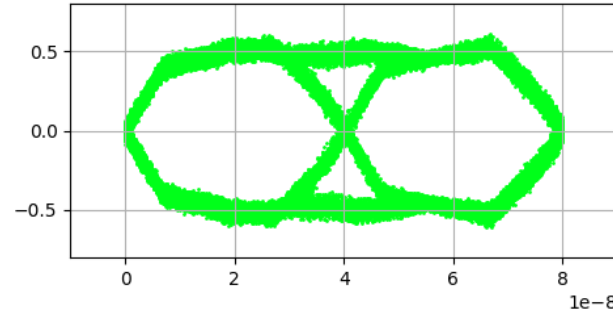
Cap. Tee



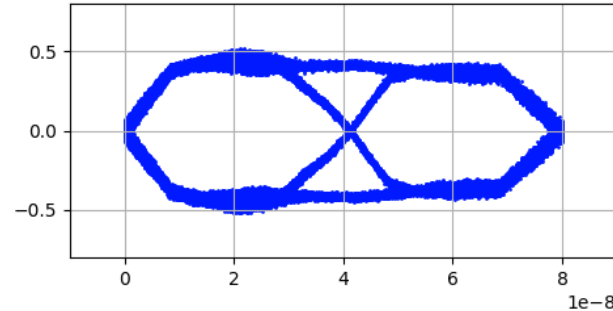
Node 2 - toffset 16.15ns



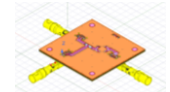
Node 9 - toffset 55.40ns



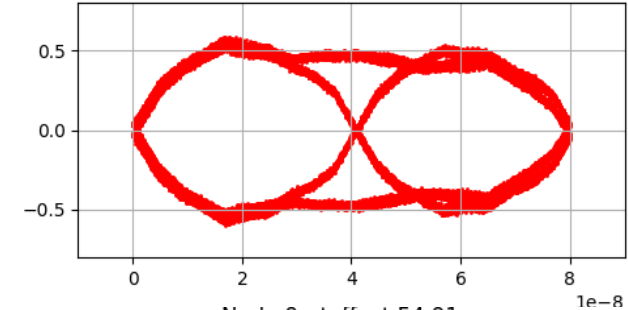
Node 15 - toffset 52.42ns



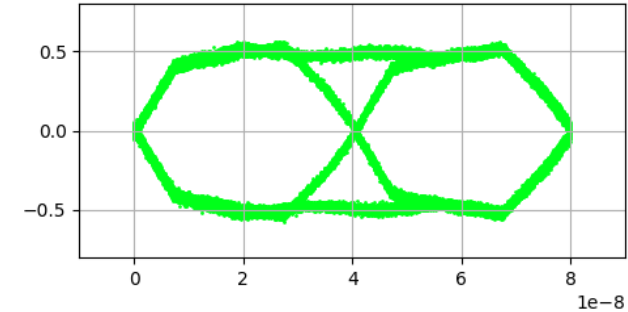
Opt. Tee



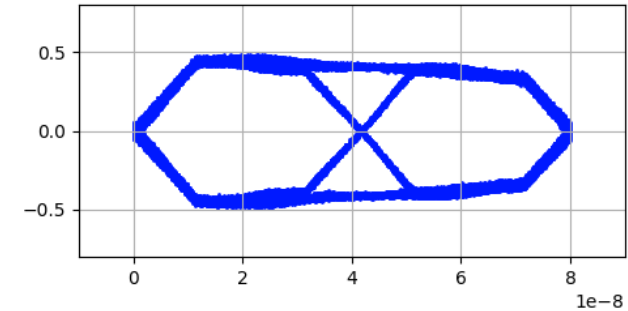
Node 2 - toffset 14.16ns



Node 9 - toffset 54.91ns



Node 15 - toffset 49.44ns



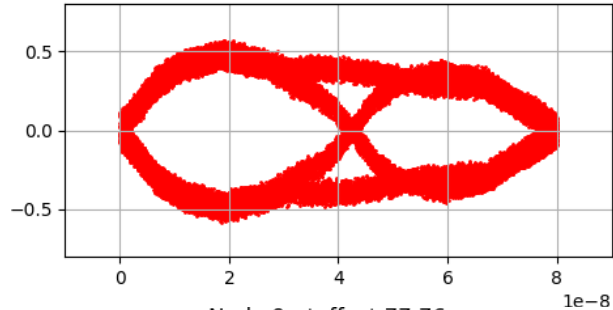
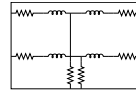
Eye Diagram Comparison TX Node 16

With compensation inductors

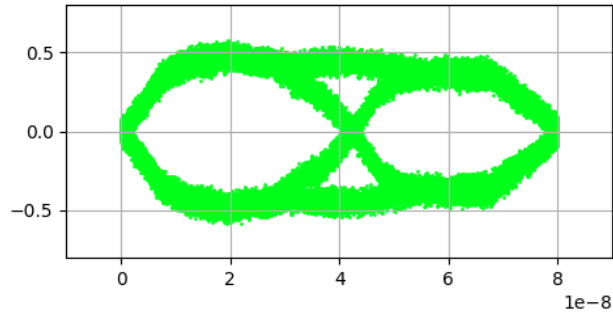


Ideal

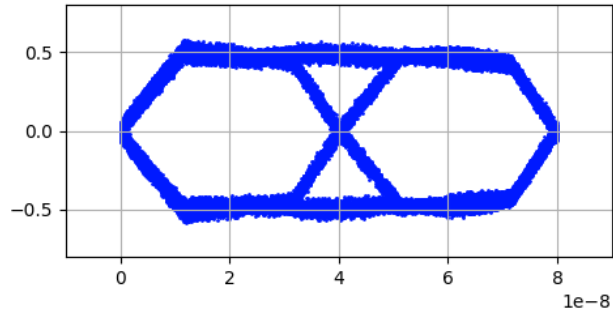
Node 2 - toffset 59.38ns



Node 9 - toffset 77.76ns

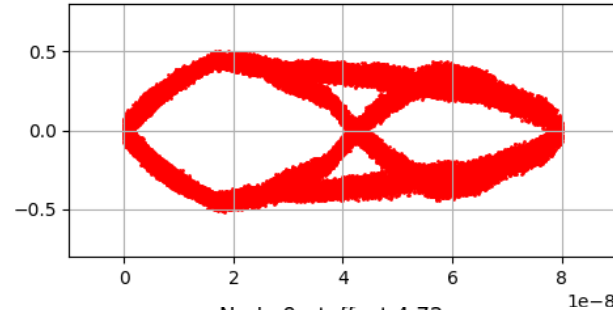
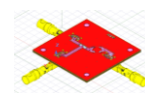


Node 15 - toffset 7.20ns

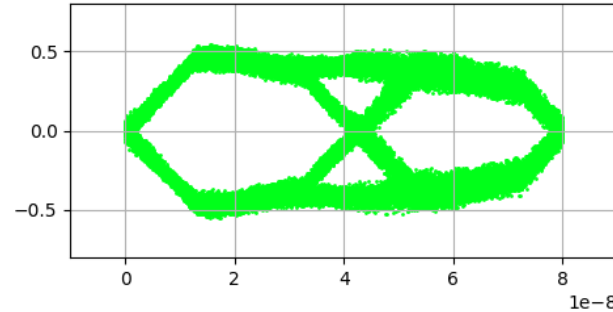


Cap. Tee

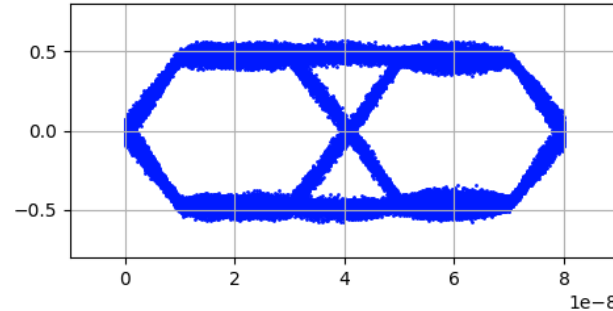
Node 2 - toffset 73.79ns



Node 9 - toffset 4.72ns

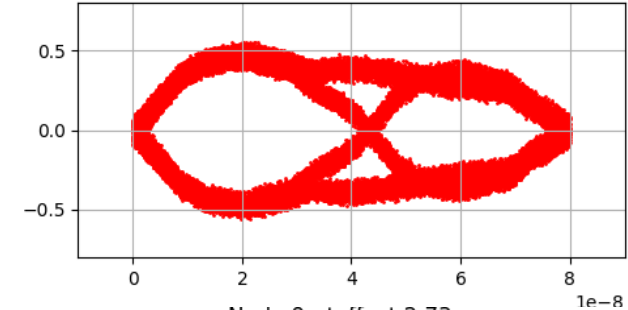
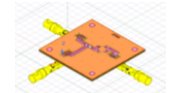


