A Limit for Cumulative Power of Micro-Reflections

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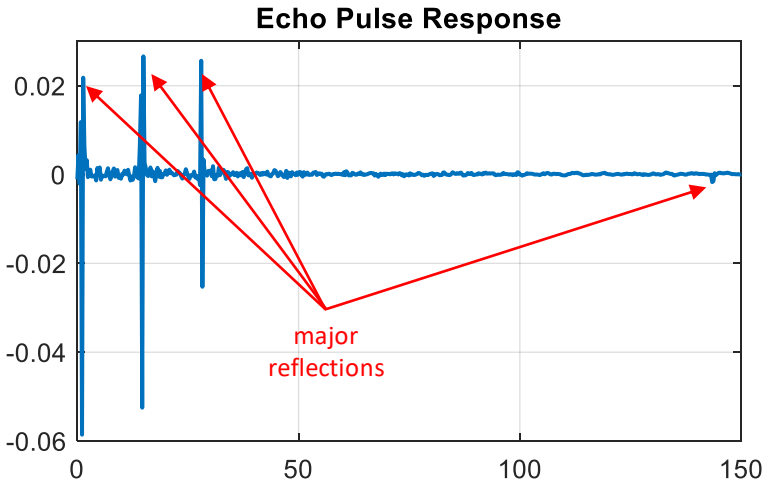
Overview

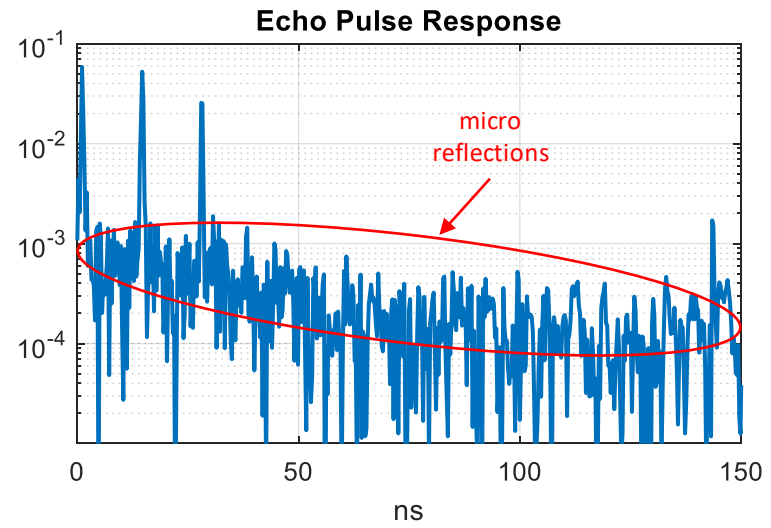
- A set of time-domain limits on return loss can help reduce the complexity of the PHY significantly (sedarat_0920, sedarat_1020, jonsson_1020, sedarat_1120, jonsson_1220, jonsson_0321)
- An upper bound on the power of micro-reflections is a key factor in these limits
- When this upper bound is not sufficiently small (partial) cancellation of micro-reflection is needed
- A limit-line on cumulative power of micro-reflections offers a path to more efficient design

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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Uncancelled Micro-Reflections

- A significant computation power may be dedicated to cancelling echo from micro-reflections
- Echo canceller may be significantly simplified if micro-reflections are sufficiently weak and remain partially or completely uncancelled
- The uncancelled echo is additional source of noise reducing the operating SNR margin

Power Limits on Micro-Reflections

- sedarat_1020: **-55 dB** with no need for cancellation and resulting in negligible loss of SNR margin
- jonsson_1020: **-40 dB** with 5 dB partial cancellation and resulting in 1.6 dB loss in SNR margin

Design Tradeoff		
Impulse Error Rate:	1.00E-04	1.00E-04
AFE-noise [dBm/Hz]:	-140	-140
EC cancelation [dB]:	5	5
EC Connector cancelation [%]:	100%	100%
Implementation Loss [dB]:	0	0
Simulation Parameters		
Cable Model:	mueller*sdp	
Connector Echo Model:	hard	
Temperature [°C]:	20	
Max Simulation Frequency:	9.00E+09	

