Time-Domain Limits on Reflections

Hossein Sedarat

November 2020

Overview

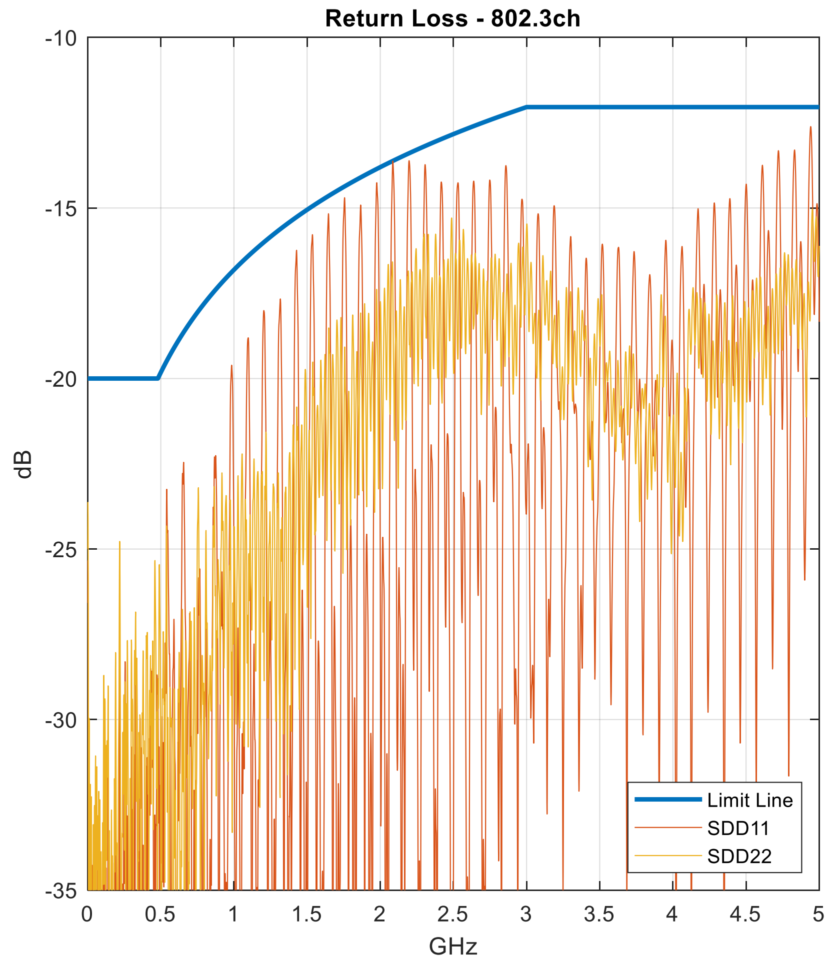
- Echo canceller is one of the most complex blocks in high-speed, full-duplex PHYs
- Time domain limits on return loss can reduce the complexity of echo canceller
  - sedarat_3cy_01_0920
  - sedarat_3cy_02_10_14_20
  - jonsson_3cy_01a_10_14_20
- This presentation explores some of these limits

Agenda

- Traditional limit on return loss in frequency domain
- Time-domain behavior of echo response and the complexity of echo canceller
- Decomposition of echo response to major and micro reflections
- Limits on major reflection points
- Limit on micro reflections
- Other limits including dynamic limits

Limit Line for Return Loss

- Traditional limit on return loss is defined as an envelope of the echo response in frequency domain
- This limit does not provide information on the structure of reflections in time domain:
  - Magnitude and position of reflection points
  - Span of echo response
  - Overall power of echo signal



