Multi-drop node distribution challenges

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Rockwell Automation

Multi-drop link node distribution challenges

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References

This presentation attempts to build upon:

- **[1] SPE Multidrop Enhancements Mixing Segment Considerations Update**

https://www.ieee802.org/3/da/public/111820/diminico_SPMD_01_1120.pdf

by Chris DiMinico, Bob Voss, and Paul Wachtel

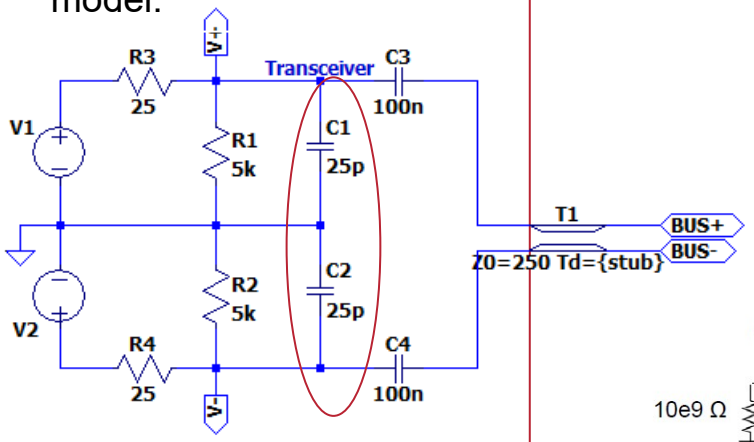
- previous related SPMD Mixing Segment Considerations from Chirs DiMinico

- 3cg presentations by David Brandt and Scott Griffiths:
  - **[2]** https://www.ieee802.org/3/cg/public/Sept2018/griffiths_3cg_01a_0918.pdf
  - **[3]** https://www.ieee802.org/3/cg/public/Mar2018/brandt_cg_01a_0318.pdf

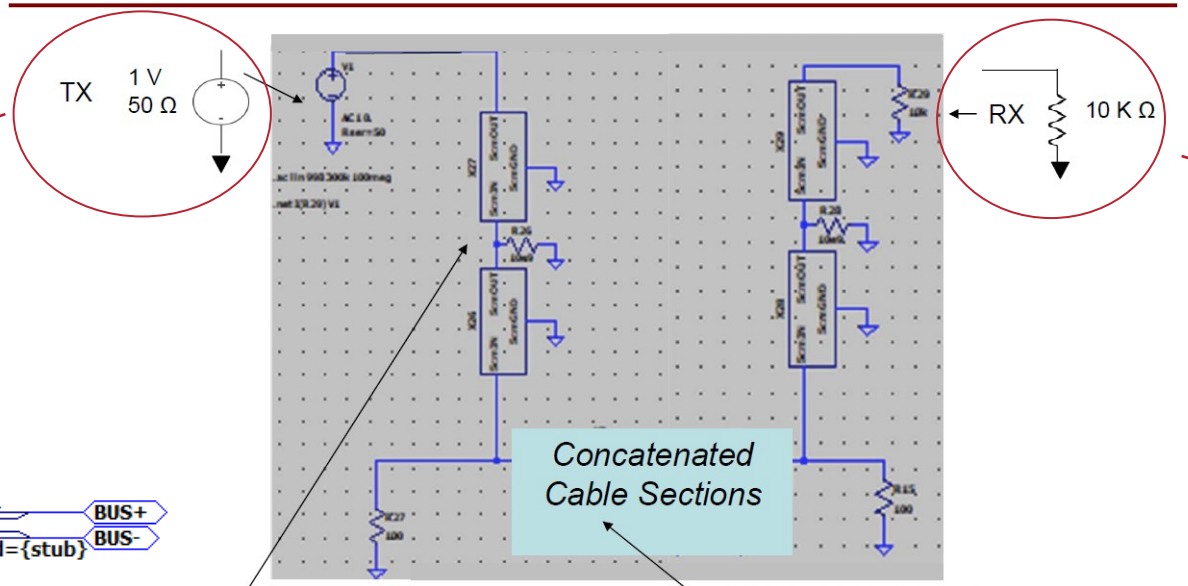
Kudos to all contributors for addressing this complex topic!

[1] Node model without PoDL – need to include MDI capacitance

Substituting with [2]/[3] model:



Source and Load without PoDL



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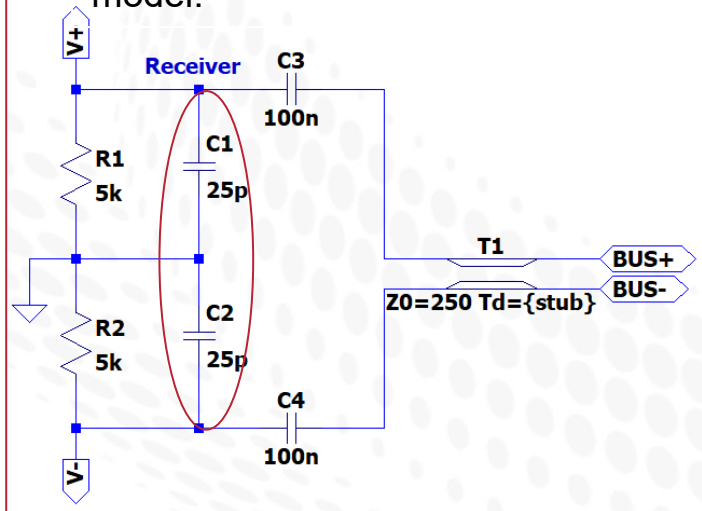
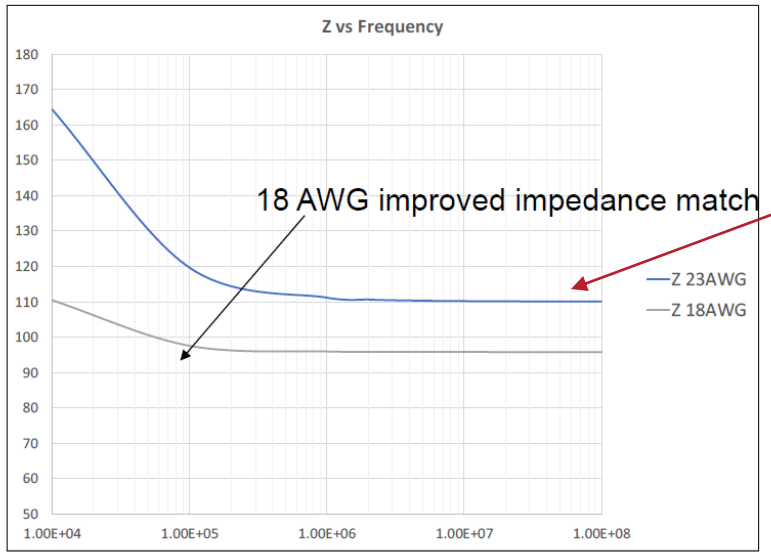
10 Mb/s SPMD Enhancement TG

