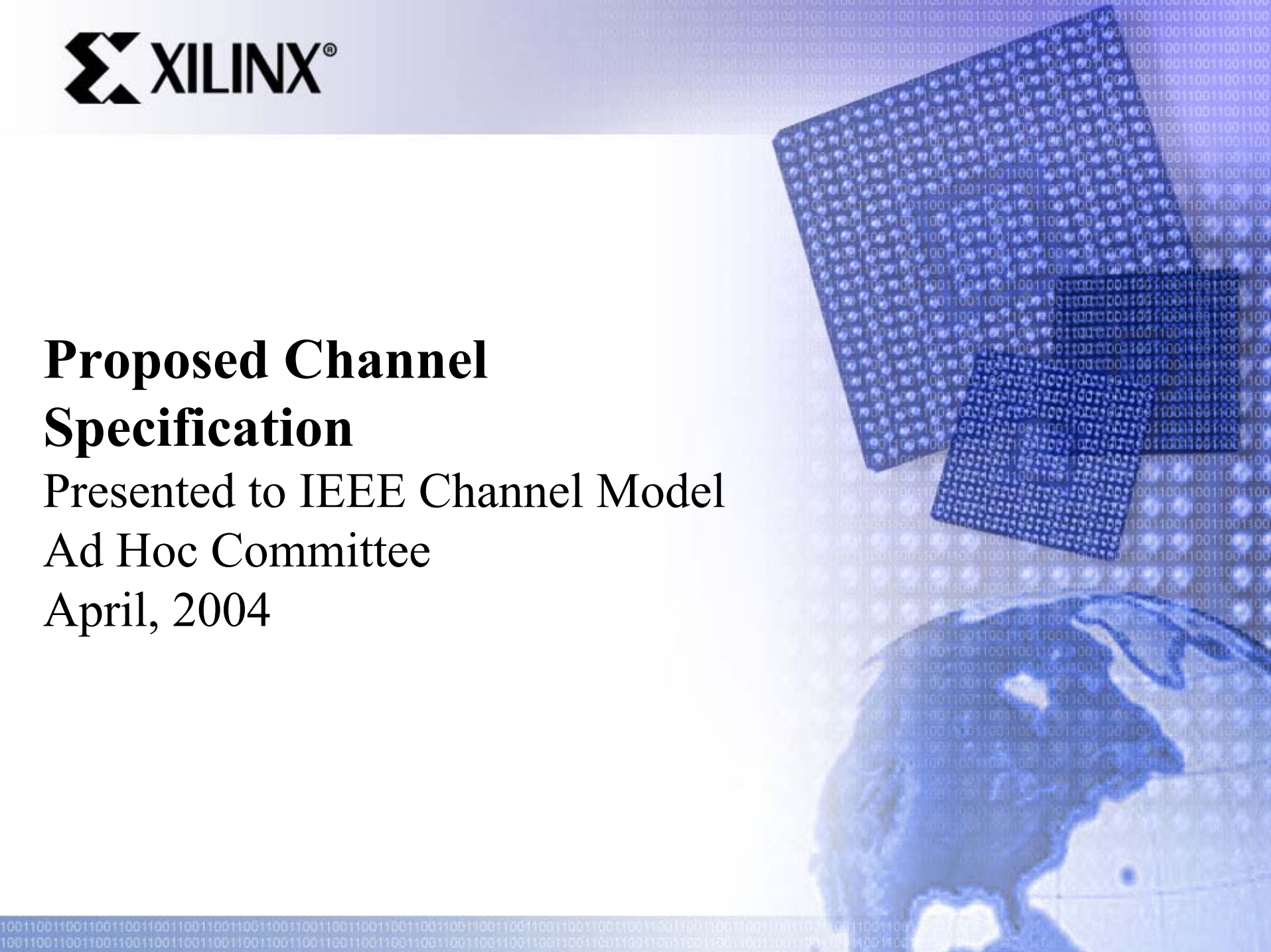


Proposed Channel Specification

Presented to IEEE Channel Model Ad Hoc Committee

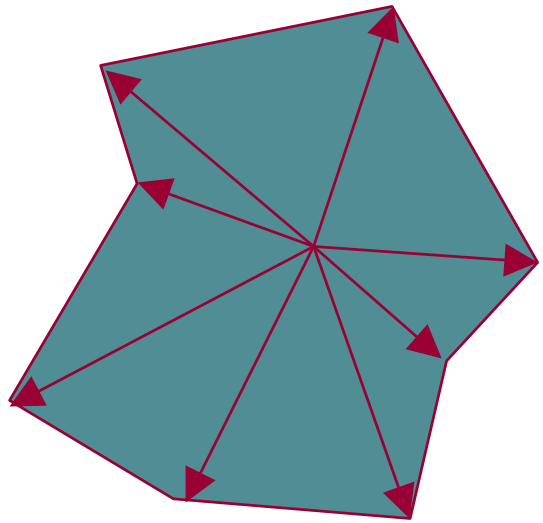
April, 2004

Outline

- Problem Space vs. Solution Space
- The Available Channel
  - What we control and what we measure
- Pulse Response: An Approach
- Pulse Response Description of a Channel
- Dealing With Impairments
  - Crosstalk
  - Reflections
- Conclusion

What is a Space?

