10BaseT1S / Mixed Segment Evaluation

A Leading Provider of Smart, Connected and Secure Embedded Solutions

Galin Ivanov
May 23, 2022

Agenda

- Postulations/assumptions
- 10Base-T1S system – SNR model
- Stressed vs Unstressed system
- System Inherent noise composition
- Mixed segment contribution
- How to specify Mixed Segment

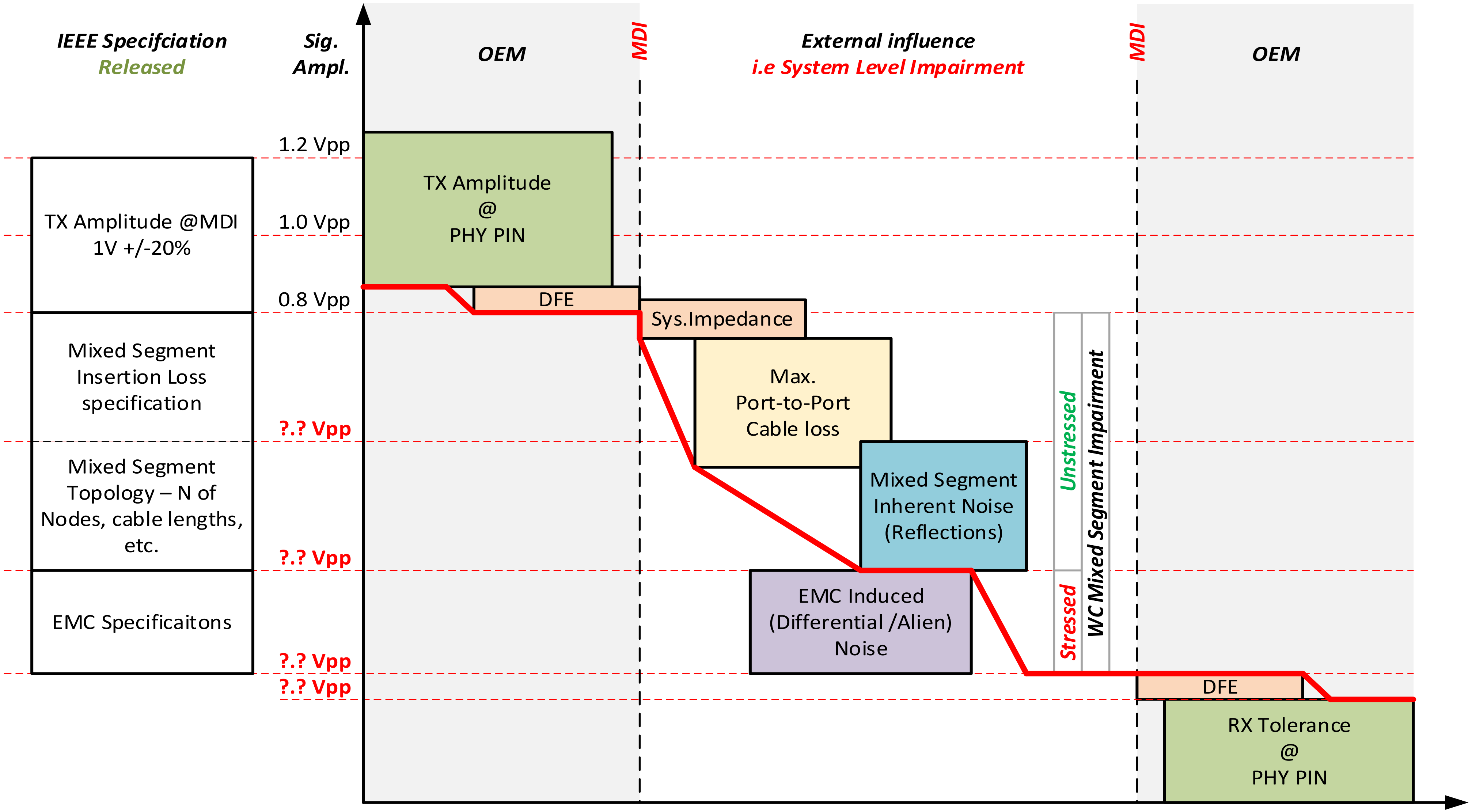
Postulations/assumptions

https://en.wikipedia.org/wiki/A_Mathematical_Theory_of_Communication

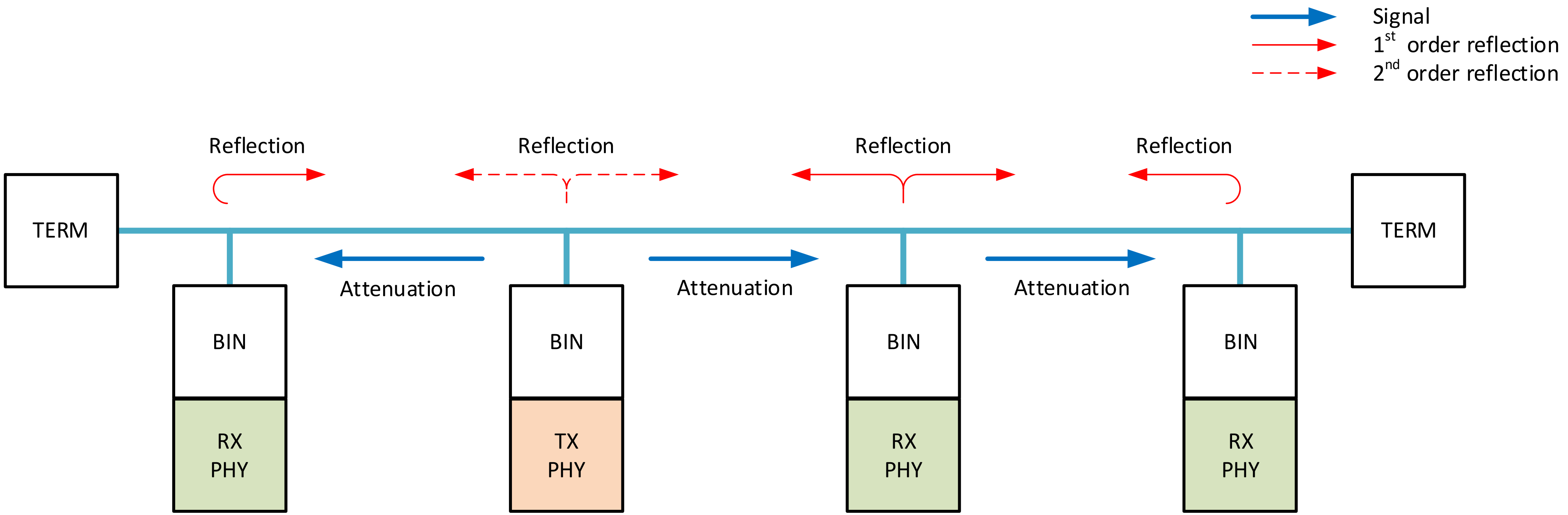
- **Data transmission quality criteria**
  - SNR
    - Signal Amplitude (attenuation)
    - Noise Amplitude (correlated/reflections, uncorrelated/alien)
    - Jitter (synchronization, clock recovery)
  - Dynamic range (CM vs DM Noise)

- **Mixed-Segment purpose**
  - Interconnect multiple devices
  - Bus topology (100 Ohm, balanced, end terminated)

10Base-T1S System – SNR Model

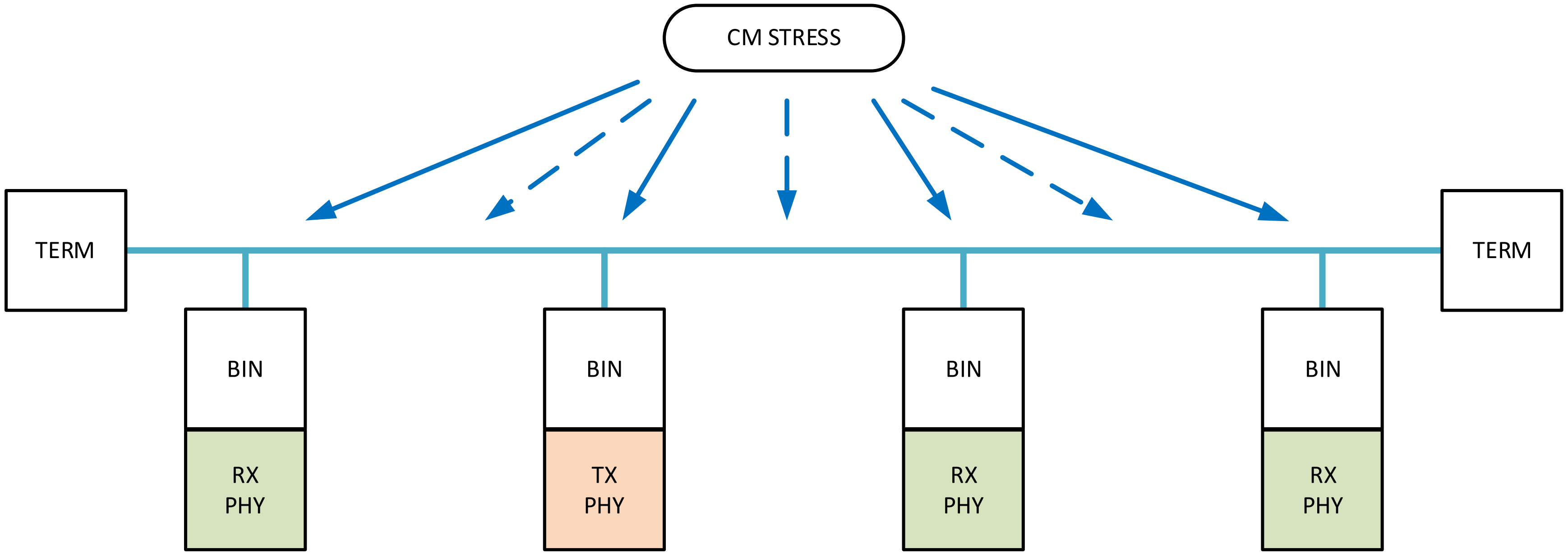


10SPE Signal quality – Unstressed system



- **Signal quality at (any) receiver is a function of signal attenuation and reflections**
- **Depends on topology and components quality (launch/TX signal, attenuation, impedances, etc.)**
- **Can easily be assessed based on simulations/lab measurements**