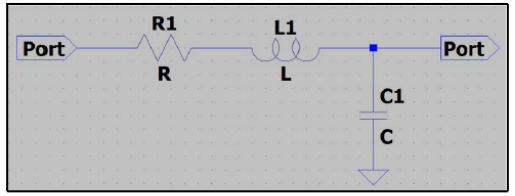
Substituting with [2]/[3] model:



[1] Cable impedance mismatch and workaround

RLCG Model – 23 AWG, 18 AWG



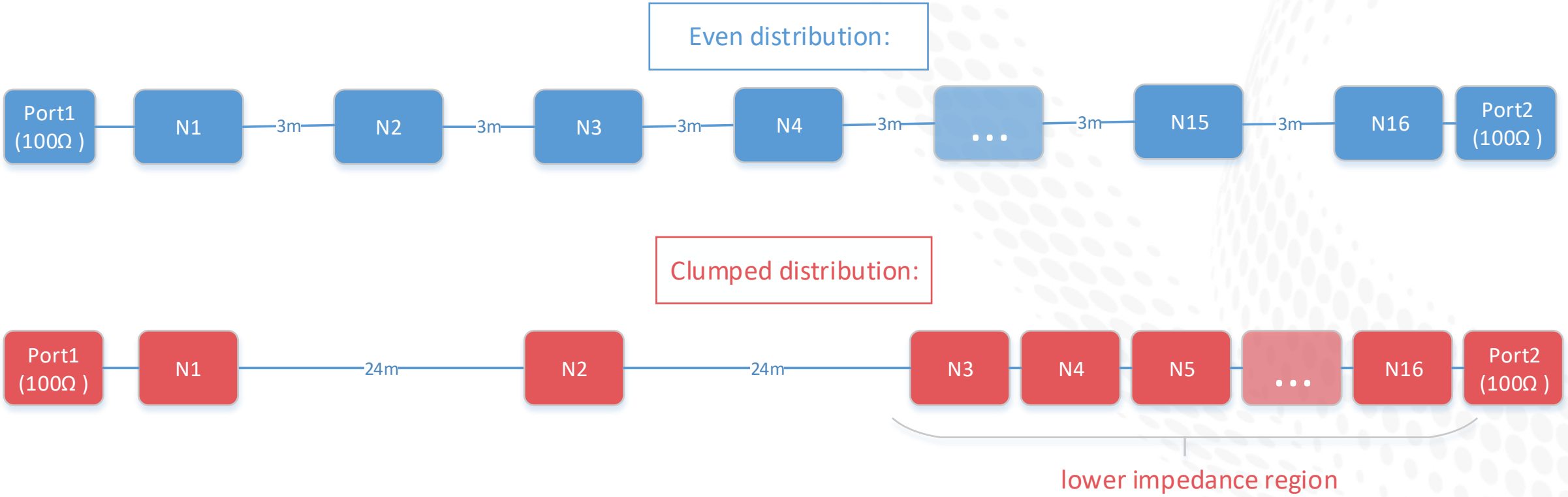


Dk of 23AWG can be altered to better match 100 Ω

Substituting with matched 100 Ω lossy transmission lines, as in [2]/[3] presentations
(imperfect, but allows to easily parametrize the length)


```
.model SPE_BUS LTRA(L={L_media} C={C_media} R={R_media} LEN=cable_length_m)
.param L_media={525n}   ; nH/m
.param C_media={52.5p}   ; pF/m
.param R_media={0.188}   ; ohm/m
```

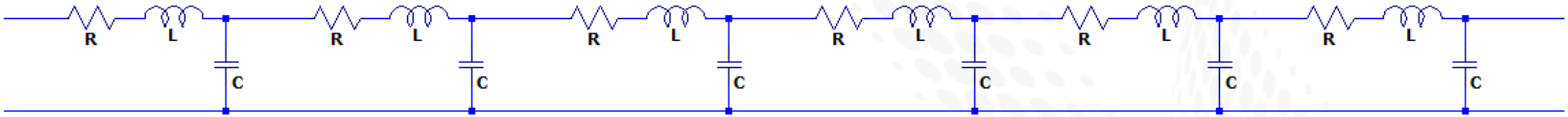
Main node distribution topologies in two-port simulation



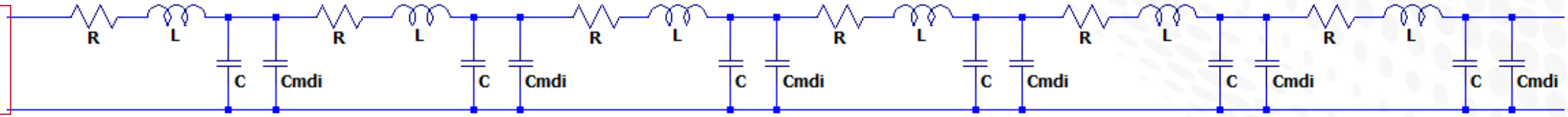
Impedance drop in clumped nodes regions

Cable model

$$Z_0 \cong \sqrt{\frac{L}{C}} = 100\ \Omega$$



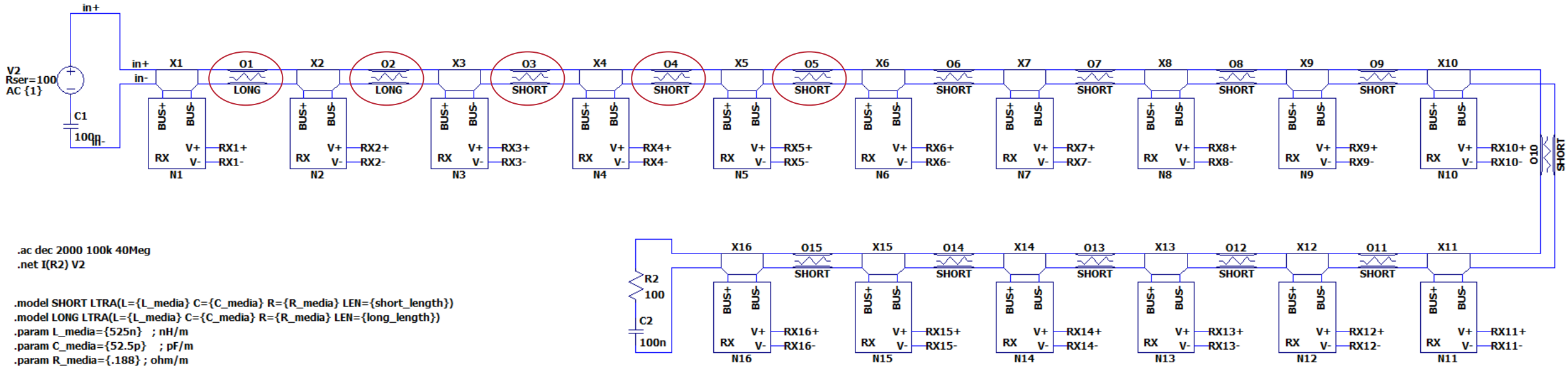
Cable with clumped drop nodes model



$$Z_0 \cong \sqrt{\frac{L}{C+CMDI}} \ll 100\ \Omega \text{ (e.g. 45–60}\Omega\text{)}$$

Node distributions comparison – SPICE .AC simulation setup

To make IL < 3dB possible in multidrop, SPE bus needs to be driven directly.
Replacing left terminator with source impedance (100R).