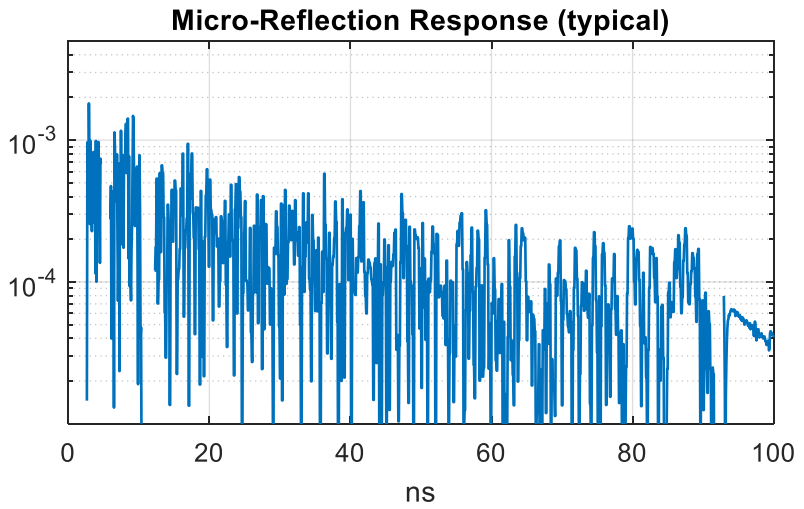
Calculated Values	Upstream	Downstream
Theoretical Slicer SNR [dB]:	23.22	23.22
Estimated Slicer SNR [dB]:	23.22	23.22
Required Slicer SNR [dB]:	17.78	17.78
SNR Margin [dB]:	5.44	5.44
Nyquist Frequency [GHz]:	7.03	7.03
Insertion Loss @ Nyquist [dB]:	26.64	26.64

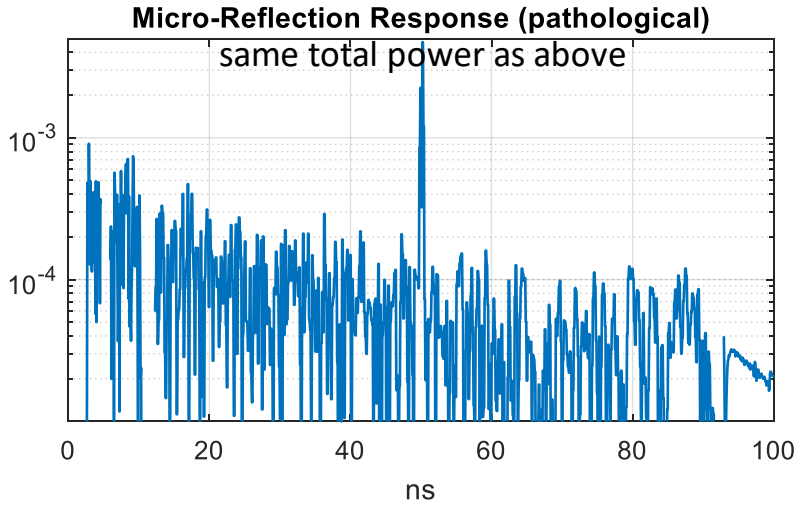
Design Tradeoff		
Impulse Error Rate:	1.00E-04	1.00E-04
AFE-noise [dBm/Hz]:	-140	-140
EC cancelation [dB]:	100	100
EC Connector cancelation [%]:	100%	100%
Implementation Loss [dB]:	0	0
Simulation Parameters		
Cable Model:	mueller*sdp	
Connector Echo Model:	hard	
Temperature [°C]:	20	
Max Simulation Frequency:	9.00E+09	

Calculated Values	Upstream	Downstream
Theoretical Slicer SNR [dB]:	24.83	24.83
Estimated Slicer SNR [dB]:	24.83	24.83
Required Slicer SNR [dB]:	17.78	17.78
SNR Margin [dB]:	7.05	7.05
Nyquist Frequency [GHz]:	7.03	7.03
Insertion Loss @ Nyquist [dB]:	26.64	26.64