Node 15 - toffset 8.70ns

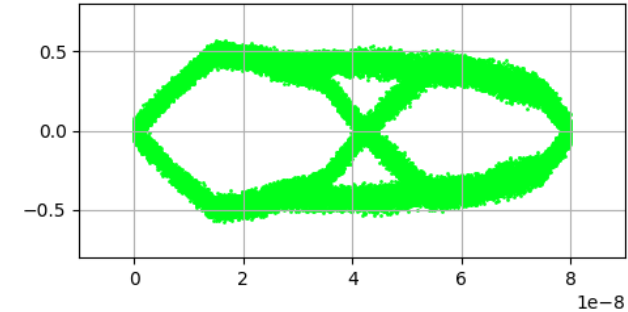


Opt. Tee

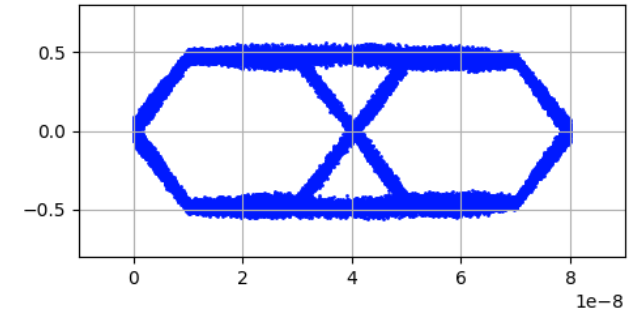
Node 2 - toffset 69.81ns



Node 9 - toffset 2.73ns



Node 15 - toffset 8.70ns



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

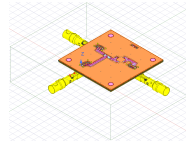
Thanks for Listening!
Questions

Appendix: Eye Diagram Comparison

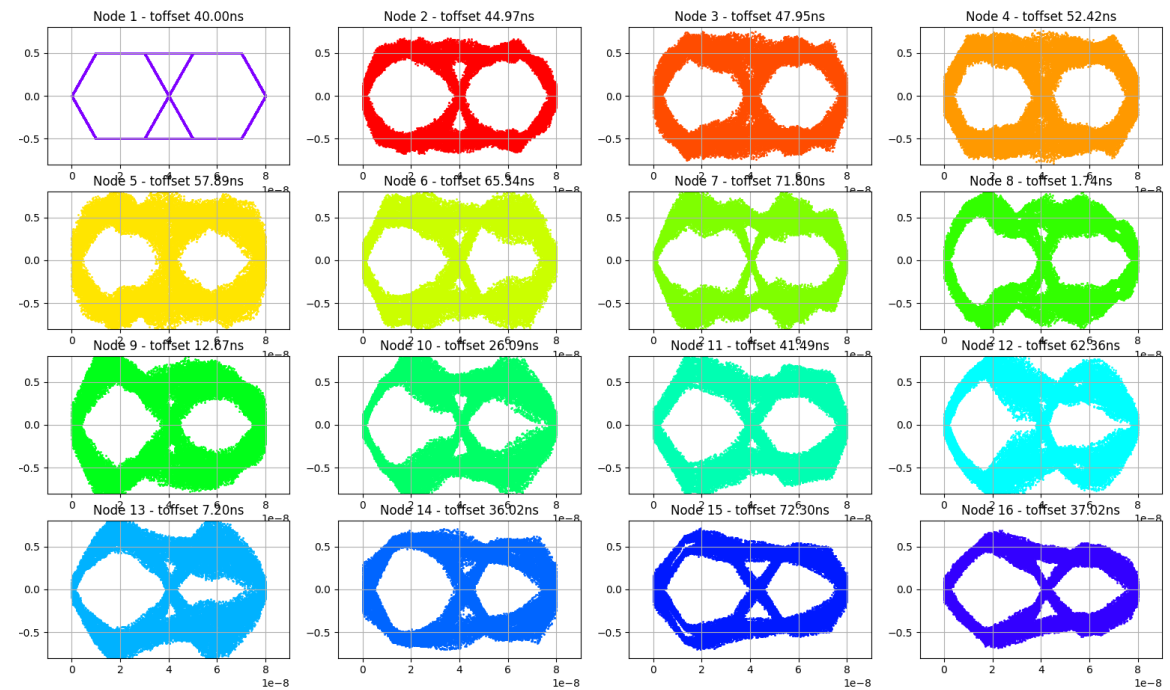
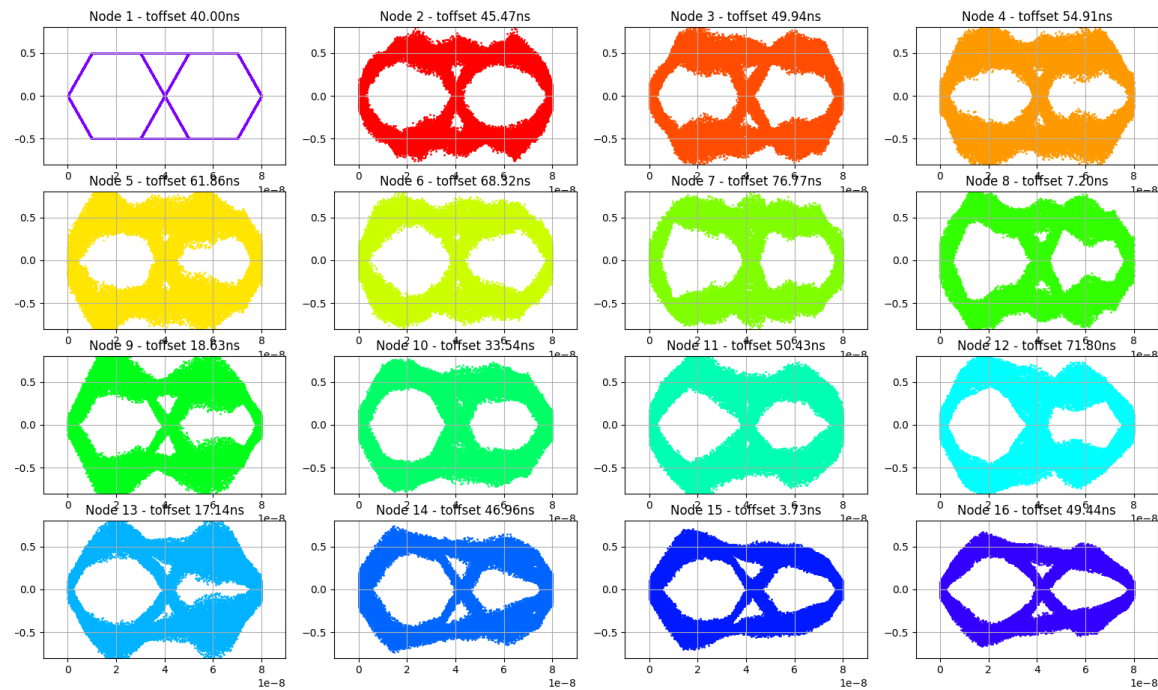
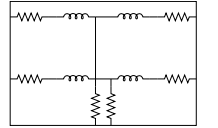
Without compensation inductors, TX Node 1



S-Parameter based Tee



Ideal Tee

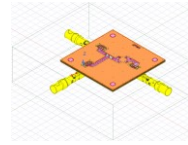


Appendix: Eye Diagram Comparison

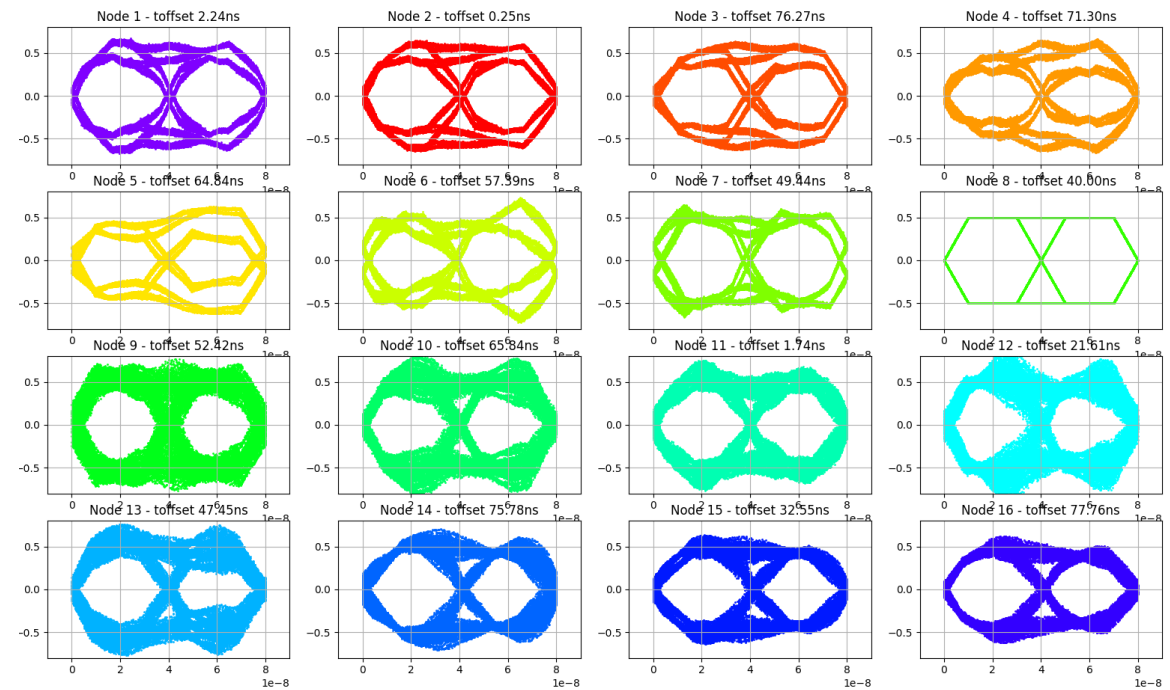
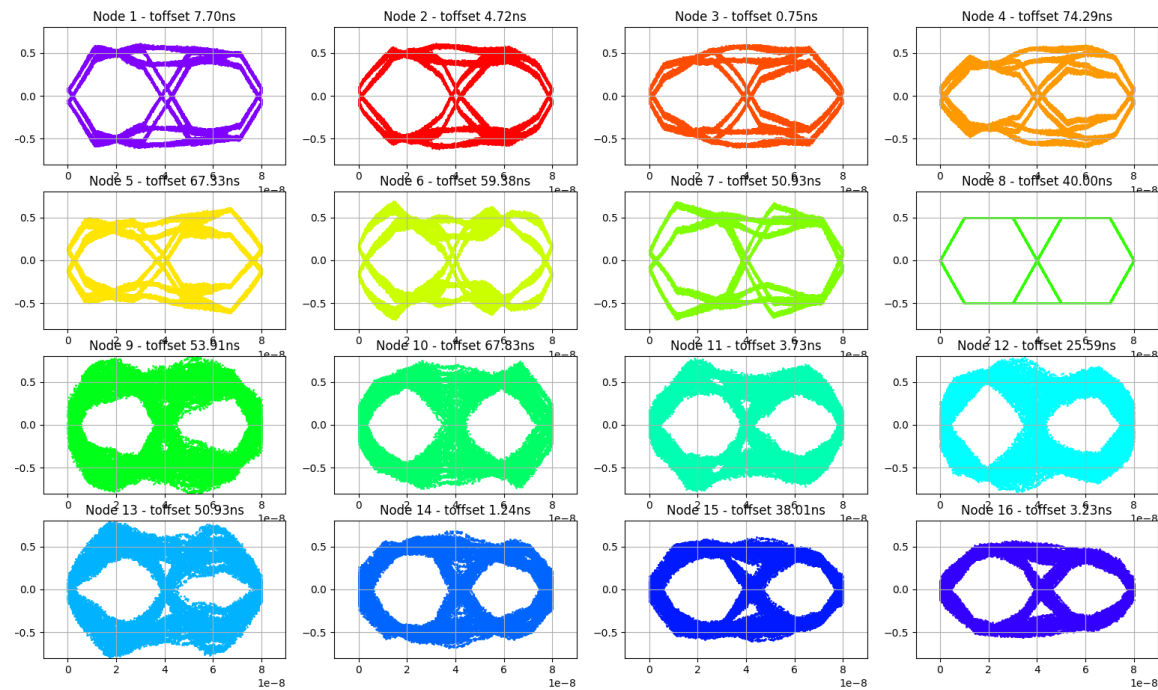
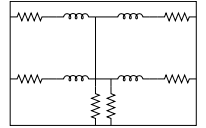
Without compensation inductors, TX Node 8