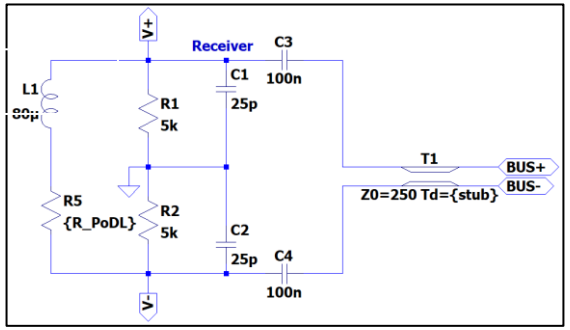

```
.ac dec 2000 100k 40Meg
.net I(R2) V2


.model SHORT LTRA(L={L_media} C={C_media} R={R_media} LEN={short_length})
.model LONG LTRA(L={L_media} C={C_media} R={R_media} LEN={long_length})
.param L_media={525n}   ; nH/m
.param C_media={52.5p}    ; pF/m
.param R_media={.188} ; ohm/m
.param stub_length=0.1
.param stub={{stub_length}*{sqrt(L_media*C_media)}}
```

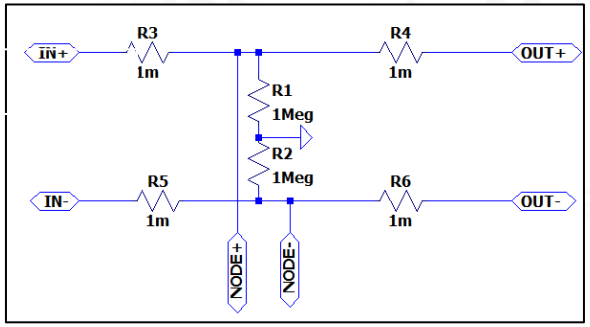
parametrizing by Rswitch: even spacing (0.1m), even spacing with PoDL (0.5m), clumped spacing (2m), clumped spacing with PoDL(2.2m)

```
.step param Rswitch list 0.1m 0.5m 2m 2.2m
.param short_length={if(Rswitch>1m,0.045,3)}
.param long_length {if(Rswitch>1m,24,short_length)}
.param R_PoDL={if((Rswitch > 0.4m & Rswitch <1m)|(Rswitch > 2.1m & Rswitch <2.5m), 1m, 1Meg)}
```

nodes:

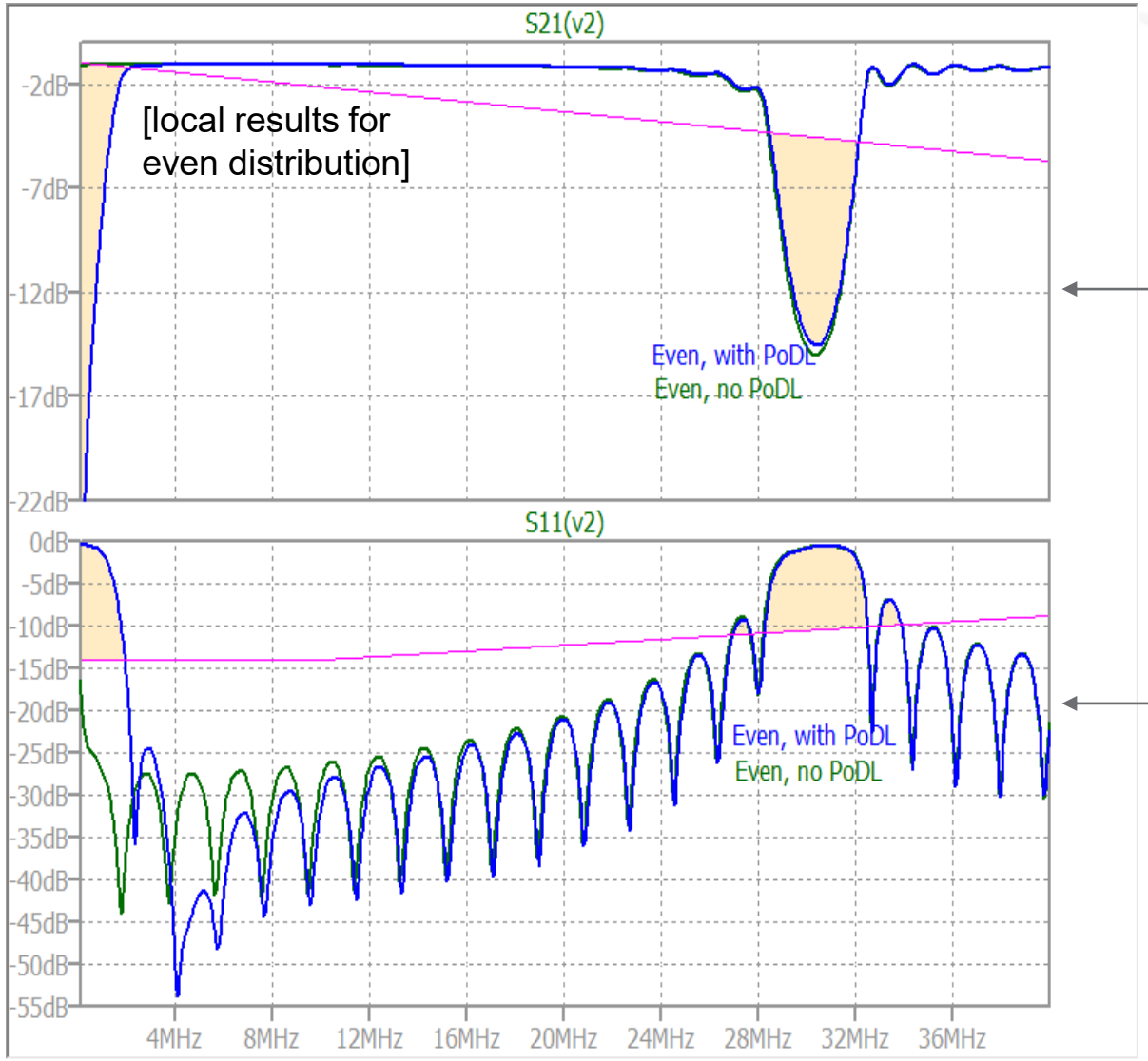


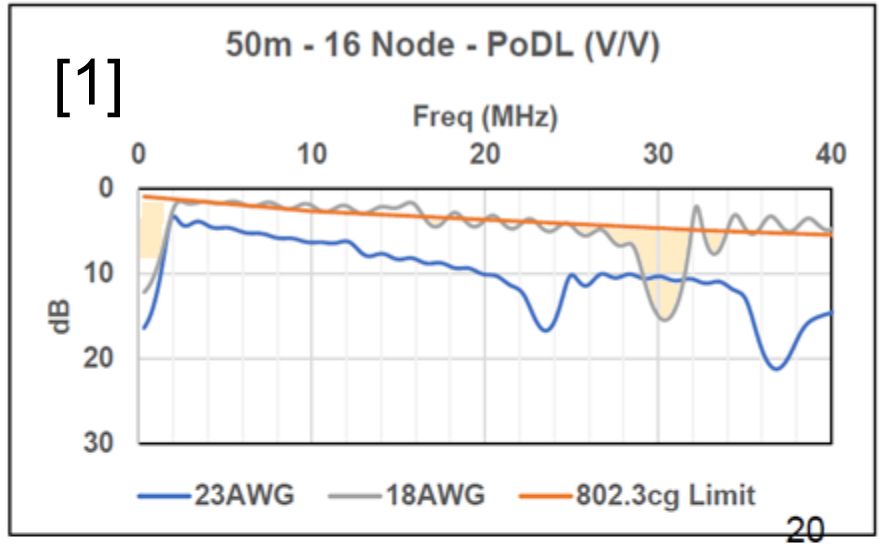
connectors:



Even distribution vs. results reported in presentation [1] :

Main problem points **do overlap**. Differences are likely due to simplified cable model, and slightly different node spacing than in [1]





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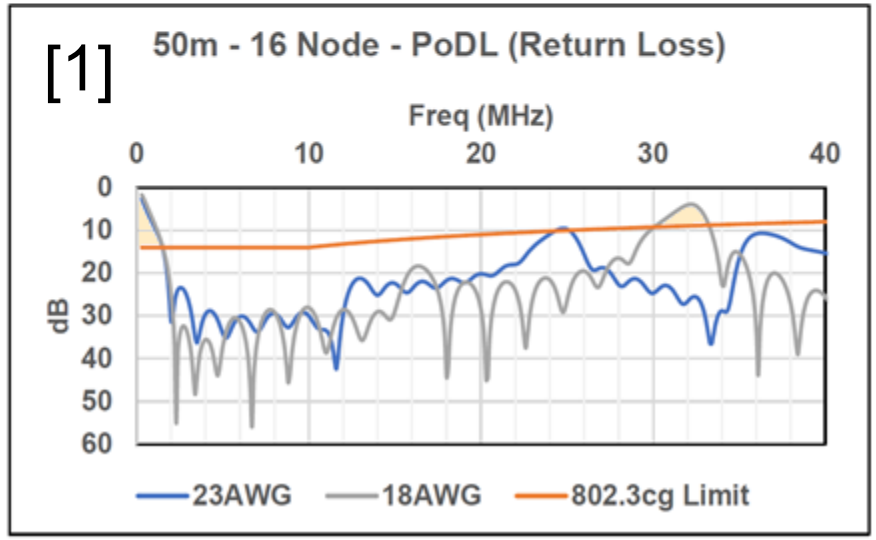
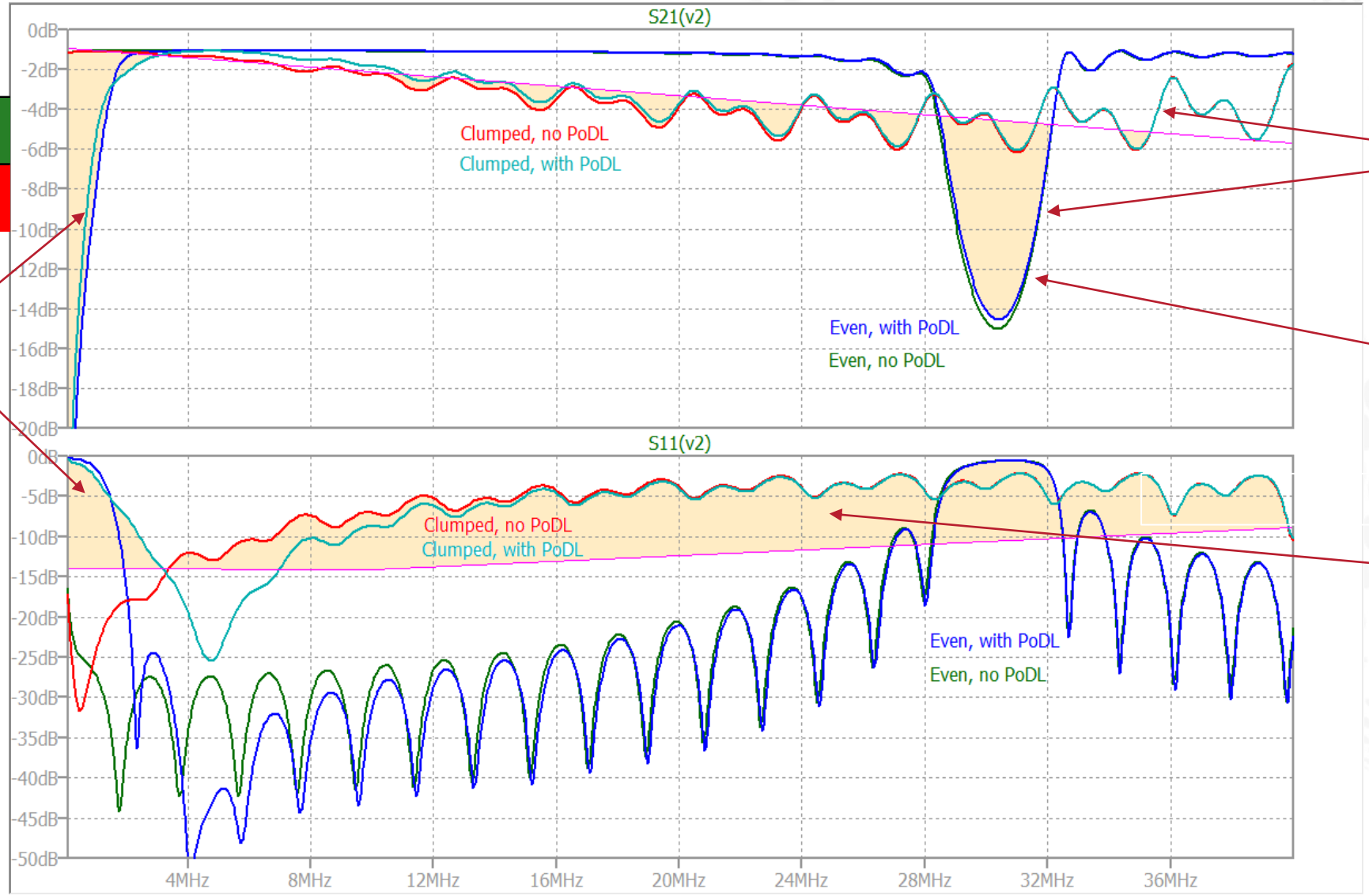


Even vs. clumped distribution, PoDL influence

	with PoDL	without PoDL
Even distribution	blue	green
Clumped distribution	cyan	red