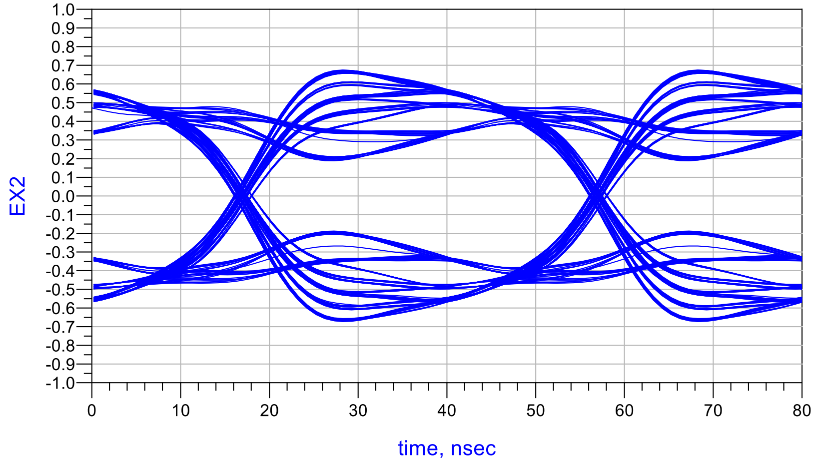
10SPE Signal quality – EMC Stressed system



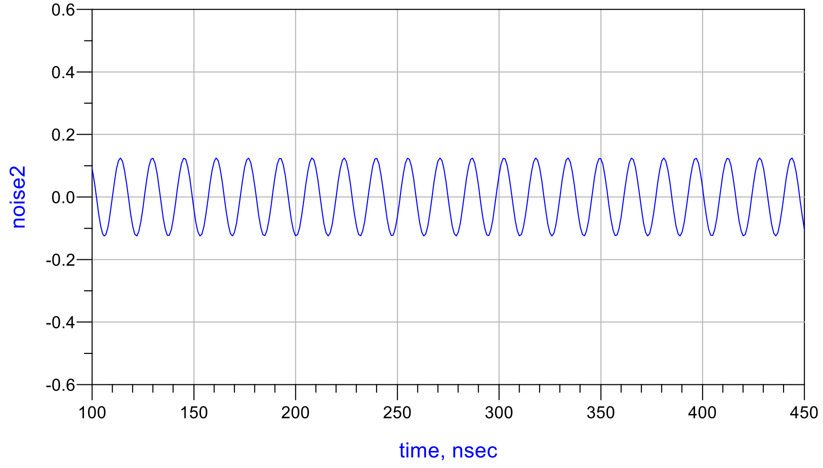
- <u>Every</u> component in the system is (or at least can be) exposed to CM stress
- Every real component in a balanced system has <u>imperfections</u> -> Mode conversion
- Every component in the CM stressed system contributes to adding differential noise!
- Noise at every transceiver is a function of CM stress levels and system components parameters (mostly TCL, LCTL) and a small portion of direct DM noise coupling (crosstalk)
- Both Signal and Noise define the signal quality each PHY transceiver needs to tolerate

Signal quality at PHY receiver pins

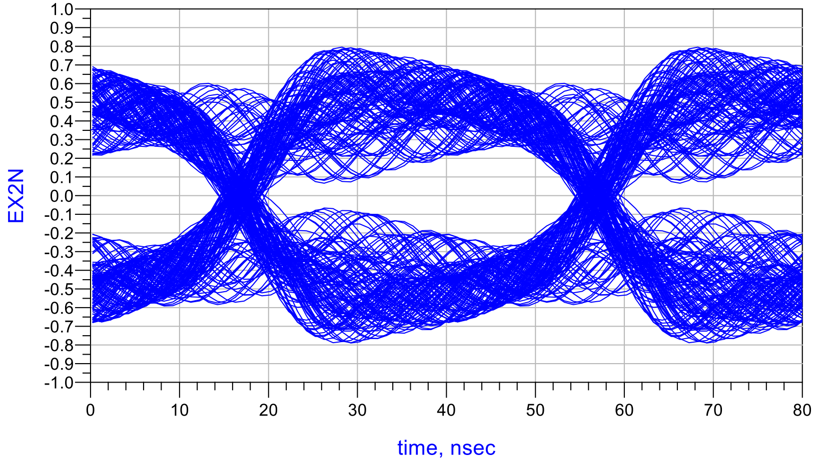
Signal (unstressed system)



(Alien) Noise



Signal + Noise (at PHY pins)



Note: within certain limits (dynamic range) CM induced noise does not affect/interact with (unstressed-system) signal quality!

MICROCHIP

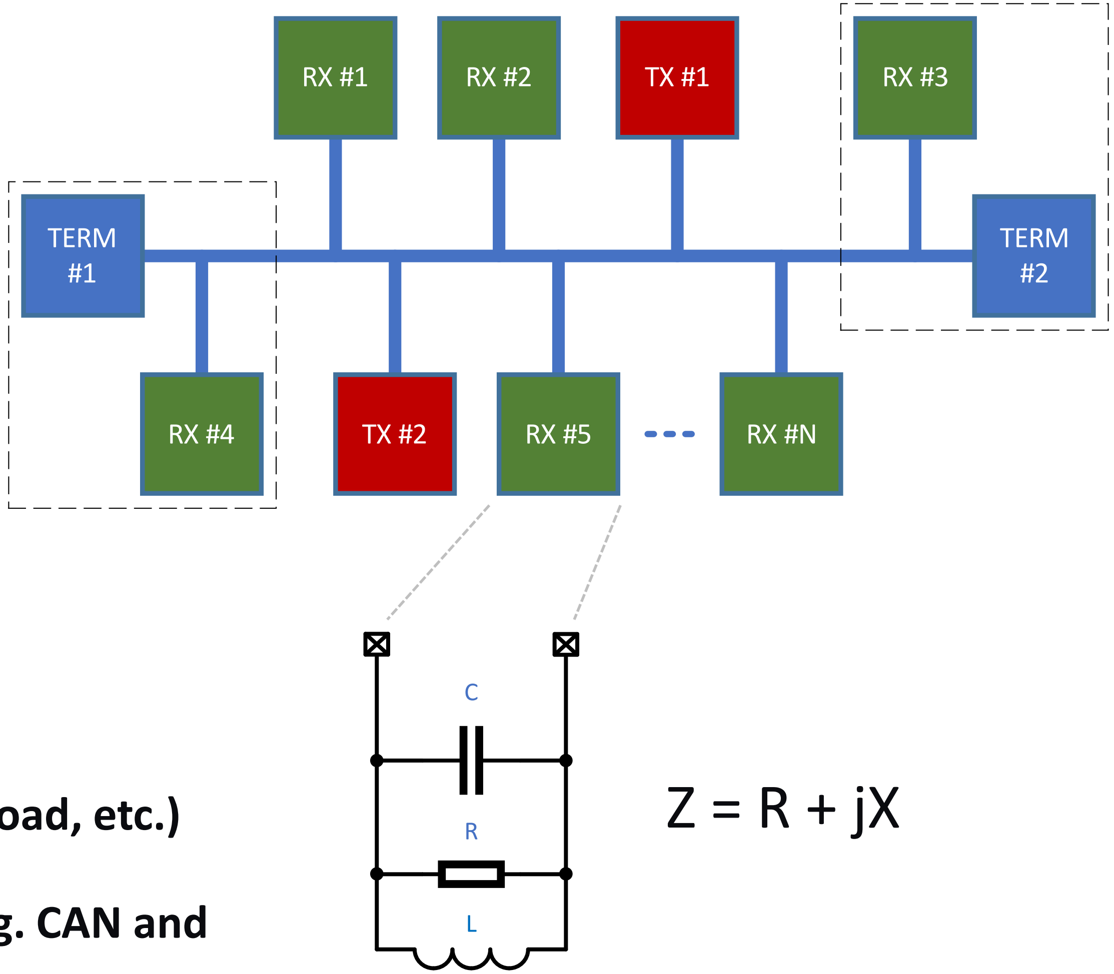
System Inherent Noise - Components

- **Cable segments impedance variation**
  - Number of segments
  - Max deviation of segment impedance

- **Stub length/impedance**

- **(Drop/passive) node load/impedance**
  - Resistive component contribution
  - Capacitive component contribution
  - Inductive component contribution

- **Noise components aggregation**



Note:

- **Contributing components reviewed stand alone only (e.g. damping losses not considered, capacitance as bulk load, etc.)**