S-Parameter base Tee



Ideal Tee

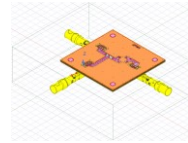


Appendix: Eye Diagram Comparison

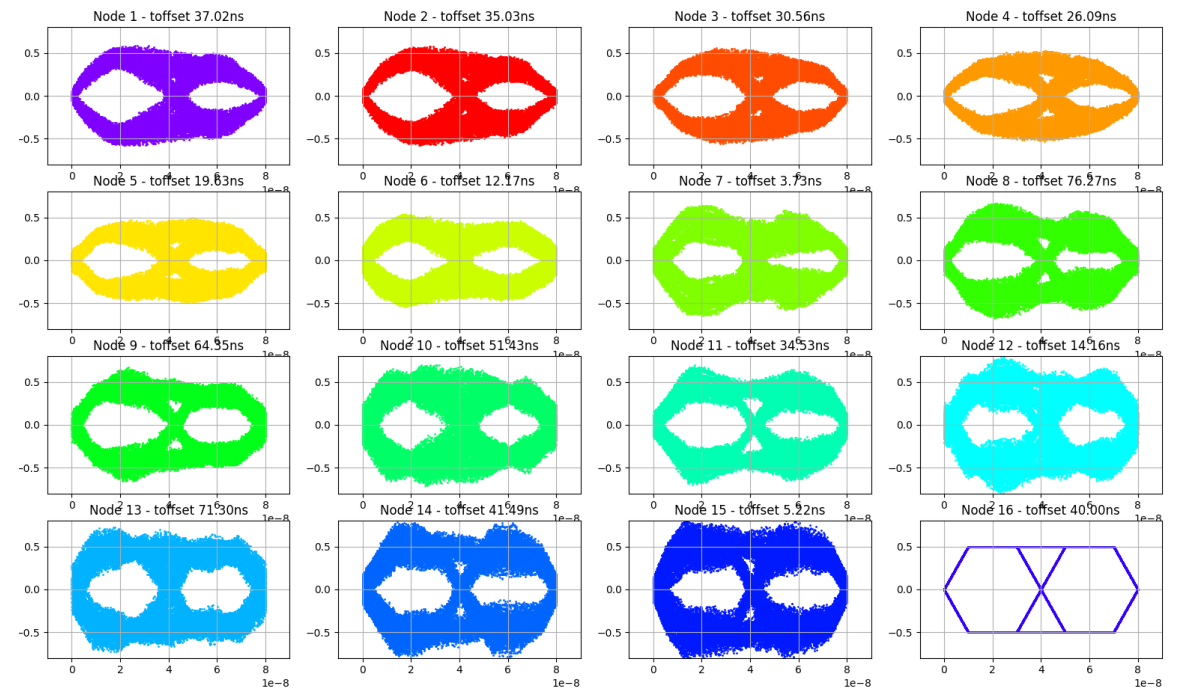
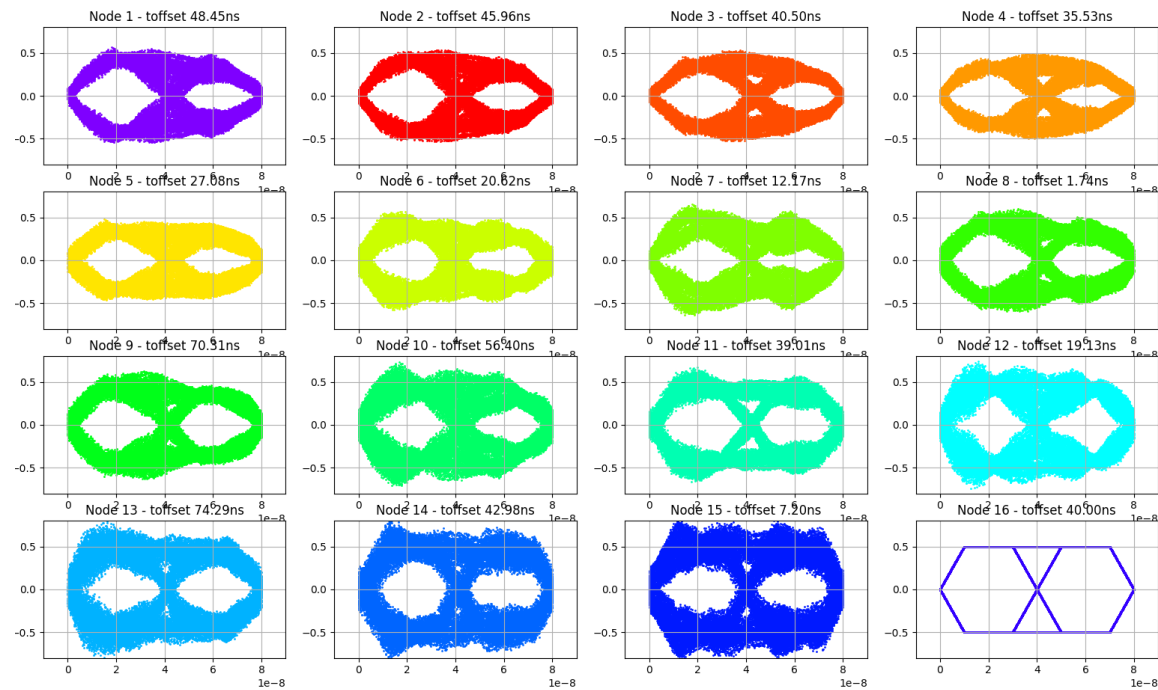
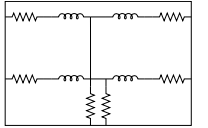
Without compensation inductors, TX Node 16



