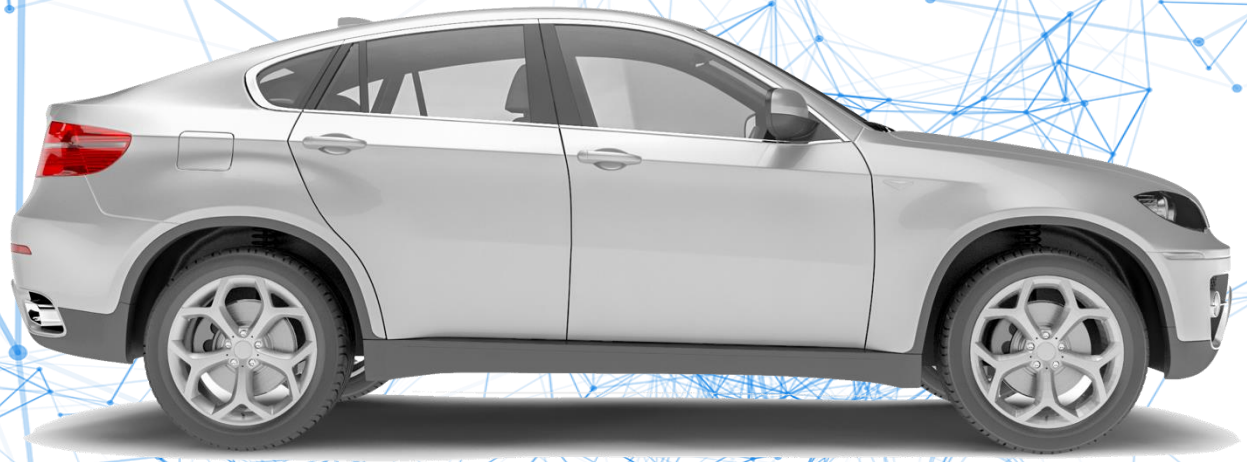

Time Domain Limits for Return Loss

Hossein Sedarat

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Overview

- Exploring a specification for limit line of return loss in time domain

- Independent limits on
  - Major reflections at discrete points of discontinuity (connectors)
  - Micro-reflections due to inhomogeneities within a cable segment