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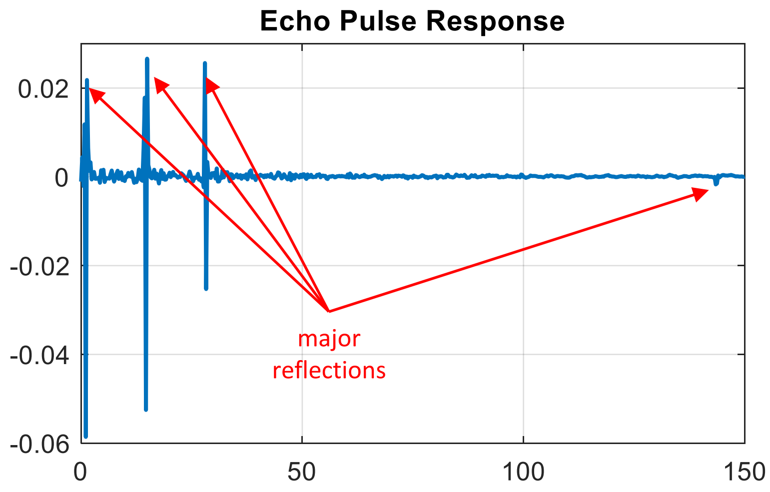
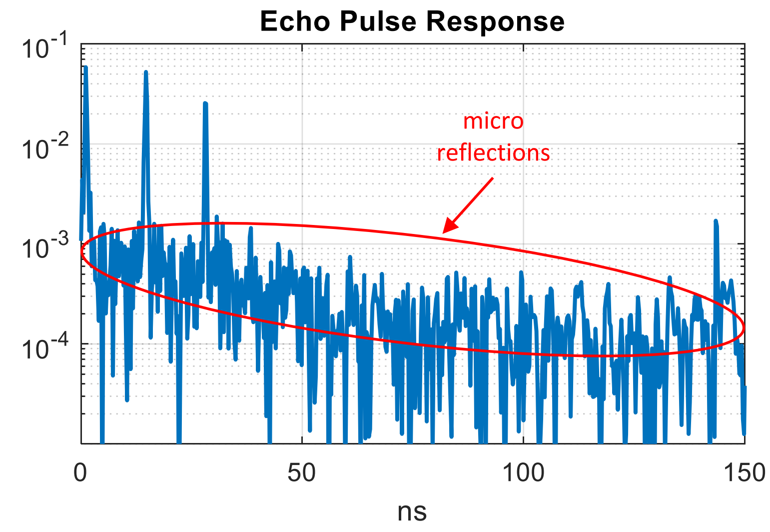
Reflections in Time Domain

- Major reflections
  - Limited to a few time segments with short span
    - MDI connections
    - Inline connectors
    - Points of compression or sharp bent in the cable
  - Contain most of the echo power

- Micro reflections
  - Spread out throughout the entire span of the echo response
  - Typically much lower power than major reflections but can be a significant limiting factor for SNR





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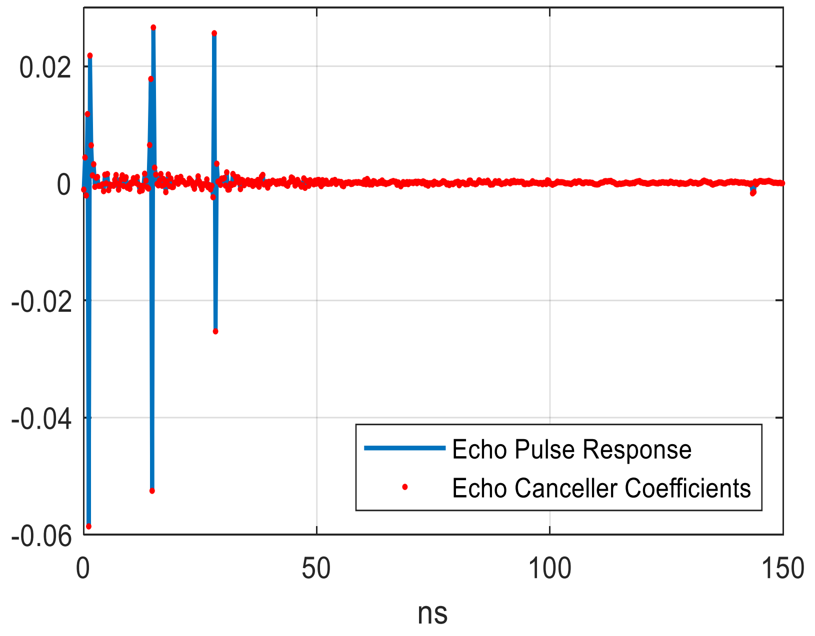
Echo Canceller