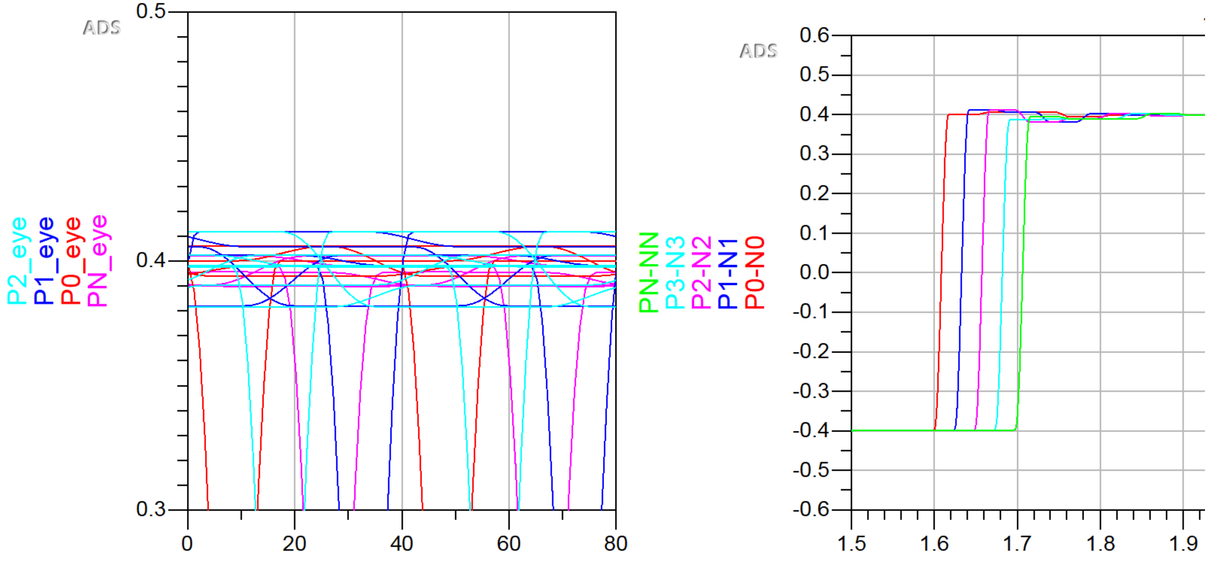
- **Effects valid for all networks using multidrop topology (e.g. CAN and derivatives)**

Cable Segments Impedance Variation

For assessment of maximal noise contribution:

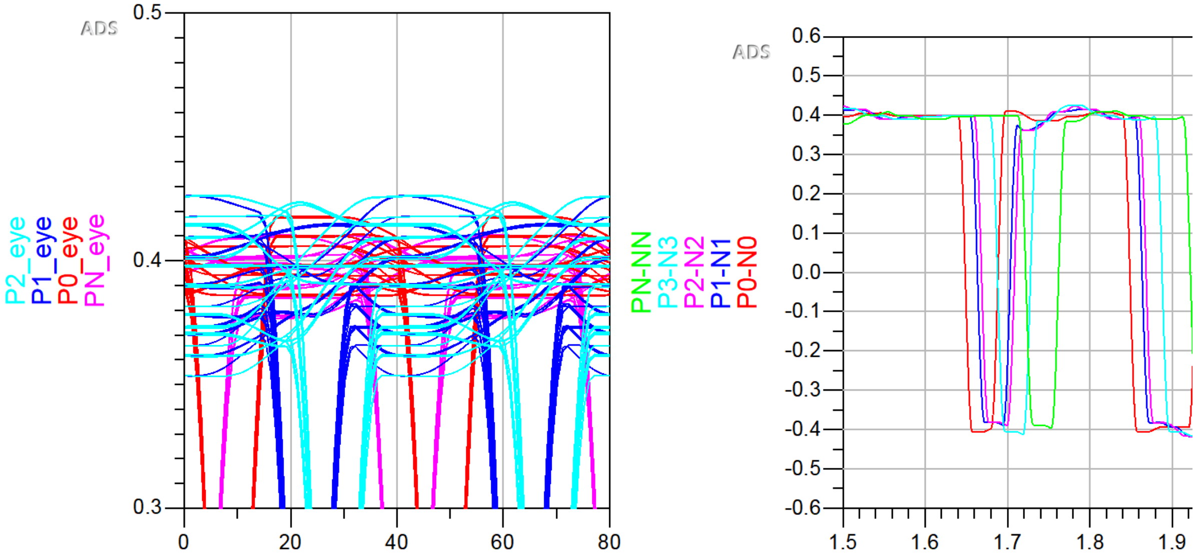
- Termination Tolerance: +/- 1 % (Ohm)
- Number of segments: 7
- Max deviation of segment differential impedance: +/- 3 Ohm

w. no ISI Effect



Added eye closure: -37 mV

with ISI Effects

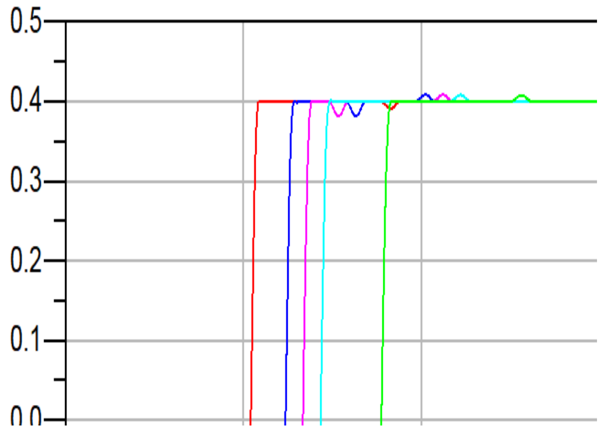


Added eye closure: -92 mV

MICROCHIP

Stubs

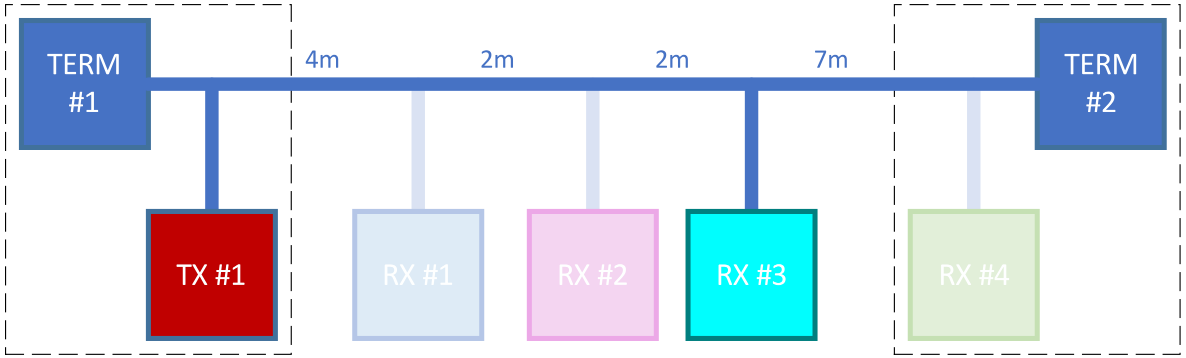
- **Electrical length of 10 cm cable is ca. 500 ps**
  - Several times (>10?) smaller than 10Base-T1S transition times
  - Impedance variations have negligible effect on added noise
  - Reactance at the bus junction (or T) point is mostly capacitive