- Motivation: lower complexity of PHY with guaranteed performance

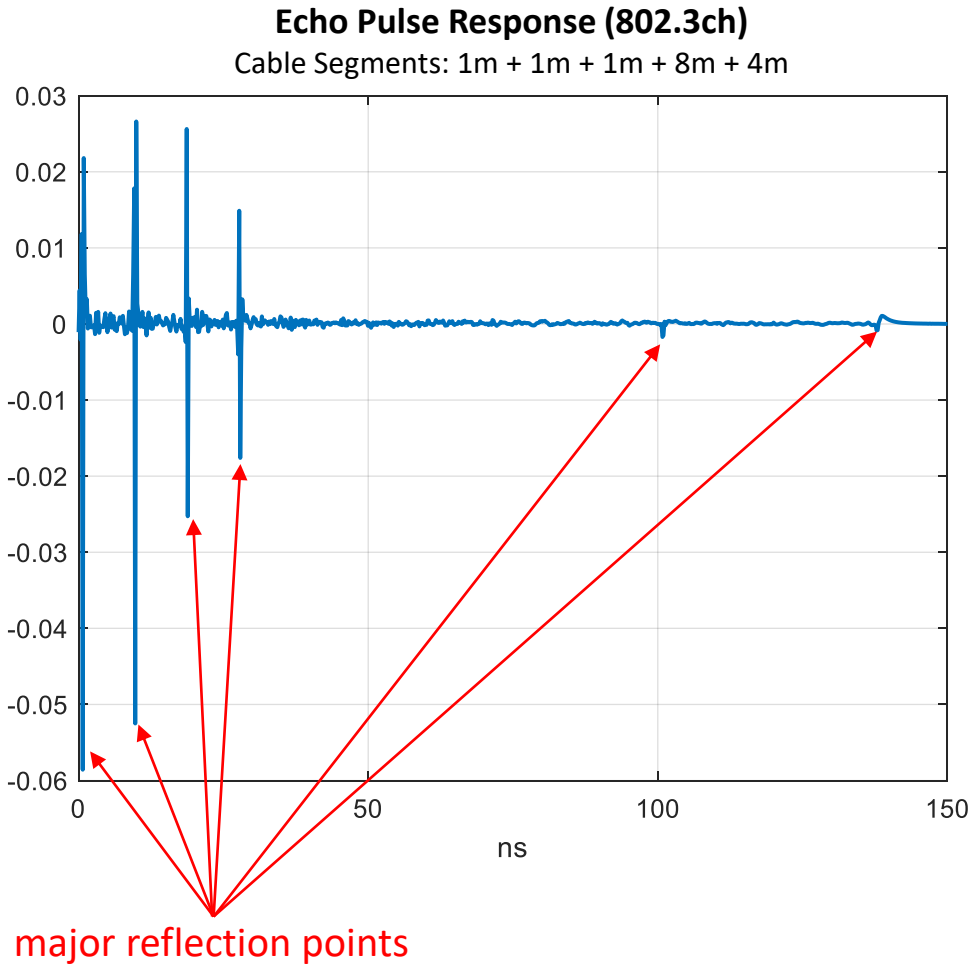
Agenda

- Echo channel pulse response and RL limit line
  (using 802.3ch as an example for the channel response)
- Echo canceller complexity and its dependency on limit line
- Return loss limits in time domain
- Potential echo canceller simplifications
- Summary and suggested next steps

