On the feasibility of 25Gbps

Contribution to 802.3 ISAAC Study Group

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Introduction

- There has been considerable discussion about the need for data rates above 10Gbps in the ISAAC project
- Presentation Feyh_ISAAC_01A_01092024 by German Feyh & Ahmad Chini evaluated the theoretical performance for asymmetric 25Gbps link over specific cable, and concluded "*Future technical feasibility study is required*"
- This presentation does further feasibility study
- The following theoretical calculations show that for realistic assumptions about cables, PHY design, and noise environment, the **SNR margin is 2dB**

It is reasonable to assume that 25Gbps asymmetric link can operate over 15m coax

Background

- There have been several presentations calling for supporting data rates above 10Gbps
  - ringle_ISAAC_01_092723.pdf,
  - Lo_01_1023.pdf,
  - jonsson_3ISAAC_01_082823.pdf
  - 20231114_On_the_need_for_25Gbps_updated_post_presentation
- The last presentation in the list had 17 supporters in addition to the four authors
- Straw poll taken at the November 2023 Plenary Meeting showed that majority (57%) supported the inclusion of 25Gbps
- There have been three arguments given against data rates above 10Gbps:
  - It might slow things down in the Task Force
  - It does not have sufficient volume to justify standardizing it
  - It may not be technically feasible
- This presentation addresses the last concern, about technical feasibility

Motivation

- Presentation Feyh_ISAAC_01A_01092024 by German Feyh & Ahmad Chini evaluated the theoretical performance for asymmetric 25Gbps link over specific cable, and concluded
  - For the 15m and 17m coax used in the analysis SNR margin was negative
  - For the 10.2m coax used in the analysis SNR margin was positive
  - "*Future technical feasibility study is required*"
- Follow-up discussions on the ISAAC mailing reflector included comments that showed that different people interpreted the results from the Feyh & Chini presentation differently, which prompted the analysis in this presentation
- More detailed analysis should be done by the ISAAC Task Force, but the analysis in this presentation shows that it is clearly theoretically possible to support 25Gbps over coax cables

Reproducing the Feyh & Chini Results

- The first step in the analysis was to reproduce the results in the presentation from Feyh & Chini: Feyh_ISAAC_01A_01092024
- The Feyh & Chini Presentation had very clear documentation of assumptions made in the theoretical calculations, so it was relatively easy to reproduce the theoretical calculations
- The only difficulty was that the Feyh & Chini calculations are based on coax cable measurements that are not available to the author of this presentation
- To address the lack of the raw measurement data, the Insertion Loss (ILK) of the coax cable was approximated with simple parametric model

  $IL = b_0 \sqrt{f} + b_1 f$ [dB/m], where

  b_0 = -5.19E-11 and b_1 = -1.04E-05
- This model gave reasonable match with the IL plotted in the Feyh & Chini Presentation

Establishing the Base Line

- During the development of 802.3cy, Ragnar developed and shared a spreadsheet to calculate theoretical performance:
  - https://www.ieee802.org/3/cy/public/adhoc/jonsson_3cy_01_04_20_21.xlsx
- This spreadsheet was used in the theoretical calculations in this presentation
- The spreadsheet with the parameters given in the Feyh & Chini Presentation, and the cable model from previous slide, we go very good match:

Cable Length	Feyh & Chini	Our Results
15m	dpSNR = -2.93dB	dpSNR = -2.95dB
17m	dpSNR = -5.38dB	dpSNR = -5.42dB

- For more details about the calculations, see Case 1 and Case 2 in the Theoretical Calculation section later in this presentation