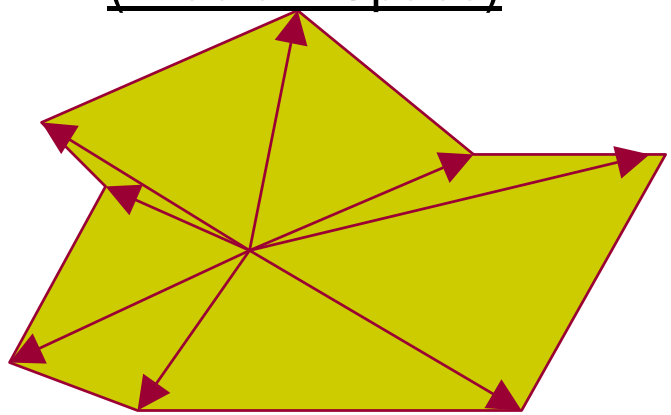
- Operating Envelope
- Can generally be staked out in either the…
  - Frequency domain
    - Loss
    - Phase
    - Noise energy
  - Time domain
    - Pulse response
    - Jitter



Different Causes = Different Effects

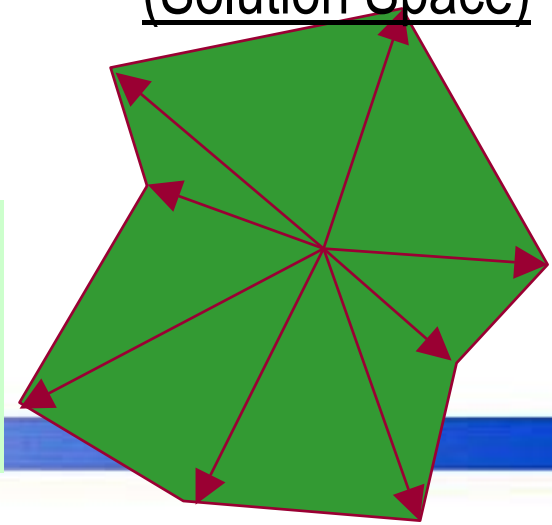
Channel Physics
Materials
Dimensions
Shapes

Channel Electrical Characteristics
(Problem Space)



Transceiver Physics
Voltage
Gain BW
Semiconductor Physics

Transceiver Electrical Characteristics
(Solution Space)

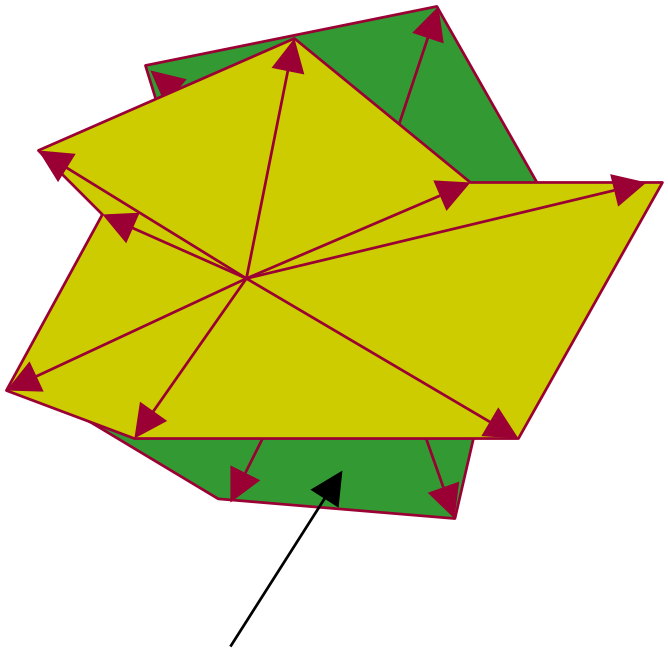


- Because the underlying physical layers are fundamentally different, the spaces are different shapes
  - Great example: Emulating a tube amplifier with transistors