- Echo canceller is one of the most complex blocks in the PHY
- It is typically implemented as a finite impulse response (FIR) filter with coefficients that match the sampled echo response
- For an 11 m cable, the span of echo is mostly limited to roughly 150 ns
- Assuming a baud rate of 14 GHz, the echo canceller needs more than 2000 coefficients



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Echo Canceller Complexity

- An implementation of echo canceller as a generic FIR filter requires 28 TOPS

- The required resolution of the coefficients of the echo canceller has a direct impact on the complexity of that filter
  - The resolution depends on the magnitude of the echo pulse response
  - If a reflection point is sufficiently weak the corresponding filter coefficient may be negligible and eliminated

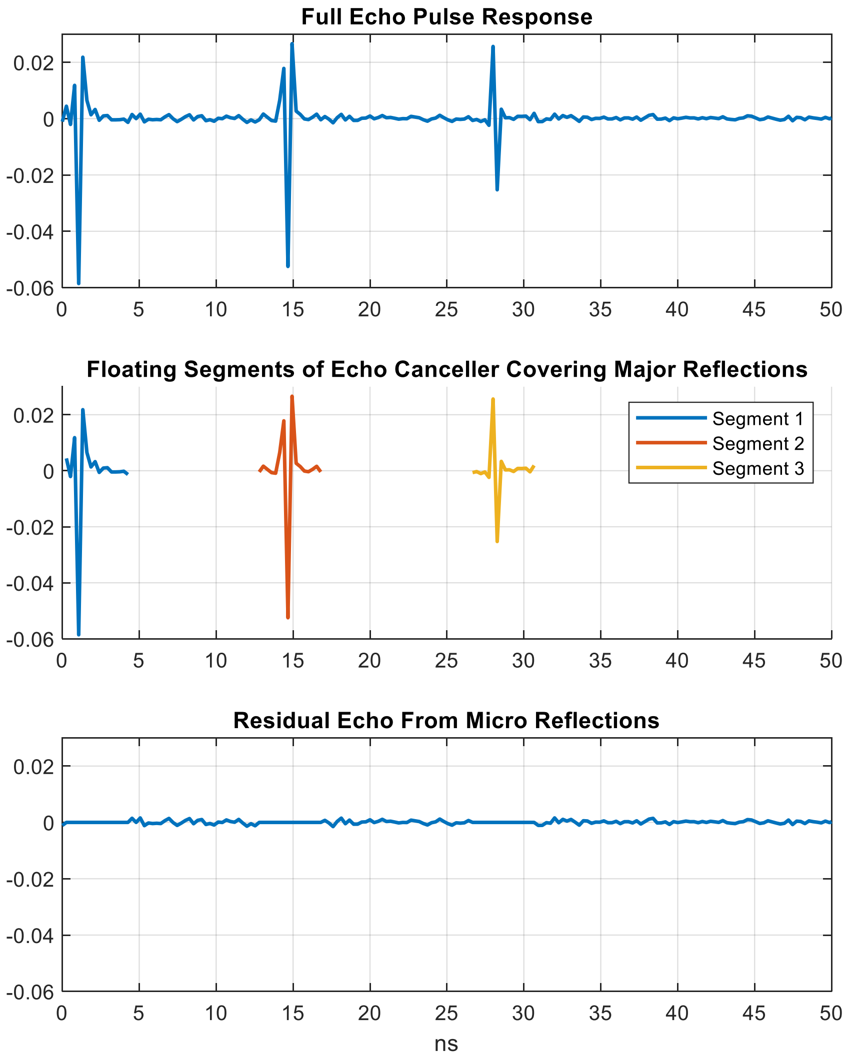
- Clear limits on the magnitude of the echo response in time domain can significantly reduce the complexity of echo canceller

Efficient Echo Cancelling Filter

- A few floating segments of coefficients are placed optimally to cancel major reflection points

- These segments have narrow width covering reflections with high magnitude which translates to few coefficients with high resolution

