A Limit on Micro Reflections

Hossein Sedarat

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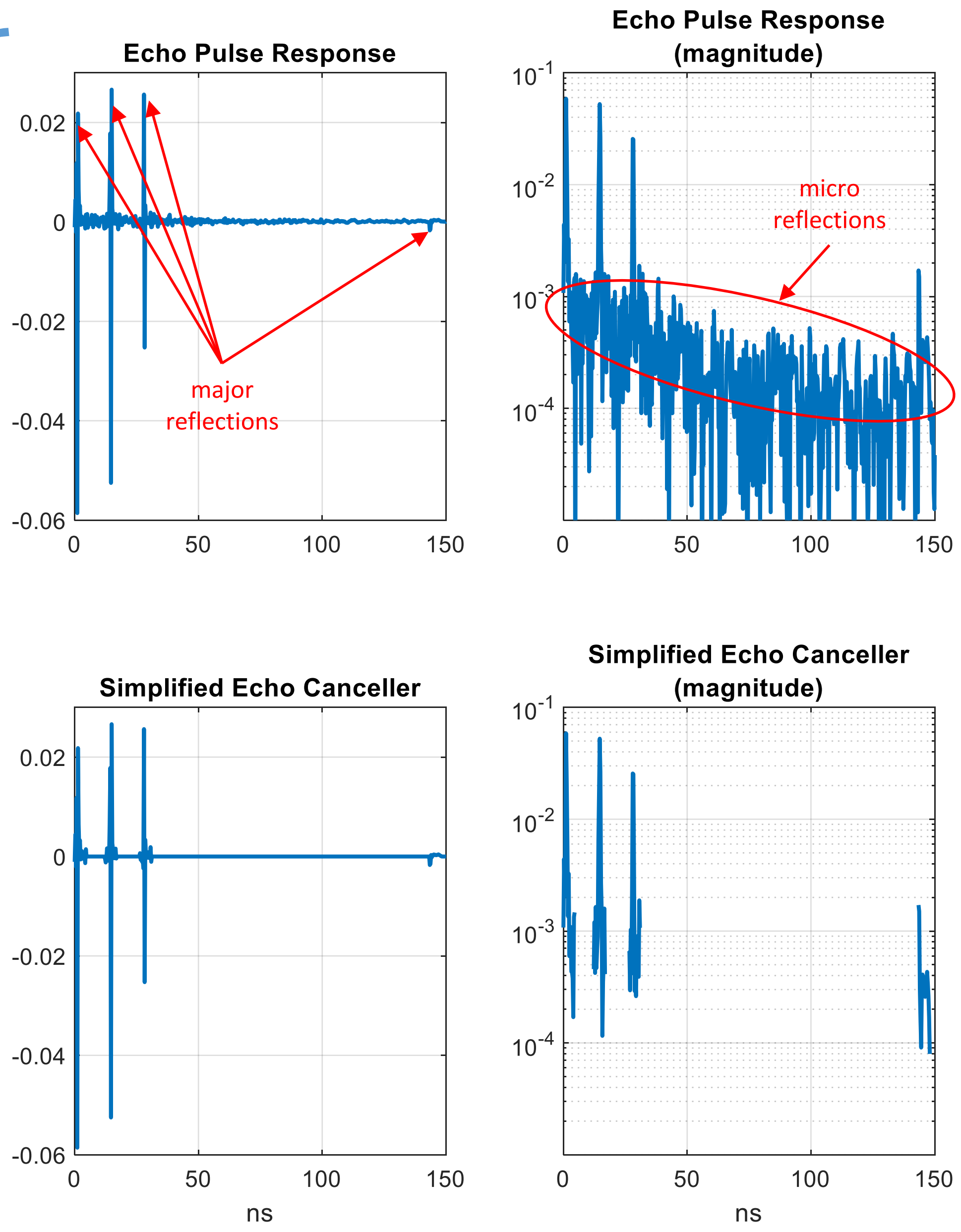
Overview

- Echo canceller is one of the most complex blocks in high-speed, full-duplex PHYs
- A proper limit of return loss in time domain can simplify the complexity of this block significantly (sedarat_3cy_01_0920)
- The simplification comes in part by limiting the power of micro reflections to eliminate the need for their cancellation
- A limit for micro-reflections is explored in this presentation