Echo Response and RL Limit Line

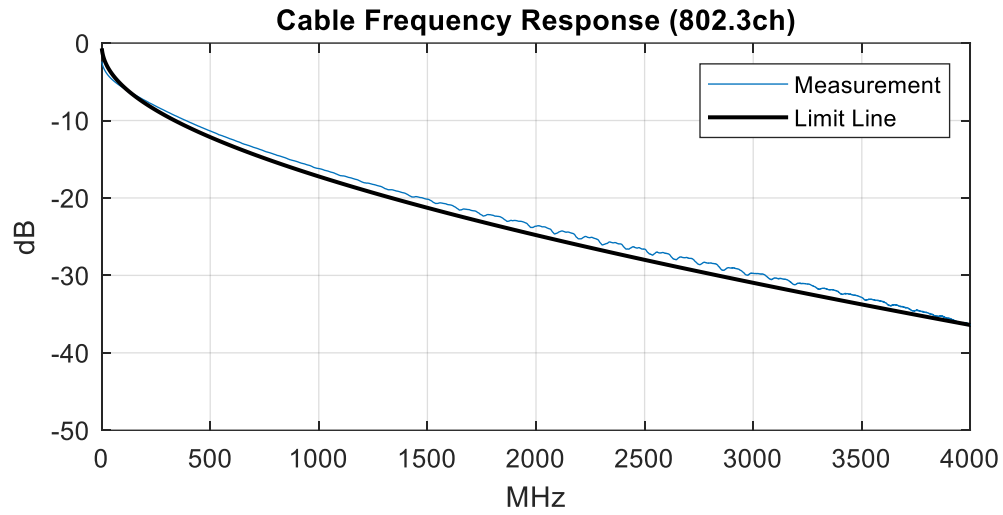
Echo Response in Time

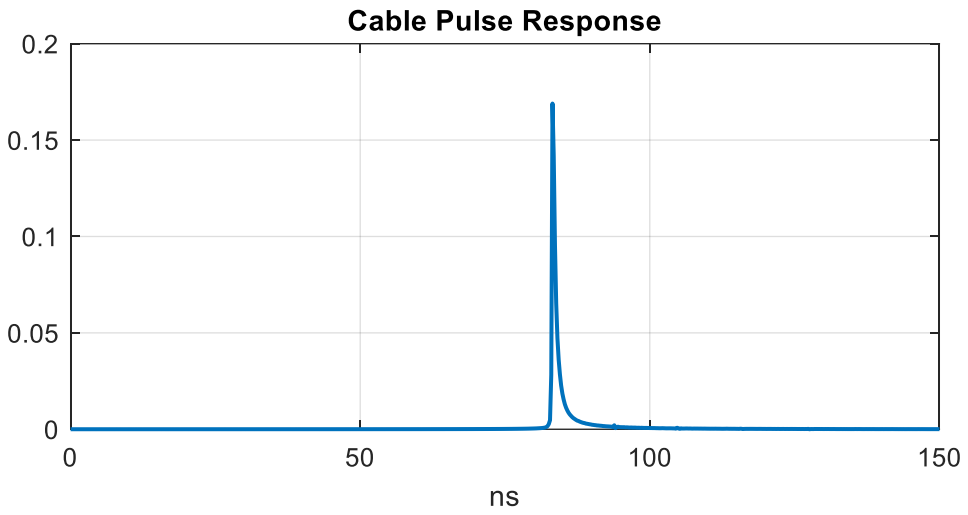
- The echo pulse response consists of major reflections from a maximum of 6 discontinuities in the link segment
  - 2 MDI interfaces
  - No more than 4 connectors
- There are micro reflections, in between discontinuities and spread throughout the cable, due to cable inhomogeneity (nonuniform characteristic impedance)



Insertion Loss Limit Line

- Specifies the maximum channel loss in frequency
- The limit line is a good match to the cable measurements
- The pulse response is predictable from the limit line
  - Delay
  - Magnitude
  - Spread





