Correlation of Model and Measurement for 10SPE Multi-Drop System

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- Measurement Setup – System level
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  - System Level Time-Domain Simulation Data
  - System Level Time-Domain Measurement Data
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Goal

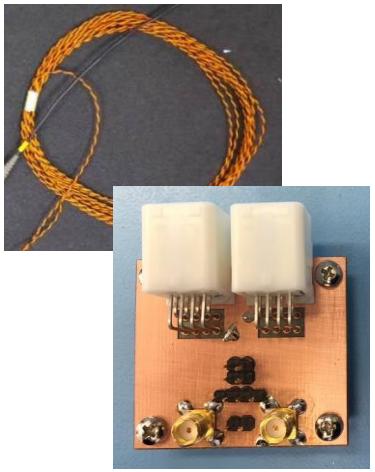
- Achieve high level of correlation between simulation results and measurement data

Reliable modeling:

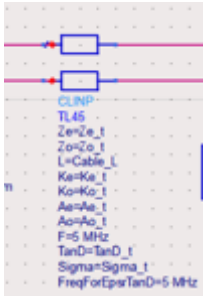
- Allows higher level of system parameter variations:
  - ✓Cable/stub lengths
  - ✓Component variations
  - ✓Impedance mismatches
  - ✓Noise variations
- Speeds up iteration cycles
- Enables flexible creation of worst case scenarios

Correlation Concept

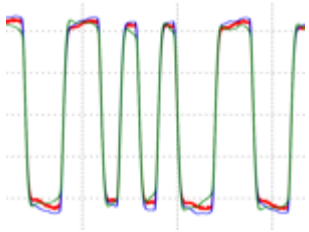
- **Measure existing example components:**
  - CAN/CAN-FD quality UTP cables (100Ω)
  - MQS based cable connectors
  - Small analog front-end (AFE) boards to represent each node (capacitive coupling, termination resistors (100Ω or 10KΩ), variable stub lengths, drive signal SMA connectors, probing points)



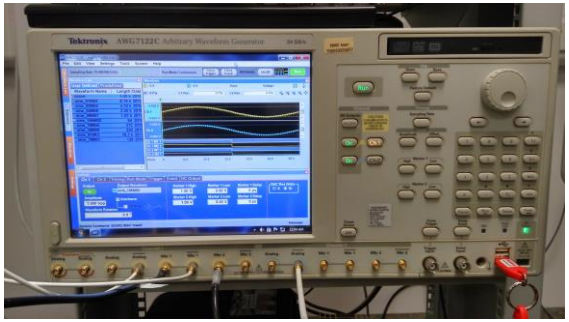
- **Create Parametric Models**



- **Compare Models vs. Measurements**
  - On Component/Link level
  - On System level