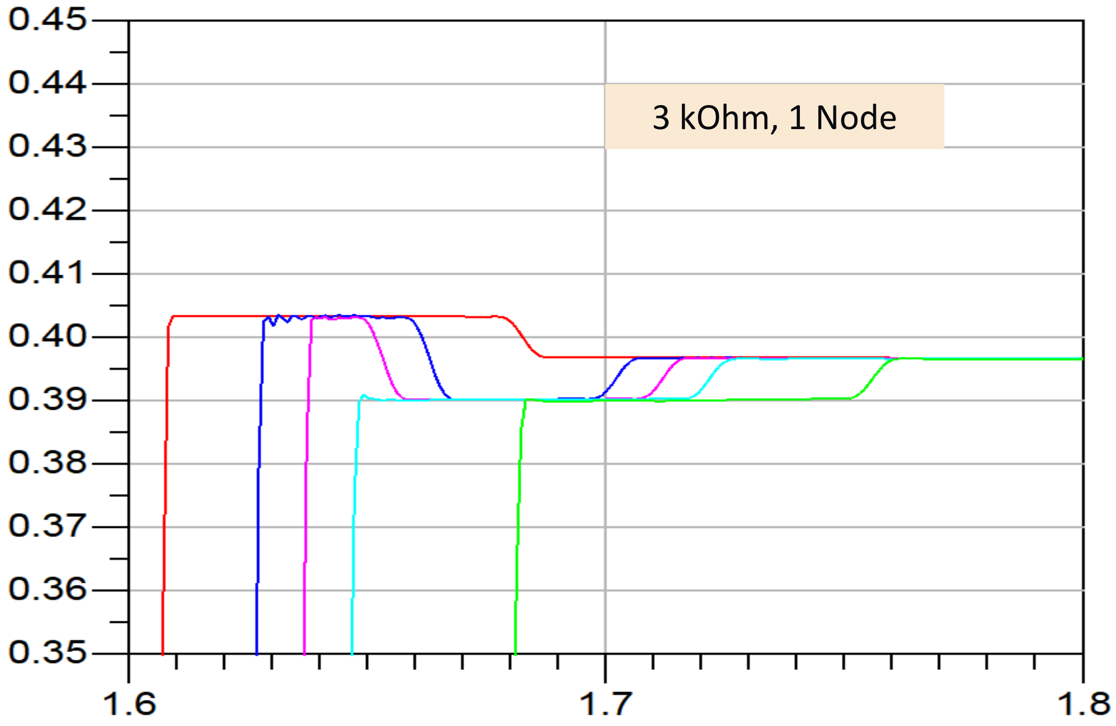


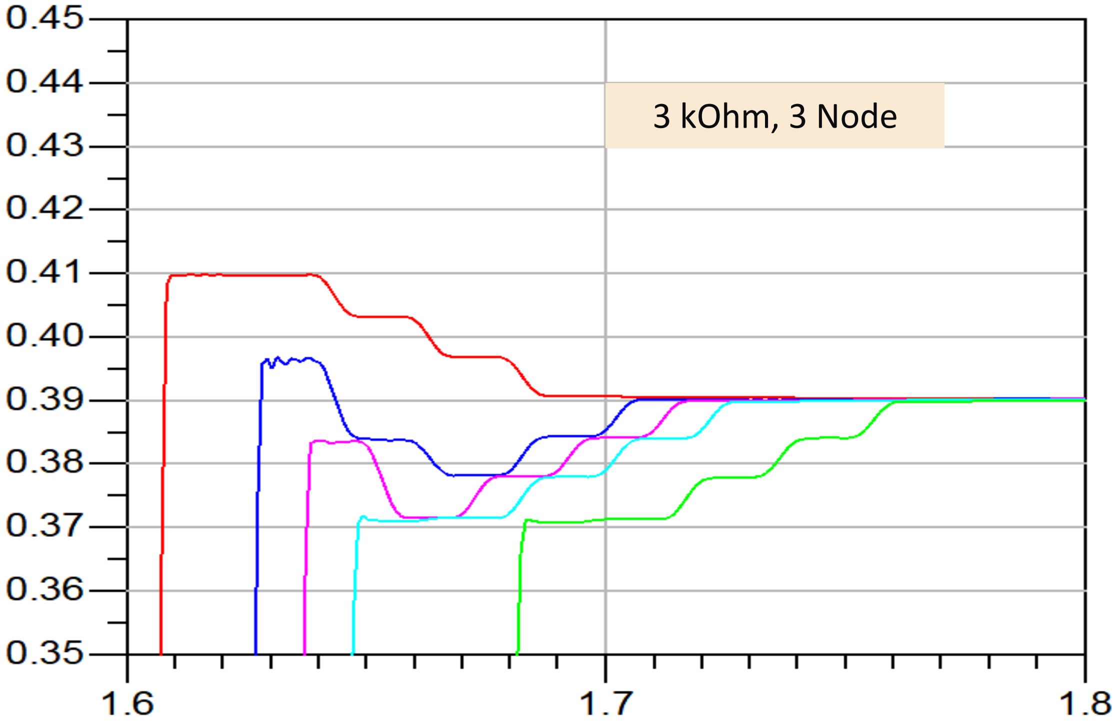
- **Can be considered as added capacitance:**
  - 1/10 of C_Cable [pF/m] i.e. ca. 3-6 pF per (Drop) Node, depending on the cable used
  - Can be easily derived from cable datasheet (pF/m)

Node Load – Resistive Component, no ISI

- **Frequency independent, i.e. no amplitude dependence on launch(TX) signal shape**
- **Amplitudes depends on only on resistor value and number of nodes**

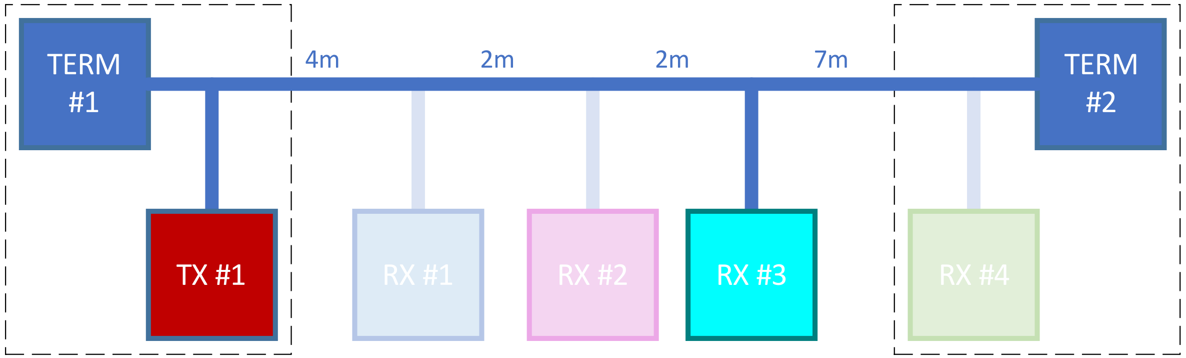


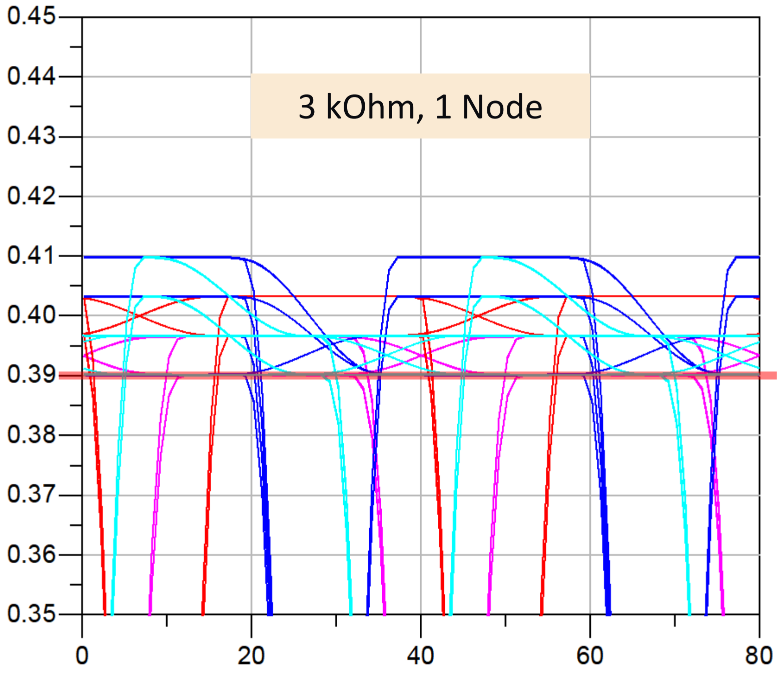


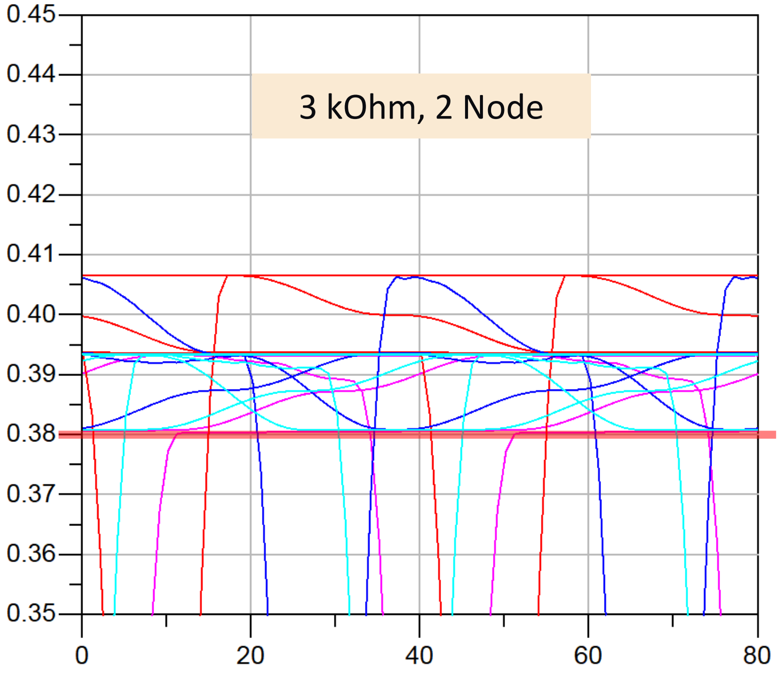


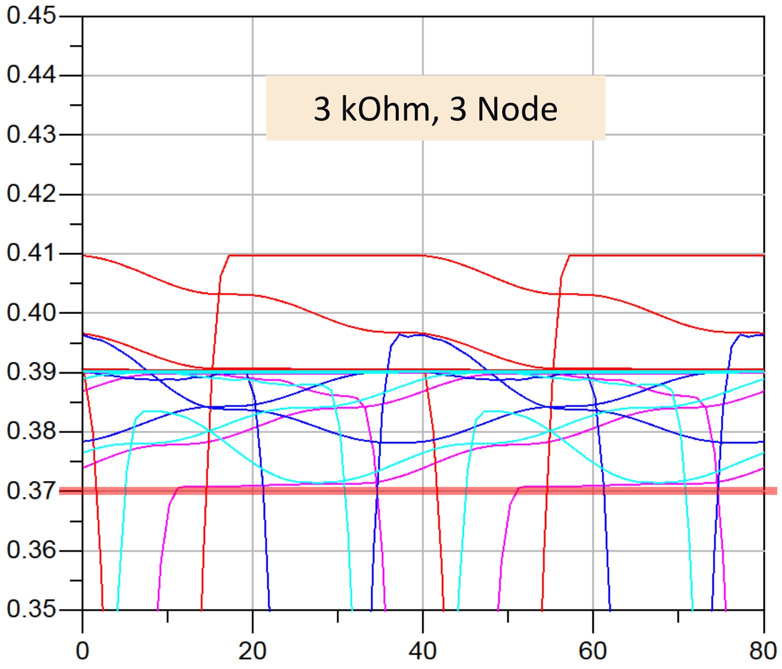
Node Load – Resistive Component, with ISI

No significant ISI dependence ,but
linearly accumulate with each (drop) node,
independent of distance:
@ 3kOhm ca. -20 mVpp per (drop) node
(-120 mVpp for 6 nodes/ 8 node system)