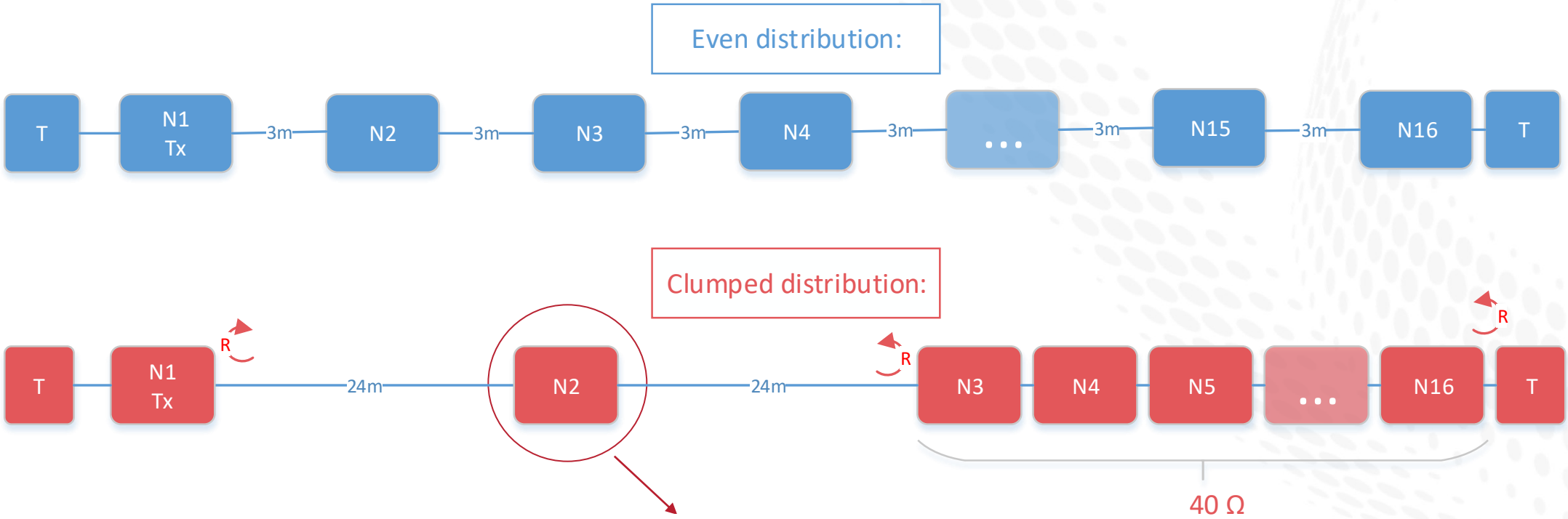
PoDL penalty in low frequencies

PoDL makes little to no difference for higher frequencies

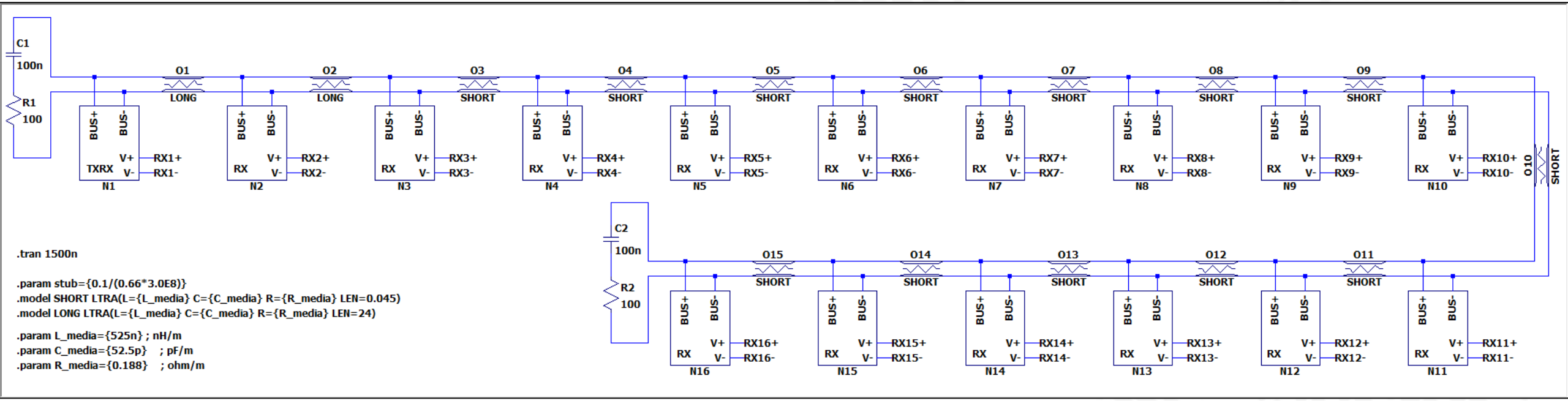
IL dip comes from even distribution of node capacitance

Serious RL problem with clumped distribution

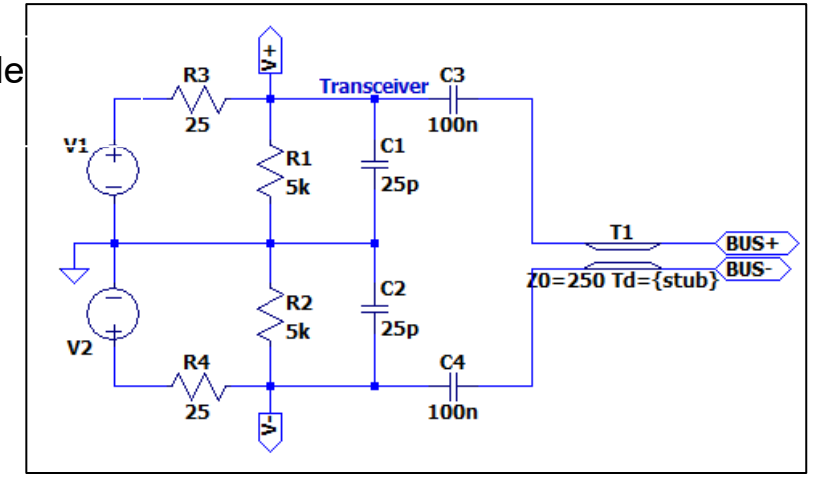
Node distribution – time domain simulation



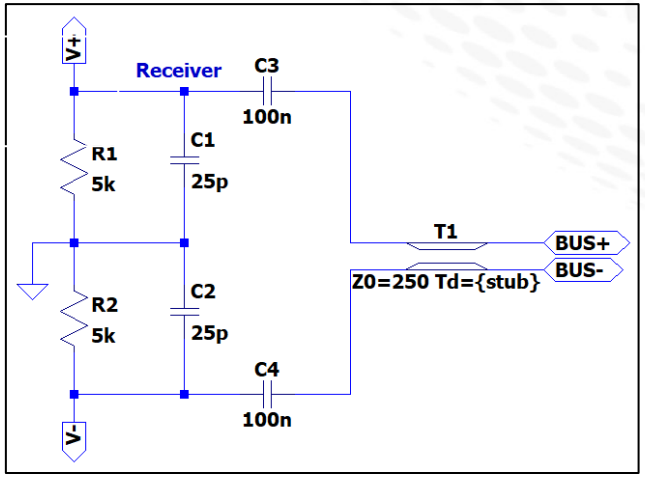
Node distribution – time domain simulation setup (as in [2]/[3])