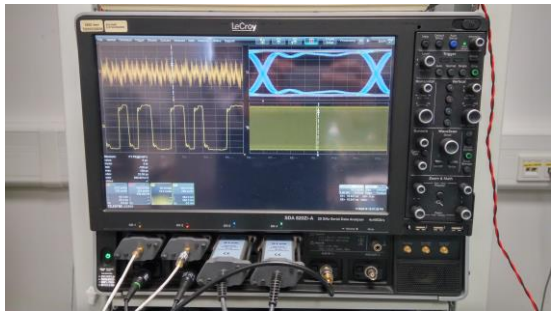


Measurement Setup – Component/Link level

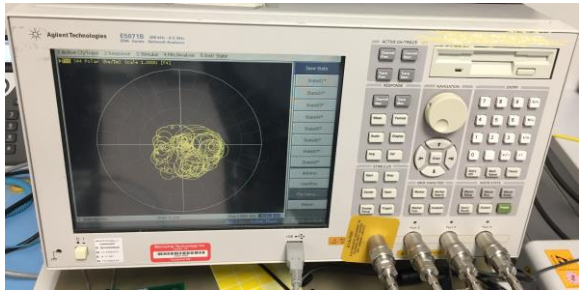


- Arbitrary Waveform Generator (AWG) – generates pre-conditioned signal

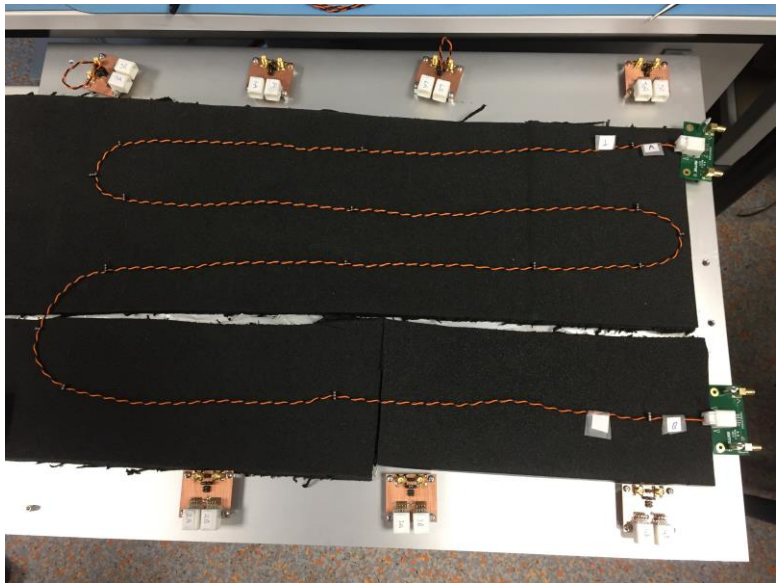
- Digital oscilloscope w. active differential probes