Using Better Cables

- The Feyh & Chini Presentation chose a 15m long “typical automotive coax cable” (RTK 031) for their theoretical calculations
- There is currently no general agreement that 25Gbps would have to operate over typical 15m coax cable or what constitutes a typical coax cable for 25Gbps
- The currently agreed objectives for data rates below 10Gbps is to support “up to at least 15m reach **on at least one type of automotive cabling**”
- It could be argued that for 25Gbps it would be sufficient to operate over 11m typical coax cable or operate over 15m good coax cable
- The theoretical calculations in Case 3 show that if the cable length is reduced to **11m**, while other parameters are the same, then **the SNR margin become positive**
- The theoretical calculations in Case 4 show that if **better coax cable** is used **the SNR margin become positive for 15m coax cable**
  - The better cable in Case 4 is modeled after LEONI Dacar 037 described in https://publications.leoni.com/fileadmin/automotive_cables/publications/catalogues/leoni_dacar.pdf

PHY Improvements

- The simulations assumptions in the Feyh & Chini presentation can be considered to be equivalent to the following
  - Transmit 0dBm differential signal at the “chip” (not the MDI)
  - Lose 6dB in the conversion from differential to single ended transmission
  - Lose about 2.4dB signal strength at Nyquist frequency due to PCB
- Therefore, the transmit level at the MDI (coax connector) is about 7dB lower than the typical 0dBm
- The Feyh & Chini presentation assumes the FEC to be (360,326) Reed-Solomon code, while the code used for 25Gbps in 802.3cy was (936,846) Reed-Solomon code, which provides more coding gain
- The theoretical calculations in Case 5 show that if we assume MDI **transmit power of 0dBm and (936,846) RS-FEC**, but otherwise the same assumptions as Feyh & Chini the **SNR margin become positive at 5.18dB**

Realistic Case

- The theoretical calculations in Case 6 represent what might be considered a realistic case:
  - Better 15m coax cable (LEONI Dacar 037)
  - Better PHY (same as in Case 5)
  - Higher gaussian noise (-135dBm/Hz which is 10dB more noise than in Feyh & Chini)
  - High frequency of impulse noise on the channel (with 1/1000 symbols corrupted)
- The resulting **SNR margin is 2dB**, which is on top of the margins implied in the assumed 5dB implementation loss

It is reasonable to assume that 25Gbps asymmetric link can operate over 15m coax

Summary

- The theoretical calculations in presentation by Feyh & Chini are reproduced as baseline for further theoretical evaluation
- The theoretically calculations for several assumptions show that with better cables or better PHY the negative margin in Feyh & Chini become positive
- Finally, for realistic assumptions about cables, PHY design, and noise environment, the **SNR margin is 2dB**

It is reasonable to assume that 25Gbps asymmetric link can operate over 15m coax

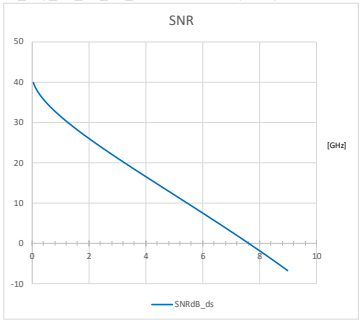
Theoretical Calculations

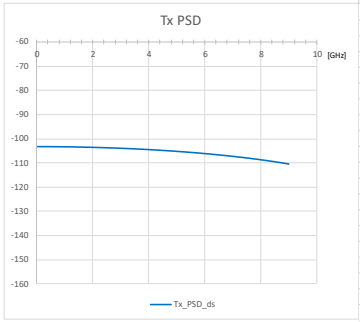
Case 1

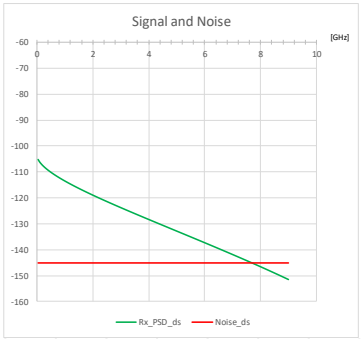
jonsson_3cy_01_04_20_21 - Channel Capacity Calculator Version 1.4