S-Parameter base Tee



Ideal Tee

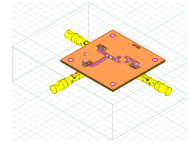


Appendix: Eye Diagram Comparison

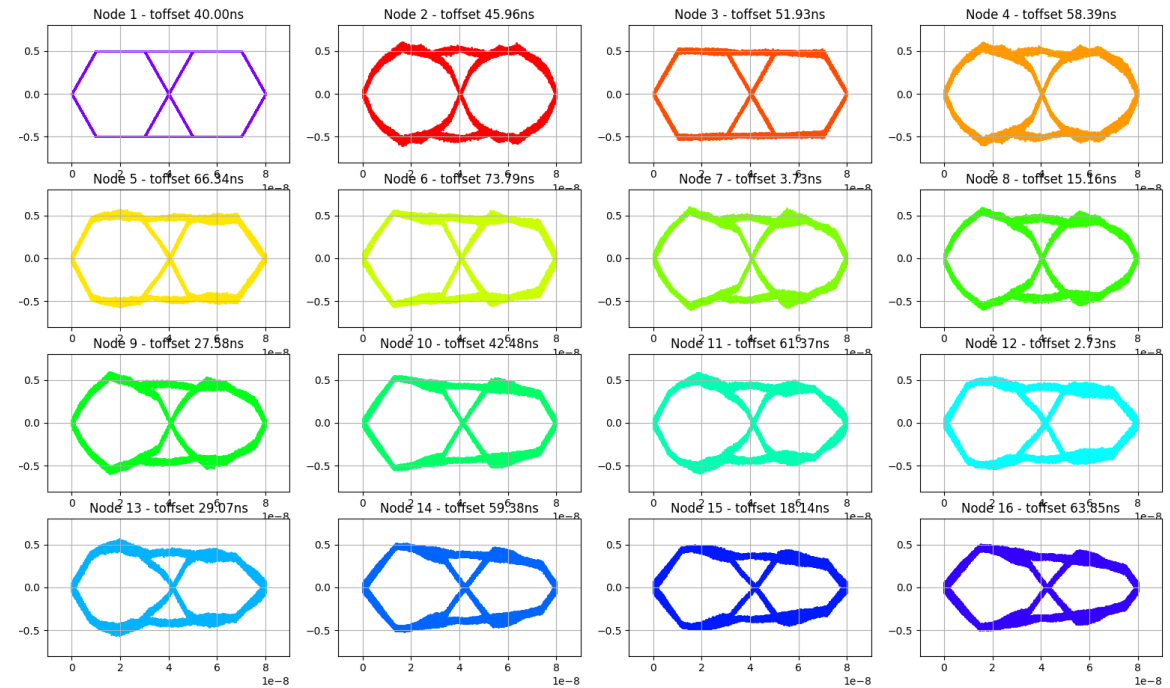
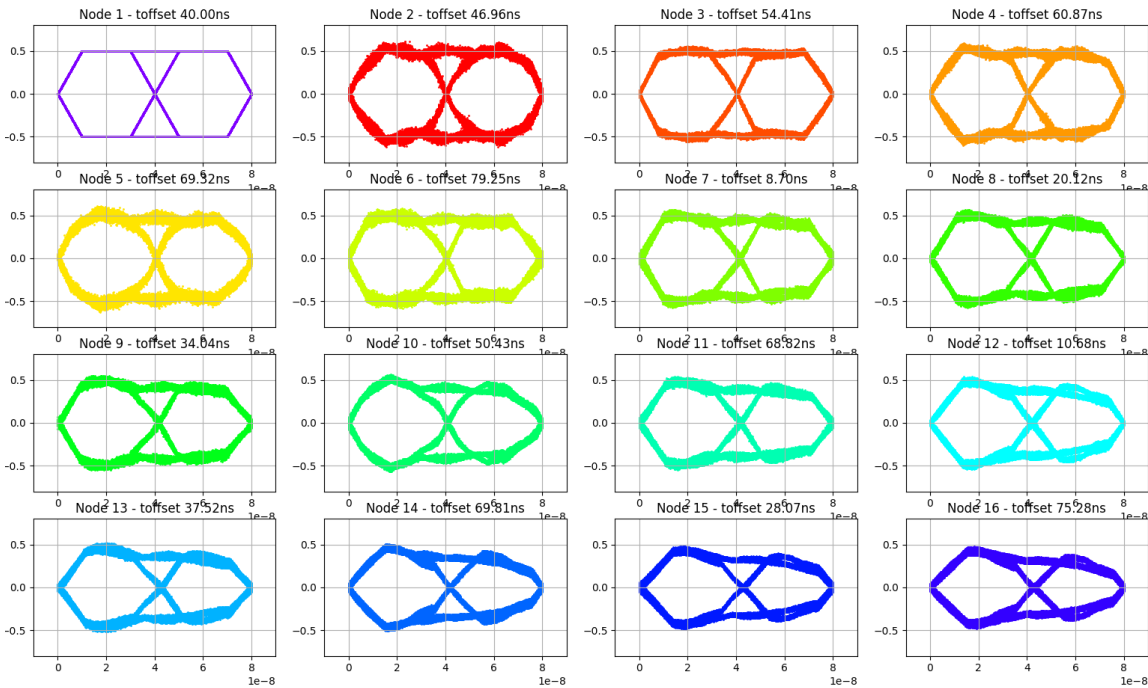
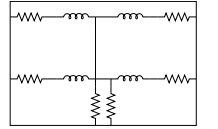
With compensation inductors, TX Node 1



S-Parameter based Tee



Ideal Tee

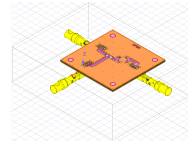


Appendix: Eye Diagram Comparison

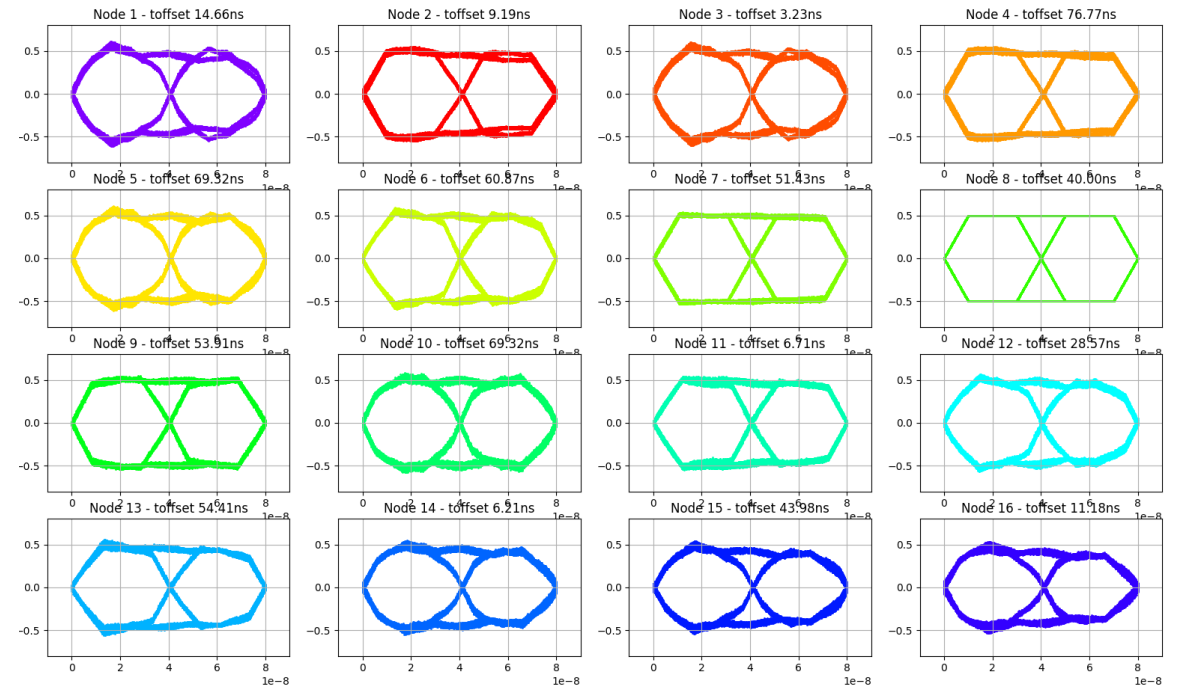
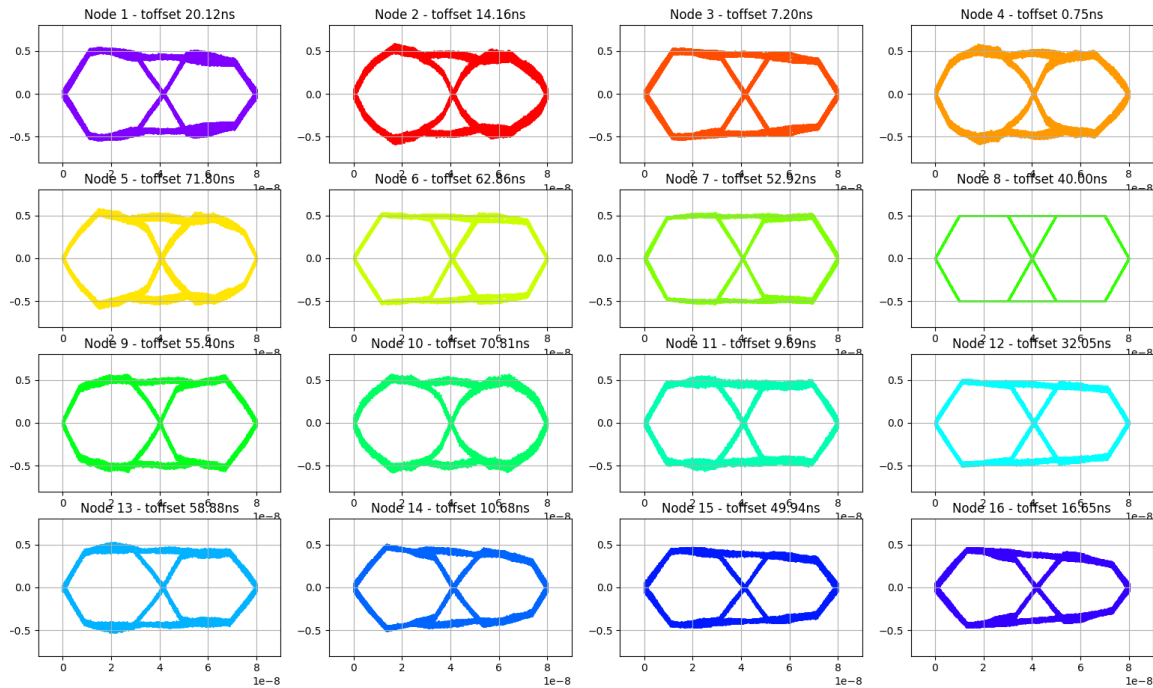
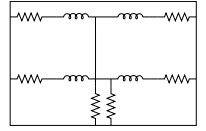
With compensation inductors, TX Node 8