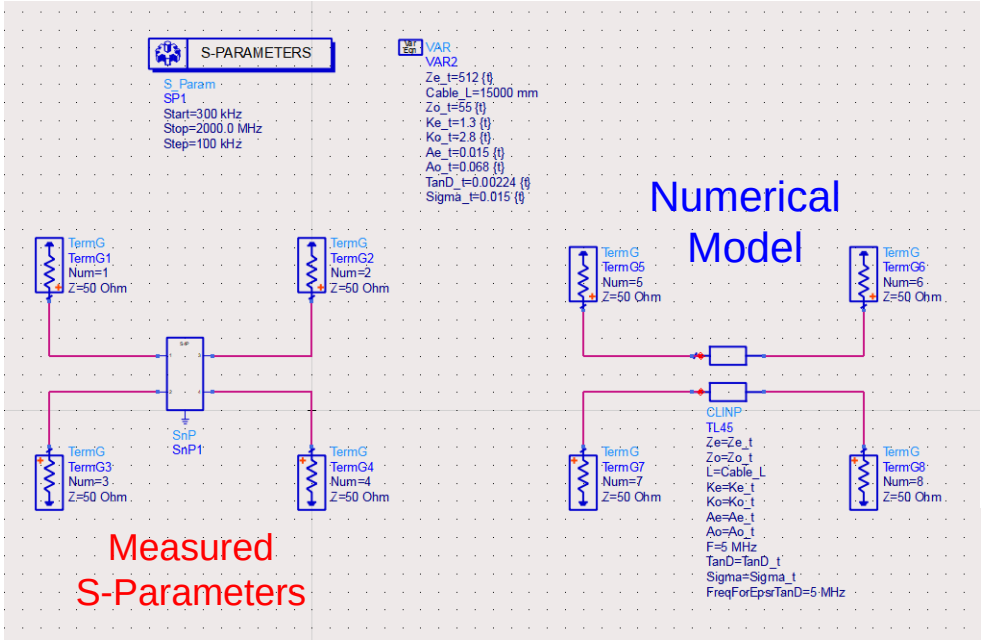
- VNA

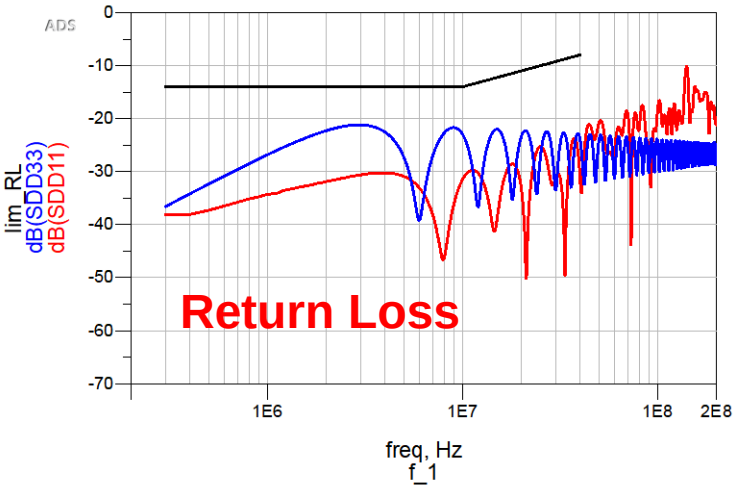


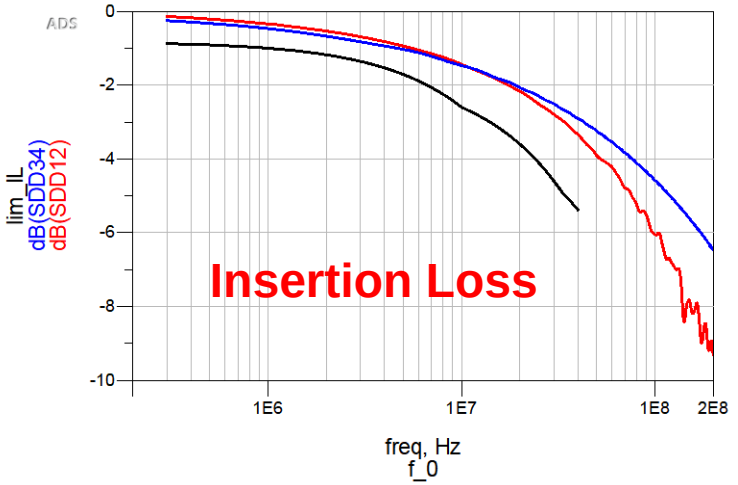
- Measured cable samples: 7.5m, 10m, 15m, etc.