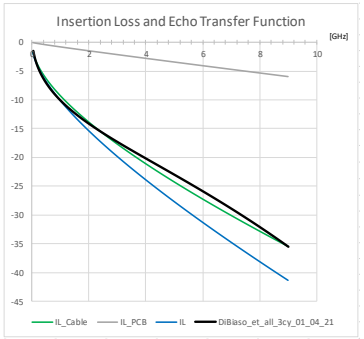
	U	Downstream
Requirements		
Data Rate [Gbps]:	#	25
Target RS-FEC output BER:	#	1.00E-12
Cable Length [m]:	#	15.000
Wire u-reflections limit:	j	jonsson*12_08_1
Number of Connectors:	4	4
Modulation		
PAM Levels:	4	4
FEC Block Size (n):	#	360
FEC Data Size (k):	#	326
RS-FEC Correction Efficiency:	#	100%
Bits per FEC Symbol:	#	10
TDD Time Duty-Cycle:	#	100%
Framing Overhead:	#	1.645%
Transmit Signal		
PSD-mask:	P	PSD_ZOH
Transmit Power [dBm]:	#	-6
Design Tradeoff		
Impulse Error Rate:	#	1.00E-04
AFE-noise [dBm/Hz]:	#	-145
Cable Reflection Echo Cancelation [dB]:	6	0
Connector Echo Cancelation [dB]:	#	0
Implementation Loss [dB]:	5	5
Simulation Parameters		
Cable Model:		ISAAC_01A_0109
PCB model:		p_kadry_3cy_02_08
PCB trace length [m]:		0.1524
Connector Echo Model:		Hard
Temperature [°C]:		20
Max Simulation Frequency:		9.00E+09

Calculated Values		
	U	Downstream
Theoretical Slicer SNR [dB]:	#	19.25
Estimated Slicer SNR [dB]:	#	14.25
Required Slicer SNR [dB]:	#	17.20
SNR Margin [dB]:	#	-2.95
Wire u-reflections [dB]:	#	-44.94
Nyquist Frequency [GHz]:	#	7.02
Channel Insertion Loss @ Nyquist [dB]:	#	34.61
Cable Insertion Loss @ Nyquist [dB]:	#	29.94







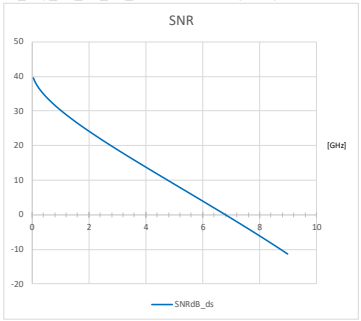


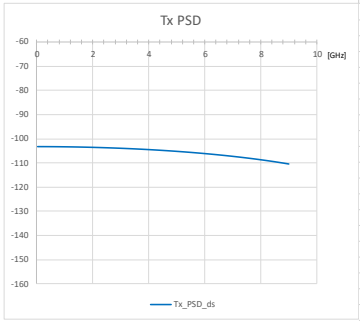
Case 2

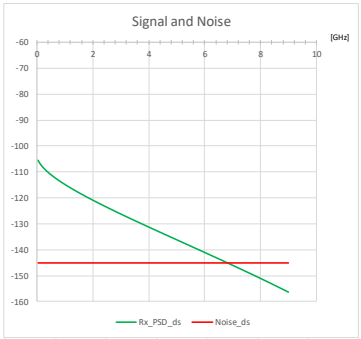
jonsson_3cy_01_04_20_21 - Channel Capacity Calculator Version 1.4

