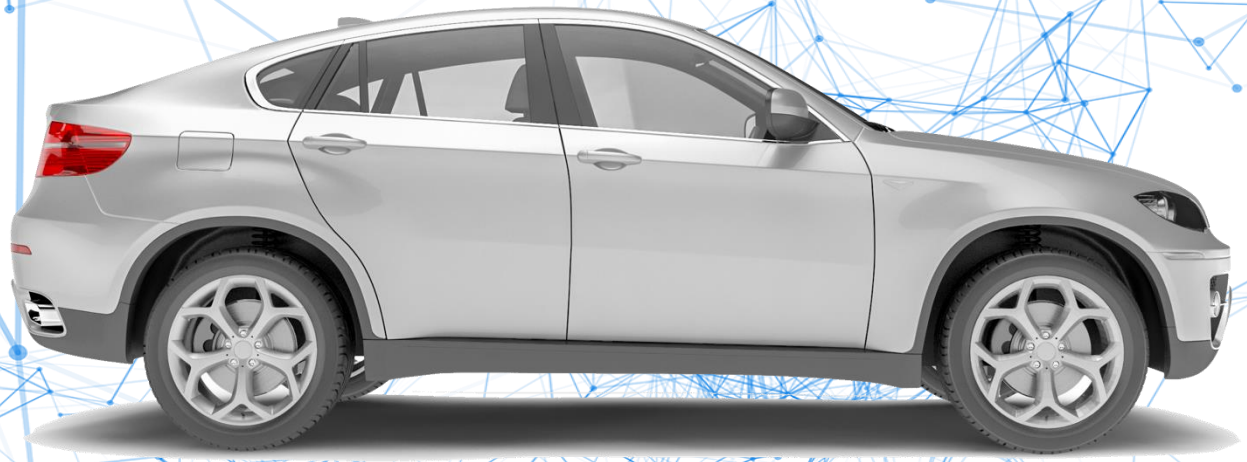

Limit Line for Insertion Loss

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Overview

- A limit line for insertion loss is needed as a foundation to derive other specifications of the transceiver
- A summary of relevant contributions:
  - kadry_081920: Length-scaling of 802.ch – 37 dB @ Nyquist
  - sedarat_101420: PHY complexity analysis – 24 dB @ Nyquist
  - jonsson_111820: Capacity estimation tool
  - zimmerman_111820: Frequency scaling of 802.3ch – 30 dB @ Nyquist
  - Many cable measurements over different lengths and types (STP, SDP)
- This presentation introduces a limit line that yields reasonable PHY operating margin considering other sources of signal loss

Outline

- A review of reported SNR margin with frequency-scaled limit of insertion loss
- A review of important factors not covered in that calculation
- A review of SNR margin considering the additional sources of loss in SNR
- Introducing a limit line that results in 0 dB margin

SNR with Frequency-Scaled Limit Line

- jonsson_120120 shows 2.5 dB SNR margin using an insertion loss derived from frequency scaling of 802.3ch limit

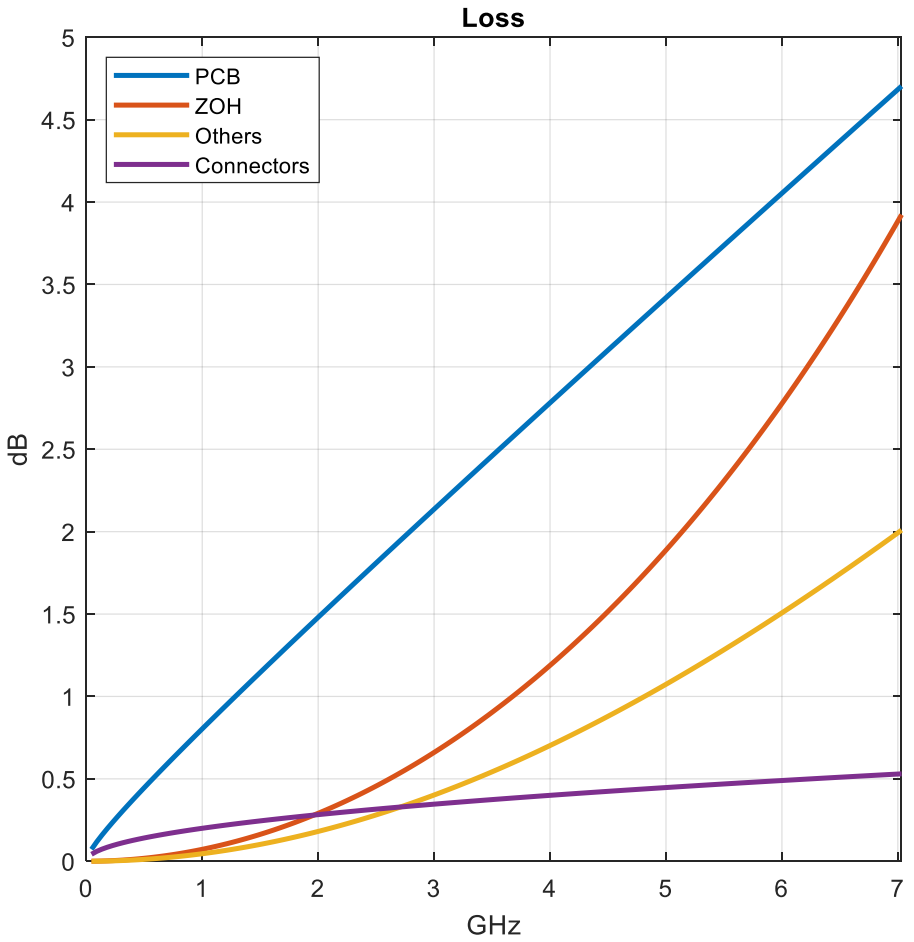
- Assumptions:
  - No sources of insertion loss other than the cable
  - Flat transmit PSD with 0 dBm power
  - No allocation of margin for EMI
  - No allocation for implementation loss