Frequency-Domain Correlation Example

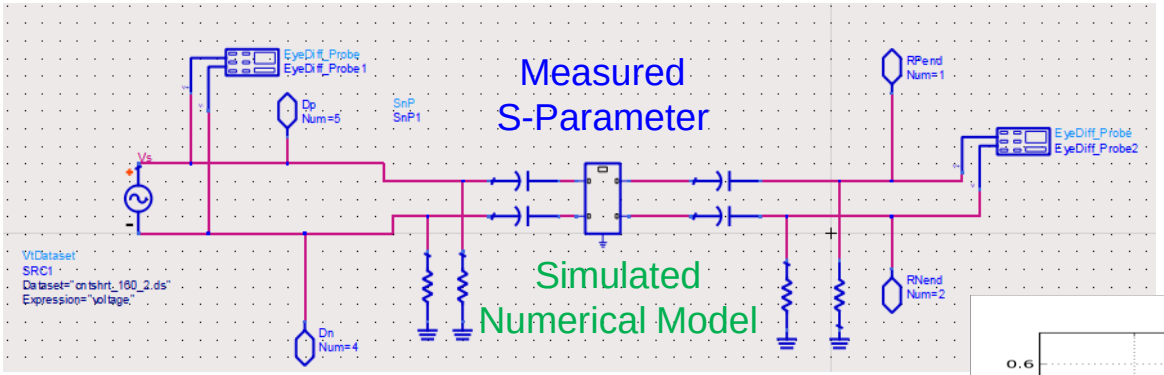






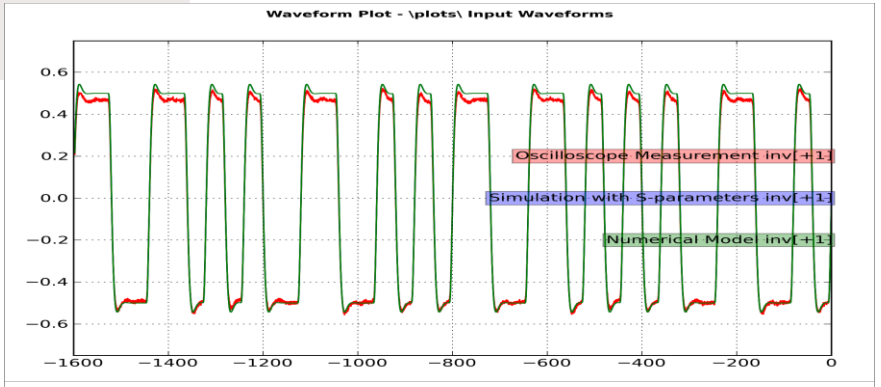
- ✓ Comparison of VNA measurement vs. simulation model for 15m cable length
- ✓ Initial model parameters same as in: “buntz_10SPE_03_1005.pdf”
- ✓ Further parameter adjustment gives better correlation levels

Time-Domain Correlation Example



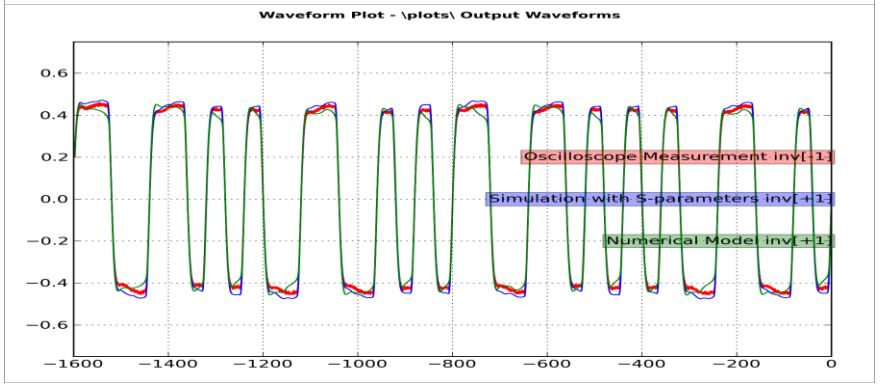
- **Red – measured time-domain (oscilloscope) data**
- **Blue – simulation data with measured S-parameter**
- **Green – simulation data with numerical model**

Input (driver side) waveforms



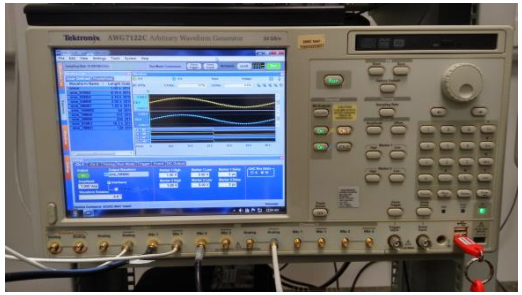
- 15m cable
- 2 nodes
- Stub lengths – 0cm