- The residual echo is only from micro reflections with much lower power



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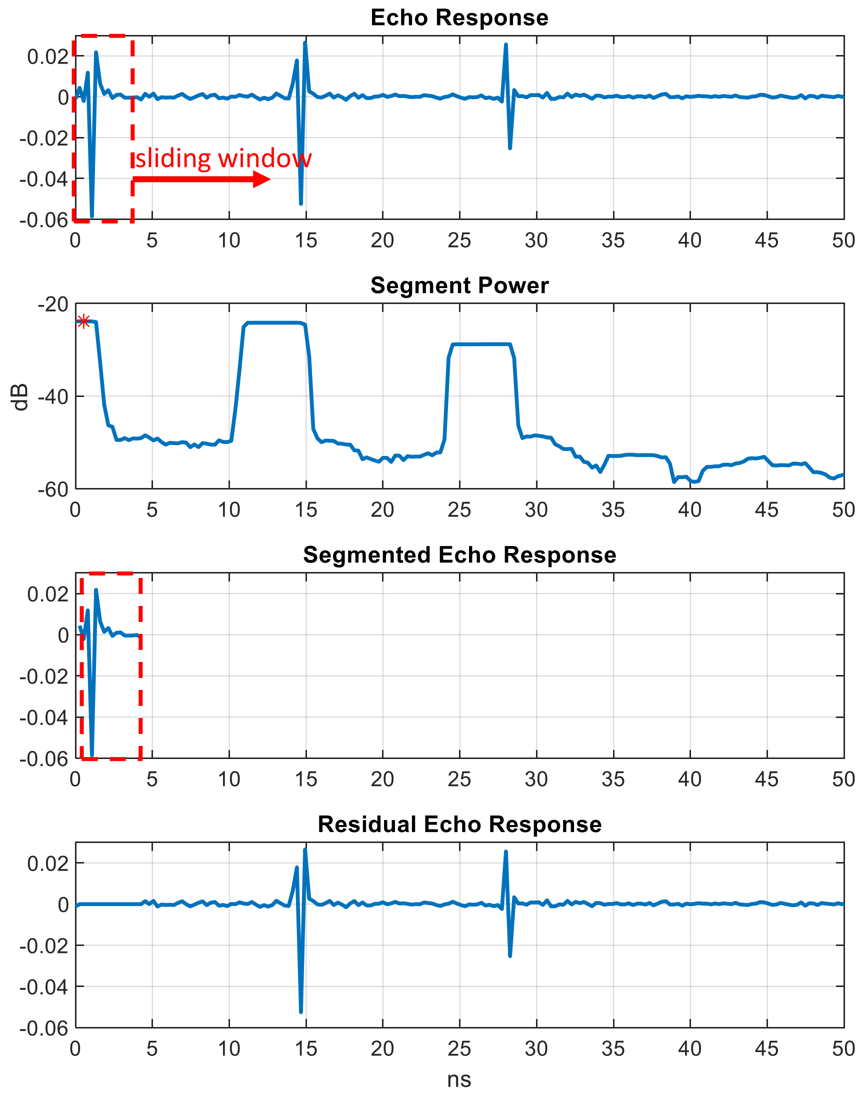
Reflection Decomposition

Optimal Placement of Segments:

1. Slide a segment from the beginning to the end of echo response
2. For each position, find the power of echo within the segment
3. The position with maximum power identifies the first major reflection
4. Zero out the echo response within this segment position to get residual echo