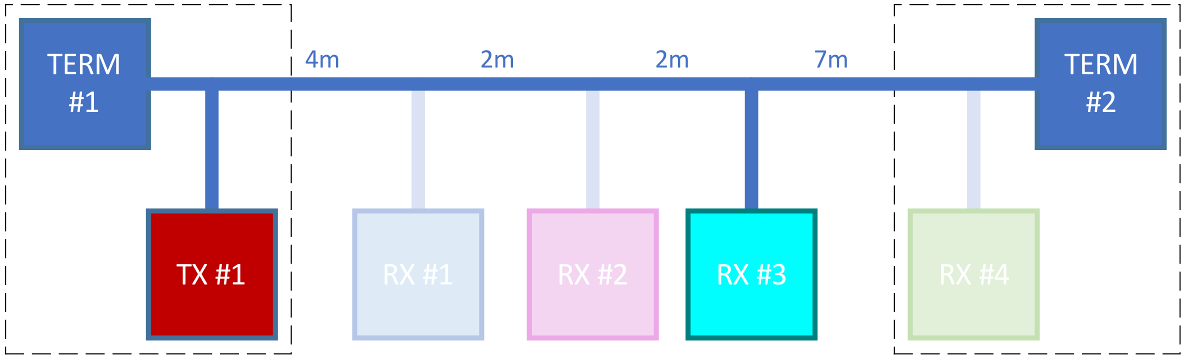


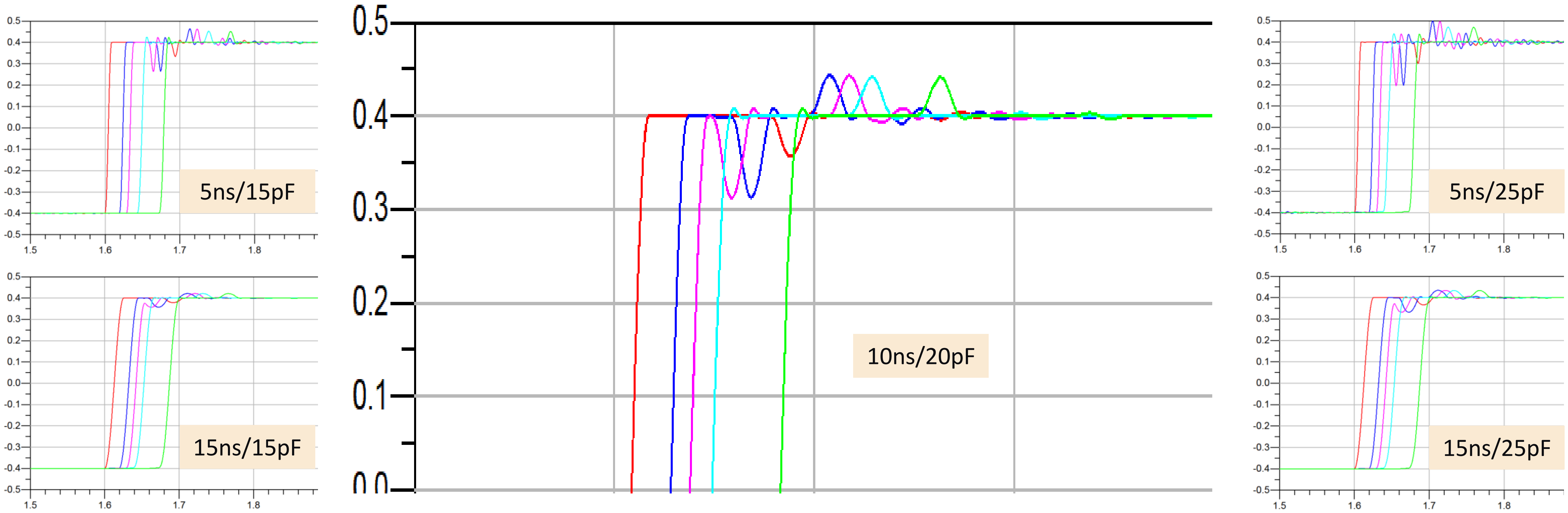
MICROCHIP

Node Load – Capacitive Component, no ISI

$Noise/Eye\_closure = f(T_{TX\_R/F}, C_{RX})$

Note: damping losses not considered, capacitance as bulk load





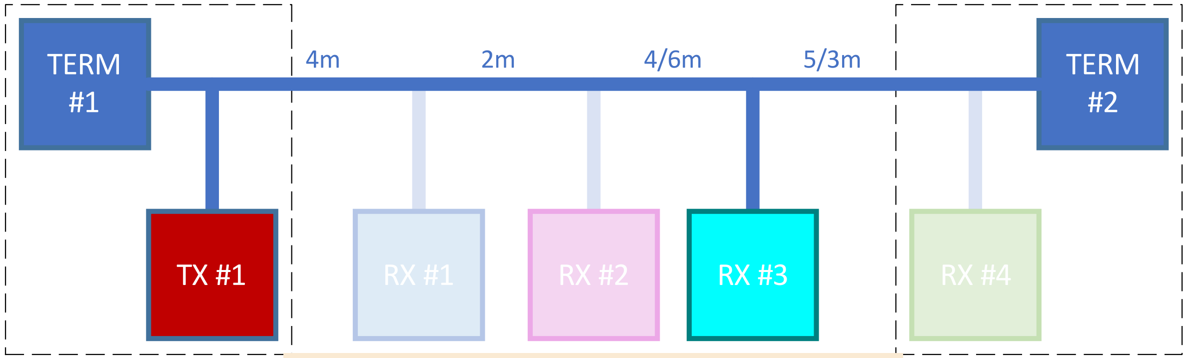
Node Load – Capacitive Component, with ISI

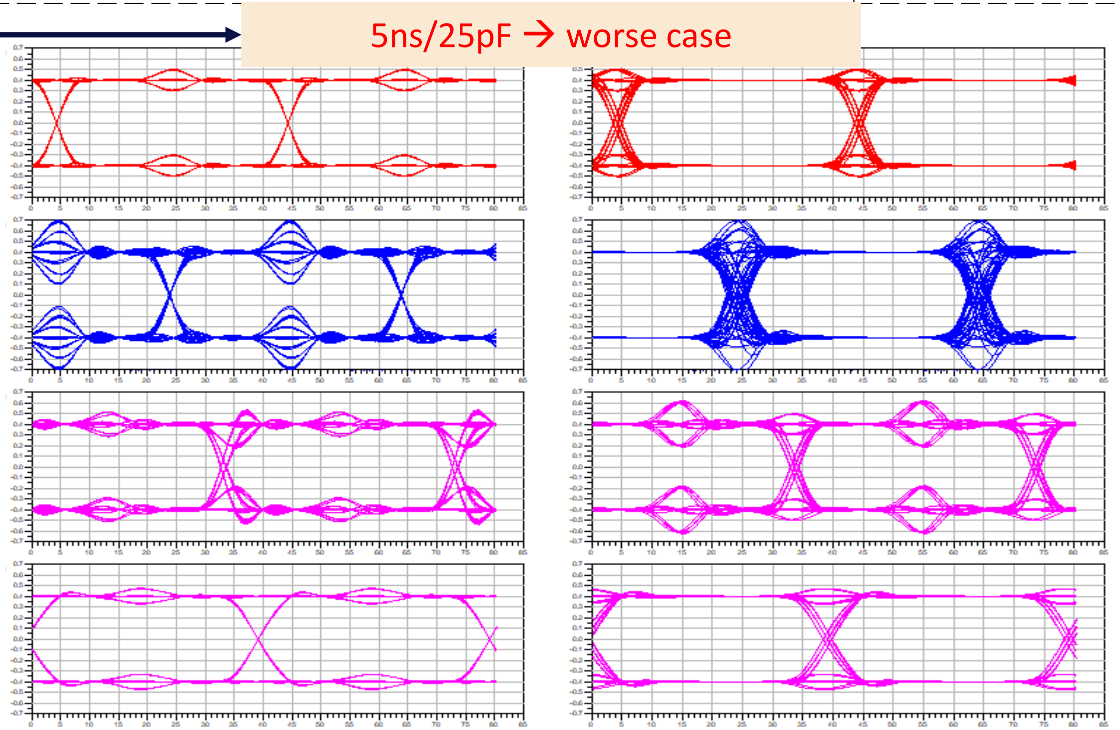
Noise/Eye_closure = f($T_{TX\_R/F}$, C_{RX})

Single node noise quantification (mVpp):

C_{RX} / $T_{TX\_R/F}$	15 pF	20 pF	25 pF
5 ns	-395	-506	-603
10 ns	-200	-265	-329
15 ns	-131	-169	-209

Actual/realistic node implementation are expected to yield better figures!





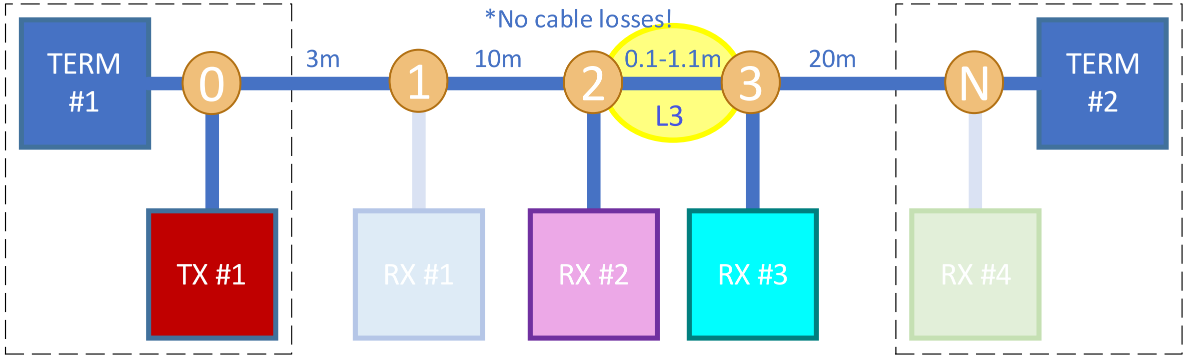
Additional specification limit for $T_{TX\_R/F}$ need to be introduced!