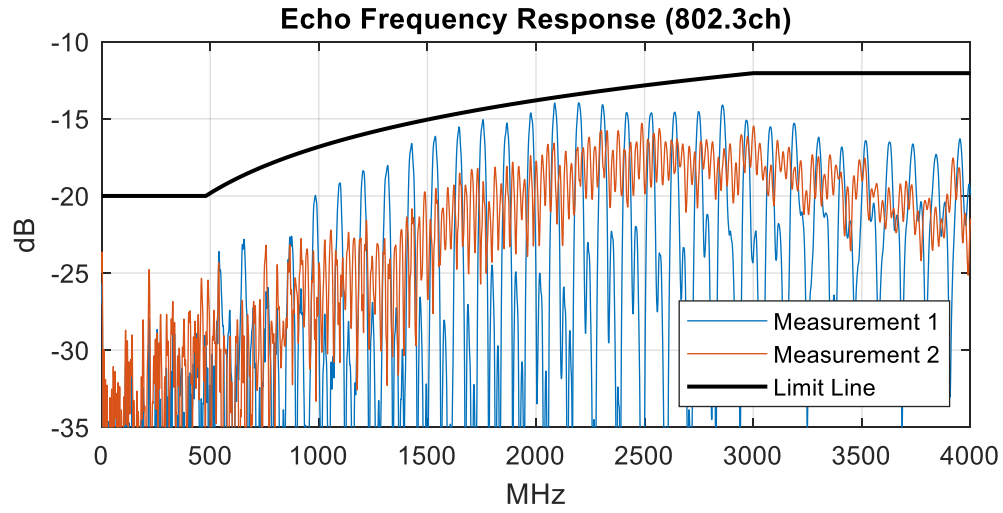
Return Loss Limit Line

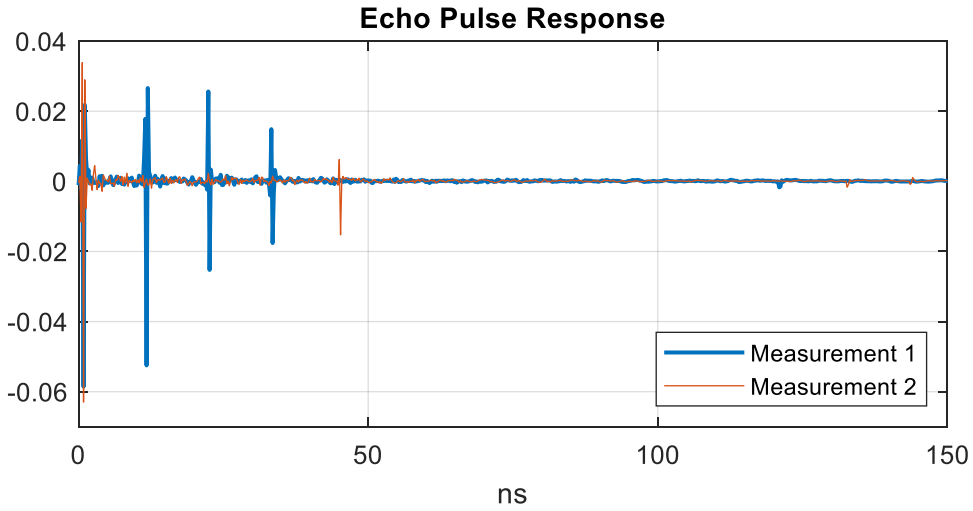
- Specifies the minimum channel loss in frequency
- The limit line is only an upper bound and envelope for the measurements
- The limit line does not provide much insight into the salient features of echo:
  - Major and micro-reflections

➔ conservative design of echo canceller

  - Overall echo power

➔ excessive dynamic range for PHY front-end





Echo Canceller Complexity

Echo Canceller Complexity

- Echo canceller is a filter with coefficients that replicate the echo pulse response
- Echo canceller is one of the more complex blocks in the receiver
- The complexity, in a straight implementation, grows with:
  - Operating frequency: baud rate
  - Number of coefficients:
    - (propagation delay) × (baud rate)
    - proportional to (cable length) × (baud rate)
  - Coefficient resolution: magnitude of reflections
- Complexity grows with:

$(\text{baud rate})^2 \times (\text{cable length}) \times (\text{magnitude of reflections})$

Echo Canceller Complexity: 25G vs 10G

- Assuming:
  - Baud rate scales by 2.5x
  - Max cable length of 11 m in 25G system vs 15 m in 10G system
  - Similar amplitude of reflections
- Number of filter coefficients:
  - 10GT1 ≈ 1060 taps
  - 25GT1 ≈ 1940 taps
- Number of operations per second
  - 10GT1 ≈ 6 TOPS
  - 25GT1 ≈ 27 TOPS

Echo Canceller Complexity and RL Limit Line

- Complexity: **(baud rate)^2 × (cable length) × (mag of reflections)**

- Cable specification does not directly impact the baud rate or max cable reach
  - RL limit line can only impact the amplitude of reflections

- RL limit line, if specified in frequency domain,
  - does not differentiate between micro and major reflections
  - does not provide a direct limit on the magnitude of the reflections

  ➔ Echo canceller is designed with some conservative assumptions resulting in excessive complexity