Micro-Reflection Cancellation

- Micro-reflections should be (partially) cancelled if their total power is not small enough
- The echo canceller is implemented more efficiently if the profile of the reflections in time is known in advance
- A limit on total power does not provide a limit on the time profile of micro-reflections
  - The 2 cases in this plot shows similar total power but very different time profile
  - An echo canceller designed efficiently for typical case may not work well for pathological case





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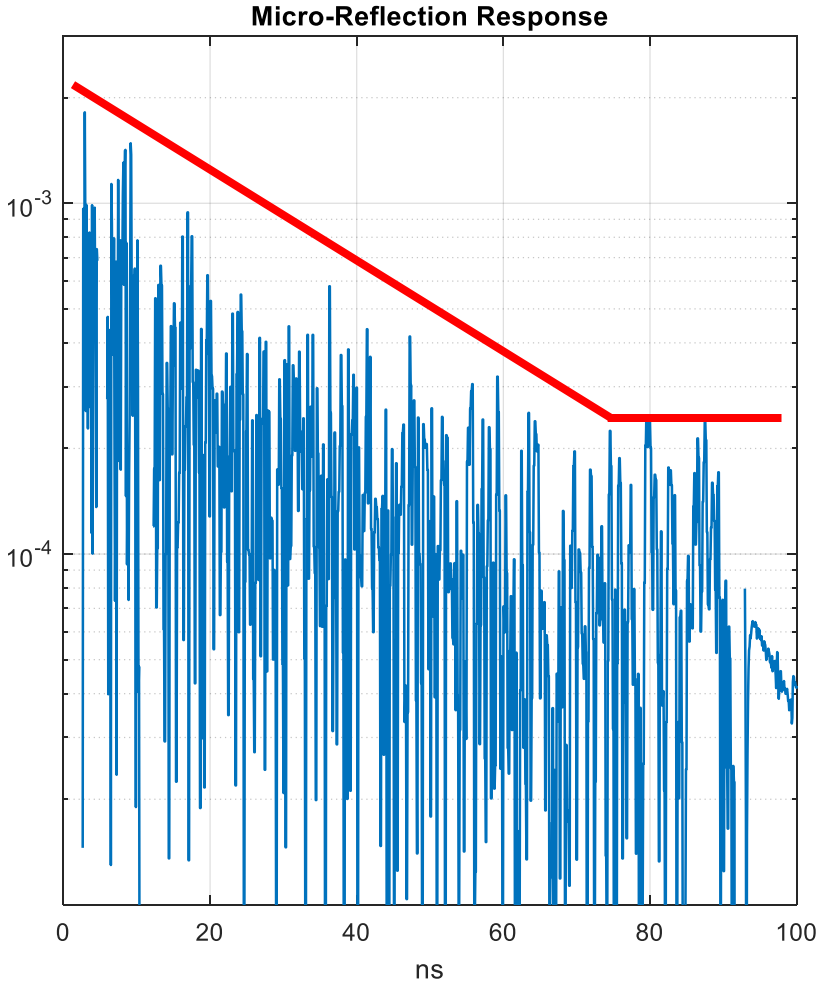
Micro-Reflection Limit: Magnitude

- A limit on the magnitude of the reflections can be used for an efficient design of the echo canceller
  - Near-end reflections need high resolution coefficients
  - Mid-range reflection need low resolution coefficients
  - Far-end reflections may remain uncancelled
- The magnitude of the micro-reflections have large variance resulting in a loose limit



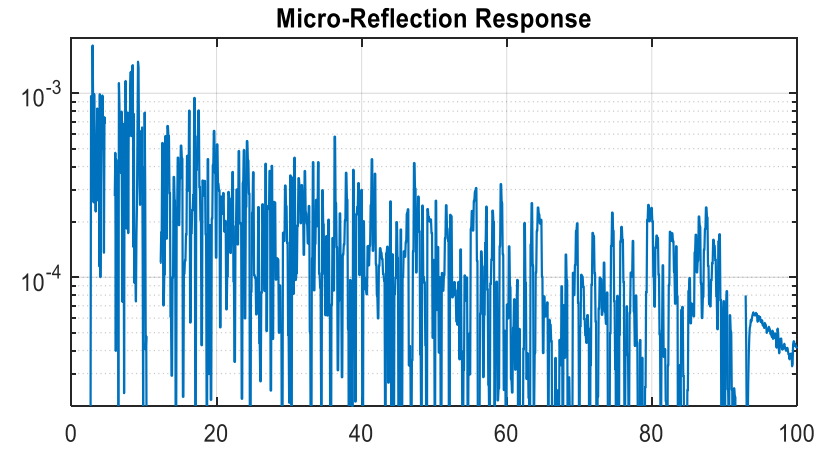
Micro-Reflection Limit: Cumulative Power