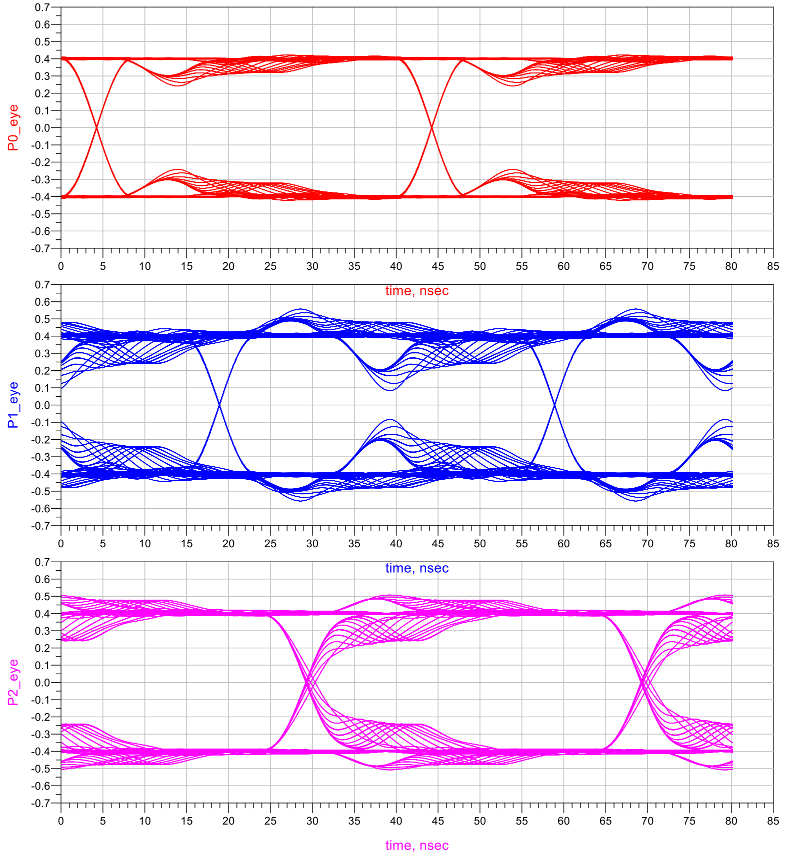
MICROCHIP

Node Load – Capacitive Component, multiple nodes

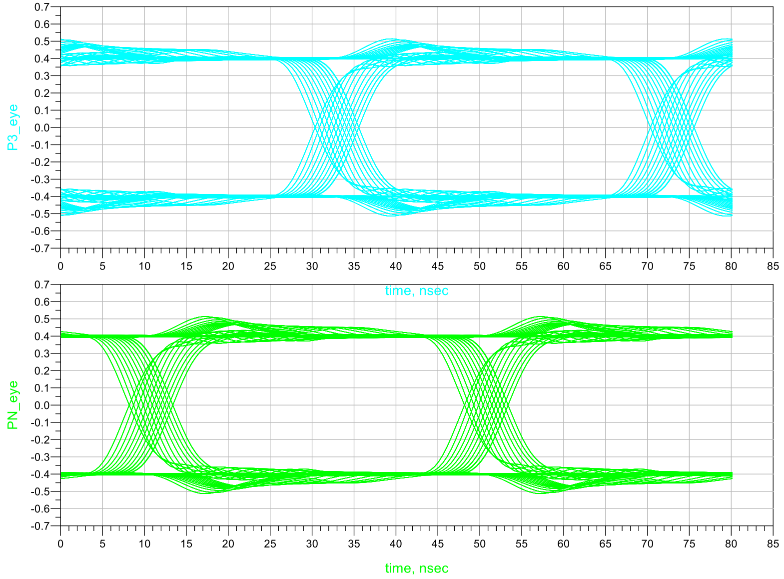
$T_{TX\_R/F}$, reduced after (away from TX) each capacitive node!

=> Every consecutive reflection smaller





5ns / 2x 25pF → worst case



- No ISI effects (T_{Symbol} = 10 x Target),
- Tr/f [ns] derived from slope of signal at 0-crossing (10-90% ref.)

L3	..._0	..._1	..._2	..._3	...N
0.1	5.0	5.0	7.4	6.3	6.4
0.2	5.0	5.0	7.7	5.6	5.6
0.3	5.0	5.0	6.8	5.5	5.5
0.4	5.0	5.0	5.8	5.6	5.6
0.5	5.0	5.0	5.5	5.8	5.7
0.6	5.0	5.0	5.5	5.9	6.0
0.7	5.0	5.0	5.5	6.1	6.0
0.8	5.0	5.0	5.5	6.0	6.1
0.9	5.0	5.0	5.5	6.0	6.1
1.0	5.0	5.0	5.6	6.1	6.1
1.1	5.0	5.0	5.6	6.1	6.1

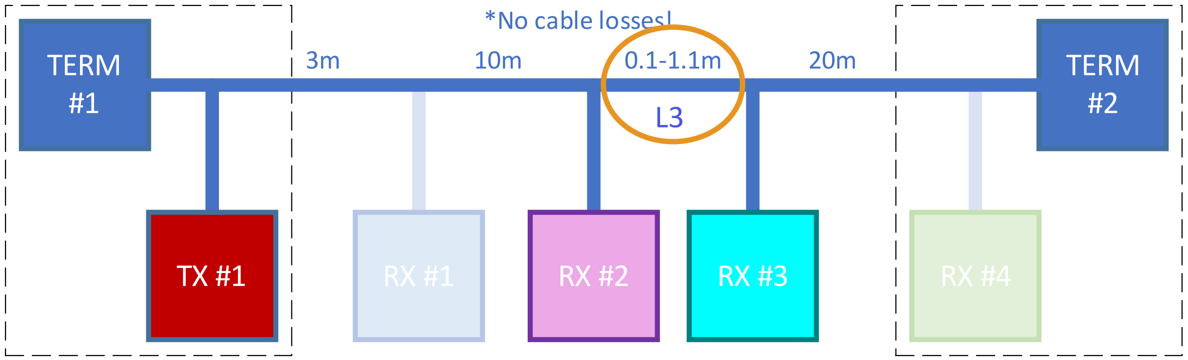
Note: Cable losses will have further effect (reduction) on transition times!

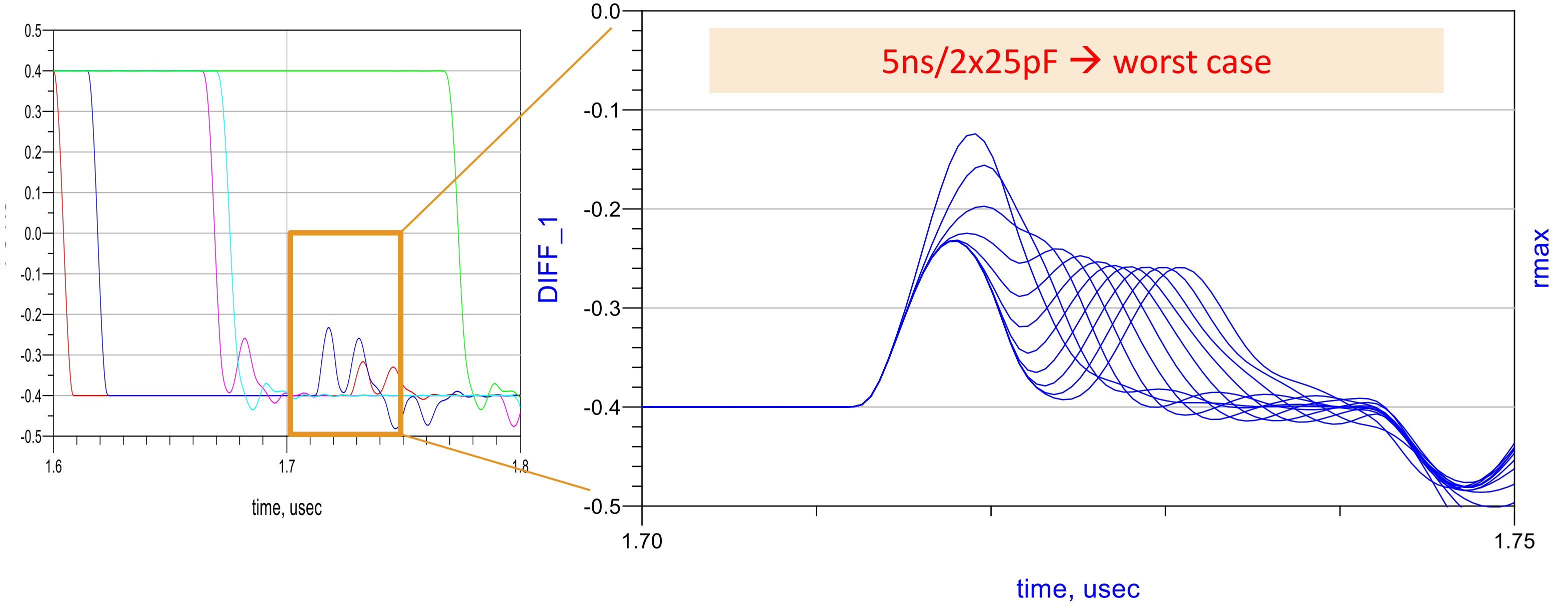
Node Load – Capacitive Component, node distance

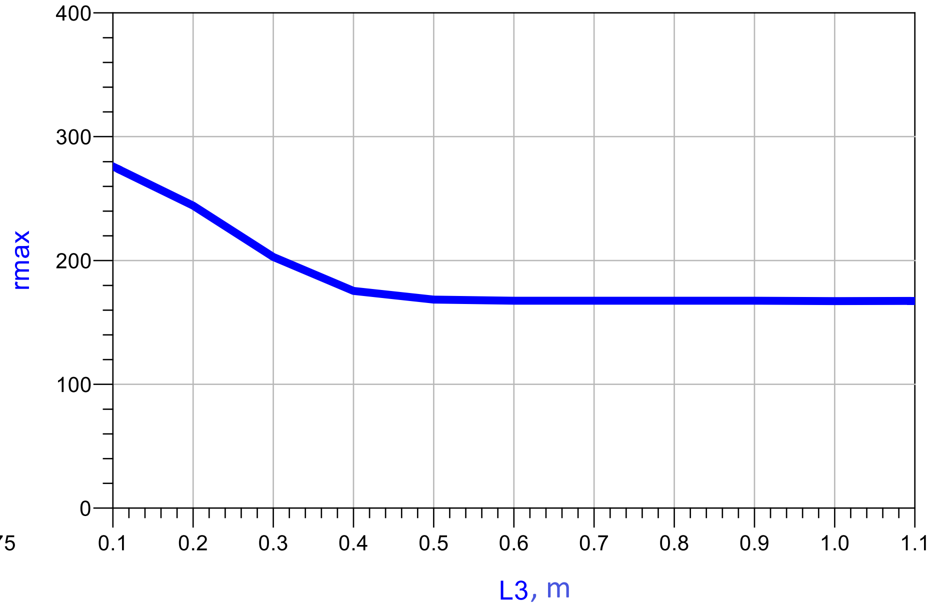
When:

(electr.) distance between nodes < ½ $T_{TX\_R/F}$

-> Effect of "proximity capacitive stacking"







Definition of minimal distance between nodes may be beneficial, in order to limit this effect!