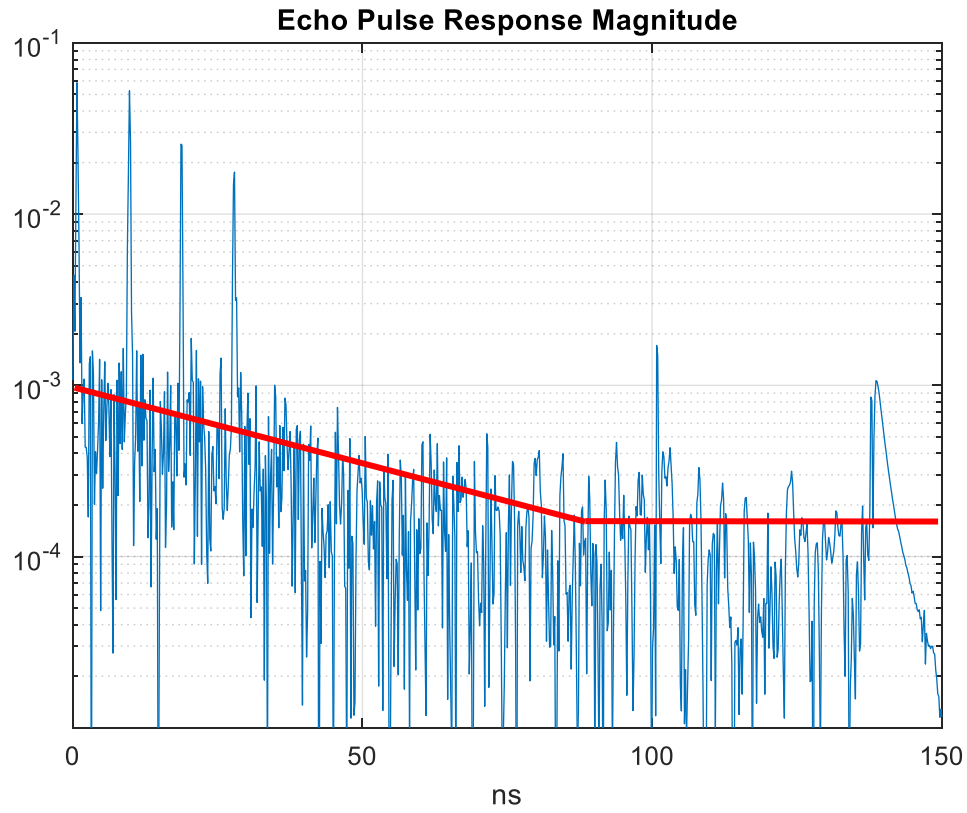
Return loss limits in time domain

RL Time-Domain Limits

- Based on behavior of echo channel pulse response
- Separate limits for
  - Micro reflections
  - Major reflections
- Closely tied to the physical sources of reflections

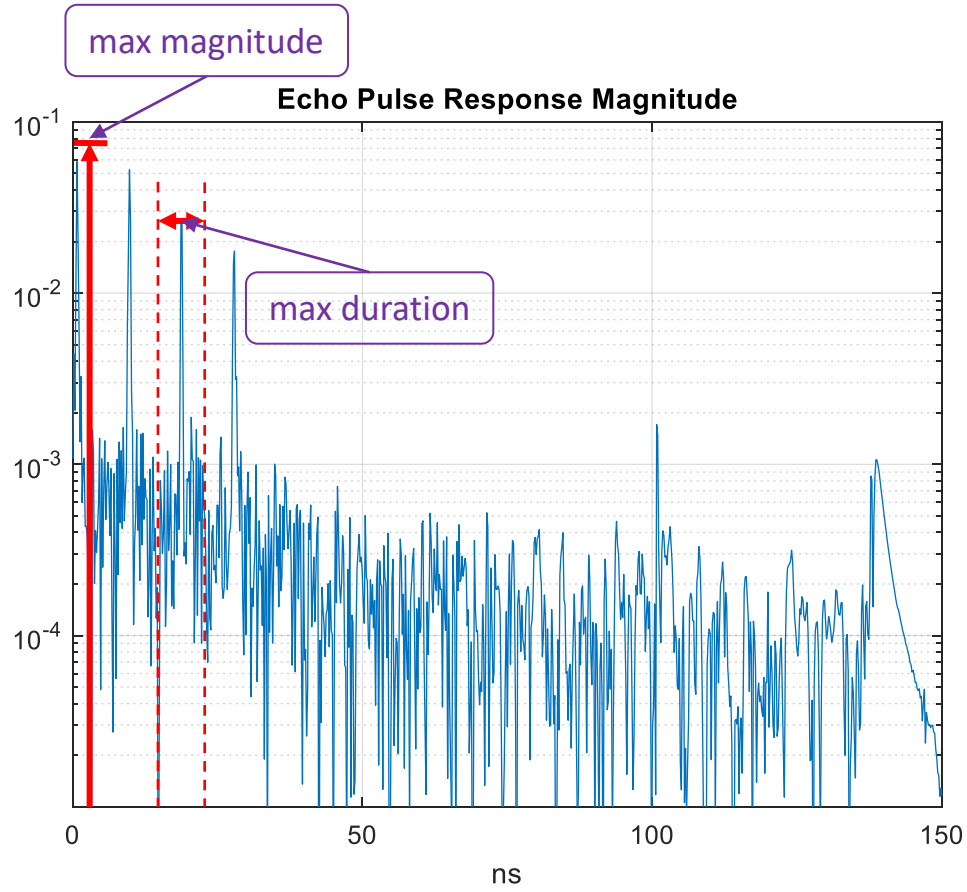
RL Time-Domain Limits – Micro-Reflections