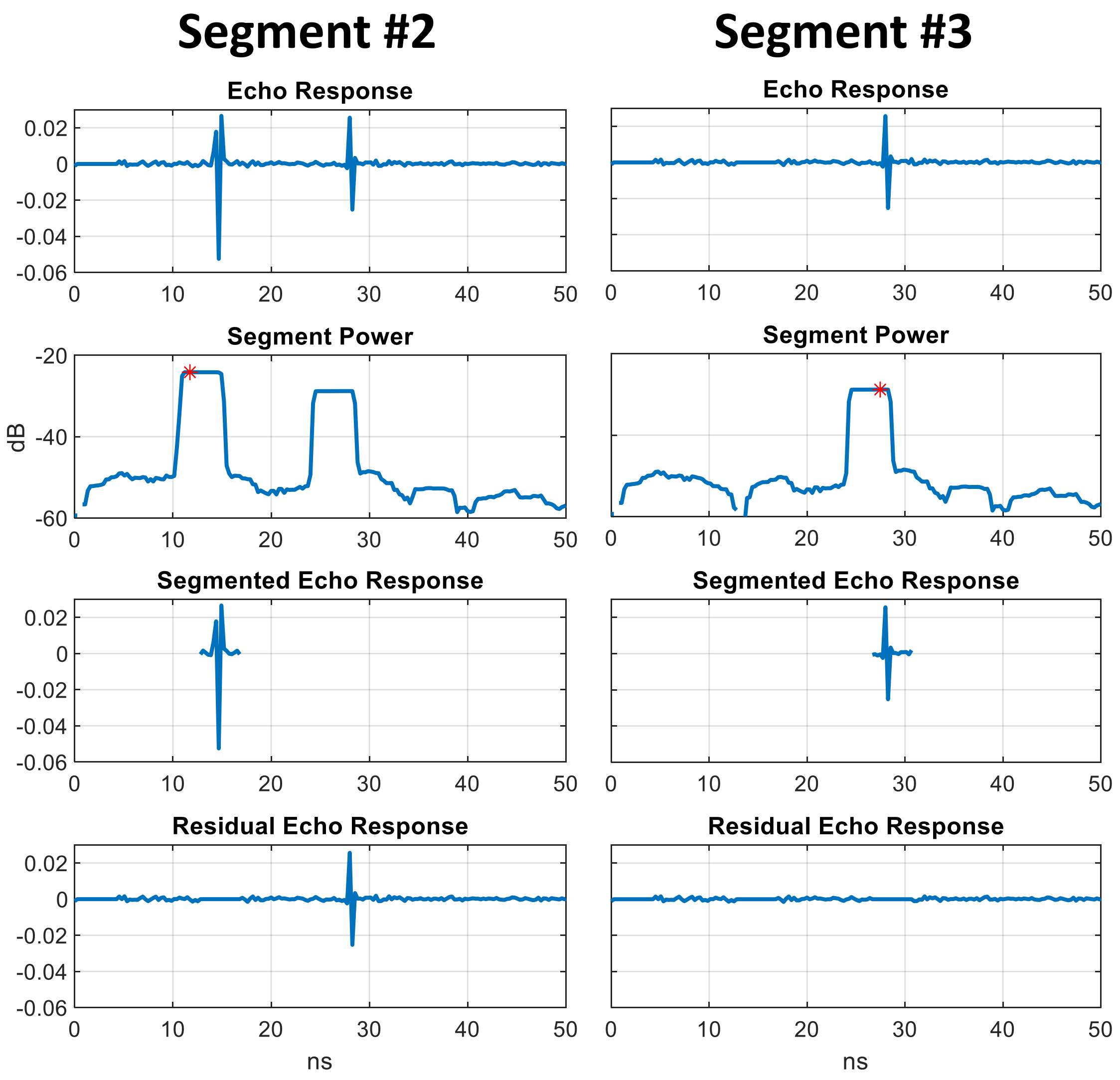


Reflection Decomposition – cont'd

5. Repeat the process recursively
   - Use the residual signal from the previous step as the echo response
   - Identify the optimal position for the next major reflection segment
   - Update the residual echo signal