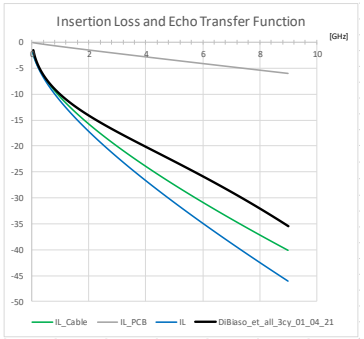
	U	Downstream
Requirements		
Data Rate [Gbps]:	#	25
Target RS-FEC output BER:	#	1.00E-12
Cable Length [m]:	#	17.000
Wire u-reflections limit:	j	jonsson*12_08_1
Number of Connectors:	4	4
Modulation		
PAM Levels:	4	4
FEC Block Size (n):	#	360
FEC Data Size (k):	#	326
RS-FEC Correction Efficiency:	#	100%
Bits per FEC Symbol:	#	10
TDD Time Duty-Cycle:	#	100%
Framing Overhead:	#	1.645%
Transmit Signal		
PSD-mask:	P	PSD_ZOH
Transmit Power [dBm]:	#	-6
Design Tradeoff		
Impulse Error Rate:	#	1.00E-04
AFE-noise [dBm/Hz]:	#	-145
Cable Reflection Echo Cancelation [dB]:	6	0
Connector Echo Cancelation [dB]:	#	0
Implementation Loss [dB]:	5	5
Simulation Parameters		
Cable Model:		ISAAC_01A_0109
PCB model:		b_kadry_3cy_02_08
PCB trace length [m]:		0.1524
Connector Echo Model:		Hard
Temperature [°C]:		20
Max Simulation Frequency:		9.00E+09

Calculated Values		
	U	Downstream
Theoretical Slicer SNR [dB]:	#	16.79
Estimated Slicer SNR [dB]:	#	11.79
Required Slicer SNR [dB]:	#	17.20
SNR Margin [dB]:	#	-5.41
Wire u-reflections [dB]:	#	-48.93
Nyquist Frequency [GHz]:	#	7.02
Channel Insertion Loss @ Nyquist [dB]:	#	38.60
Cable Insertion Loss @ Nyquist [dB]:	#	33.93







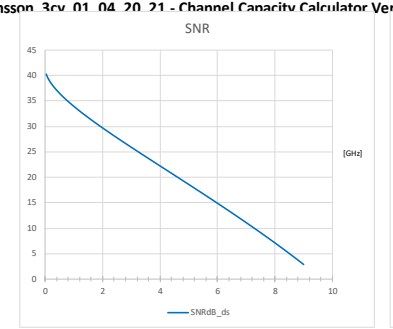


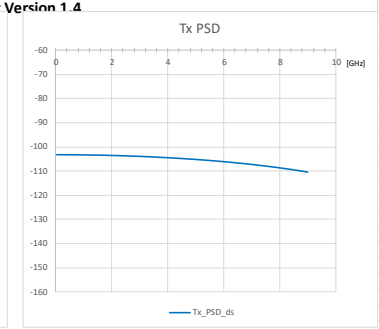
Case 3

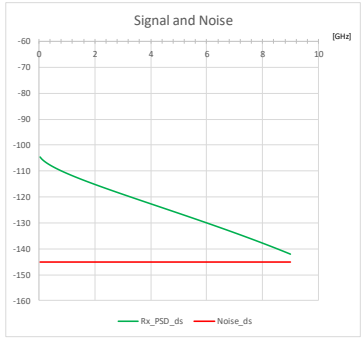
jonsson_3cy_01_04_20_21 - Channel Capacity Calculator Version 1.4

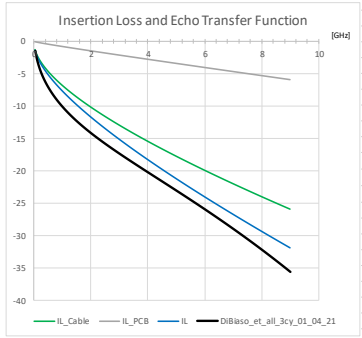
	U	Downstream
Requirements		
Data Rate [Gbps]:	#	25
Target RS-FEC output BER:	#	1.00E-12
Cable Length [m]:	#	11.000
Wire u-reflections limit:	j	jonsson*12_08_1
Number of Connectors:	4	4
Modulation		
PAM Levels:	4	4
FEC Block Size (n):	#	360
FEC Data Size (k):	#	326
RS-FEC Correction Efficiency:	#	100%
Bits per FEC Symbol:	#	10
TDD Time Duty-Cycle:	#	100%
Framing Overhead:	#	1.645%
Transmit Signal		
PSD-mask:	P	PSD_ZOH
Transmit Power [dBm]:	#	-6
Design Tradeoff		
Impulse Error Rate:	#	1.00E-04
AFE-noise [dBm/Hz]:	#	-145
Cable Reflection Echo Cancelation [dB]:	6	0
Connector Echo Cancelation [dB]:	#	0
Implementation Loss [dB]:	5	5
Simulation Parameters		
Cable Model:		ISAAC_01A_0109
PCB model:		p_kadry_3cy_02_08
PCB trace length [m]:		0.1524
Connector Echo Model:		Hard
Temperature [°C]:		20
Max Simulation Frequency:		9.00E+09

