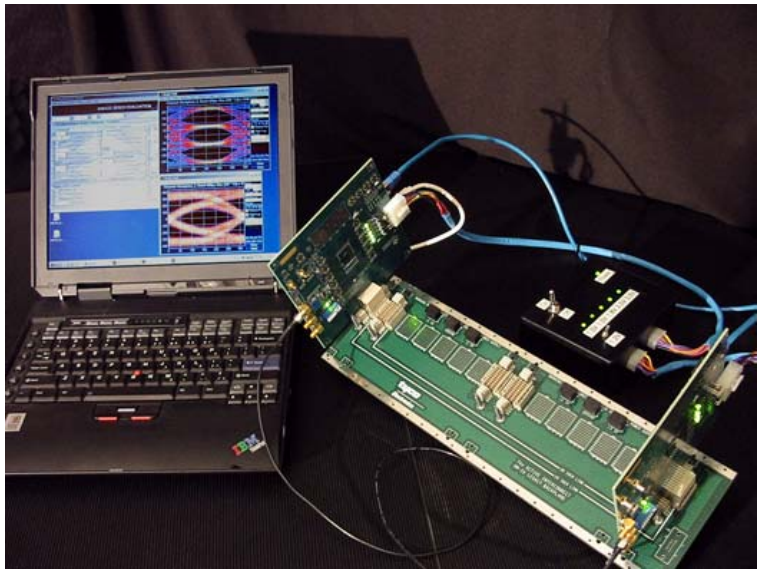
PAM-4 Link Analysis

John D'Ambrosia, Tyco Electronics
John Stonick, Synopsys

10G Payload Measured Feasibility Data

- 6 backplane configurations
  - 4000-6, 4000-13, 4000-13SI, 6000, 6000SI, and ISOLA 620
  - 4.75 mil wide traces (4 mil on 4000-6 variants)
- 3 Lengths
  - 8”, 22” and 36” lengths
- 3 types of HM-Zd signal routing (4 FEXT, 4 NEXT)
  - QuadRoute Tx to Tx, Rx to Rx
  - QuadRoute Tx to Rx, Rx to Tx
  - Non QuadRoute



	Pair A/B	Pair C/D	Pair E/F	Pair G/H
Column 5	Tx_0	Tx_1	Tx_2	Tx_3
Column 6	Rx_0	Rx_1	Rx_2	Rx_3

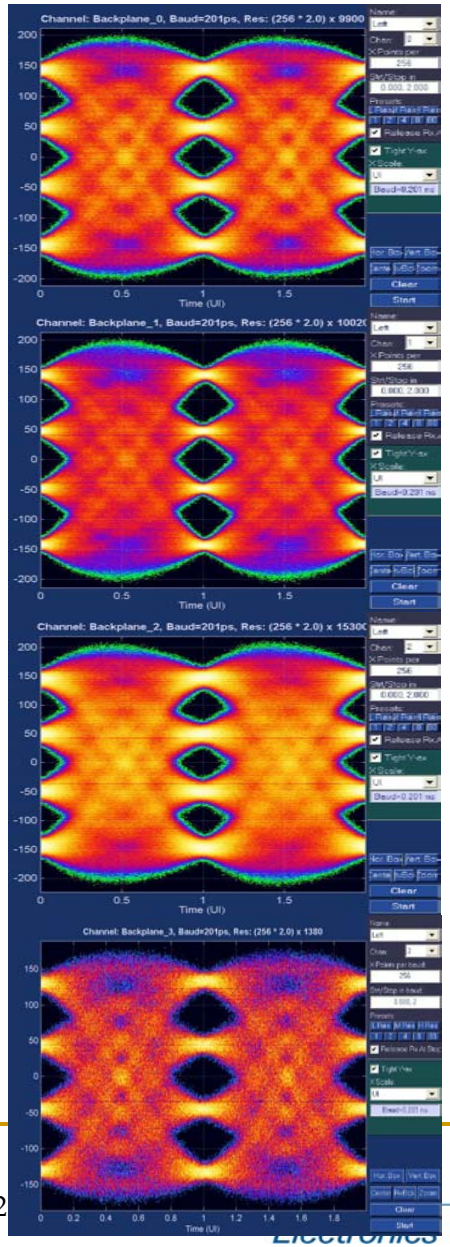
Accelerant Networks / Synopsys Measured 10G Payload Data