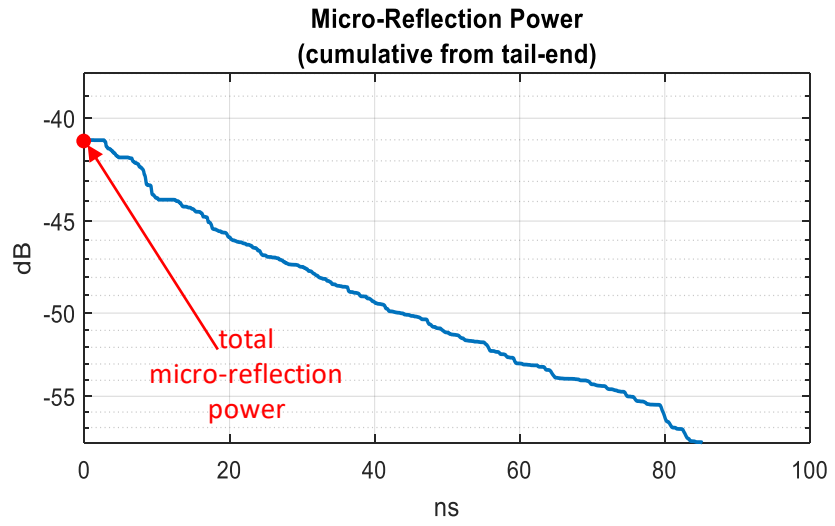
- Cumulative power: sum of instantaneous reflection power from the tail-end of the echo response

$$P_c(t) = \int_t^{\infty} h^2(\tau) \cdot d\tau$$

$h(\tau)$ = micro-reflection at time τ

- $P_c(0)$ = total power of micro-reflections





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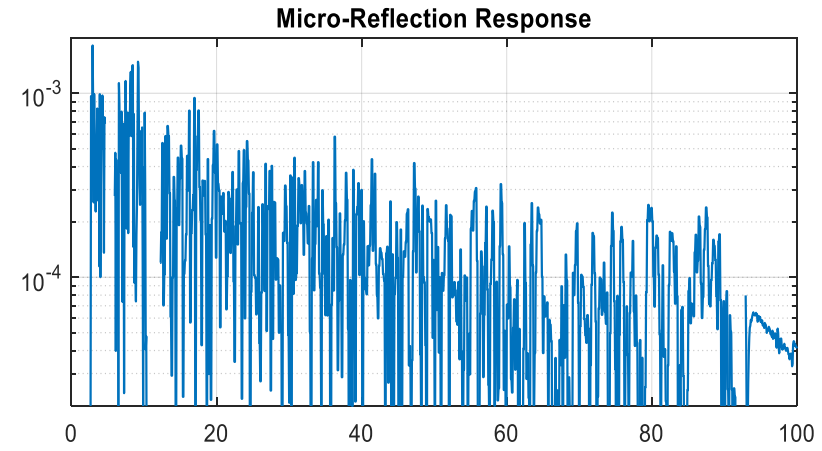
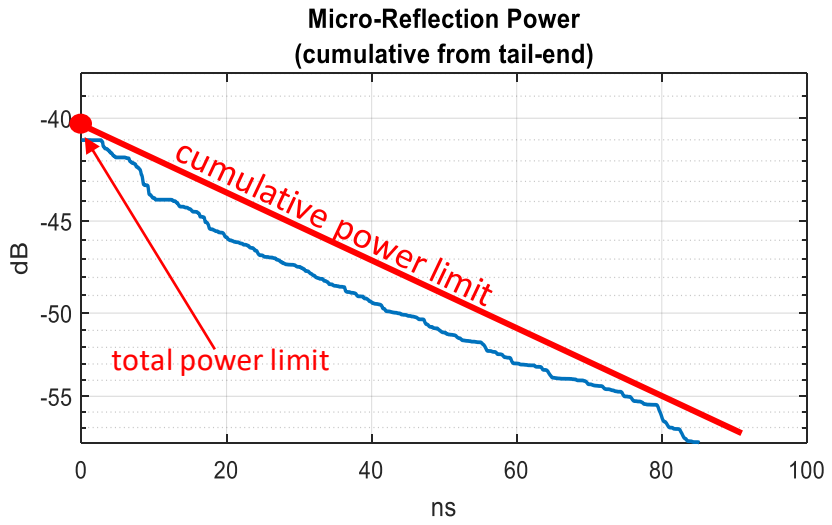
Micro-Reflection: Cumulative Power Limit