Calculated Values		
	U	Downstream
Theoretical Slicer SNR [dB]:	#	24.18
Estimated Slicer SNR [dB]:	#	19.18
Required Slicer SNR [dB]:	#	17.20
SNR Margin [dB]:	#	1.98
Wire u-reflections [dB]:	#	-36.95
Nyquist Frequency [GHz]:	#	7.02
Channel Insertion Loss @ Nyquist [dB]:	#	26.62
Cable Insertion Loss @ Nyquist [dB]:	#	21.95







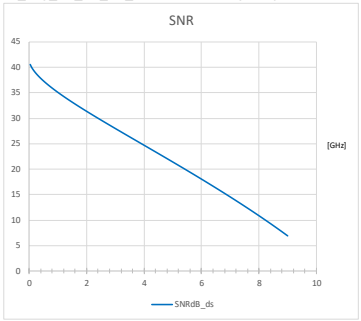


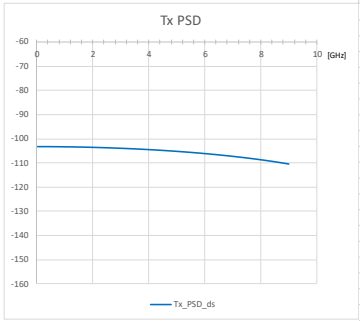
Case 4

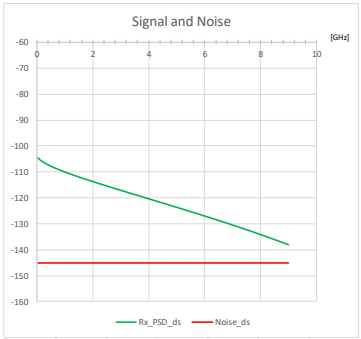
jonsson_3cy_01_04_20_21 - Channel Capacity Calculator Version 1.4

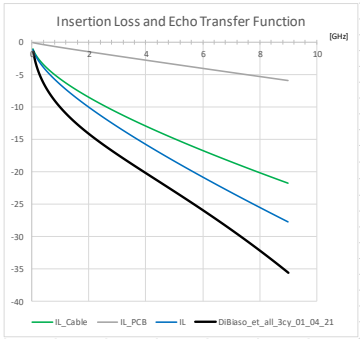
	U	Downstream
Requirements		
Data Rate [Gbps]:	#	25
Target RS-FEC output BER:	#	1.00E-12
Cable Length [m]:	#	15.000
Wire u-reflections limit:	j	jonsson*12_08_1
Number of Connectors:	4	4
Modulation		
PAM Levels:	4	4
FEC Block Size (n):	#	360
FEC Data Size (k):	#	326
RS-FEC Correction Efficiency:	#	100%
Bits per FEC Symbol:	#	10
TDD Time Duty-Cycle:	#	100%
Framing Overhead:	#	1.645%
Transmit Signal		
PSD-mask:	P	PSD_ZOH
Transmit Power [dBm]:	#	-6
Design Tradeoff		
Impulse Error Rate:	#	1.00E-04
AFE-noise [dBm/Hz]:	#	-145
Cable Reflection Echo Cancelation [dB]:	6	0
Connector Echo Cancelation [dB]:	#	0
Implementation Loss [dB]:	5	5
Simulation Parameters		
Cable Model:		LeoniDacar037
PCB model:		b_kadry_3cy_02_08
PCB trace length [m]:		0.1524
Connector Echo Model:		Hard
Temperature [°C]:		20
Max Simulation Frequency:		9.00E+09