	Upstream	Downstream
Requrements		
Data Rate [Gbps]:	25	25
Target RS-FEC output BER:	1.00E-12	1E-12
Cable Length [m]:	11	11
Wire u-reflections [dB]:	-40	-40
Number of Connectors:	4	4
Modulation		
PAM Levels:	4	4
FEC Block Size (n):	360	360
FEC Data Size (k):	326	326
RS-FEC Correction Efficiency:	100%	100%
Bits per FEC Symbol:	10	10
TDD Time Duty-Cycle:	100%	100%
Framing Overhead	1.875%	1.875%
Transmit Signal		
PSD-mask:	PSD_brick	PSD_brick
Transmit Power [dBm]:	0	0
Design Tradeoff		
Impulse Error Rate:	1.00E-04	0.0001
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:	Zimmerman*	
Connector Echo Model:	hard	
Temperature [°C]	20	
Max Simulation Frequency:	9.00E+09	

Calculated Values		
	Upstream	Downstream
Theoretical Slicer SNR [dB]:	20.28	20.28
Estimated Slicer SNR [dB]:	20.28	20.28
Required Slicer SNR [dB]:	17.78	17.78
SNR Margin [dB]:	2.49	2.49
Nyquist Frequency [GHz]:	7.031	7.031
Insertion Loss @ Nyquist [dB]:	29.84	29.84

Other Sources of Signal Loss

- Considering other sources of signal loss introduced in sedarat_0820 :
  - Loss of PCB (kadry_0820)
  - Loss of MDI connectors (kadry_0820)
  - Loss of other components (1 dB on each end of the link)
- Zero order hold for transmit PSD



SNR Margin – Loss Included

- The insertion loss from zimmerman_1120 is combined with other sources of signal loss and represented as ‘column2’
- 5 dB design margin to account for:
  - Implementation loss, RF immunity, crosstalk noise, FEC coding gain reduction, etc.
- Considering the lower limit of the transmit power of -1 dBm (802.3ch: -1 to +2 dBm)

➔ Operating margin = -5.5

	Upstream	Downstream
Requrements		
Data Rate [Gbps]:	25	25
Target RS-FEC output BER:	1.00E-12	1.00E-12
Cable Length [m]:	11	11
Wire u-reflections [dB]:	-40	-40
Number of Connectors:	4	4
Modulation		
PAM Levels:	4	4
FEC Block Size (n):	360	360
FEC Data Size (k):	326	326
RS-FEC Correction Efficiency:	100%	100%
Bits per FEC Symbol:	10	10
TDD Time Duty-Cycle:	100%	100%
Framing Overhead:	1.875%	1.875%
Transmit Signal		
PSD-mask:	PSD_brick	PSD_brick
Transmit Power [dBm]:	-1	-1
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]:	5	5
Simulation Parameters		
Cable Model:	column2	
Connector Echo Model:	hard	
Temperature [°C]:	20	
Max Simulation Frequency:	9.00E+09	

Calculated Values		
	Upstream	Downstream
Theoretical Slicer SNR [dB]:	17.32	17.32
Estimated Slicer SNR [dB]:	12.32	12.32
Required Slicer SNR [dB]:	17.78	17.78
SNR Margin [dB]:	-5.47	-5.47
Nyquist Frequency [GHz]:	7.03	7.03
Insertion Loss @ Nyquist [dB]:	38.45	38.45