- Cumulative power is a smooth curve with much lower variance
  - ➔ A tight limit may be defined
- Cumulative power correlates with manufacturing parameters
  - A bigger variations of characteristic impedance shifts the curve up vertically
  - Insertion loss and the propagation delay of the cable determines the slope
- Cumulative power limit helps the PHY designer with proper allocation of computational resources for cancellation of micro-reflections





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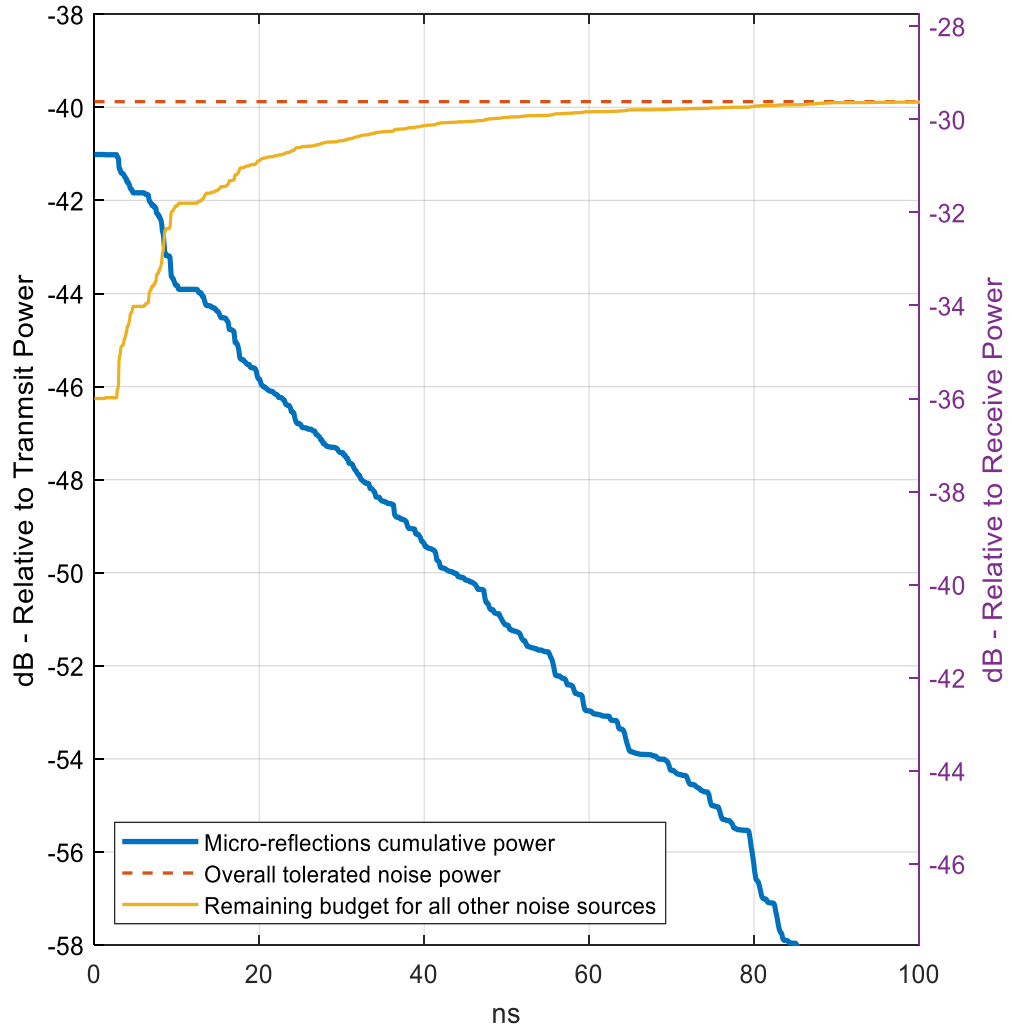
Cumulative Power and SNR Loss