MICROCHIP

Node Load – Capacitive Component, summary

Worst case aggregation of capacitive component depends on:

1. **Transmitter transition times**
2. **Capacitance of receiving nodes**
3. **Minimal distance between nodes (which depends on / interacts with #1 and #2)**
4. **Electrical properties of cable segments:**
   A. Attenuation (min value for the critical lengths of t_{PD_Cable} = [½*T_{Symbol}, n*T_{Symbol}] ?)
   B. Propagation delay (t_{PD_Cable})
   C. Capacitance (for stub-segments)
5. **Source impedance of driver (TX)**

Worst case aggregation of capacitive component does NOT directly depend on:

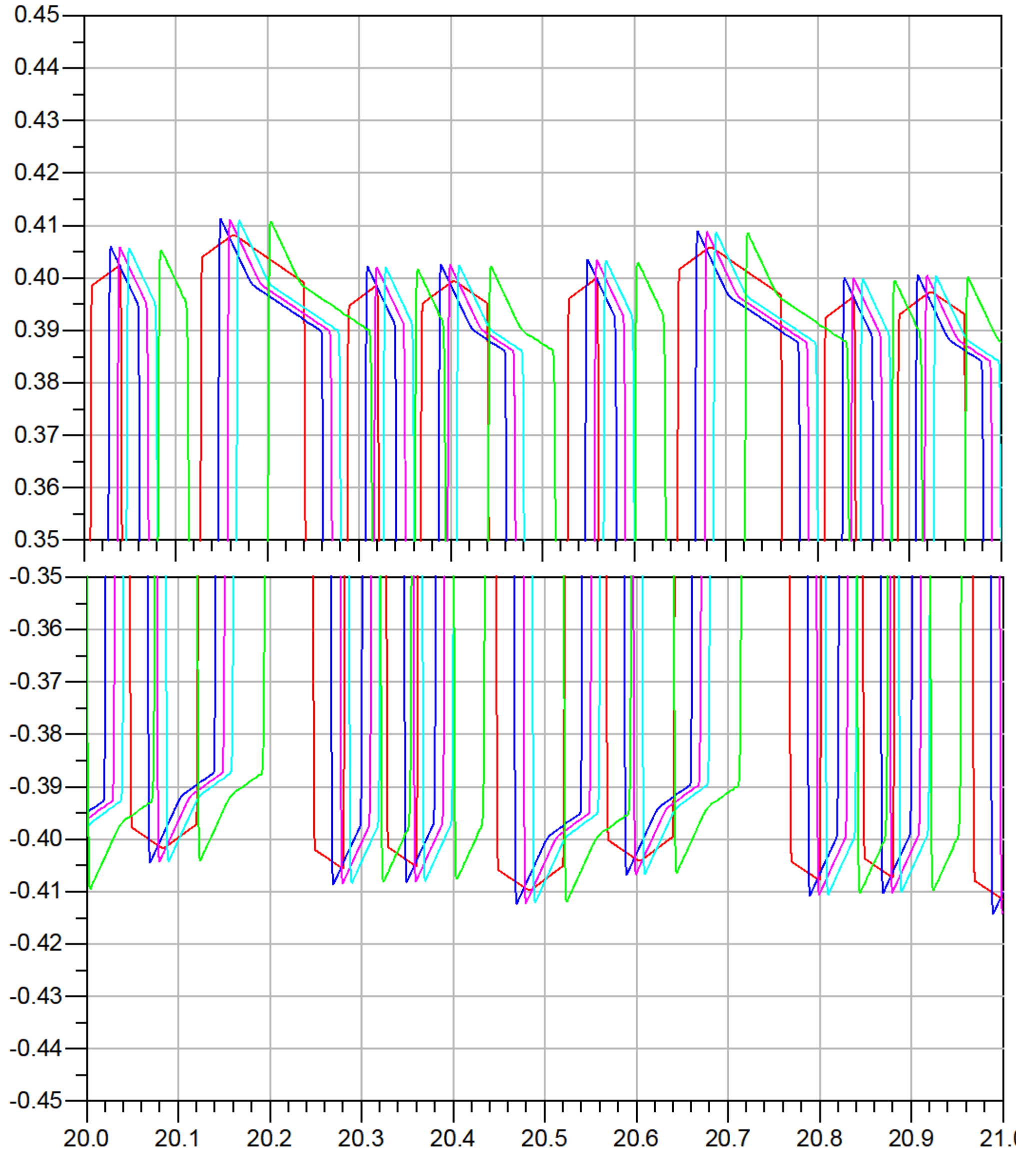
1. **Number of nodes**

In order to properly quantify (limit, reduce?) the worst-case effect,
the above listed dependencies need to be constrained!

MICROCHIP

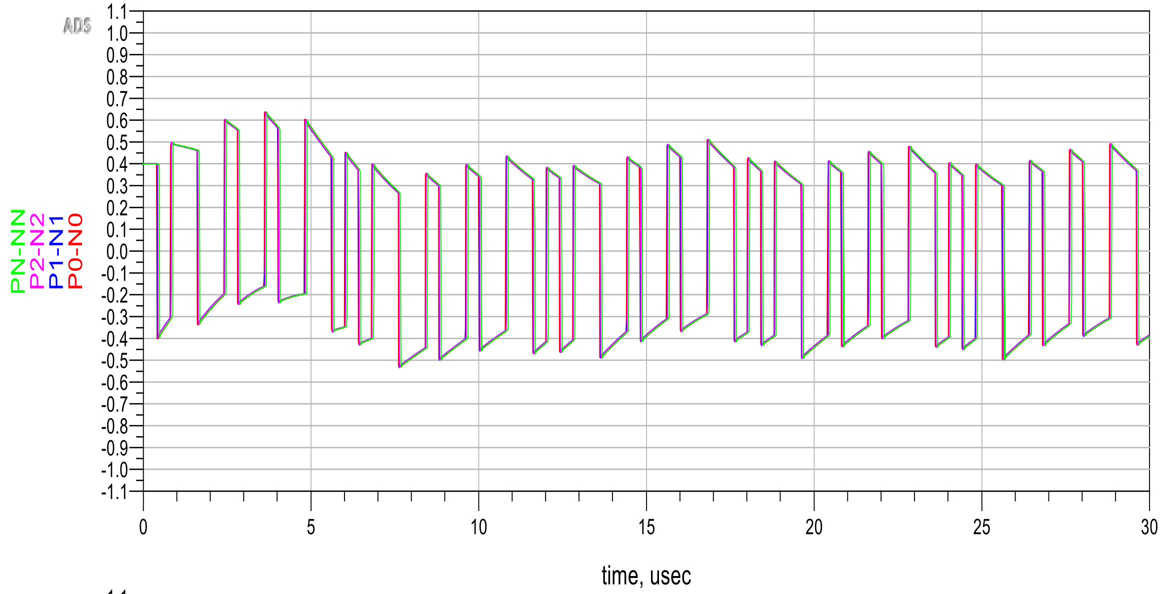
Node Load – Inductive Component

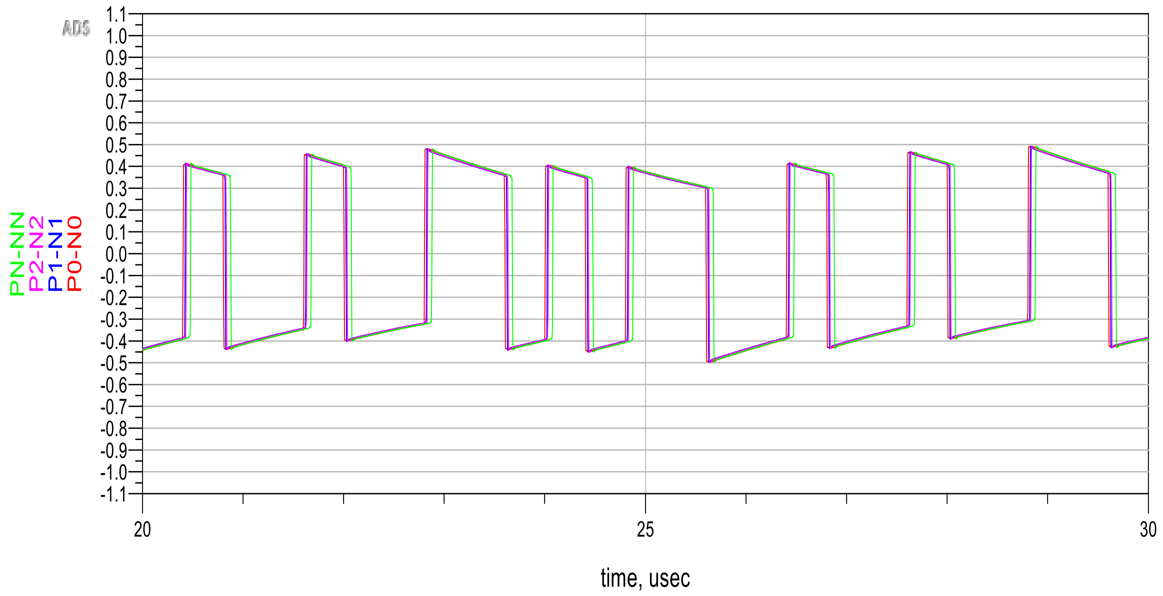
- **Drooping, base-line-wander**
- **Limited, due to Manchester-type coding**
- **Adds linearly with each node (similar to R component)**
- **No significant transmission line effects, due to the slow transition (high inductance)**
- **Interact with decoupling capacitors:**
  - cut-off-frequency raised further
  - Slow (differential) transient effects, increasing with number of nodes (simulation artefact?!)