1 C0

1 C1

1 C2

1 C3



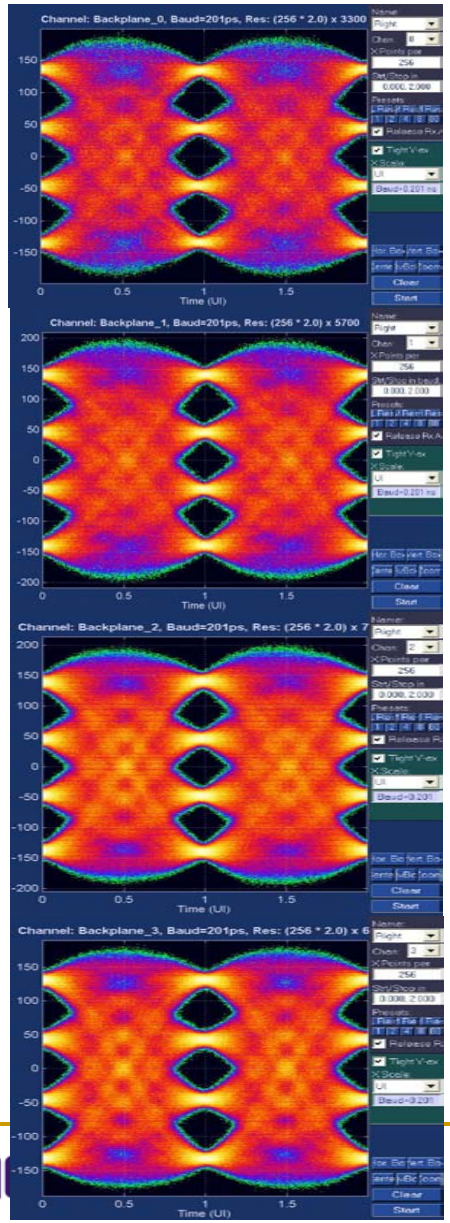
5G PAM4 .13u device running at 10G. Gray Encoding, 0% Overhead

All 8 pairs active on QuadRoute FR4 4000-13SI, full crosstalk conditions (4 FEXT, 4 NEXT)

All devices tested to BER 10^-12 using 2^31 PRBS Pattern over 36 inches

8" and 22" link conditions across all 6 materials passed BER 10^-12 using 2^31 PRBS Pattern

Out of 336 links tested, 34 36" link configurations did not pass and will be the subject of future simulation work on a mutually agreed to channel model with purpose built 10G designs