S-Parameter based Tee



Ideal Tee

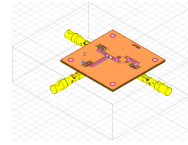


Appendix: Eye Diagram Comparison

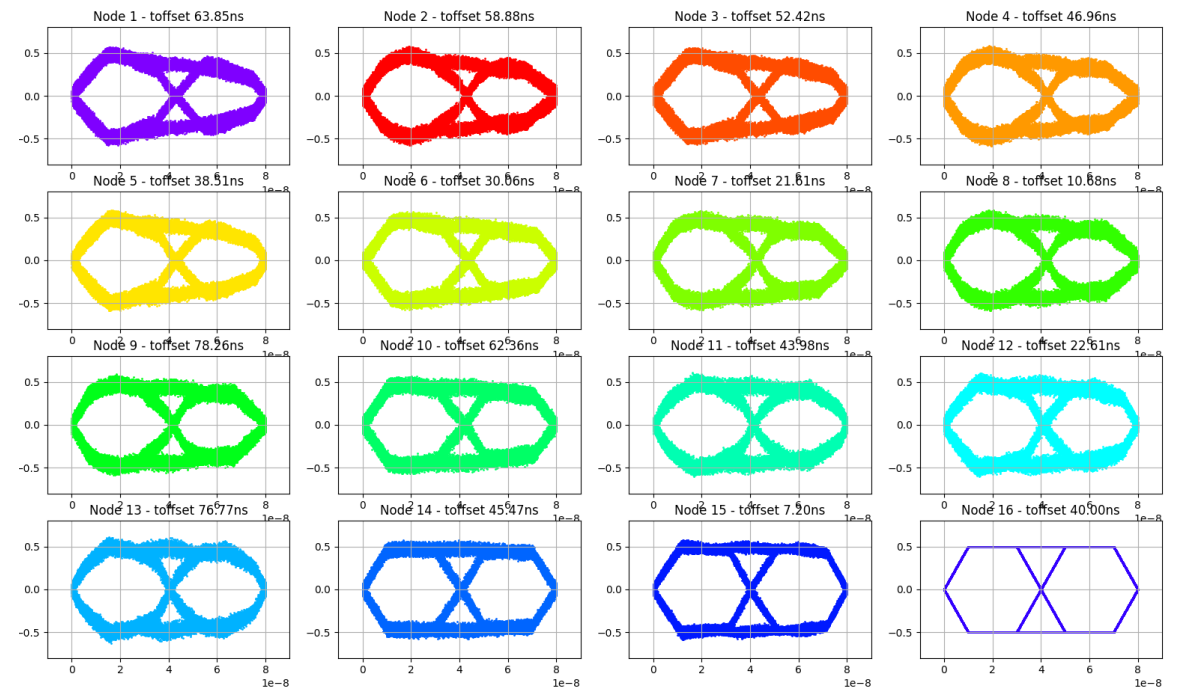
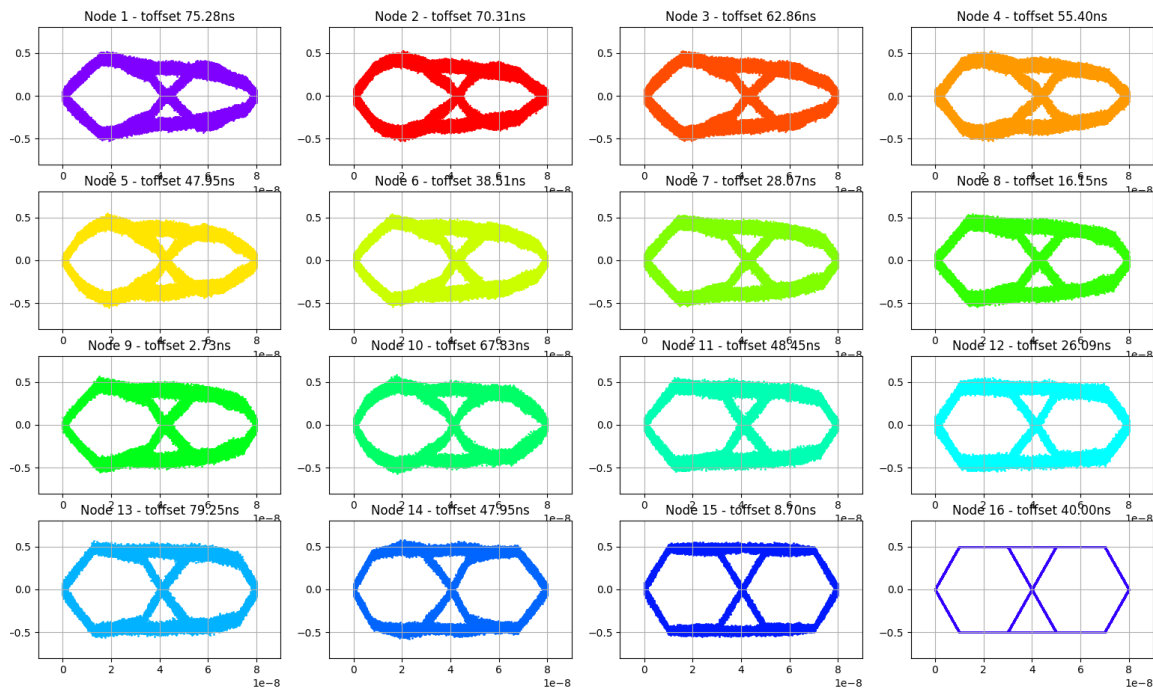
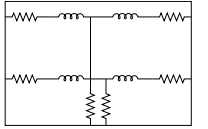
With compensation inductors, TX Node 16



S-Parameter based Tee



Ideal Tee

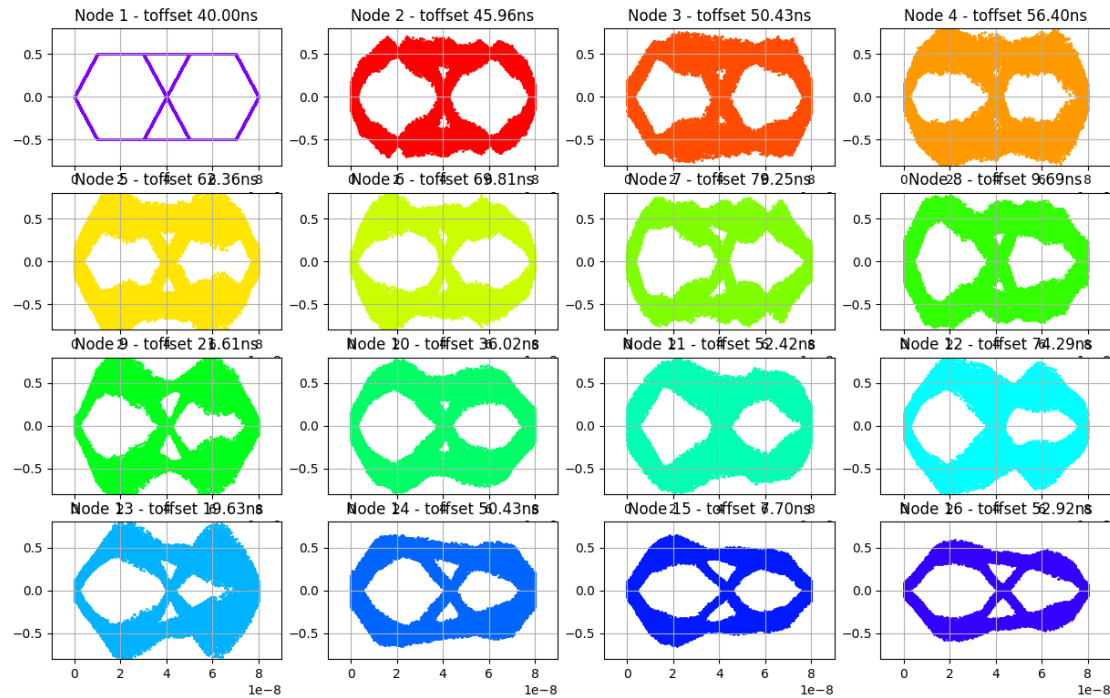
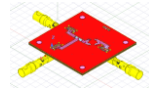


Appendix: Eye Diagram Comparison

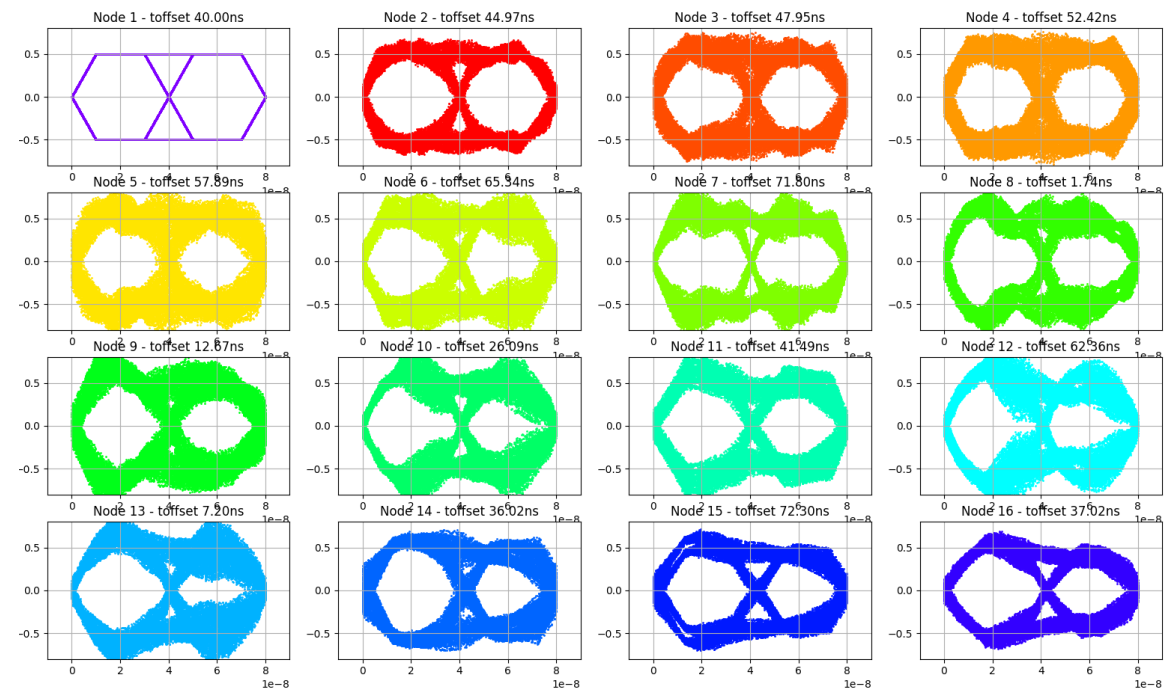
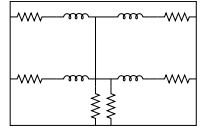
Without compensation inductors, TX Node 1