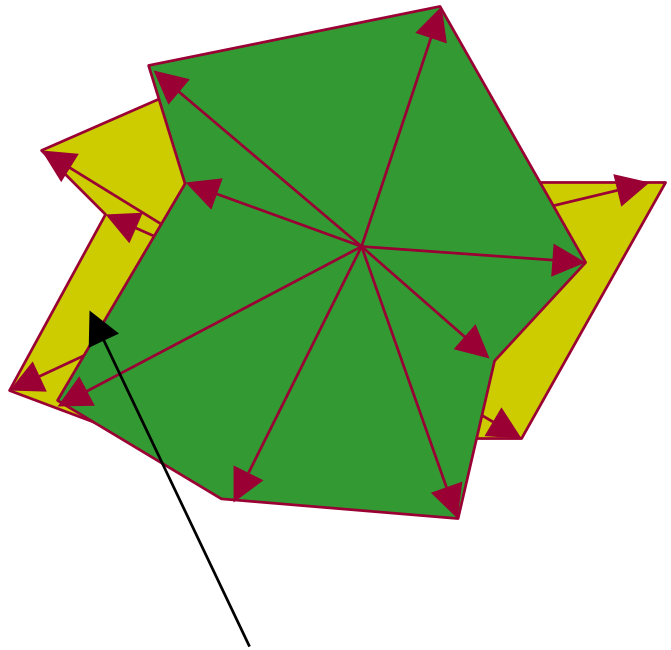
Solution vs. Problem Space

- Goal is to answer whether…
  - Solution space (Transceiver capability) and the
  - Problem space (Channel difficulty) intersect in a volume that is…
  - Valuable in the customers' eyes