Calculated Values		
	U	Downstream
Theoretical Slicer SNR [dB]:	#	26.36
Estimated Slicer SNR [dB]:	#	21.36
Required Slicer SNR [dB]:	#	17.20
SNR Margin [dB]:	#	4.16
Wire u-reflections [dB]:	#	-35.00
Nyquist Frequency [GHz]:	#	7.02
Channel Insertion Loss @ Nyquist [dB]:	#	23.10
Cable Insertion Loss @ Nyquist [dB]:	#	18.43







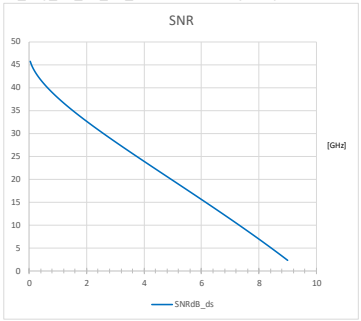


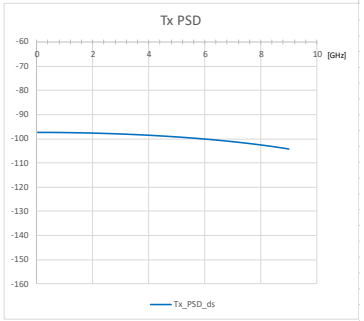
Case 5

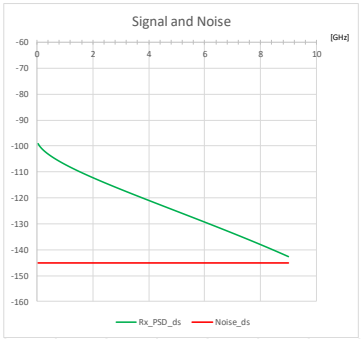
jonsson_3cy_01_04_20_21 - Channel Capacity Calculator Version 1.4

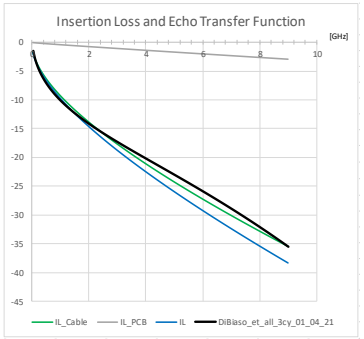
	U	Downstream
Requirements		
Data Rate [Gbps]:	#	25
Target RS-FEC output BER:	#	1.00E-12
Cable Length [m]:	#	15.000
Wire u-reflections limit:	j	jonsson*12_08_1
Number of Connectors:	4	4
Modulation		
PAM Levels:	4	4
FEC Block Size (n):	#	936
FEC Data Size (k):	#	846
RS-FEC Correction Efficiency:	#	100%
Bits per FEC Symbol:	#	10
TDD Time Duty-Cycle:	#	100%
Framing Overhead:	#	1.645%
Transmit Signal		
PSD-mask:	P	PSD_ZOH
Transmit Power [dBm]:	#	0
Design Tradeoff		
Impulse Error Rate:	#	1.00E-04
AFE-noise [dBm/Hz]:	#	-145
Cable Reflection Echo Cancelation [dB]:	6	0
Connector Echo Cancelation [dB]:	#	0
Implementation Loss [dB]:	5	5
Simulation Parameters		
Cable Model:		ISAAC_01A_0109
PCB model:		b_kadry_3cy_02_08
PCB trace length [m]:		0.0762
Connector Echo Model:		Hard
Temperature [°C]:		20
Max Simulation Frequency:		9.00E+09