Output (receiver side) waveforms

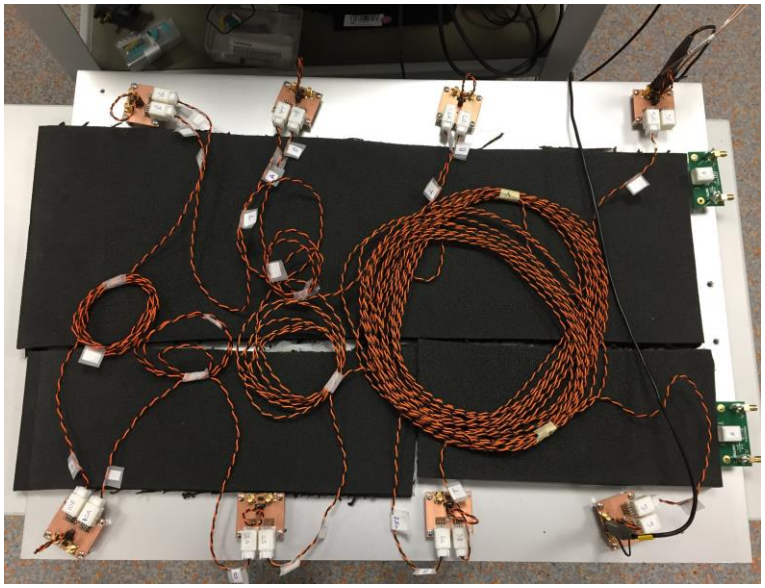


Measurement Setup – System level

Data Source: AWG

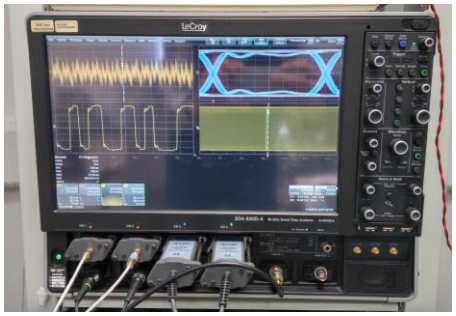


Source data type: preconditioned (filtered) differential Manchester encoded 10SPE sample packet