The Problem with Compliance

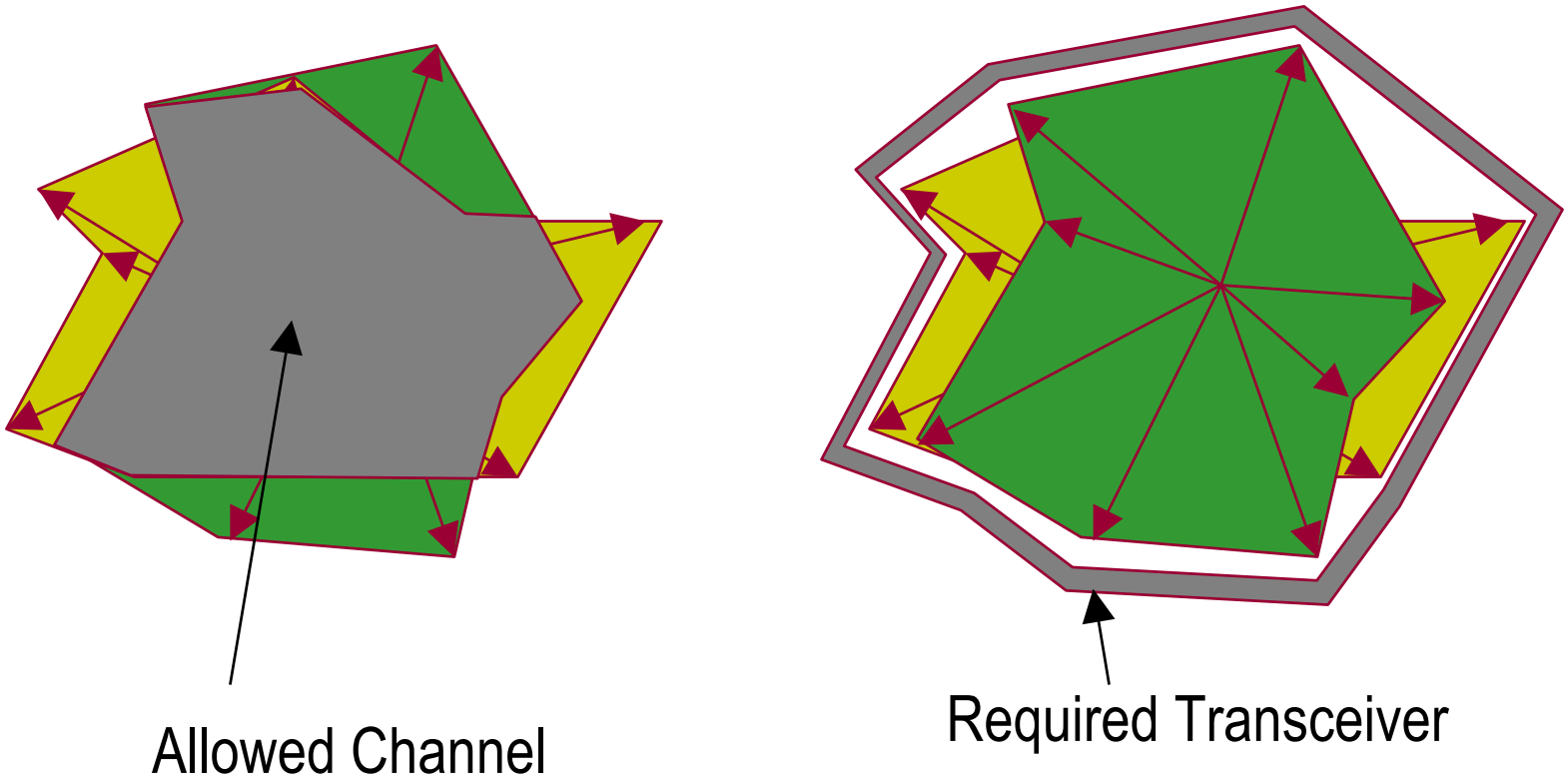


Unsused Transceiver Capability



Unserved Channels

How Mismatch is Mismanaged



Stat Eye

- A channel and it's interfering neighbors is compliant if a designated transmitted pulse travelling through the channel can be received by a designated receiver with some probability

Advantages of the Stat Eye

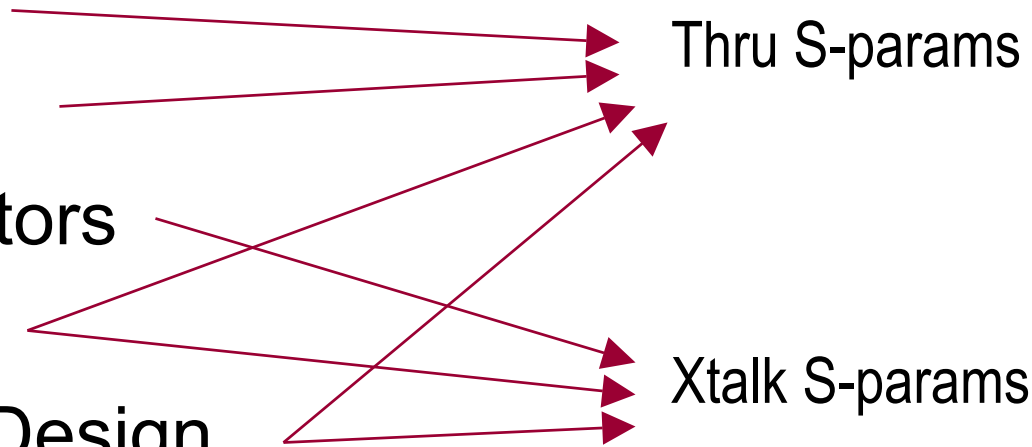
- Makes the best fit ever attempted in determining whether a particular channel was within the transceiver solution space
- Minimizes false positive/negatives
- Exploits the fact that the variability in the universe of transceivers will be miniscule compared to the variability in the universe of channels
- Provides a BER capability of a channel

Issues with the Stat Eye

- Small number of individuals
  - understand it
  - control it
- Black box – “Pay no attention to the algorithm behind the curtain”
- Si designers feel constrained to the designated receiver
- Receiver compliance requires throwing every possible compliant channel at it

Factors Influencing the Available Channel

- Length
- Material
- Connectors
- Density
- Layout Design



We control these

We measure these

Simple Compliance Approach (algorithmic, but too simple)

- Utilize the two key transceiver characteristics:
  - Rx sensitivity
  - Signal to noise ratio limit
- On any particular channel…
  - Loss < Rx sensitivity
  - Loss – Net Crosstalk < SNR limit
- Allows lower loss channels to have more crosstalk
- But still ignores jitter, phase, signal content

How Do S-params Tell Us Whether Channel is OK?

- Answer: They *indicate*, but don't confirm
- The information is not in an useful form
  - contains both real and imaginary matrix elements
  - Not clear how or whether fluctuations in freq domain translate into signal impairments
  - Receivers do not fundamentally operate in the frequency domain