Tx node N1:

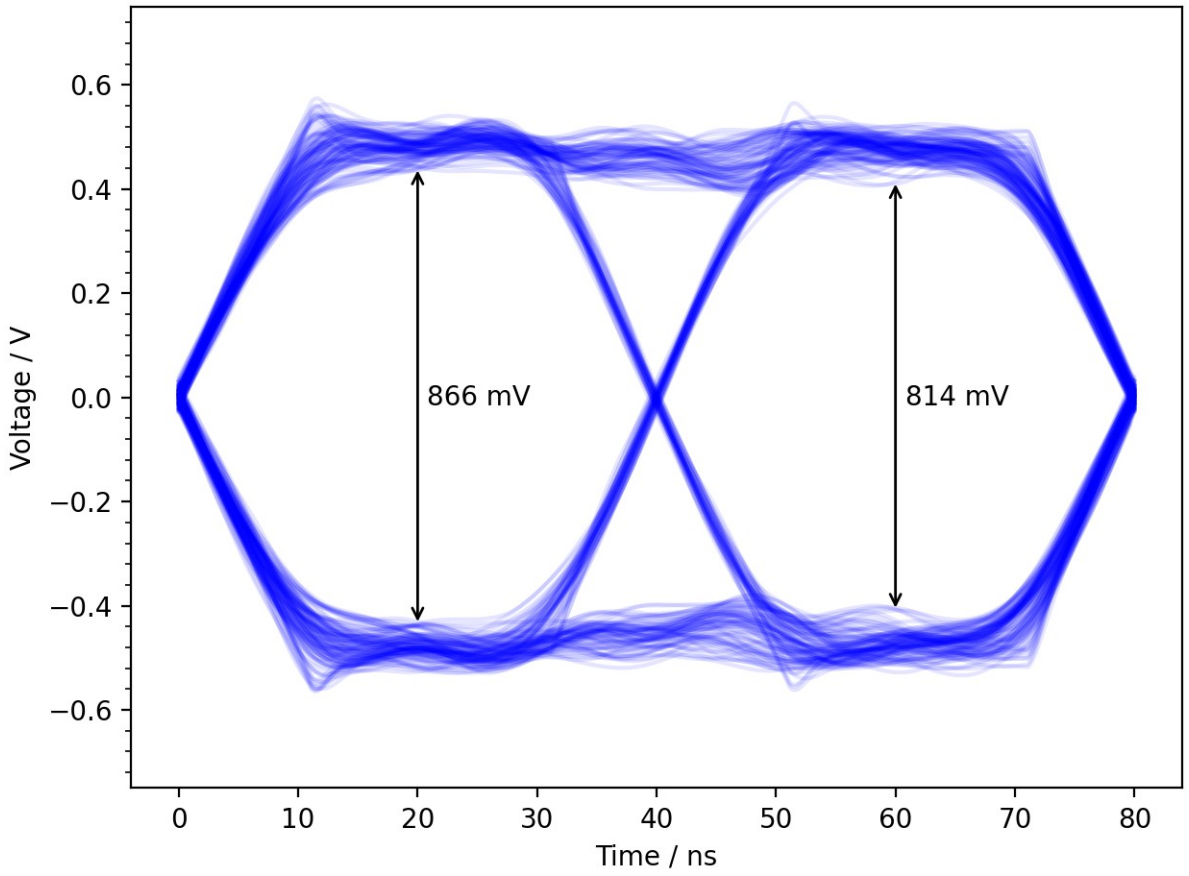


Rx nodes N2 to N16:

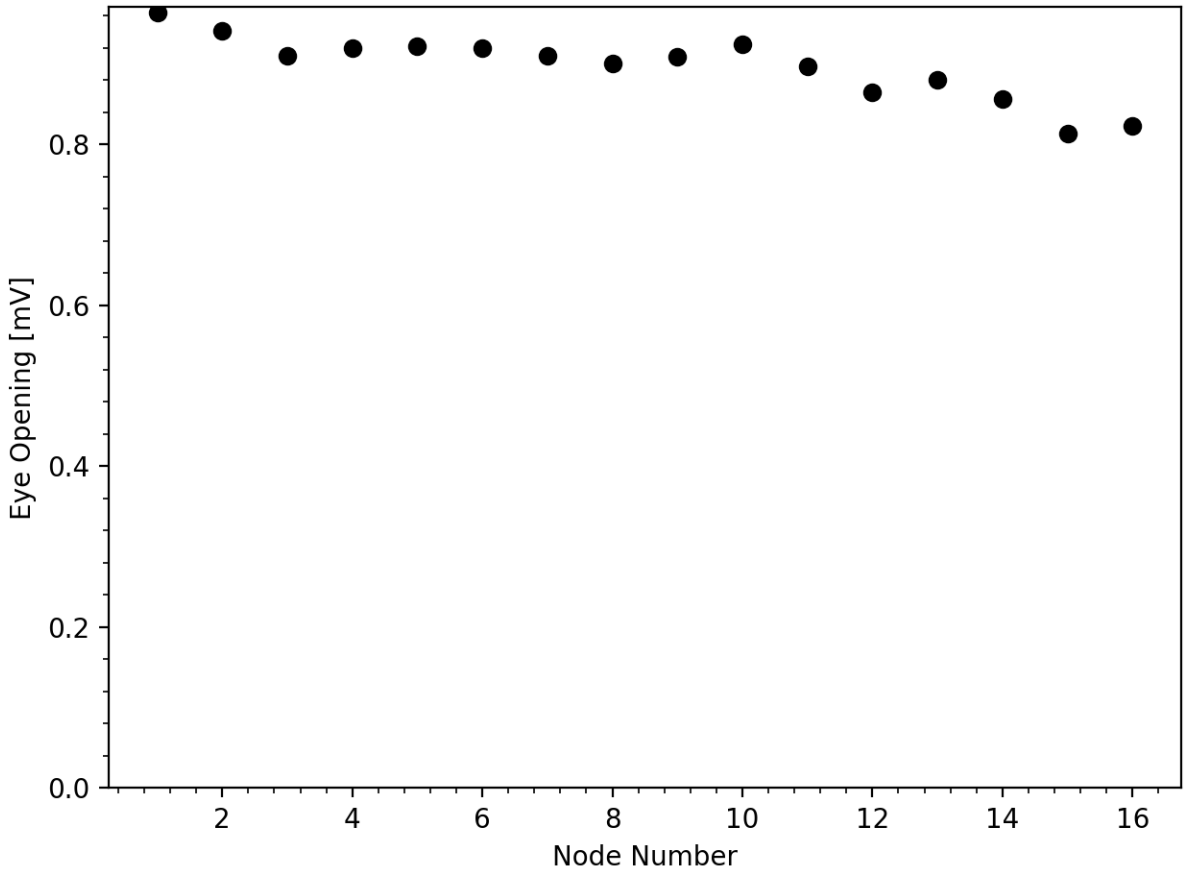


Time domain simulation: even distribution (3m spacing)