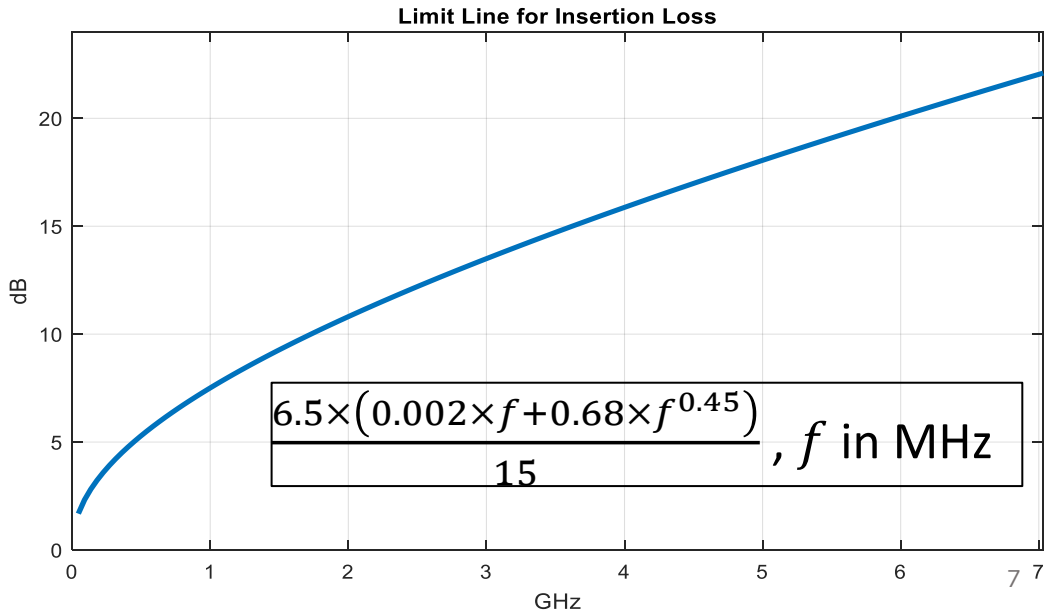
Limit on Insertion Loss

Based on 802.3ch limit line

- Frequency extended (not scaled)
- Length-scaled to 6.5 m

➔ 22 dB loss at Nyquist

Resulting in 0 dB operating margin



	Upstream	Downstream
Requrements		
Data Rate [Gbps]:	25	25
Target RS-FEC output BER:	1.00E-12	1.00E-12
Cable Length [m]:	6.54	6.54
Wire u-reflections [dB]:	-40	-40
Number of Connectors:	4	4
Modulation		
PAM Levels:	4	4
FEC Block Size (n):	360	360
FEC Data Size (k):	326	326
RS-FEC Correction Efficiency:	100%	100%
Bits per FEC Symbol:	10	10
TDD Time Duty-Cycle:	100%	100%
Framing Overhead:	1.875%	1.875%
Transmit Signal		
PSD-mask:	PSD_brick	PSD_brick
Transmit Power [dBm]:	-1	-1
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]:	5	5
Simulation Parameters		
Cable Model:	column2	
Connector Echo Model:	hard	
Temperature [°C]:	20	
Max Simulation Frequency:	9.00E+09	

Calculated Values		
	Upstream	Downstream
Theoretical Slicer SNR [dB]:	22.79	22.79
Estimated Slicer SNR [dB]:	17.79	17.79
Required Slicer SNR [dB]:	17.78	17.78
SNR Margin [dB]:	0.00	0.00
Nyquist Frequency [GHz]:	7.03	7.03
Insertion Loss @ Nyquist [dB]:	30.68	30.68

Future Considerations

- Is the reported PCB loss too conservative?
  - Better PCB material in future?
  - Shorter trace lengths?
- Is 1 dB loss for discrete components too optimistic?
- Is there room to increase the minimum transmit power?
  - Trade-offs: emission, driver linearity and power consumption, etc.
- Is 5 dB a reasonable budget for implementation loss, EMI, FEC coding gain, alien crosstalk, etc.

Cable Considerations

- neulinger_121520 shows a proof of existence for a 7 m cable with inline connectors at 4 dB margin to the proposed limit
  - Need to validate across temperature and include the effects of aging

- Measurements of long cables mostly violate this limit
  - Is there better quality cables with current manufacturing technology?
  - Is there a path in future cable manufacturing to meet this limit?
  - Is the target reach of 11 m a hard requirement ?
  - Is a 2-pair solution acceptable for long-reach applications?

Summary

- It is important to consider the following effects in SNR calculations:
  - Loss of PCB, MDI connectors and other discrete components
  - Zero order hold for transmit PSD
  - Lower limit of the transmit power
  - Reasonable allocation of SNR margin for implementation loss, RF immunity, crosstalk, etc.

- With these considerations, a cable with loss profile of 802.3ch length-scaled for 22 dB of loss at Nyquist results in 0 dB of operating margin

THANK YOU

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