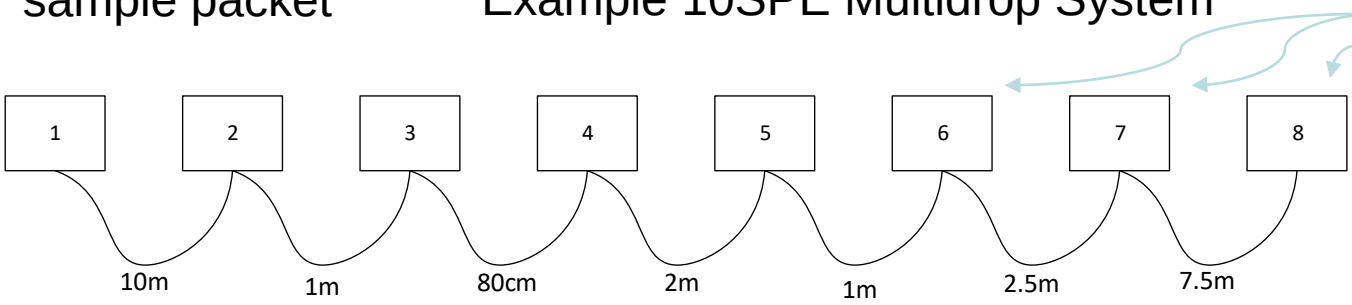


Example 10SPE Multidrop System

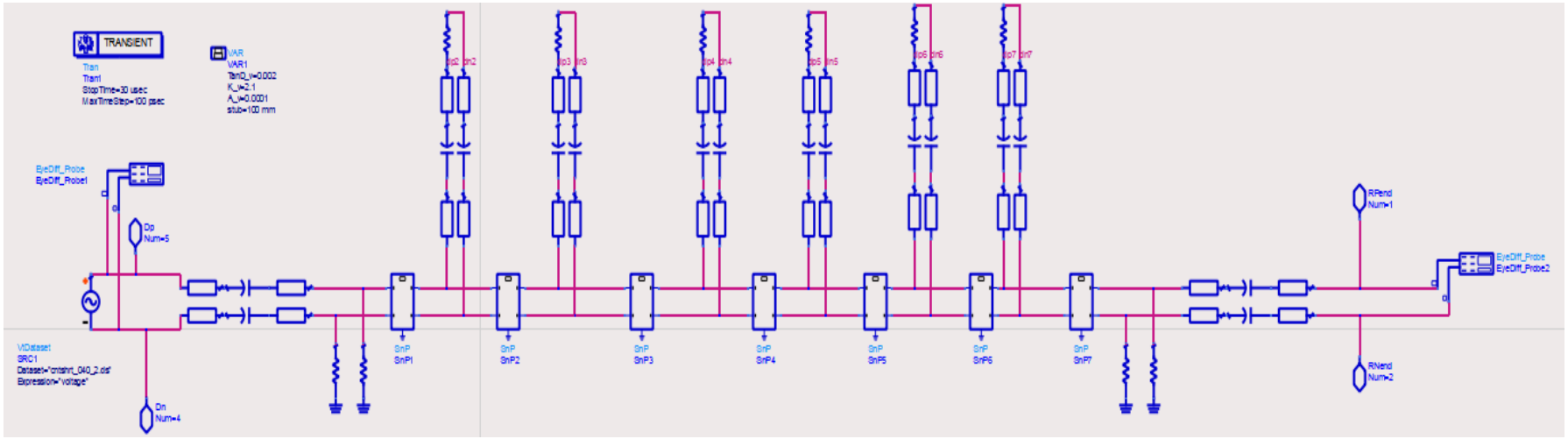
Multiple Receivers: Oscilloscope



Simplified Node



Model of Example Multidrop System

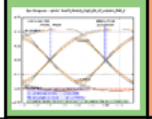


- **End-terminated configuration with 8 Nodes:**

  Distance between nodes: 10m, 1m, 80cm, 2m, 1m, 2.5m, 7.5m;10 cm stubs at each node
- **Simulated using measured (touchstone) or numerically modeled transmission lines**
- **Driving node can change position – the other nodes are receivers**
- **Parametrization: Various configurations of cable segments and stub lengths possible**

System Level Time-Domain Simulation Data

Map of signal quality (eye) at each node vs. driving node:

EYE DIAGRAMS		RECEIVER							
		1	2	3	4	5	6	7	8
DRIVER	1		0.50	0.52	0.53	0.54	0.54	0.49	0.43
	2	0.61	0.72	0.70	0.68	0.65	0.64	0.60	0.53
	3	0.58	0.67	0.72	0.69	0.66	0.66	0.60	0.54
	4	0.55	0.64	0.67	0.72	0.68	0.67	0.61	0.55
	5	0.52	0.60	0.62	0.66	0.72	0.70	0.64	0.56
	6	0.52	0.60	0.62	0.65	0.71	0.72	0.65	0.57
	7	0.55	0.63	0.66	0.69	0.75	0.75	0.72	0.62
	8	0.41	0.48	0.51	0.54	0.57	0.54	0.44	0.72

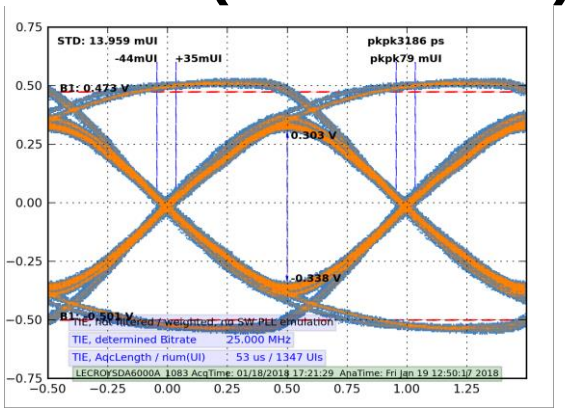
Allows identification of Worst-Case scenarios:
e.g. map of vertical eye-closure:

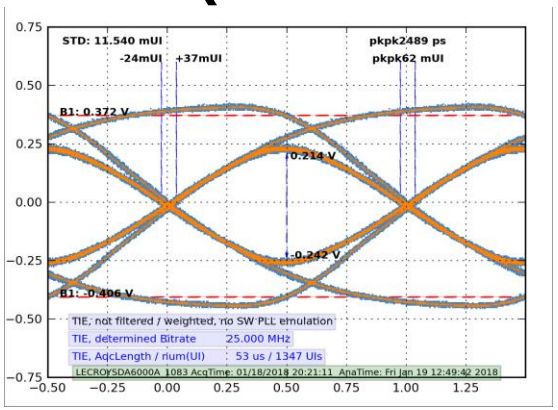
EYE HEIGHT [Volt]		RECEIVER							
		1	2	3	4	5	6	7	8
DRIVER	1	0.72	0.50	0.52	0.53	0.54	0.54	0.49	0.43
	2	0.61	0.72	0.70	0.68	0.65	0.64	0.60	0.53
	3	0.58	0.67	0.72	0.69	0.66	0.66	0.60	0.54
	4	0.55	0.64	0.67	0.72	0.68	0.67	0.61	0.55
	5	0.52	0.60	0.62	0.66	0.72	0.70	0.64	0.56
	6	0.52	0.60	0.62	0.65	0.71	0.72	0.65	0.57
	7	0.55	0.63	0.66	0.69	0.75	0.75	0.72	0.62
	8	0.41	0.48	0.51	0.54	0.57	0.54	0.44	0.72