Another Approach

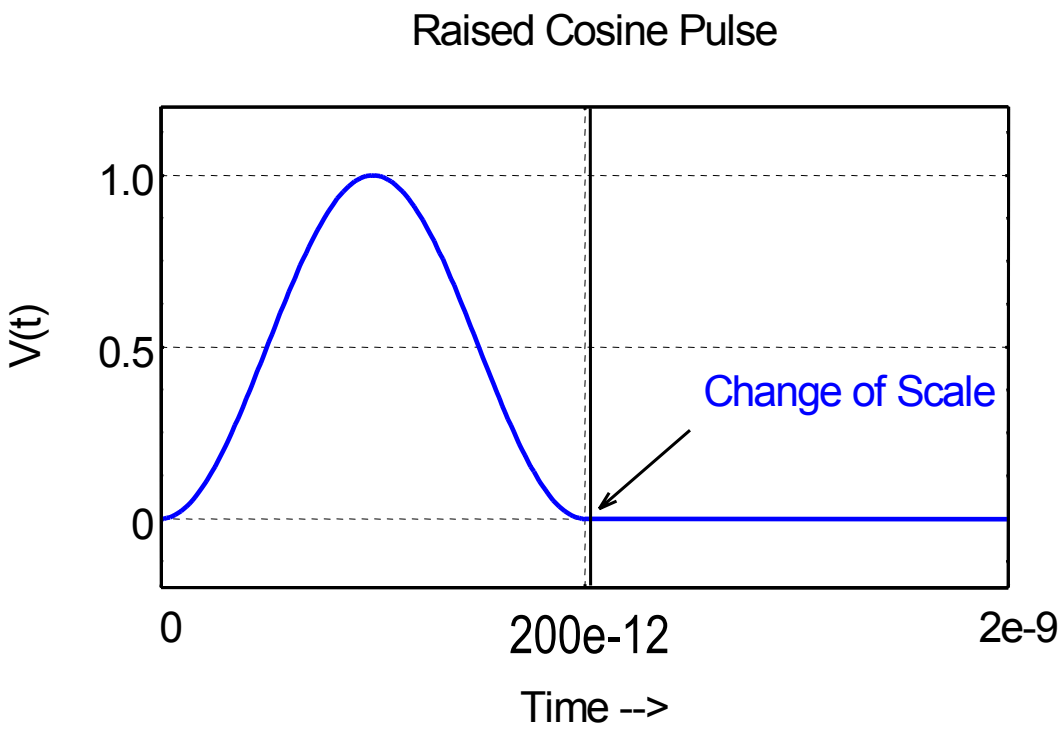
- Convert Thru SDD21 (or SDD21 + termination effects) to a Pulse Response
- Constrain the Pulse Response
- Add guard bands to Pulse Response to account for Crosstalk
- Unaddressed:
  - Tx or Rx Jitter

Generating A Pulse Response

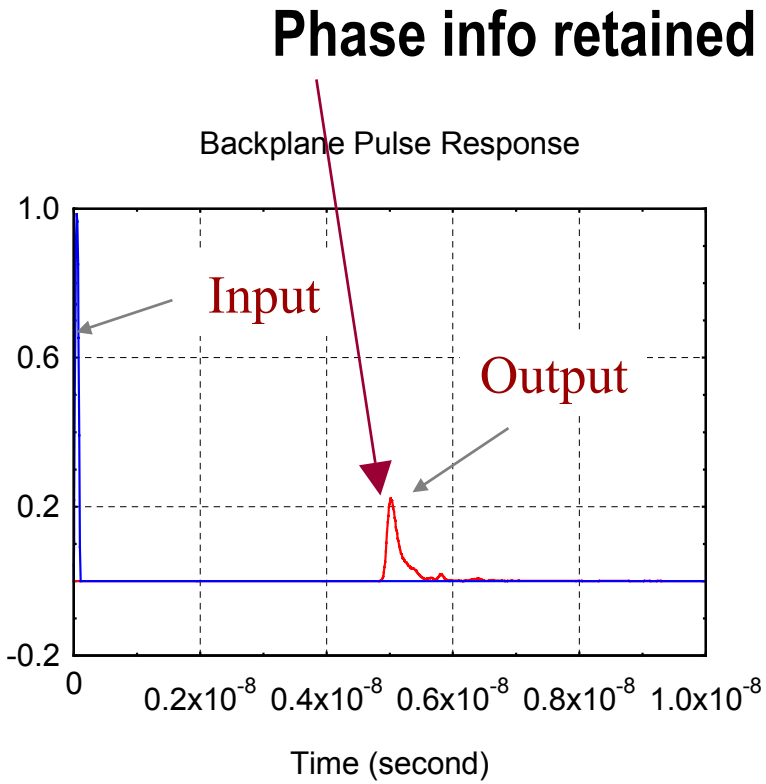
- Create a time-domain pulse
- Convert pulse to freq domain (becomes complex array)
- Multiply by Thru SDD21 (also a complex array)
- Convert result back to time domain
- Sample the result in the time domain using baud-spaced sampling
- Examples follow