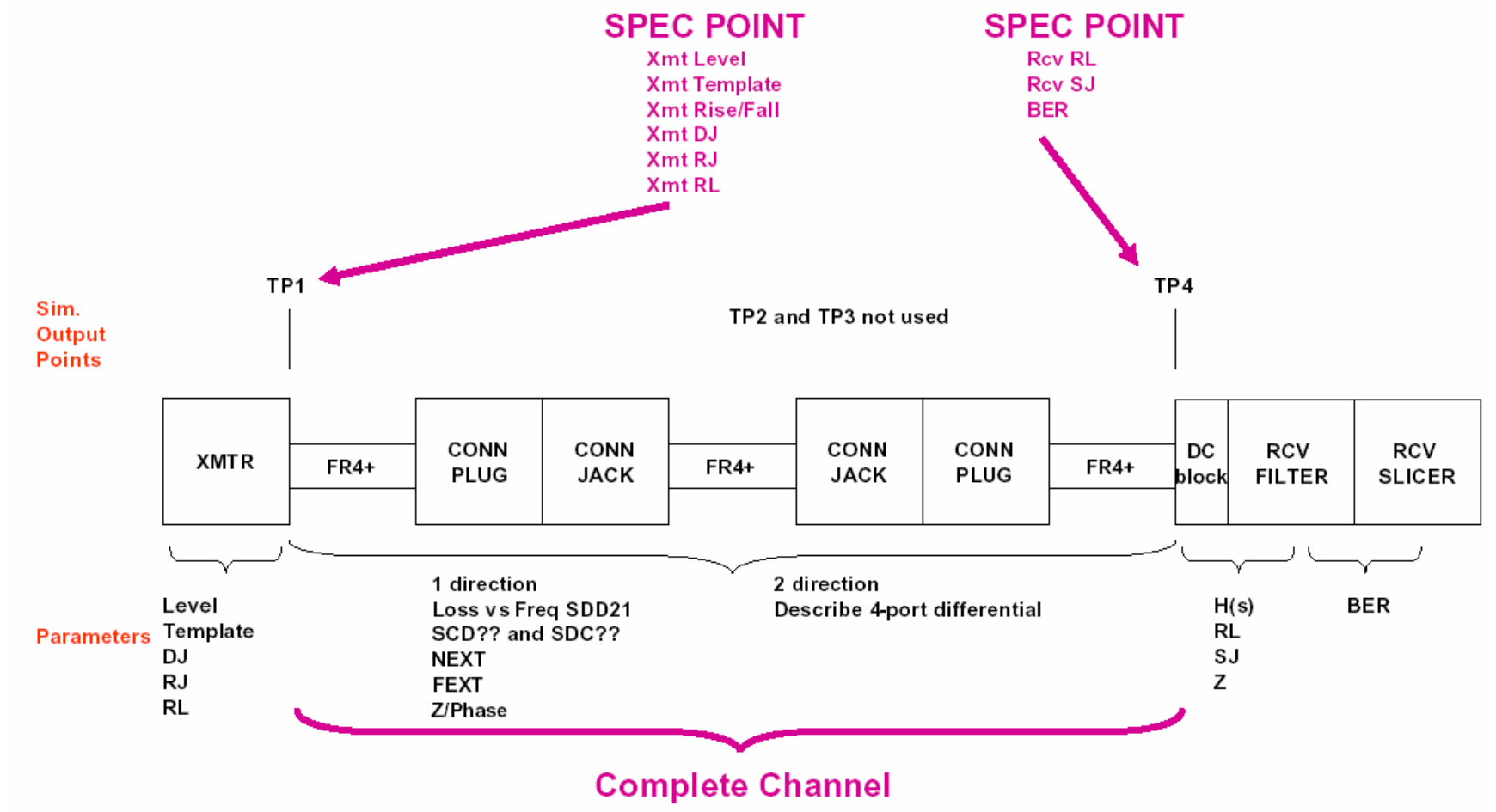
2 C0

2 C1

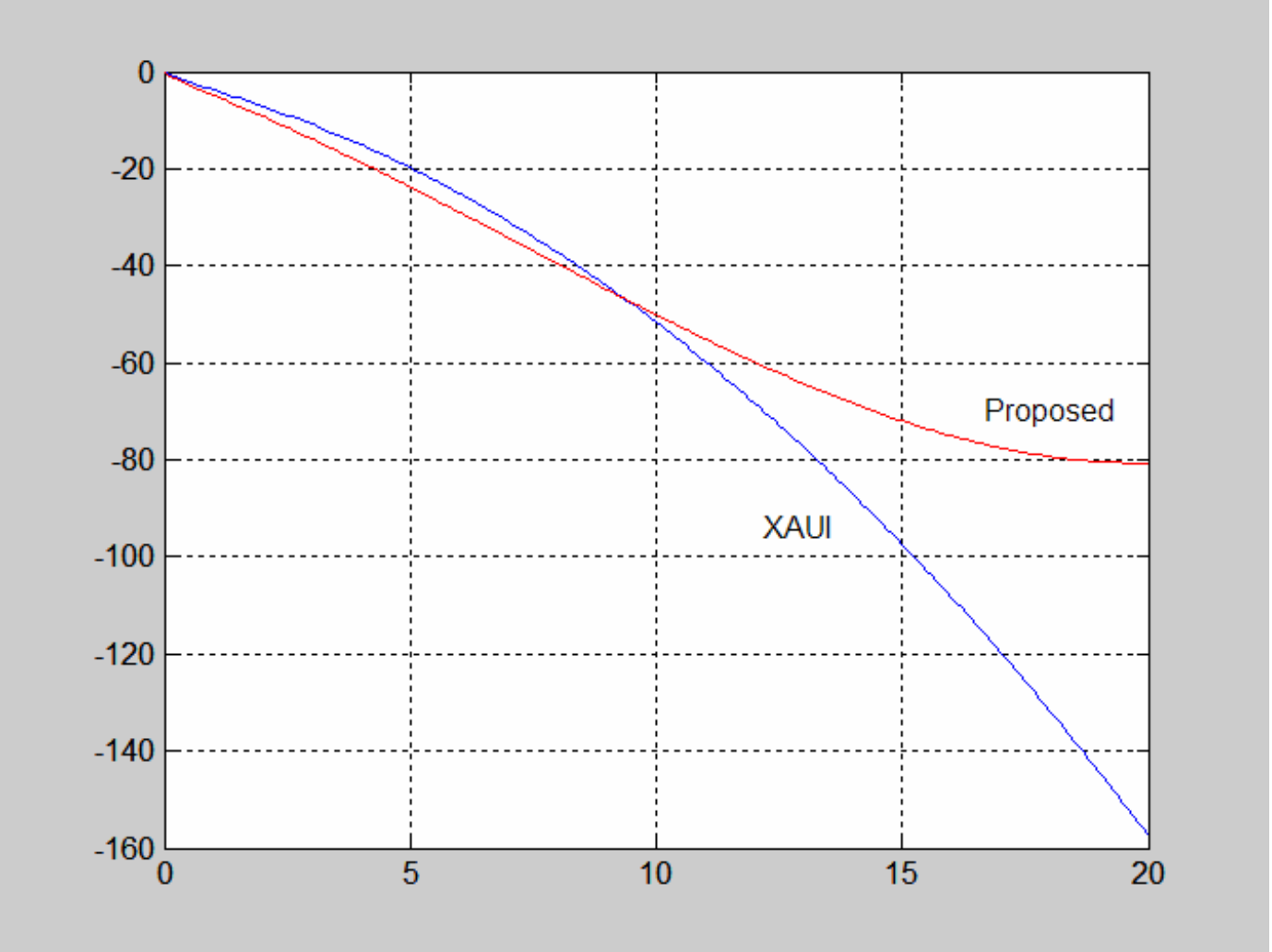
2 C2

2 C3

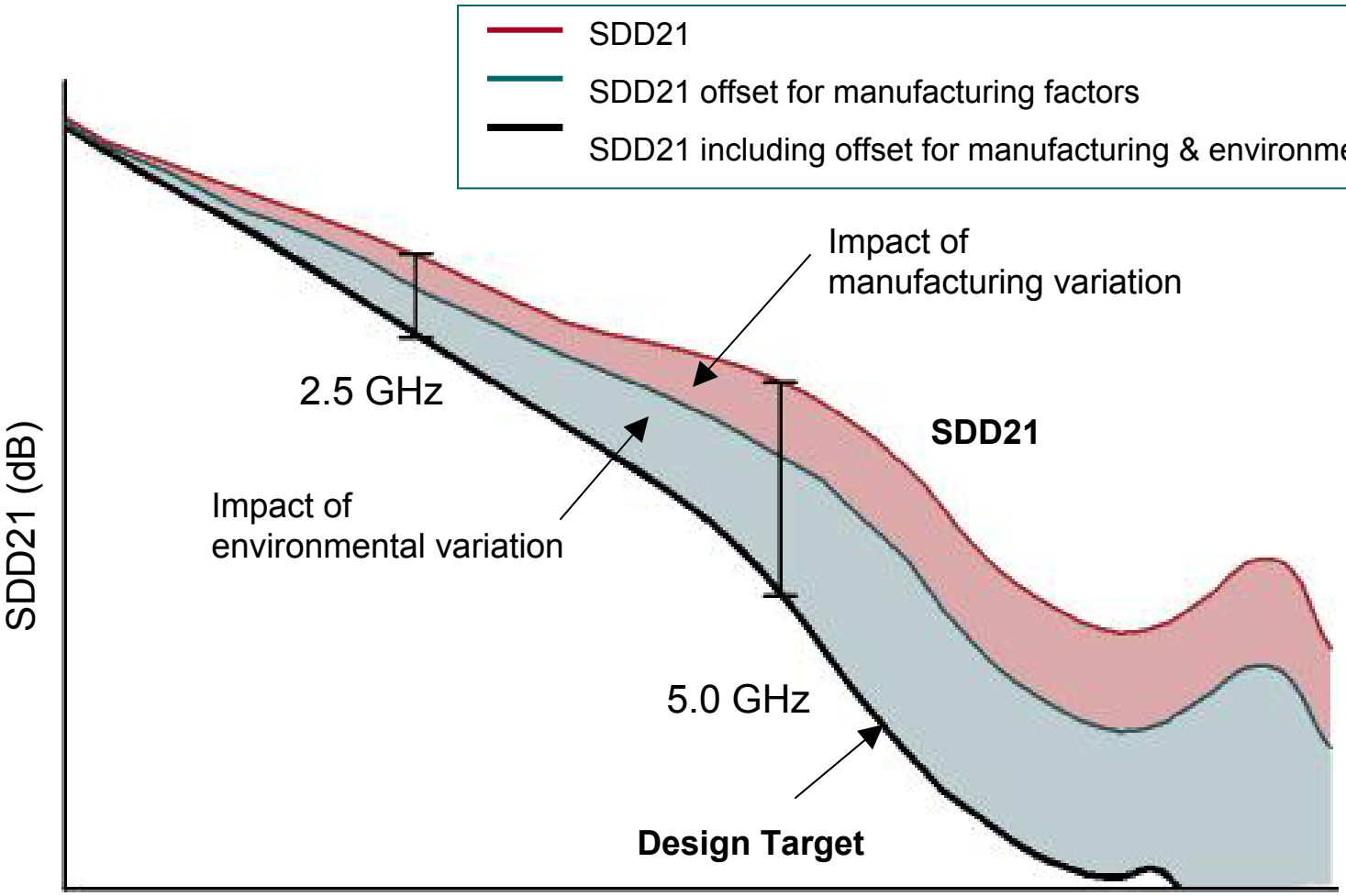
Channel Ad Hoc Model