S-Parameter based cap. Tee



Ideal Tee

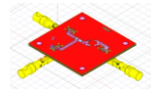


Appendix: Eye Diagram Comparison

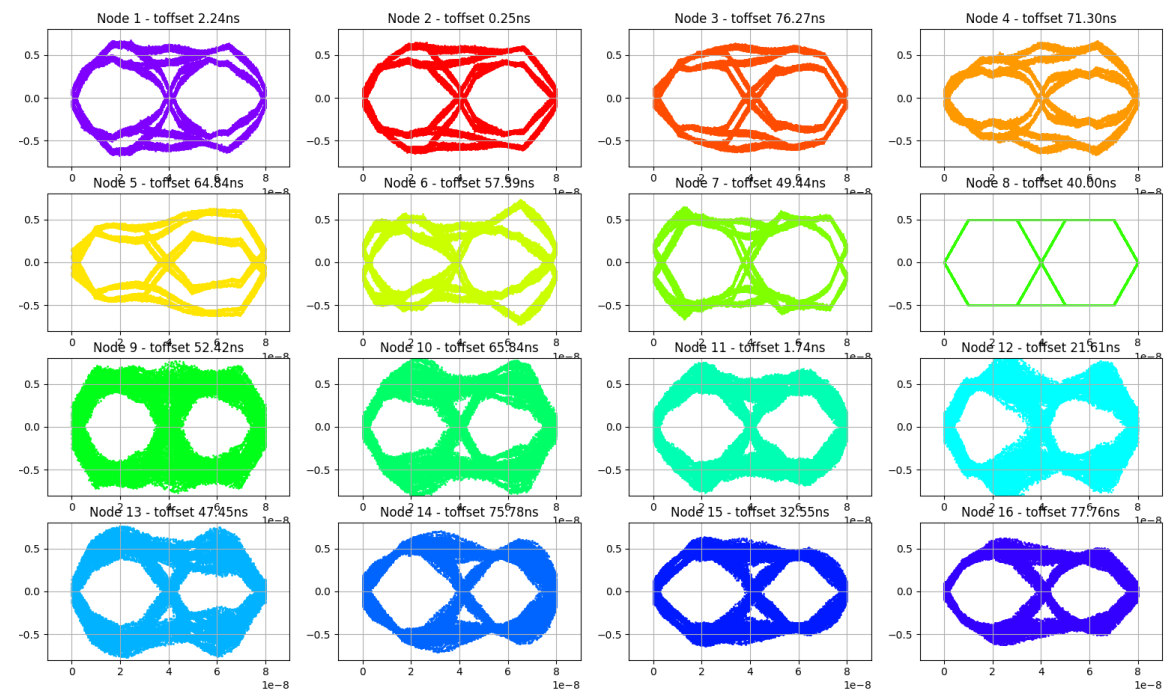
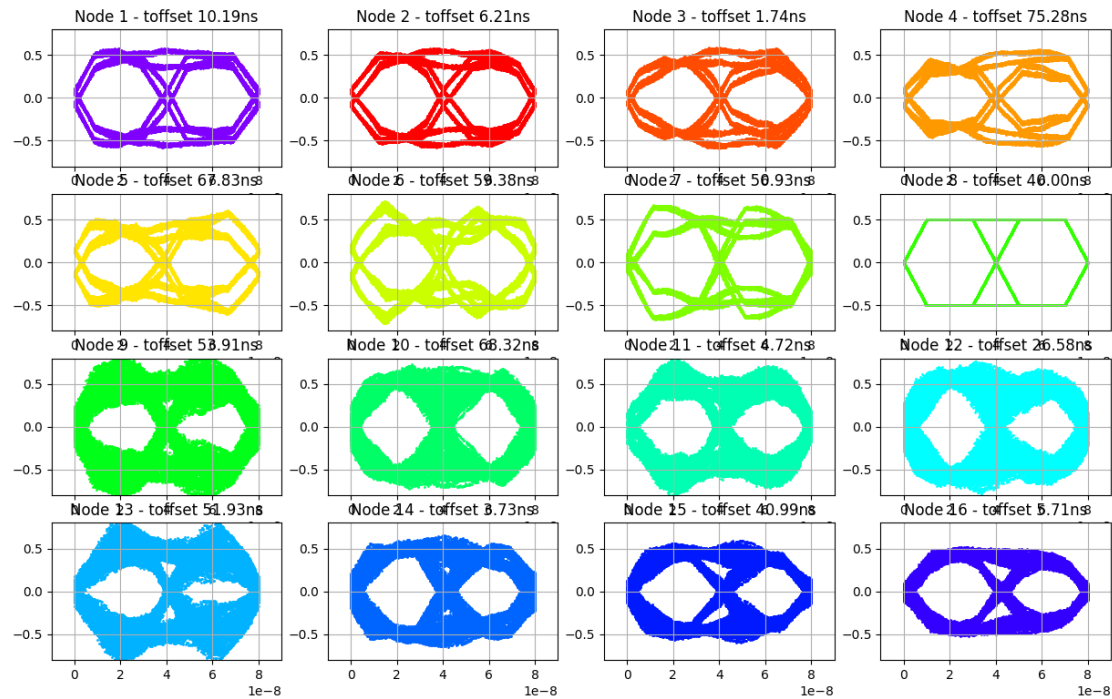
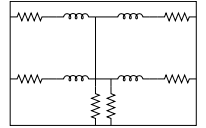
Without compensation inductors, TX Node 8



S-Parameter base cap. Tee



Ideal Tee

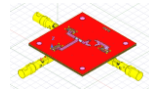


Appendix: Eye Diagram Comparison

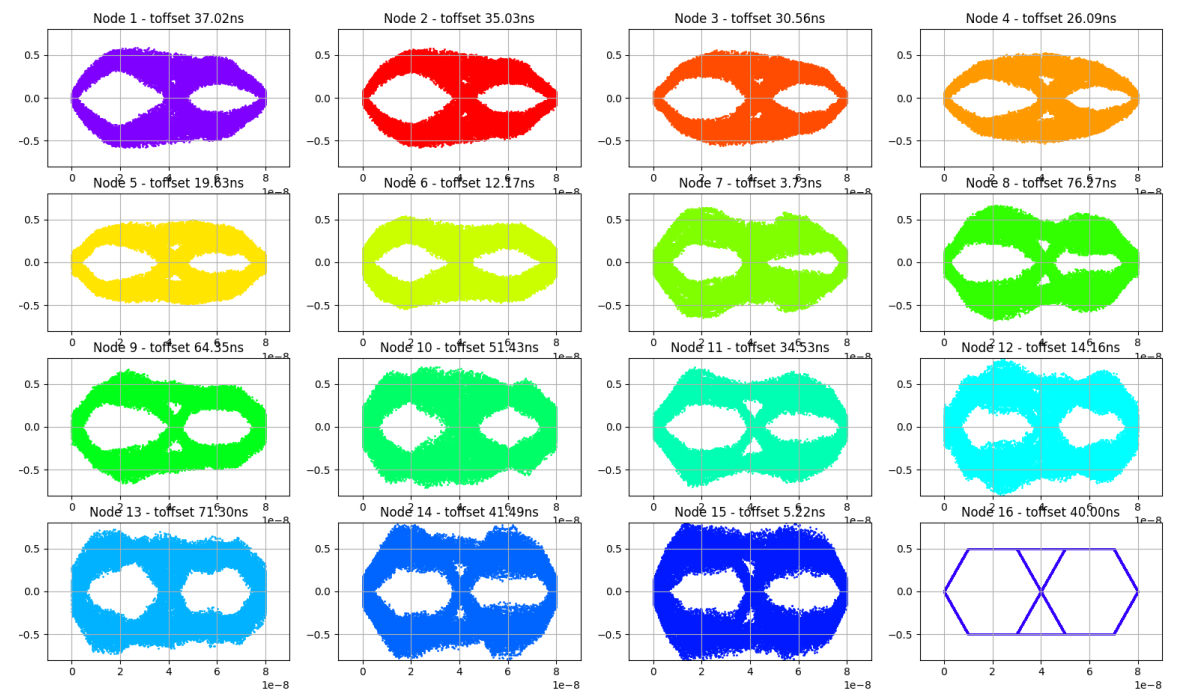
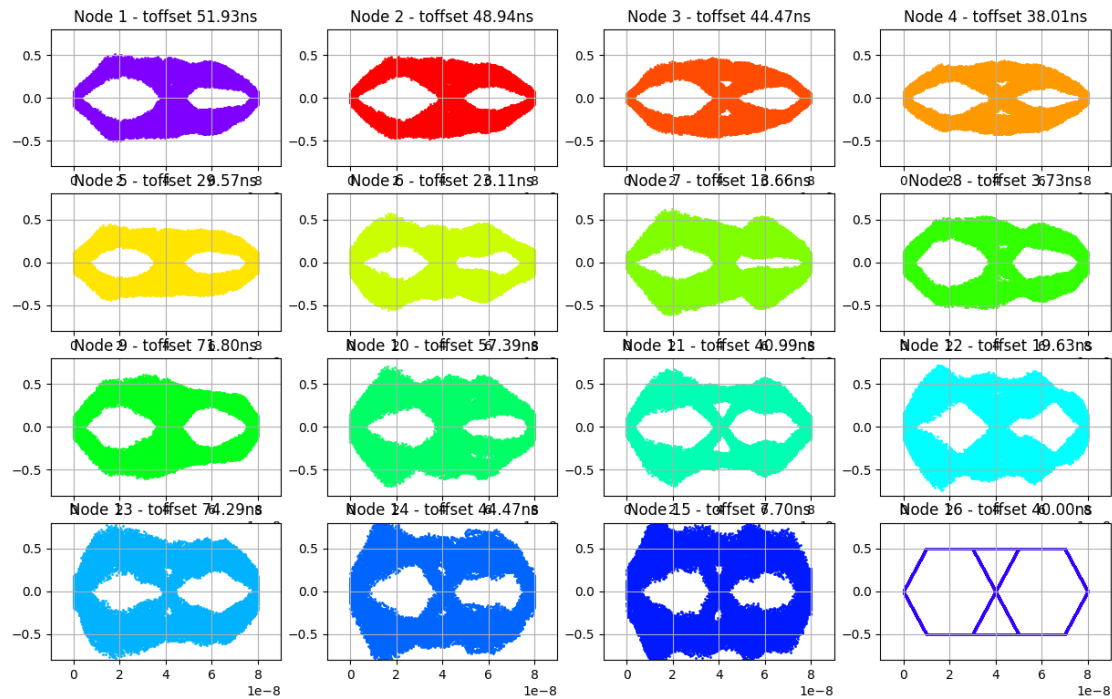
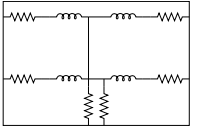
Without compensation inductors, TX Node 16