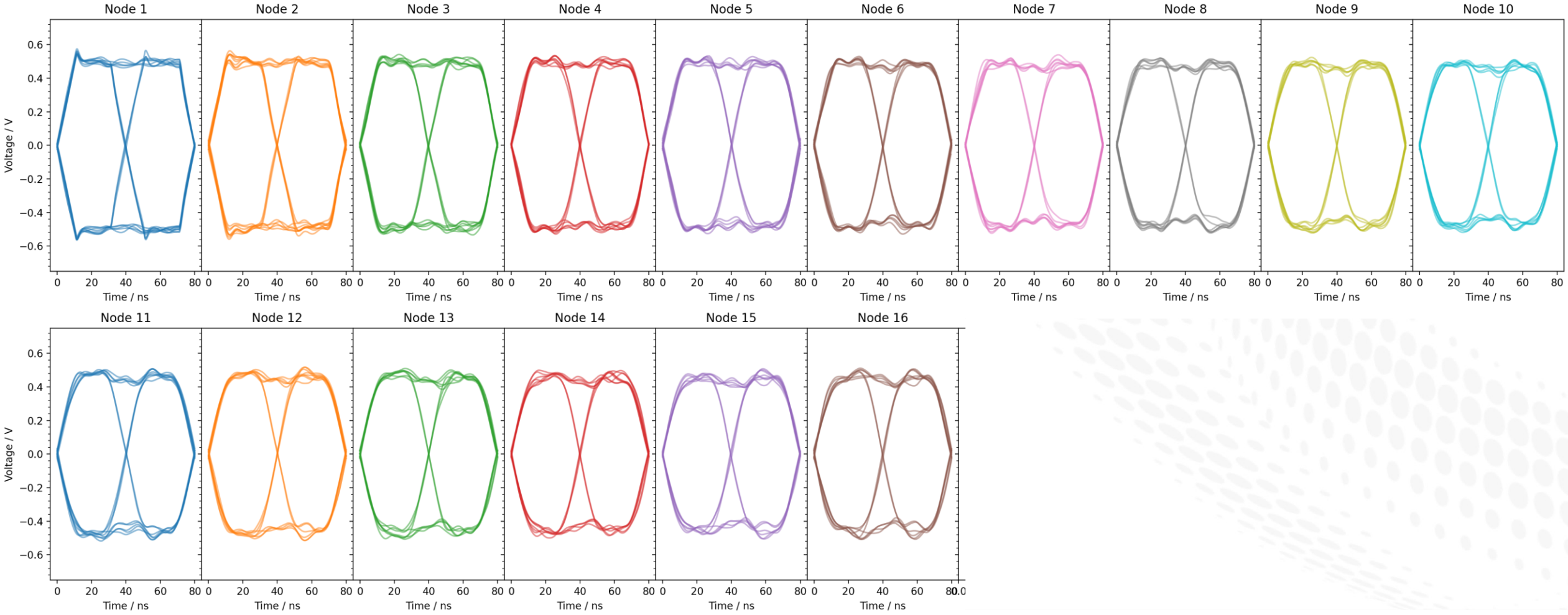
Combined eye diagram for 16 nodes:



Eye opening for each node:

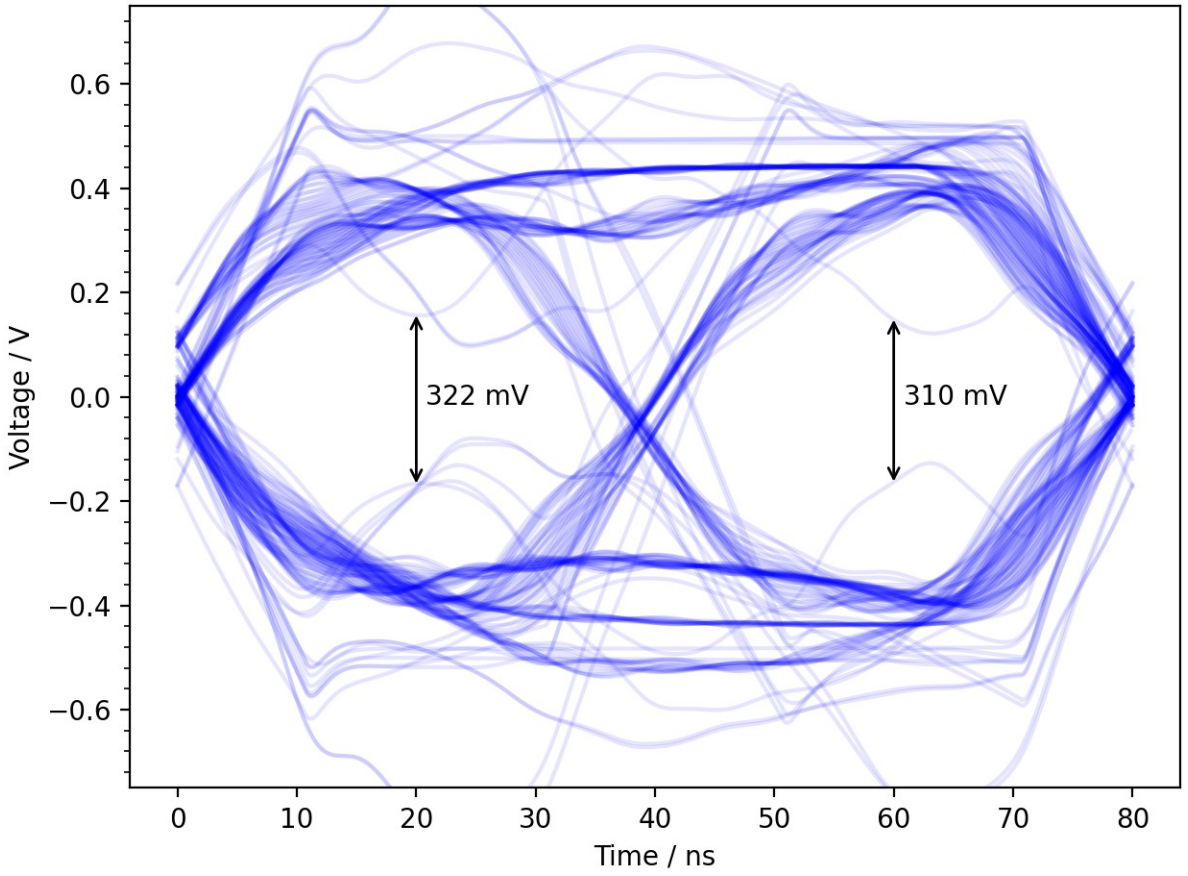


Time domain simulation: even distribution (3m spacing)