Proposed Ad Hoc SDD21 Channel Model

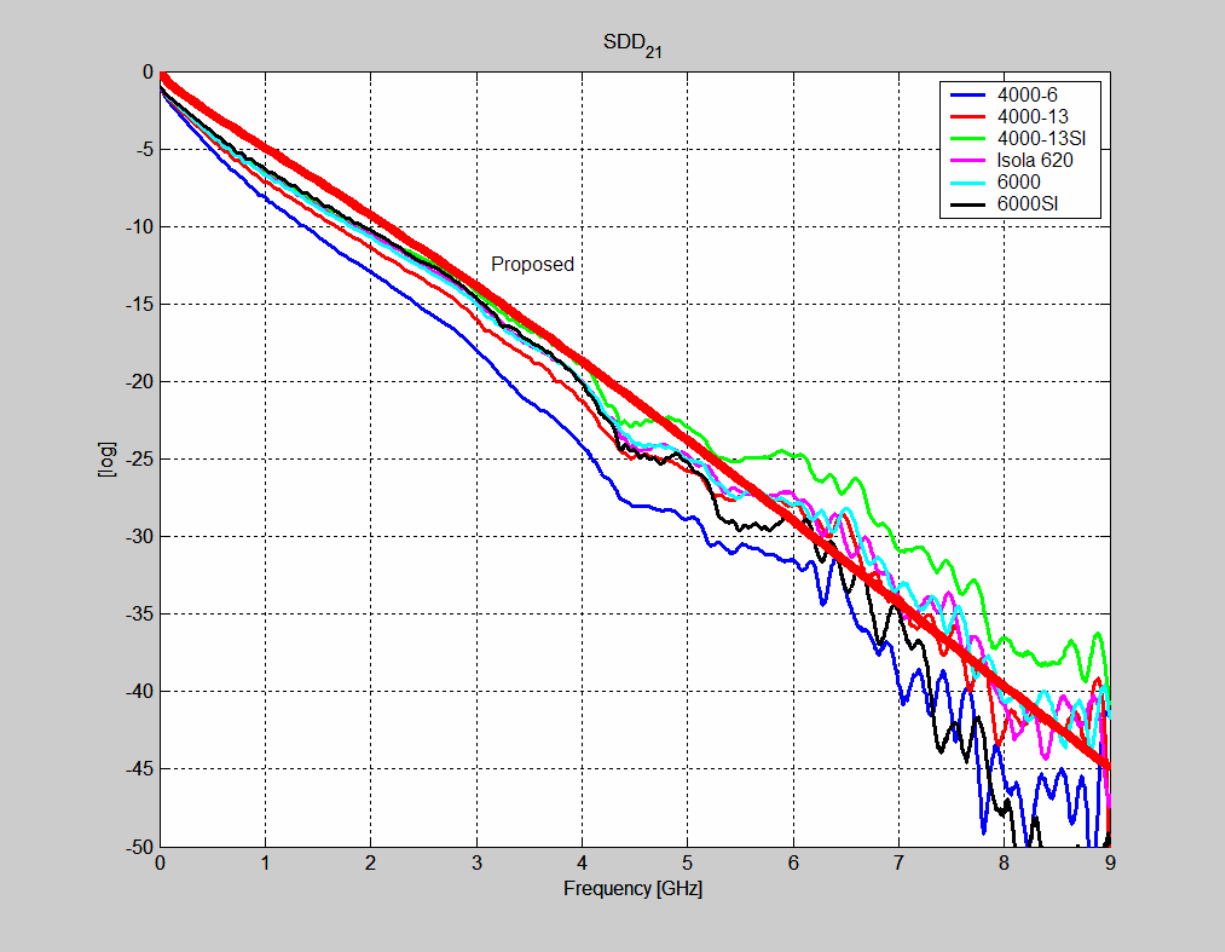


We Are Dealing with a Time-Varying Channel



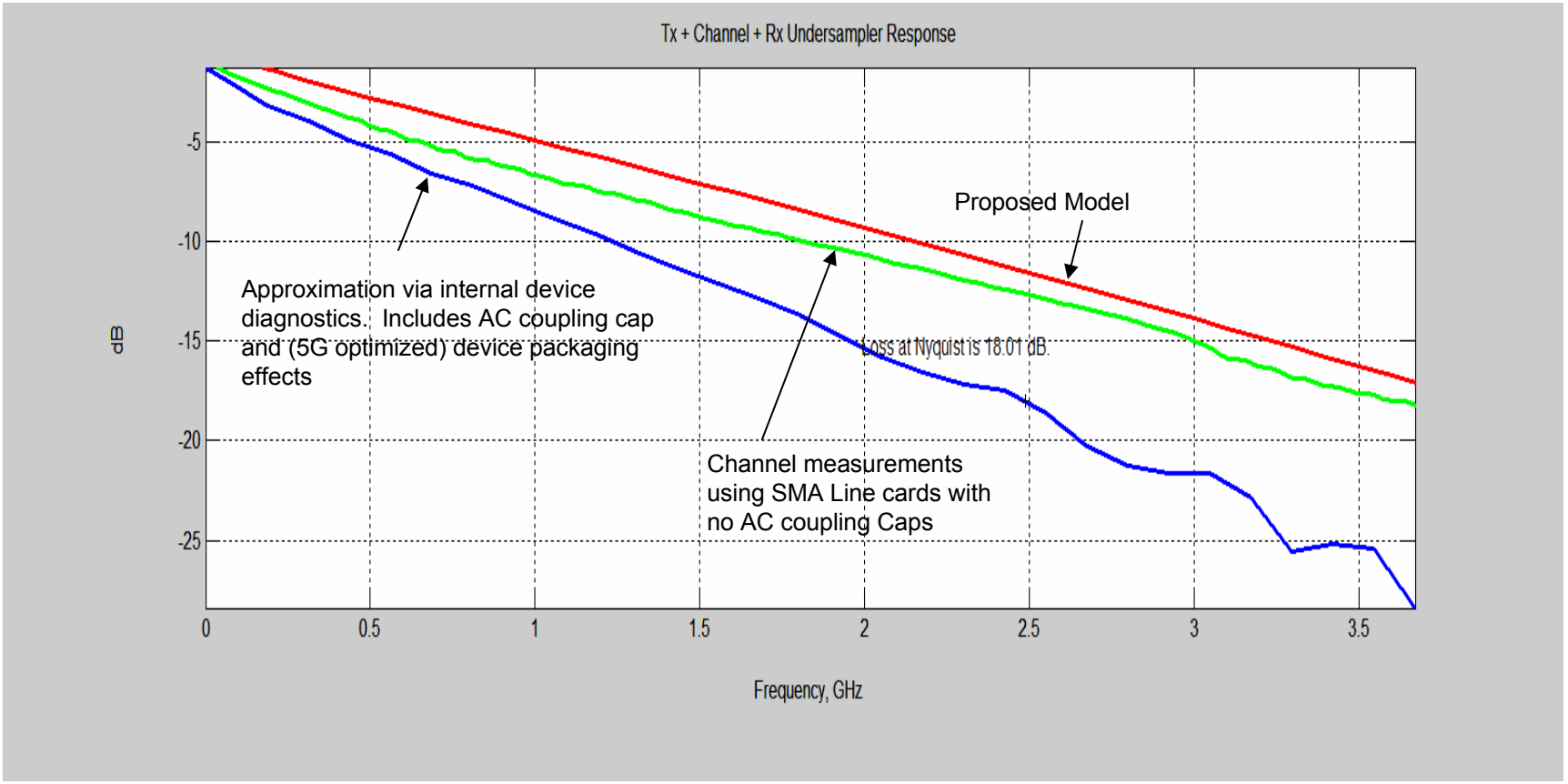
"A time-invariant system is a system whose characteristics are not a function of time" C. Phillips and R Harbor, "Feedback Control Systems, 4th ed.," Prentice-Hall, 2000, p. 581.

Measured 34” QuadRoute Channels



- QuadRoute Backplanes
  - 4.75 mil wide traces on all but 4000-6 version
- Uses HM-Zd SMA Line Card
  - 4000-2
  - 6 mil wide traces
- Out of 34 failures
  - 13 from 4000-6
  - 11 from 4000-13
- Loss was a factor!
- Removing crosstalk (4 FEXT, 4 NEXT) sources helped in limited re-testing. S/N is an issue.