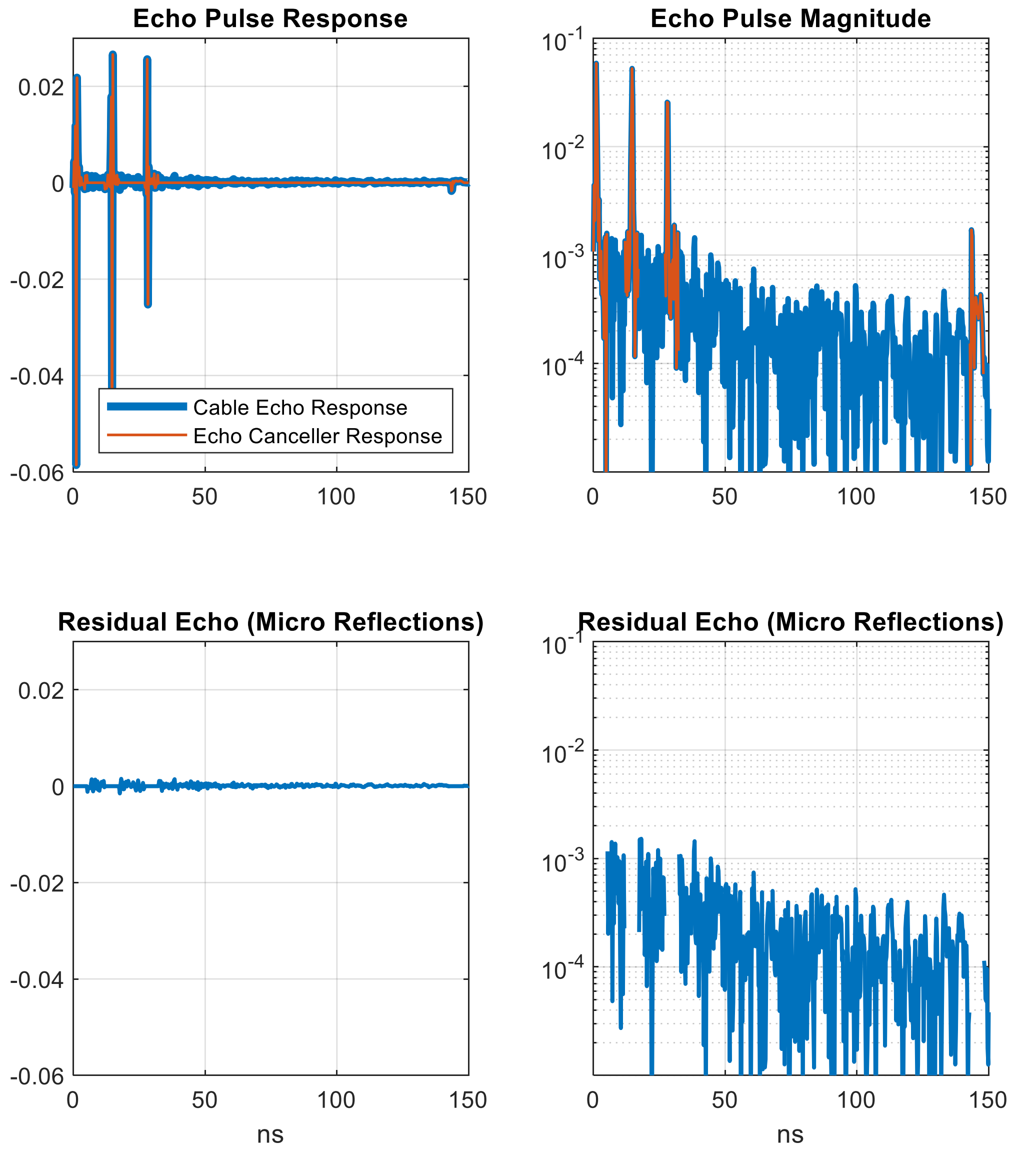
Simplified Echo Canceller

- Echo pulse response consists of
  - Major reflections at discontinuities (2 MDI and 2 connectors)
  - Micro-reflections due to cable inhomogeneity
- Echo canceller replicates the echo response for both major and micro reflections
- Significant reduction in complexity of echo canceller is possible if micro-reflections are negligible
- Need a clear limit on micro-reflections



Limit on Residual Echo

- Uncancelled micro-reflections are to be considered as part of all other sources of noise
- Additional noise source increases the complexity of the PHY
  - Analog front-end
  - Digital equalizers
- Limit the overall PHY complexity by limiting the uncancelled echo power significantly below the overall noise power budget



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Tolerated Noise Budget

Following the analysis presented in sedarat_3cy_01_10_14_20

- PAM4
- Baud rate = 14.1 GHz
- Slicer SNR = 24 dB
- Insertion loss according to 802.3ch
- IL scales linearly with length
- Transmit power ≈ 0 dBm

Bit Rate (Gbps)	Cable Length (m)	IL @ Nyquist (dB)	SNR Input (dB)	Receive power (dBm)	Tolerated Noise (dBm)
25	11	37.2	33.9	**-13.9**	**-47.8**
	9	30.4	31.2	**-12.2**	**-43.4**
	7	23.7	28.9	**-10.3**	**-39.2**

Limit on Micro-Reflections

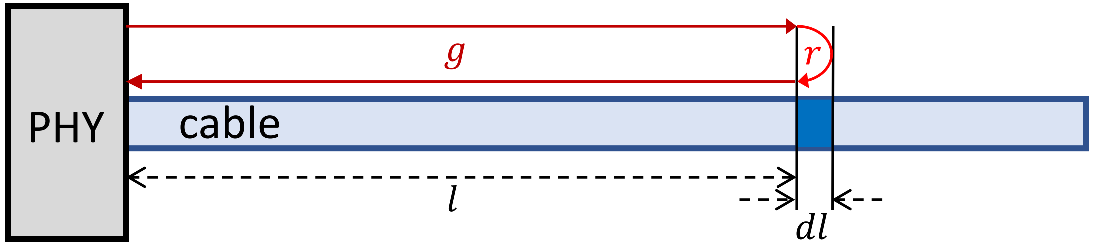
- The power of uncancelled micro-reflections should remain significantly lower than the overall tolerated budget
- Considering 15 dB margin