Calculated Values		
	U	Downstream
Theoretical Slicer SNR [dB]:	#	26.45
Estimated Slicer SNR [dB]:	#	21.45
Required Slicer SNR [dB]:	#	16.27
SNR Margin [dB]:	#	5.18
Wire u-reflections [dB]:	#	-44.94
Nyquist Frequency [GHz]:	#	7.03
Channel Insertion Loss @ Nyquist [dB]:	#	32.41
Cable Insertion Loss @ Nyquist [dB]:	#	30.06







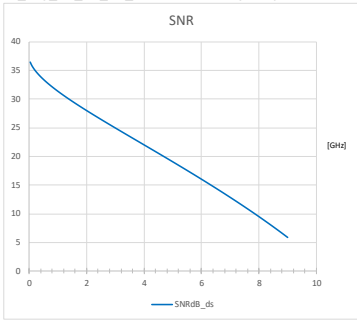


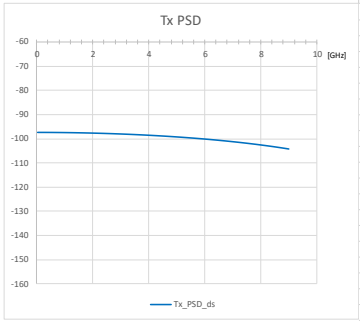
Case 6

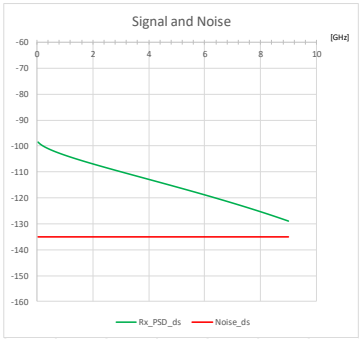
jonsson_3cy_01_04_20_21 - Channel Capacity Calculator Version 1.4

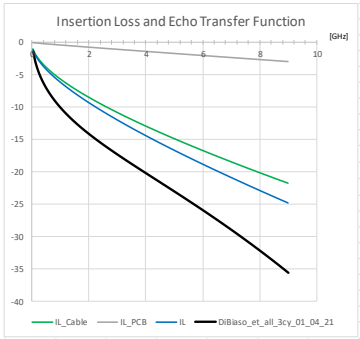
	U	Downstream
Requirements		
Data Rate [Gbps]:	#	25
Target RS-FEC output BER:	#	1.00E-12
Cable Length [m]:	#	15.000
Wire u-reflections limit:	j	jonsson*12_08_1
Number of Connectors:	4	4
Modulation		
PAM Levels:	4	4
FEC Block Size (n):	#	936
FEC Data Size (k):	#	846
RS-FEC Correction Efficiency:	#	100%
Bits per FEC Symbol:	#	10
TDD Time Duty-Cycle:	#	100%
Framing Overhead:	#	1.645%
Transmit Signal		
PSD-mask:	P	PSD_ZOH
Transmit Power [dBm]:	#	0
Design Tradeoff		
Impulse Error Rate:	#	1.00E-09
AFE-noise [dBm/Hz]:	#	-139
Cable Reflection Echo Cancelation [dB]:	6	0
Connector Echo Cancelation [dB]:	#	0
Implementation Loss [dB]:	5	5
Simulation Parameters		
Cable Model:		LeoniDacar037
PCB model:		b_kadry_3cy_02_08
PCB trace length [m]:		0.0762
Connector Echo Model:		Hard
Temperature [°C]:		20
Max Simulation Frequency:		9.00E+09

Calculated Values		
	U	Downstream
Theoretical Slicer SNR [dB]:	#	23.63
Estimated Slicer SNR [dB]:	#	18.63
Required Slicer SNR [dB]:	#	16.64
SNR Margin [dB]:	#	1.99
Wire u-reflections [dB]:	#	-35.00
Nyquist Frequency [GHz]:	#	7.03
Channel Insertion Loss @ Nyquist [dB]:	#	20.85
Cable Insertion Loss @ Nyquist [dB]:	#	18.51









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