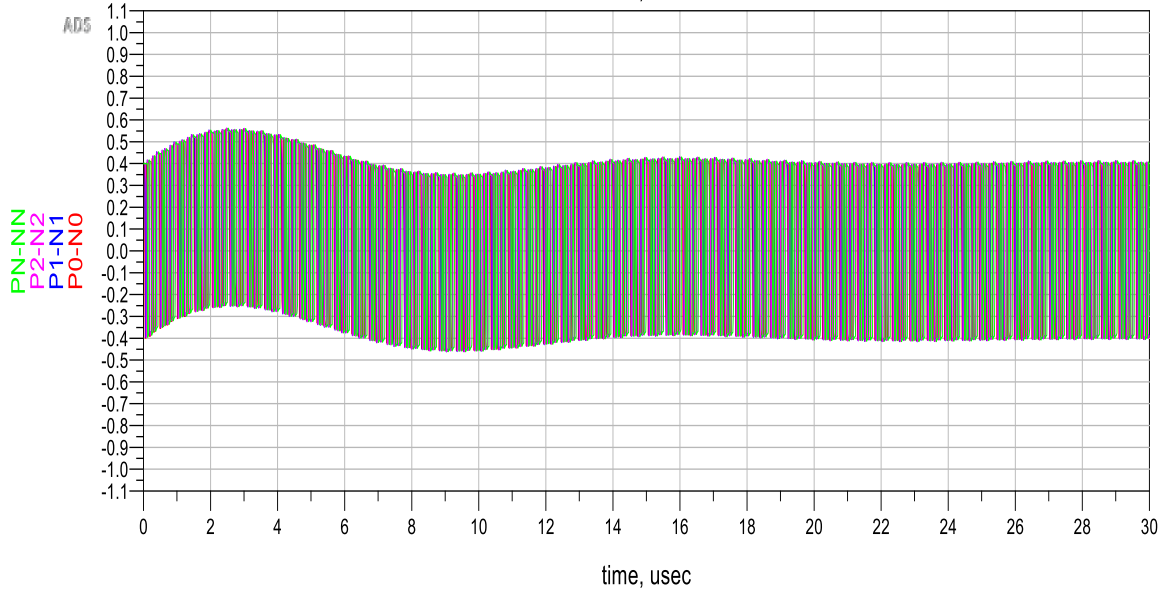


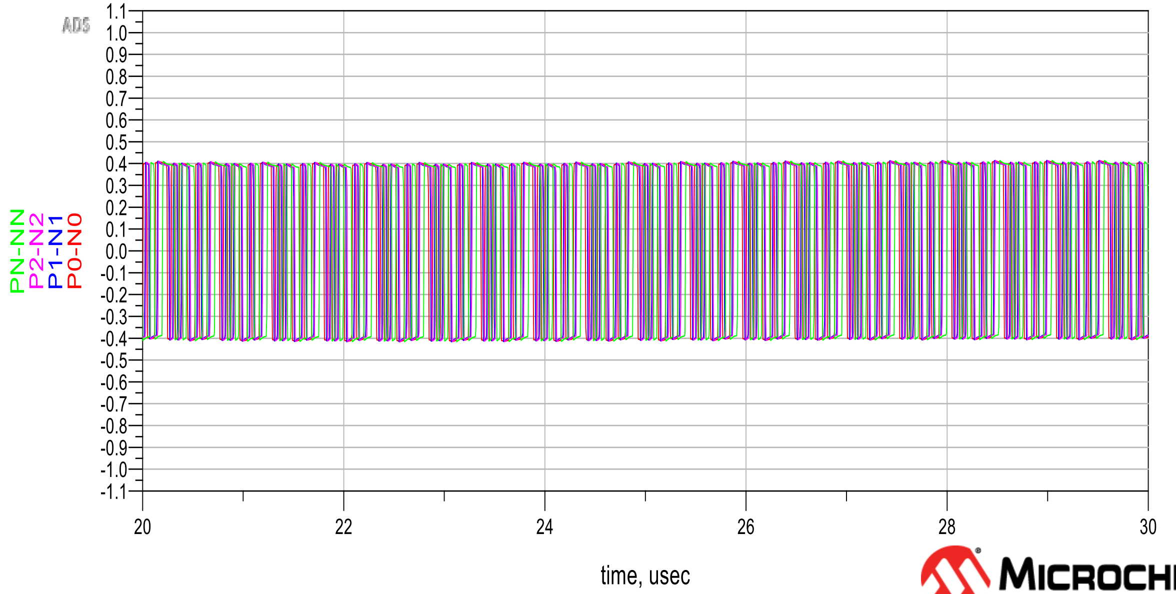
MICROCHIP

Node Load – Inductive Component, contd.



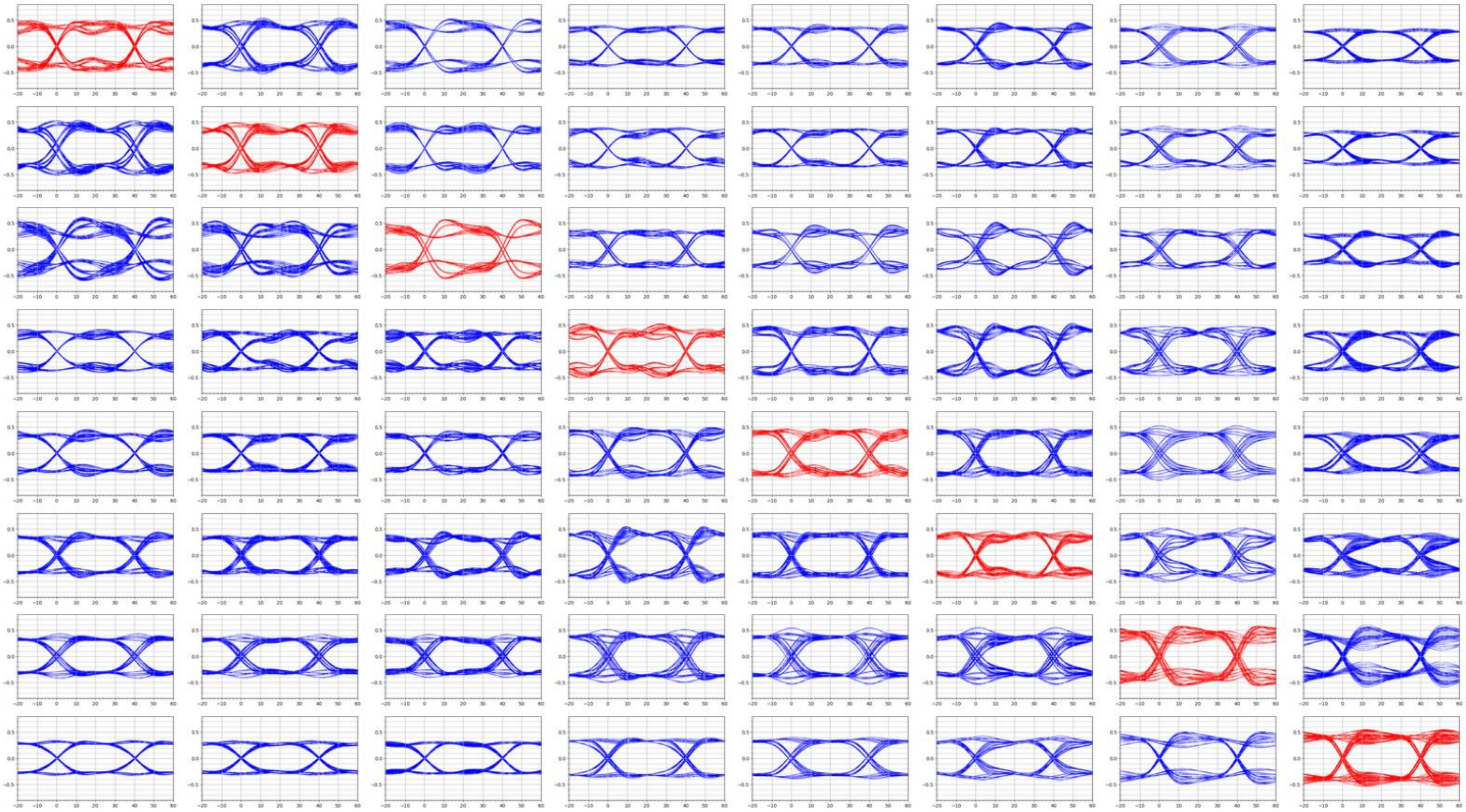






MICROCHIP

Example – 8 Nodes system (FTZ Topology)



Mixed-Segment – Specification Issues

- **Needed performance depend on multiple unconstrained parameters**
- **Frequency domain specification are ambiguous**
  - not always directly applicable
- **S-Parameter tools are sub-optimal**
  - not always 50 Ohm Terminated
  - RL is a reflection-based tool, we rather need transmission profile
- **Node loads are the most significant noise contributor**
- **Cable attenuation modulates (system inherent) noise**

Mixed-Segment – How to Specify

- **TDR (and more specifically TDT) tools are more suitable**
  - Time domain results
  - Well defined driver profile
  - Works well with HiZ receivers
  - Works well for design (simulation) and validation (measurement)
  - Gives good correlation to real results
  - Results can be mathematically adjusted (e.g. Tr/f)

- **Combination of frequency and time domain:**
  - Frequency domain for cable segments
  - TDR/TDT for Node/stub performance

- **Additional constrains needed:**
  - Driver transition times, minimal node distance, etc.