S-Parameter based Tee



Ideal Tee

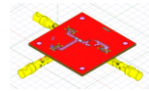


Appendix: Eye Diagram Comparison

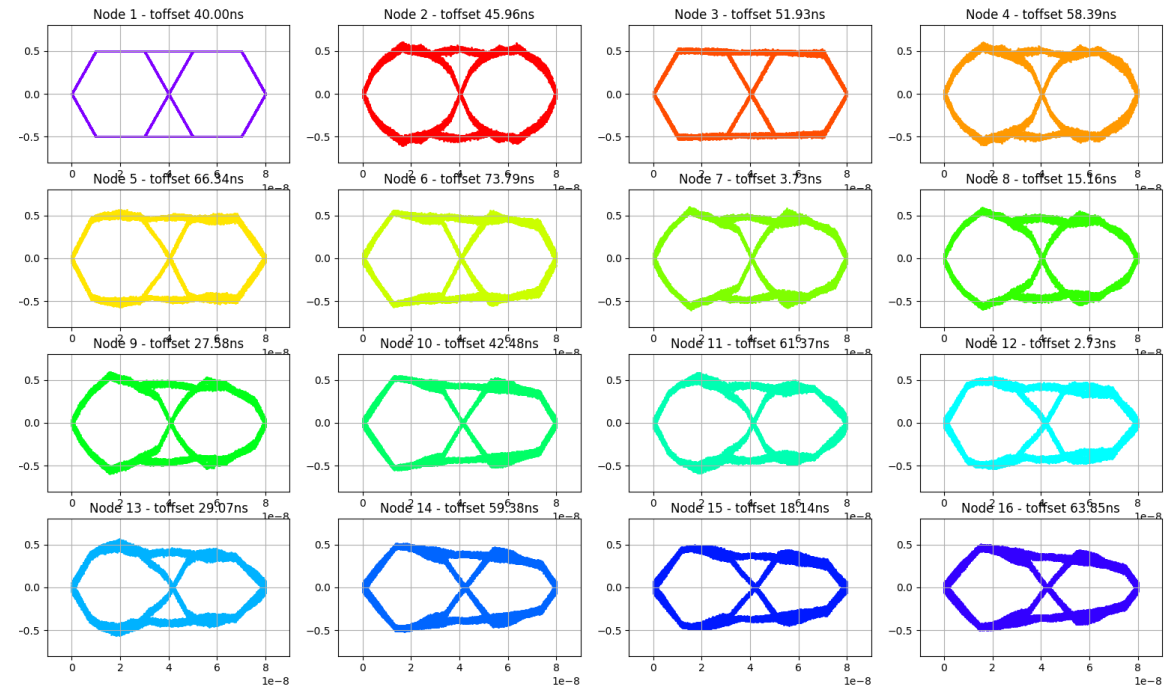
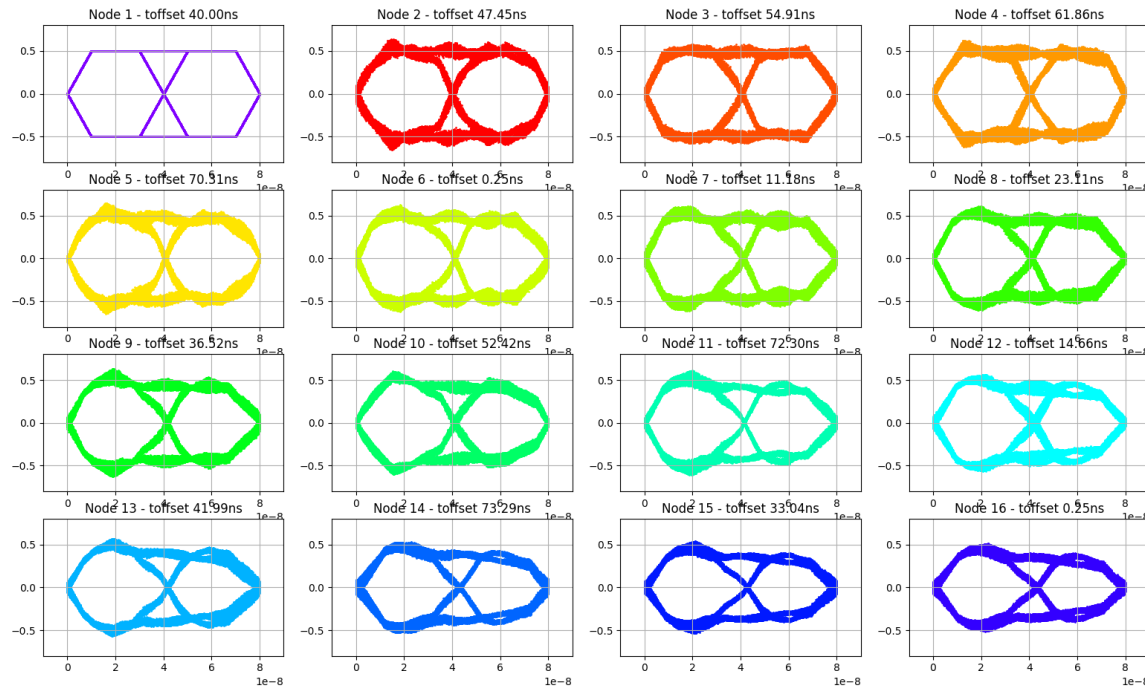
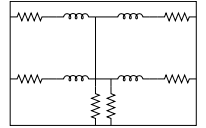
With compensation inductors, TX Node 1