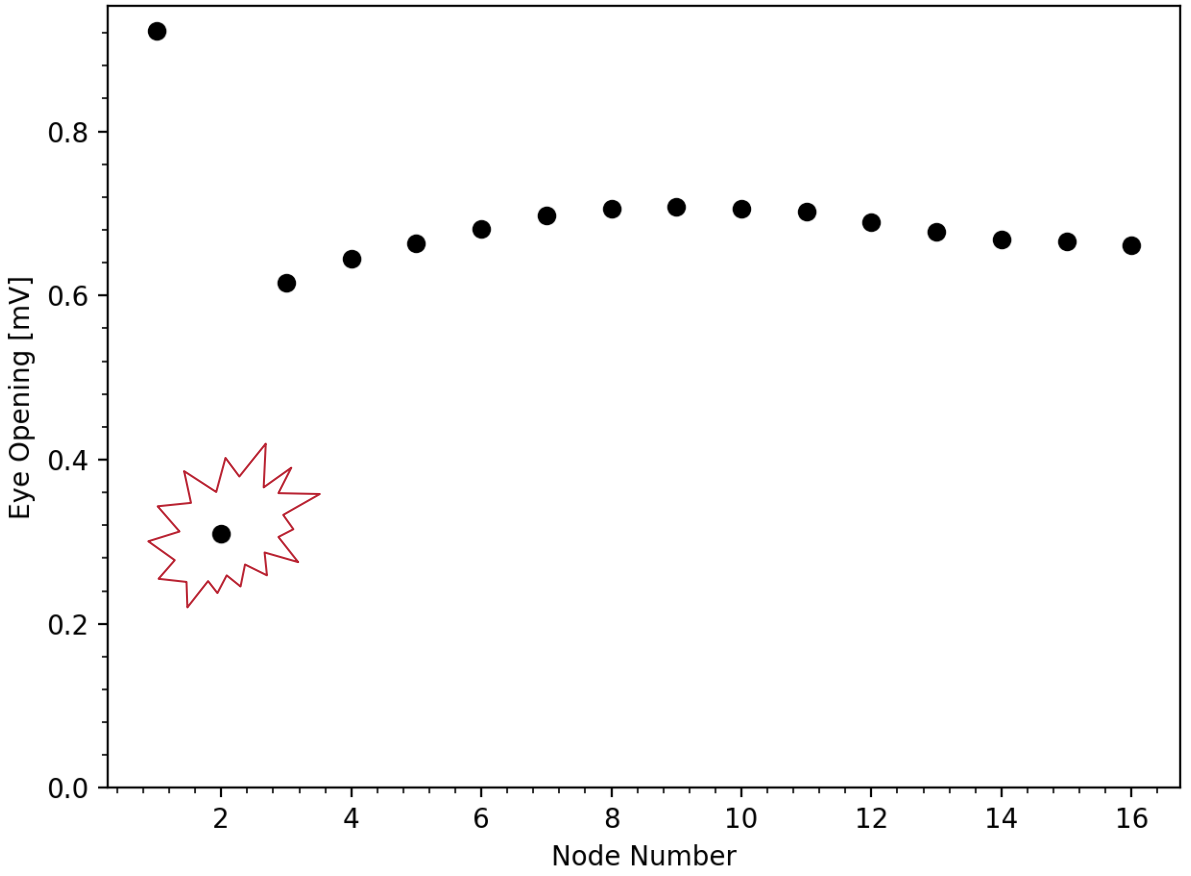


Time domain simulation: clumped distribution

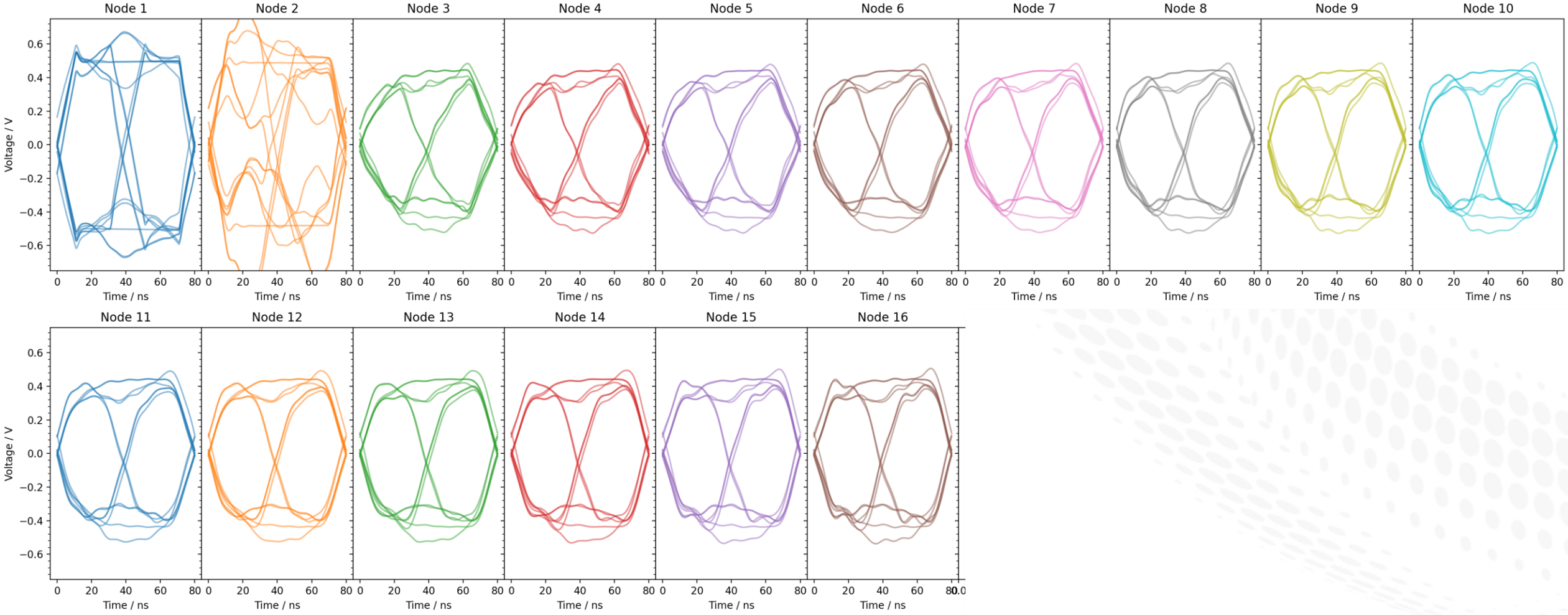
Combined eye diagram for 16 nodes:



Eye opening for each node:



Time domain simulation: clumped distribution



Takeaways:

- Node capacitance is detrimental to multi-drop link Signal Integrity
- PoDL does affect the link, but mainly under 3MHz
- Clumped node distribution creates significant signal degradation by lowering the impedance
- Link parameters can be worse for ‚inner nodes', than for ‚outer nodes' on a multi-drop link
- The worst-case multi-drop node topology may not have yet been discovered
    - Monte Carlo topology simulations estimated (outside organization) to take over 35 years (1s per simulation)
    - theoretical solution needs to be discovered

Thank you

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