Example Applied Pulse

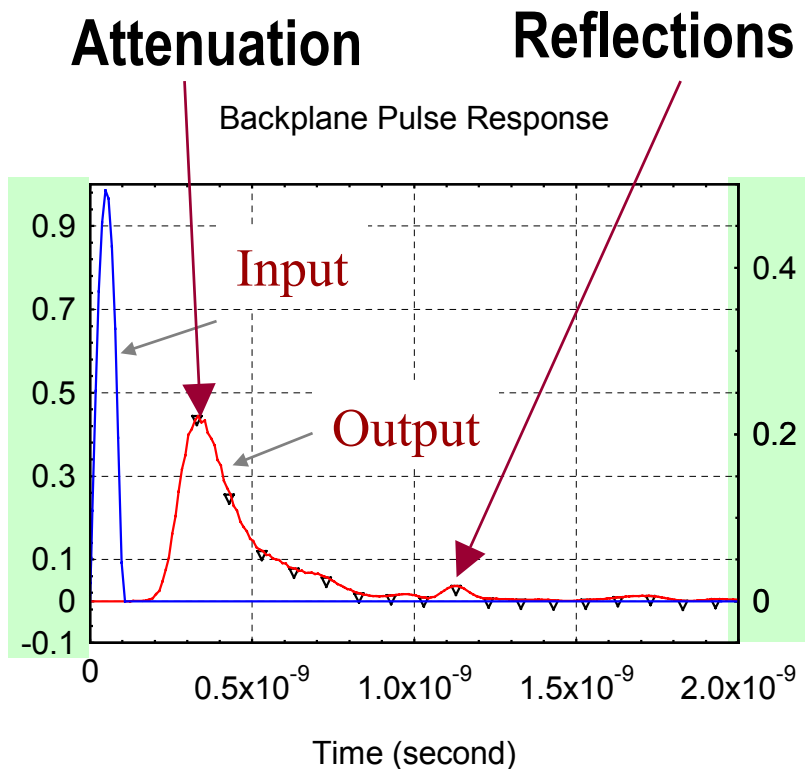
Applied Pulse
and Pulse Response
Are Mathematical
Entities Only