System Level Time-Domain Measurement Data

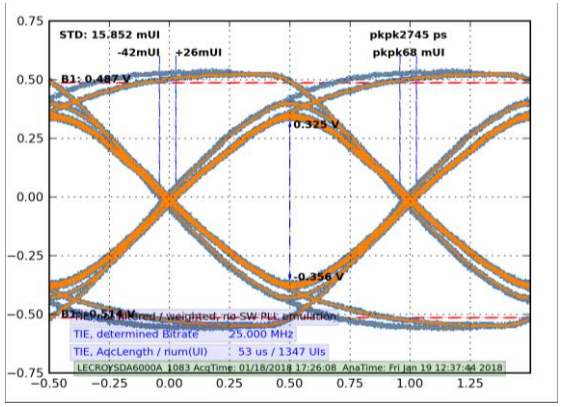
Sample measurements at:

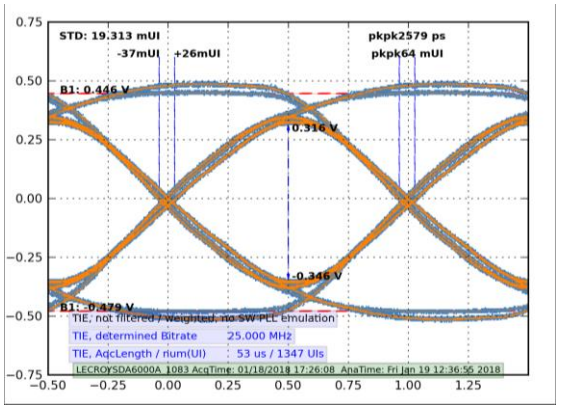
- **Node #1 (driver side) and Node #8 (receiver side)**





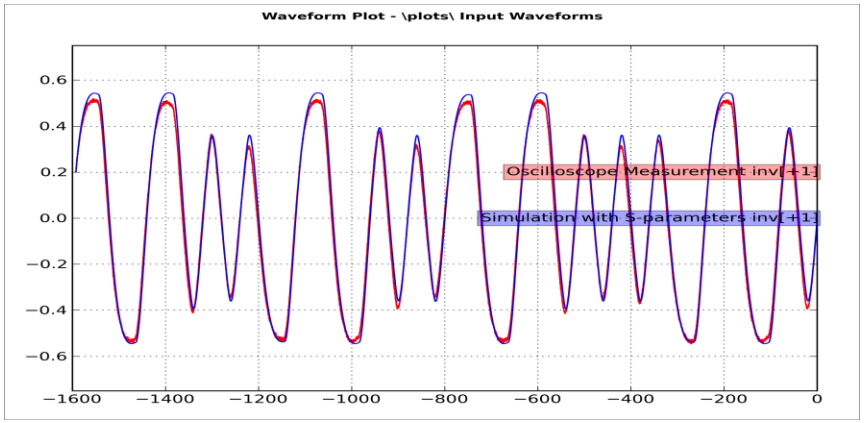
- **Node #3 (driver side) and Node #6 (receiver side)**