Bit Rate (Gbps)	Cable Length (m)	IL @ Nyquist (dB)	Tolerated Noise (dBm)	Residual Echo (dBm)	Micro-reflection power gain (dB)*
25	11	37.2	-47.8	-62.8	**-62.8**
	9	30.4	-43.4	-58.4	**-58.4**
	7	23.7	-39.2	-54.2	**-54.2**

* power gain = sum of squares of micro-reflections properly low-pass filtered and sampled at baud rate

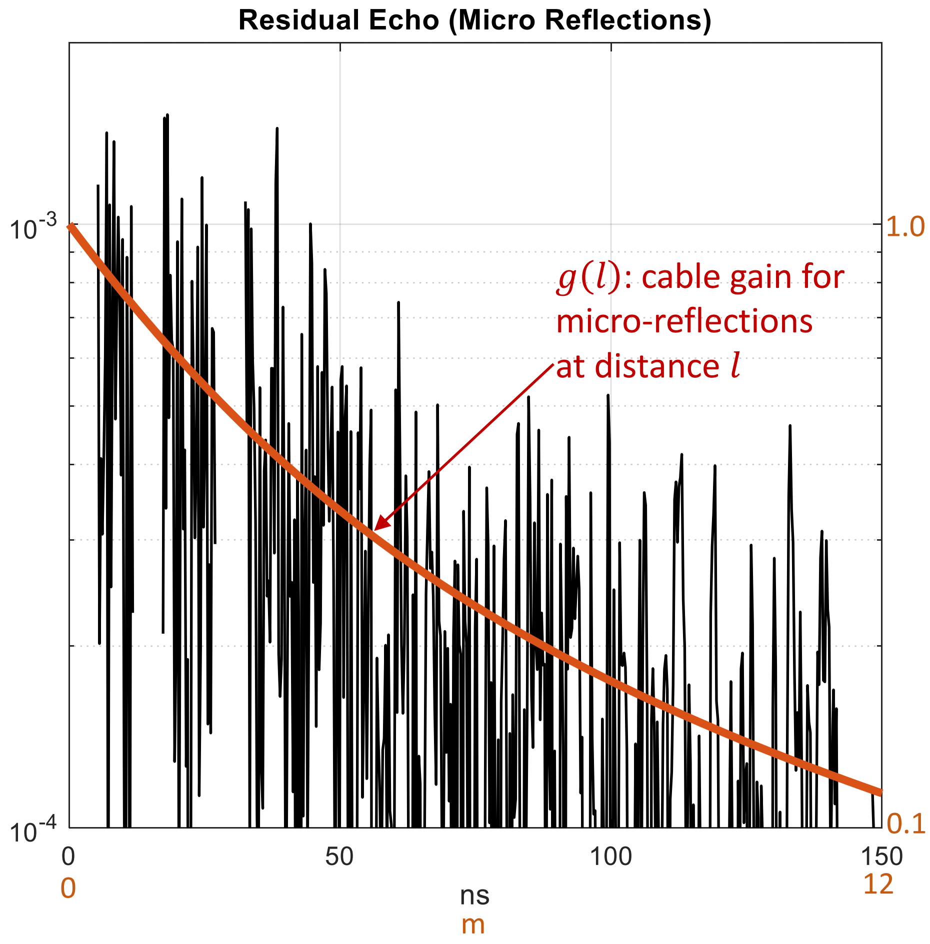
Power Gain of Micro-Reflections

A simplified analysis:



$$R = \int_0^L r(l) \cdot g(l) \cdot dl$$

- R: Total power gain of micro-reflections
- $r(l)$: Micro-reflection power gain density or power gain per unit length
- $g(l)$: Round trip gain of the cable for a reflection point at distance l
- L: Length of the cable



Relevant Cable Parameters

- Assuming uniform gain of micro-reflection throughout the cable

$$R = r \cdot \int_0^L g(l) \cdot dl \ = r . L_0$$

  - $\boldsymbol{r}$: power gain density of the micro-reflections is a cable manufacturing parameter independent of the length and loss
  - $\boldsymbol{L_0}$: effective length of an equivalent lossless cable
    - A function of cable length and loss
    - $L_0 \le L$
- Given a max on L_0, the limit on R can be translated to a limit on r

Conclusion

- A limit on the micro-reflections may be defined as the total power gain of the uncancelled residual echo
- The insertion loss of the channel has a direct impact on this limit for micro-reflections
  - Comparing to an 802.3ch 11 m cable, a 7 m cable relaxes this limit by more than 8 dB
- This power limit for micro-reflections depends on the allocated noise budget for uncancelled echo and is in the order of -55 dB
- This limit can be translated to limits on relevant manufacturing parameters (loss and reflection density)

THANK YOU

ETHERNOVIA | hossein.sedarat@ethernovia.com