- Specify a limit on the magnitude of the micro-reflections based on
  - variance of characteristic impedance within cable
  - minimum insertion loss per unit cable length
- The limit may specify the maximum average reflection power per unit cable length
  - total micro-reflection power should also remain lower than the integrated power from this limit line



RL Time-Domain Limits – Major Reflections

- Specify a limit on the maximum magnitude (or power) of major reflection at discontinuity
  - Depends on the maximum difference in characteristic impedance
  - Depends on the geometry and construction of the connector
  - Should specify the time span of reflection
  - Should also specify the <u>minimum</u> insertion loss per unit cable length



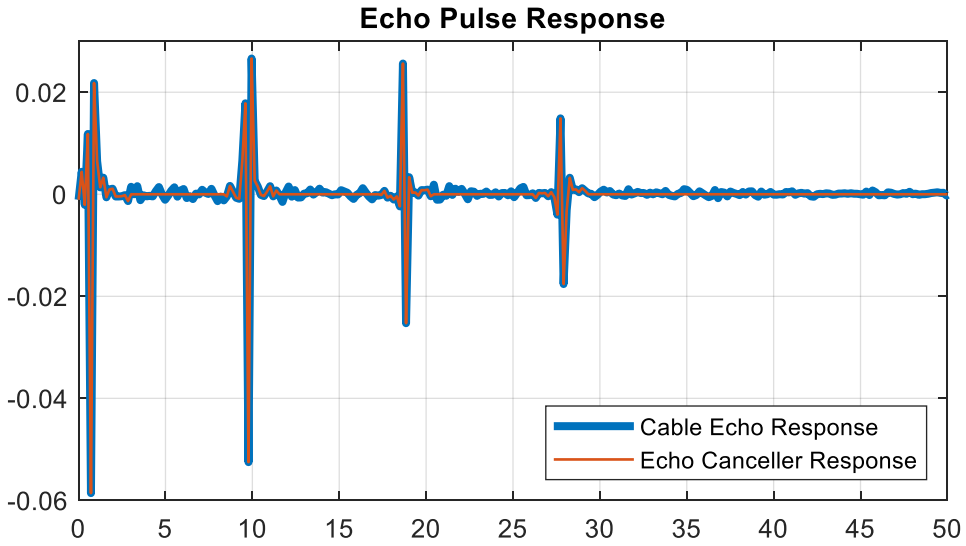
Simplified Echo Canceller

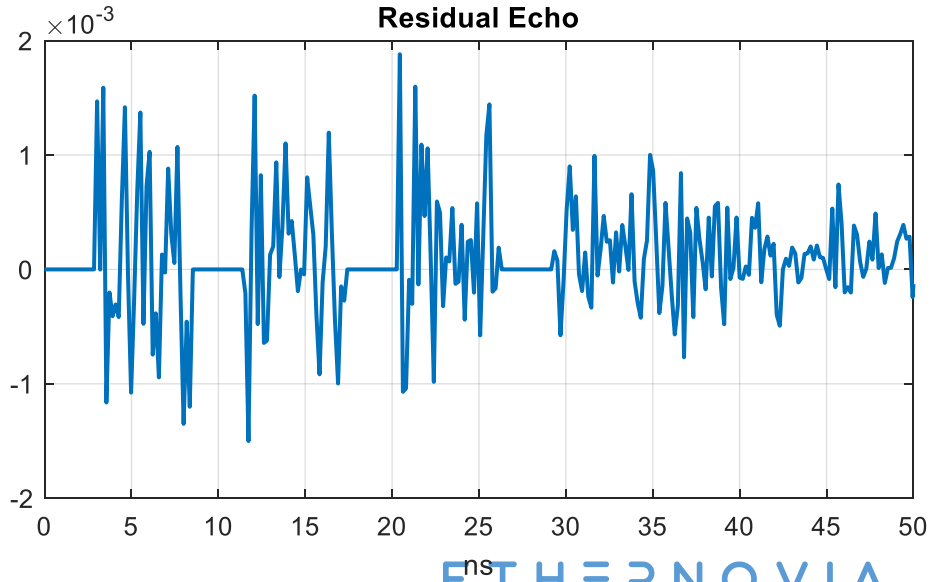
Echo Cancellation with Segmented Filter

- If micro-reflections are guaranteed to be sufficiently small beyond certain cable length, the corresponding echo canceller coefficients may be forced to zero and eliminated
- The echo cancelling filter is broken into segments that cancel local reflections with high power, leaving smaller reflections uncancelled
- The residual echo power from uncancelled minor reflections is tolerated and budgeted in the SNR margin