Calculated Response Pulse For S-params of Previous Slide

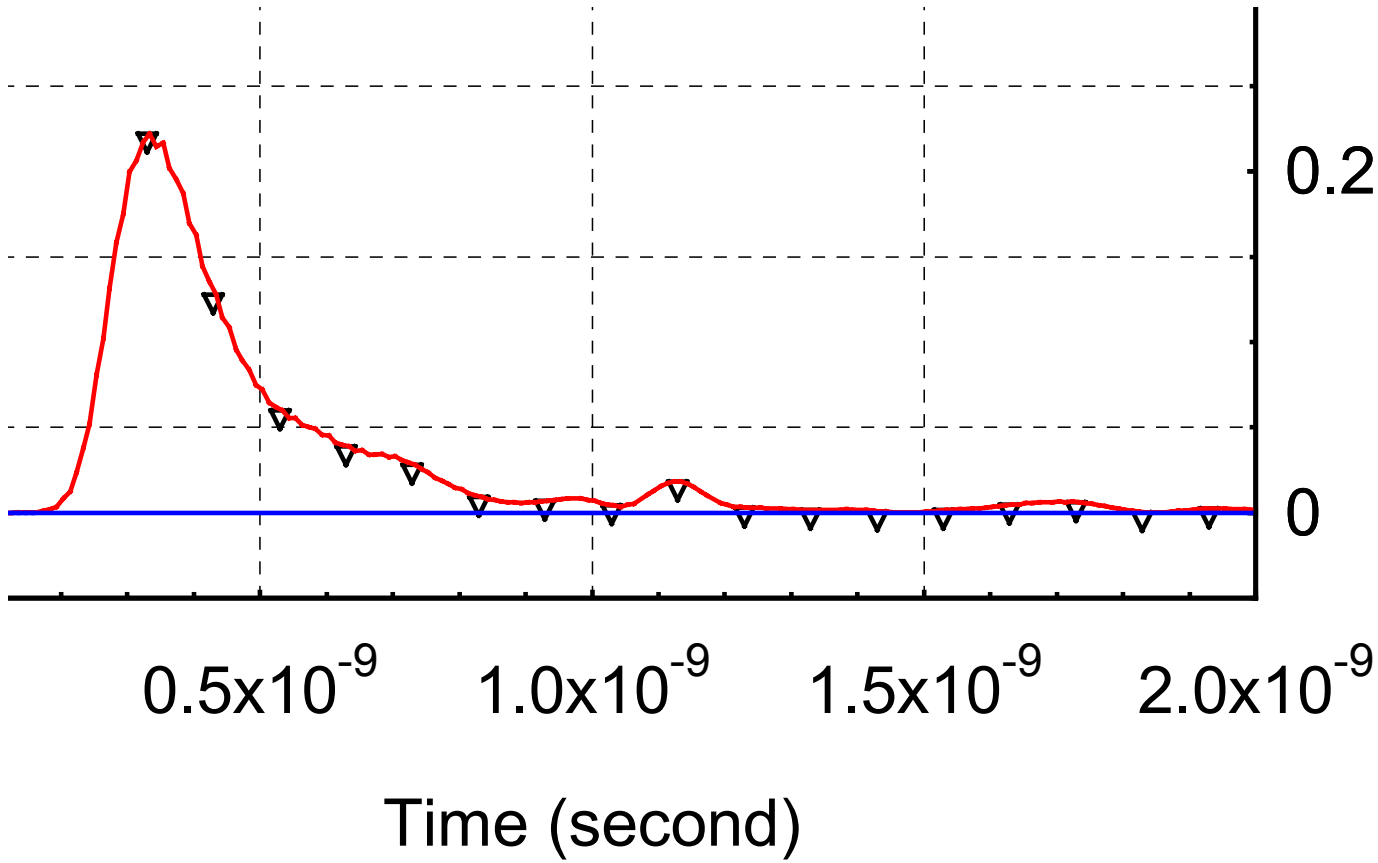


Applied and Response Pulses

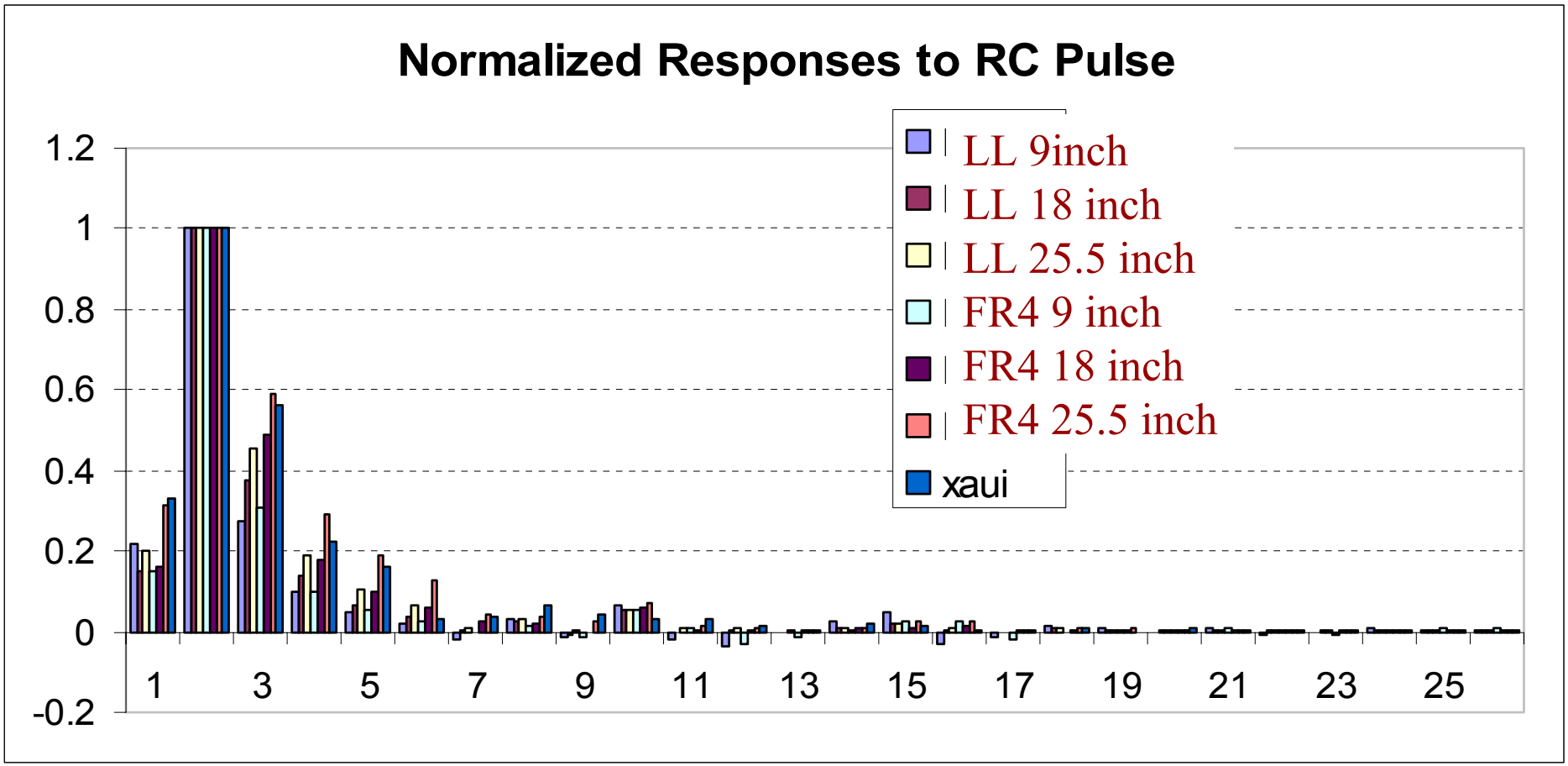


Same as graph at left with Applied and Response Pulses Expanded to Show Detail

Output Pulse Showing Sampling



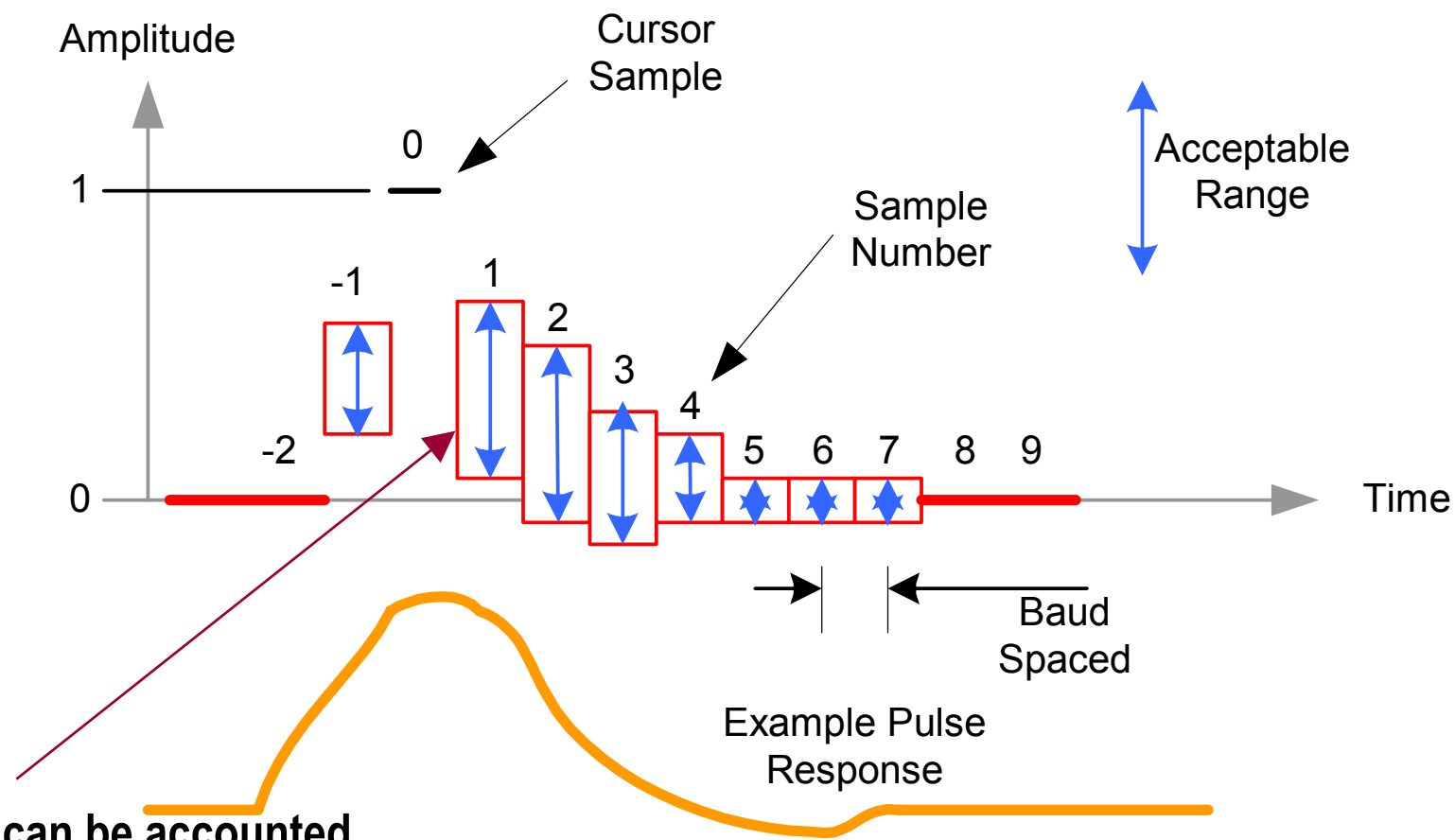
Pulse Responses for Some Example Channels



Add and Subtract a Guard Band from the Samples To Account for Crosstalk

- Need diagram

Do The Samples Fall Within Prescribed Range?



Crosstalk can be accounted for by including a scaled, constant band of variability

Example Normalized Sample Ranges

Precursor	0	0.3
Cursor	1	1
Next one	0.2	0.5
Next one	0	0.2
Next one	-0.05	0.175
Next 5	-0.05	0.1
Next 6	-0.05	0.05
Next 4	-0.025	0.025

Cursor (Largest Sample) Minimum Amplitude
Before Normalization = 0.2

Recommendations

- Rationally constrain both the channel and the transceivers
  - Don’t be arbitrary to one extreme
- Reasonably minimize the “slop” or guard-banding
  - Be careful about how much we leave on the table
- Use Pulse response as basis for channel compliance
  - Include crosstalk effects
  - Include jitter
- Stat Eye continues to have value in evaluating system BER capability