S-Parameter based bad Tee



Ideal Tee

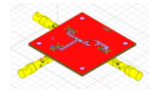


Appendix: Eye Diagram Comparison

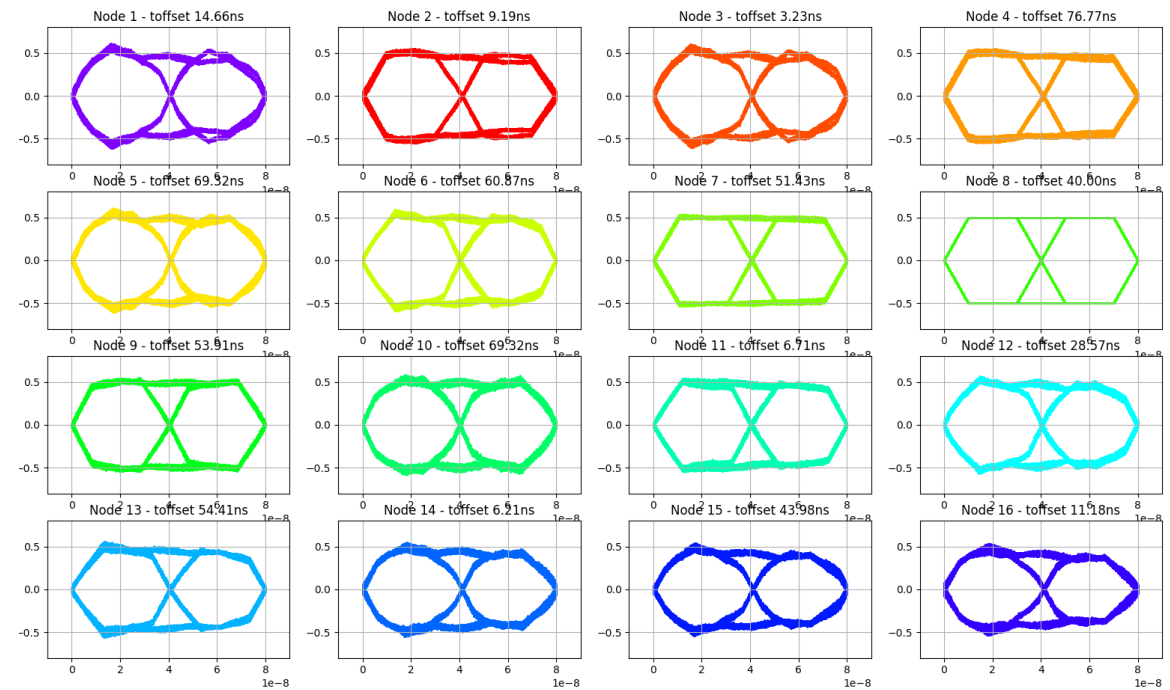
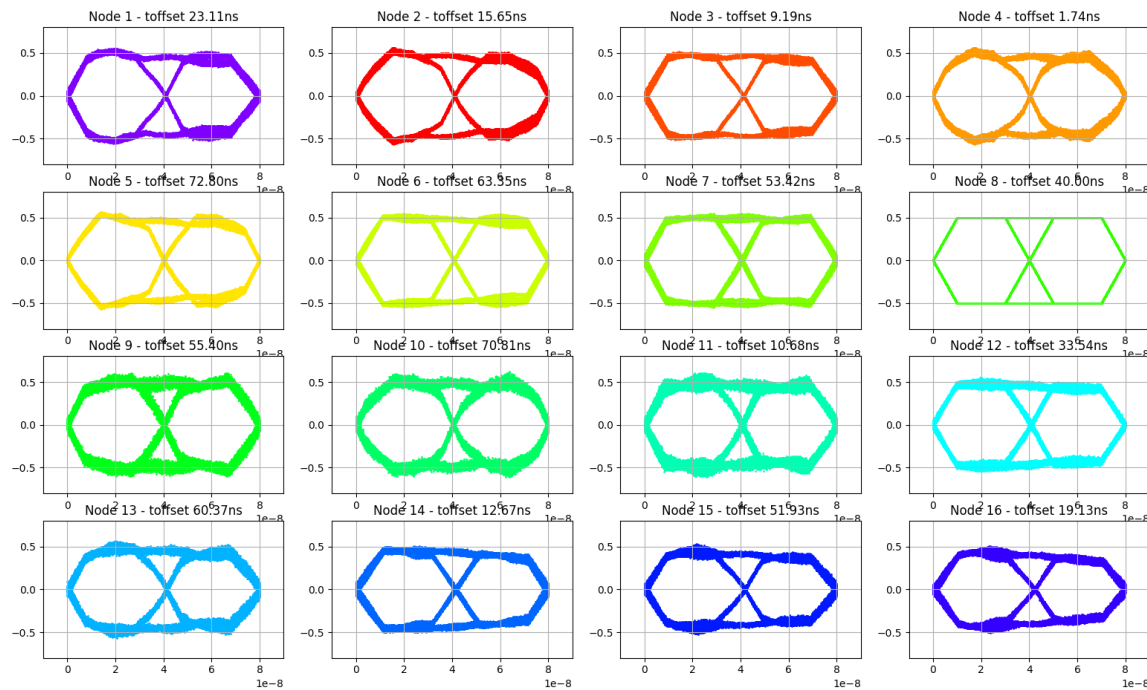
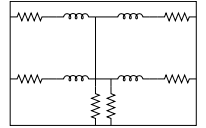
With compensation inductors, TX Node 8



S-Parameter based bad Tee



Ideal Tee

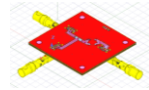


Appendix: Eye Diagram Comparison

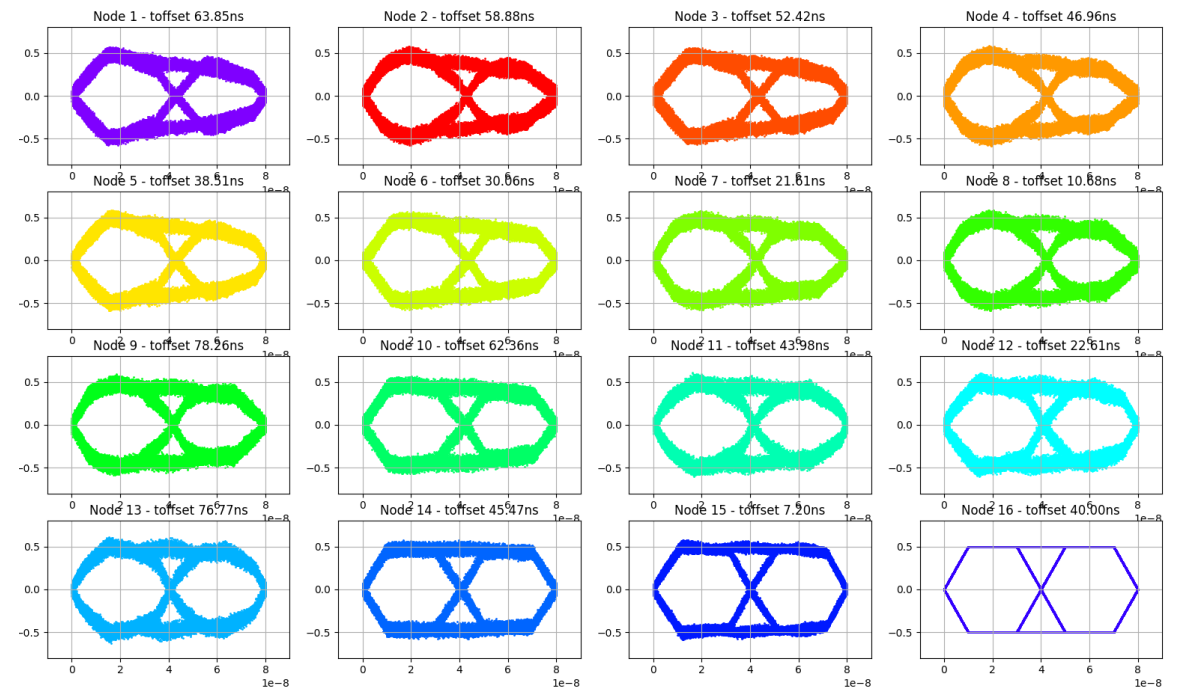
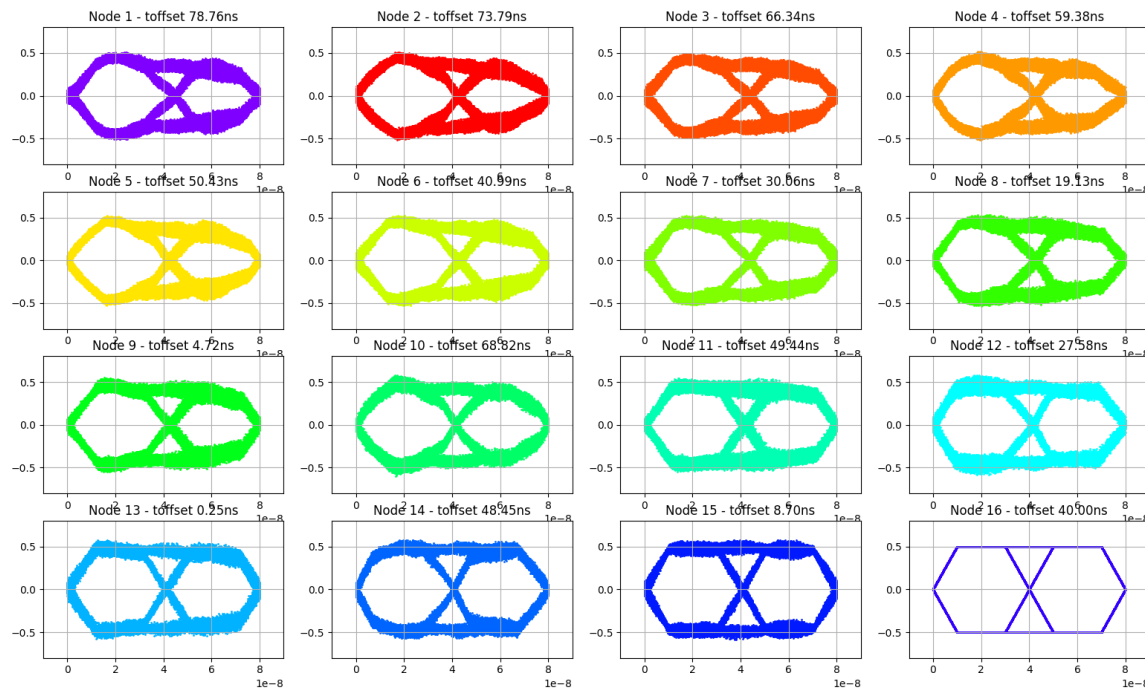
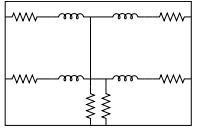
With compensation inductors, TX Node 16



S-Parameter based bad Tee



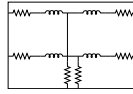
Ideal Tee



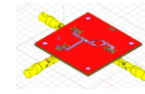
Appendix: Channel Simulation

Comparison with compensation Inductors

Ideal



Cap. Tee



Opt. Tee