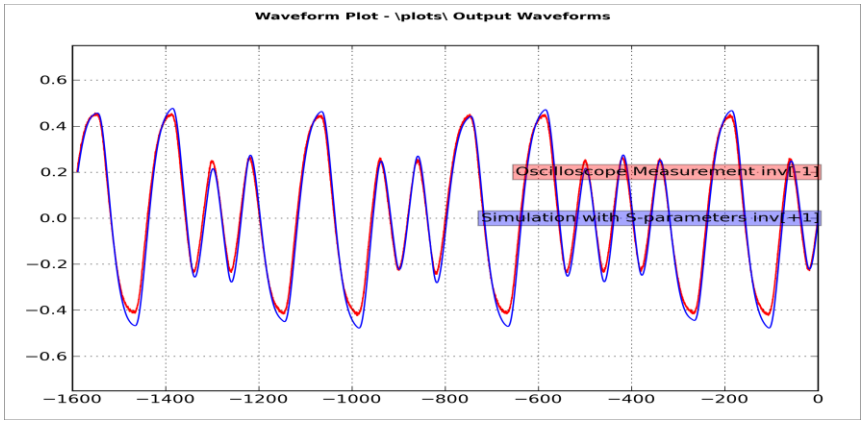


Sample Correlation of System Level Time-Domain Results

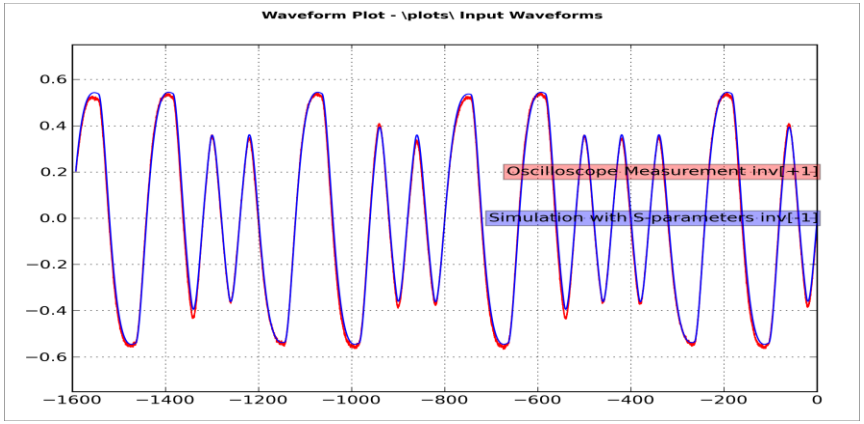
Node #1 (driver side)



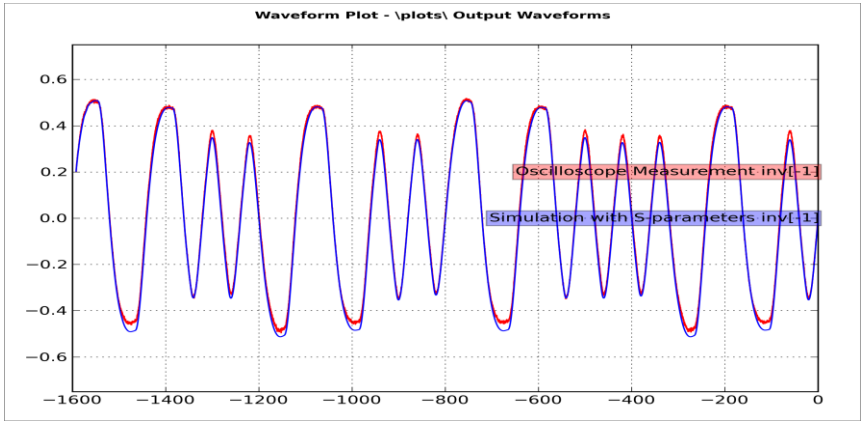
Node #8 (receiver side)



Node #3 (driver side)



Node #6 (receiver side)



- **Red – measured time-domain (oscilloscope) data**
- **Blue – simulation with measured S-parameter data**

Conclusion and outlook

- **We can achieve convenient level of correlation**
- **Allows us to vary different system parameters and exercise / study realistic 10SPE system behavior**
- **Use the system model to:**
  - Extend the system coverage to beyond what could only be measured
  - Identify Worst Case Scenarios
  - Exercise Critical Use-Cases (e.g. add noise)
  - Facilitate System requirement identification and verification