6. The final residual signal is the echo from micro reflections

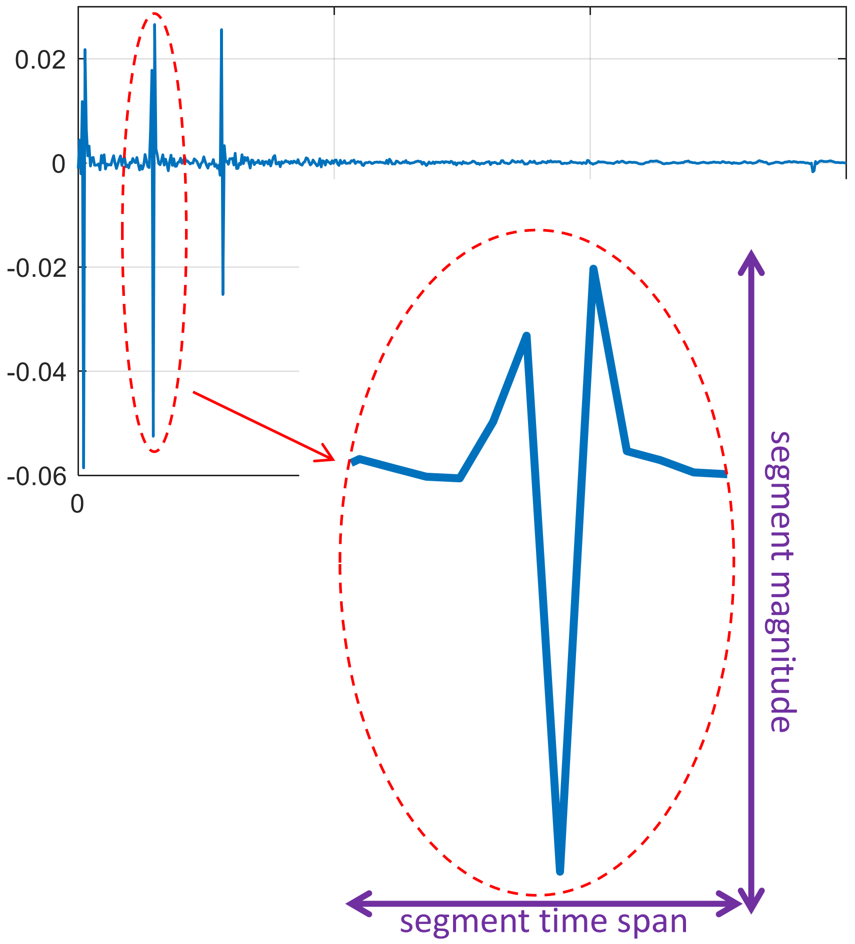
Optimality: minimum total power of residual micro reflections



* similar to jonsson_3cy_01a_10_14_20 with perhaps some subtle differences?

Limit on Major Reflections

- Limit on the number of major reflection points
  - A minimum of 4 to cover 2 end points and 2 inline connectors
- Limit on the maximum time-span of each major reflection segment
- Limit on the maximum magnitude and power for each segment
  - A function of impedance mismatch



Micro Reflections

- Micro reflections are primarily caused by variations in characteristic impedance through the cable
- They cover the entire span of echo response
- They represent a very small portion of overall power of echo
- Cancelling them requires a large number of filter coefficients
- A proper limit on micro reflections can significantly reduce the complexity of the echo canceller

Limit on Micro Reflections

- Power limit: An upper bound on the total power of micro reflections

- If this limit is low enough (mid -50 dBs), the micro reflections may remain uncancelled with minimal impact on SNR
  - The echo canceller can simply consist of only a few short segments to cover major reflections

- If this limit is moderately low (mid -40 dBs), the uncancelled micro reflections reduce the performance margin
  - The complexity of other blocks in the PHY may be increased to lower their contribution to overall noise and to meet the target SNR

Dynamic Limits

- Limit on the rate of changes in the amplitude and power due to changes in temperature, vibration and cable deformation
- Limit on maximum drift of echo response (position of major reflections) due to temperature, etc.
- Limit on cable bend ratio and compression to avoid formation of new major reflection points and new filter segments

Other Potential Limits on Echo

- Total power: Total echo power can impact the dynamic range of the analog front-end as well as portions of digital data path
  - Echo power should be sufficiently lower than the power of signal from far-end link partner in order to minimize the impact on dynamic range
  - If other limits on echo response do not provide a suitable bound, a separate limit on total echo power is to be defined

- Echo time span: The overall time-span of echo response may be longer than the round-trip delay (~150 ns) of the cable due to multiple back-and-forth reflections
  - If other limits on echo do not restrict the span of its response, a separate on power of echo outside the nominal span is needed

Summary

- A proper set of time-domain limits on echo response can significantly reduce the complexity of the PHY
- Limits to consider:
    - Total power of micro-reflections
    - Number of major reflection points
    - Width of major reflections
    - Magnitude of major reflections
    - Dynamic changes in echo response (temperature, vibration, etc.)
    - Cable deformities (bend ratio, compression points, etc.)
    - Overall power of echo
    - Time-span of echo response

- Question: What is the tightest possible limit on power of micro-reflections?

THANK YOU

ETHERNOVIA | hossein.sedarat@ethernovia.com