Example:
Very Small Micro-Reflection

- The RL limits guarantee acceptable residual echo power from uncancelled micro-reflections
- Echo canceller consists of 6 filter segments to cancel major reflections only
- Roughly 200 coefficients for 6 segments
- 10x reduction in complexity



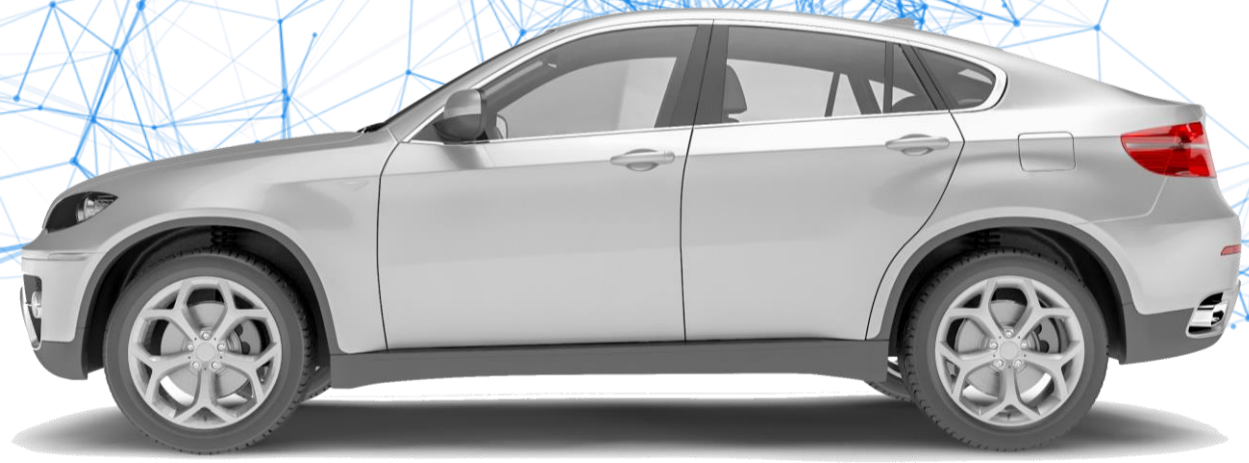


Summary

- A time-domain limit on return loss may be obtained based on
  - Variance of characteristic impedance throughout a cable segment
  - Mismatch between impedance of cable segments
  - Measurements from connectors
  - Minimum insertion loss per unit cable length
- A time-domain limit on return loss offers
  - Better correlation of channel reflections
  - Tighter estimate of the maximum echo power resulting in simpler PHY front-end
  - Clear guidelines for less complex design of PHY echo canceller

Suggested Next Steps

- Cable and connector vendors to validate the possibility of defining the limit lines in time domain
  - Limits on the magnitude of micro reflections (tighter control over cable manufacturing for better uniformity)
  - Limits on span and magnitude of major reflections at discontinuities
  - Limits on minimum insertion loss per unit cable length



THANK YOU

ETHERNOVIA | hossein.sedarat@ethernovia.com