- The uncancelled micro-reflections contributes to overall noise and reduces the noise budget on other sources
- Cumulative power can readily show the impact on noise budget for uncancelled tail-end reflections
- A limit on the cumulative power makes this impact predictable



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Limit on Cumulative Power

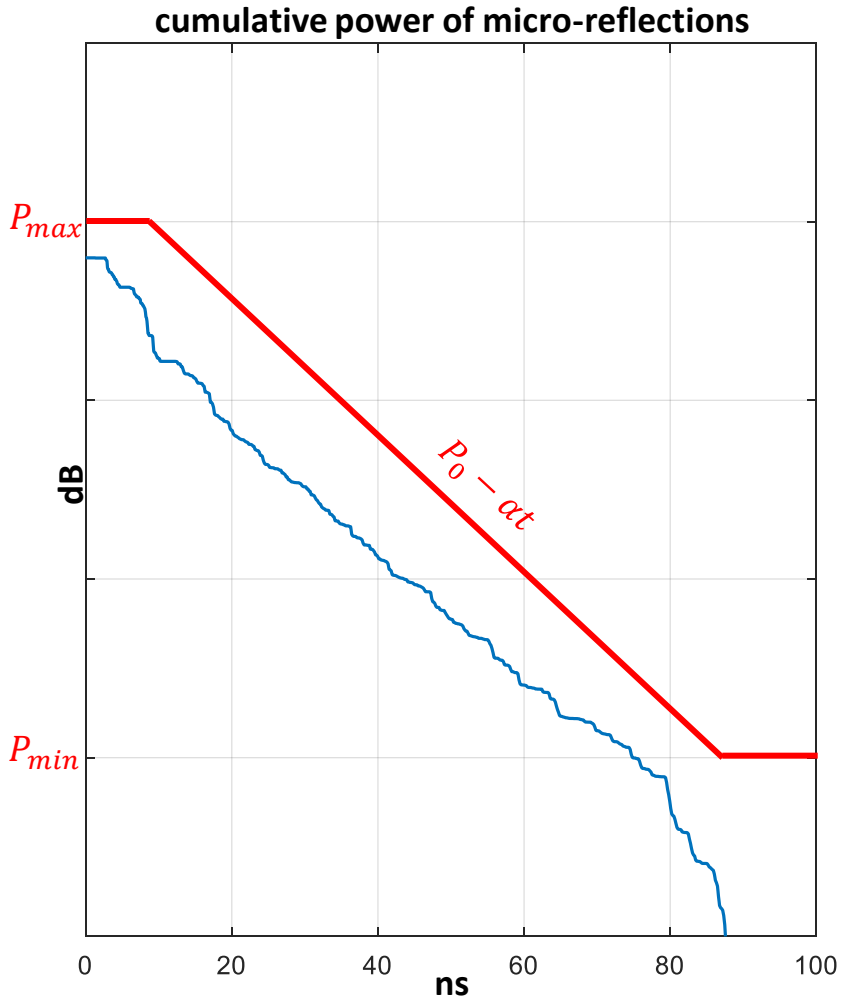
In its simplest form, defined as a linear function:

$$P_c(t) < P_0 - \alpha t$$

where,

- P_0 = total micro-reflection power
- α = rate of power loss, a function of
  - insertion loss per unit length (dB/m)
  - propagation speed (m/s)

- This limit line may also be clipped to minimum and maximum values
- These parameters may be defined as a function of the insertion loss of the cable



Summary and Conclusion

- A limit on the total power of micro-reflections is a good first limit on echo channel
- If the limit is not small enough then (partial) cancellation of micro-reflection may be needed to achieve the target SNR
- The total power does not provide any information on how the micro-reflections are distributed in time
- A limit on the cumulative power provides the additional information needed for efficient implementation of the echo canceller

THANK YOU

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