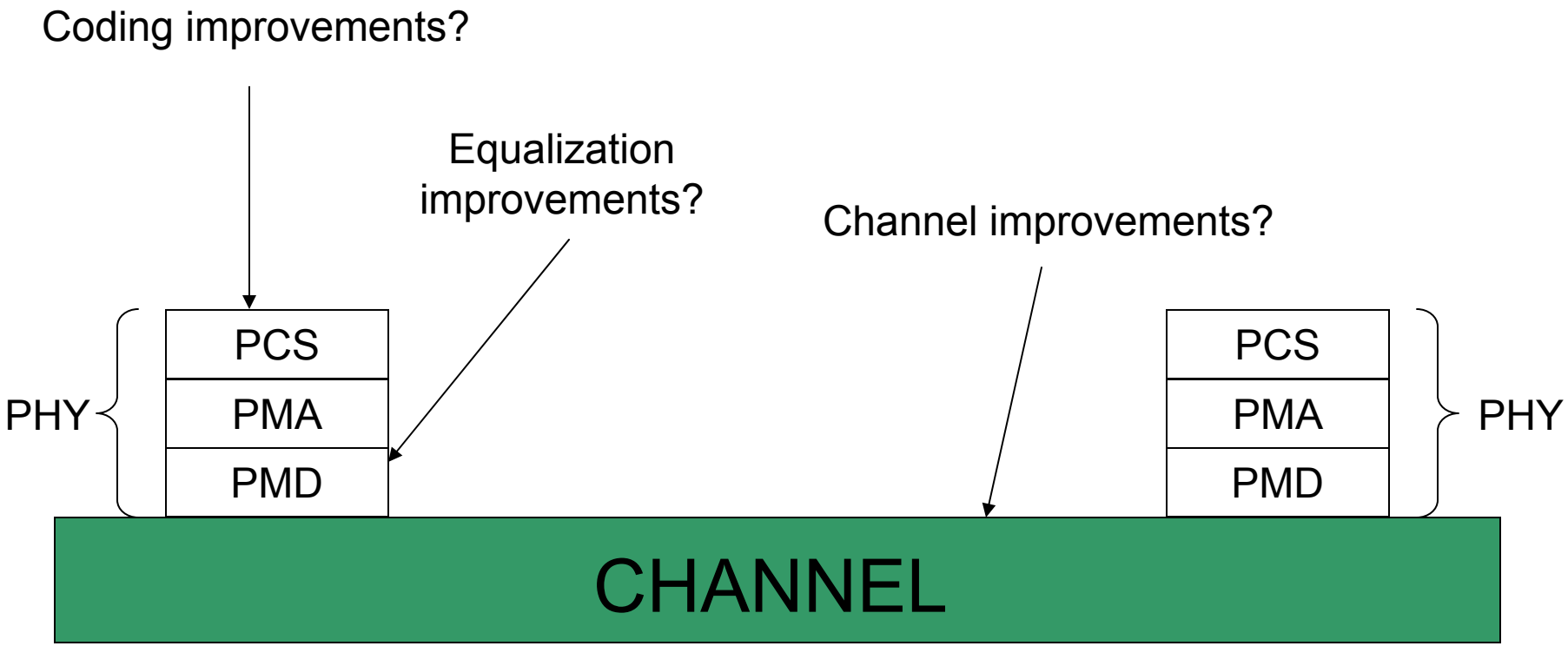
A Channel the 5G Part Didn't Go 10G



6000_Link3_Left_Channel0

The Big Picture Going Forward

- Baseline established with measured Test Data from PAM-4 5G devices overdriven to 10G
- Lots of opportunity for margin from an on purpose 10G PAM-4 device:



Conclusions

- Channel loss played a significant role in an observed number of test failures
  - Device packaging optimized for 5G operation influenced total channel loss
  - Crosstalk in relation to loss (S/N Ratio)
  - Reduction in channel loss (observed from shorter distances) yielded higher success
- Real world measurements show that PAM-4 transmit equalization will deal with approximately -15 dB (total system)
  - Under crosstalk conditions
  - Real-world device return loss
  - Non-optimized device packaging
- Areas to consider for improvement
  - Device Packaging
  - Channel Improvements
  - Equalization Improvements?
  - Coding gains?