Asymmetrical 1-pair and Symmetrical 2-pair operation

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Agenda

- Review of reach requirements and objectives
- Symmetrical operation using 2-pairs
- Asymmetrical operation with 1-pair using TDD

Reach requirements and objectives

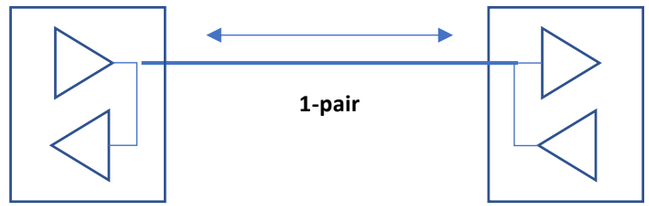
- Adopted Objectives – "at least 11 m"

Define the performance characteristics of an automotive link segment and an electrical PHY to support 25 Gb/s point-to-point operation over this link segment supporting up to 2 inline connectors for at least 11 m on at least one type of automotive cabling

- 40% of cy links are anticipated to need 11 meters
  - Combination of symmetric and asymmetric
- Several presentations have indicated that, with the cable models presented so far, 11 meters symmetrical 1-pair is not practical (echo-cancellation PHY)
- This presentation explores alternative dual-mode PHY to achieve 11 m objective
  - Symmetric using 2 pairs
  - Asymmetric using 1-pair with TDD
- Uses spreadsheet presented in
  https://www.ieee802.org/3/cy/public/adhoc/jonsson_3cy_01_10_28_20.pdf

One PHY – 2 modes of Operation

Simplex operation in each direction

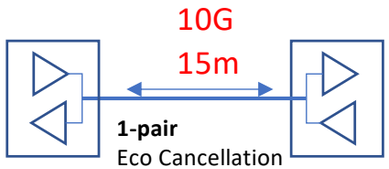


Time Division Duplex operation

- 2-pair mode – each pair runs a simplex link resulting in 25G throughput in each direction
  - Similar to Data Center SerDes
- 1-pair mode – Use TDD for asymmetrical transmission
  - Duty cycle determines net bandwidth in each direction. Easily programmable and changeable.
- Same TX and RX building blocks are used in both modes

Symmetrical operation – 1-pair Vs 2-pairs

Cable model - eq149-18



	Upstream	Downstream
Requrements		
Data Rate [Gbps]:	10	10
Target RS-FEC output BER:	1.00E-12	1E-12
Cable Length [m]:	15	15
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%
Transmit Signal		
PSD-mask:	PSD_brick	PSD_brick
Transmit Power [dBm]:	0	0
Design Tradeoff		
Impulse Error Rate:	1.00E-04	1.00E-04
AFE-noise [dB/Hz]:	-150	-150
EC cancelation [dB]:	5	5
EC Connector cancelation [%]:	100%	100%
Implementation Loss [dB]:	6	6
Simulation Parameters		
Cable Model:	eq149-18	
Connector Echo Model:	hard	
Max Simulation Frequency:	9.00E+09	

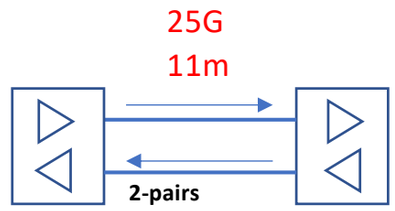
Calculated Values	Upstream	Downstream
Theoretical Slicer SNR [dB]:	24.98	24.98
Estimated Slicer SNR [dB]:	18.98	18.98
Required Slicer SNR [dB]:	17.78	17.78
SNR Margin [dB]:	1.20	1.20
Nyquist Frequency [GHz]:	2.76	2.76
Insertion Loss @ Nyquist [dB]:	29.47	29.47

Feasible

	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%
Transmit Signal		
PSD-mask:	PSD_brick	PSD_brick
Transmit Power [dBm]:	0	0
Design Tradeoff		
Impulse Error Rate:	1.00E-04	1.00E-04
AFE-noise [dB/Hz]:	-150	-150
EC cancelation [dB]:	5	5
EC Connector cancelation [%]:	100%	100%
Implementation Loss [dB]:	6	6
Simulation Parameters		
Cable Model:	eq149-18	
Connector Echo Model:	hard	
Max Simulation Frequency:	9.00E+09	

Calculated Values	Upstream	Downstream
Theoretical Slicer SNR [dB]:	20.58	20.58
Estimated Slicer SNR [dB]:	14.58	14.58
Required Slicer SNR [dB]:	17.78	17.78
SNR Margin [dB]:	-3.20	-3.20
Nyquist Frequency [GHz]:	6.90	6.90
Insertion Loss @ Nyquist [dB]:	36.70	36.70

Not Feasible



	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%
Transmit Signal		
PSD-mask:	PSD_brick	PSD_brick
Transmit Power [dBm]:	0	0
Design Tradeoff		
Impulse Error Rate:	1.00E-04	1.00E-04
AFE-noise [dB/Hz]:	-150	-150
EC cancelation [dB]:	100	100
EC Connector cancelation [%]:	100%	100%
Implementation Loss [dB]:	6	6
Simulation Parameters		
Cable Model:	eq149-18	
Connector Echo Model:	hard	
Max Simulation Frequency:	9.00E+09	

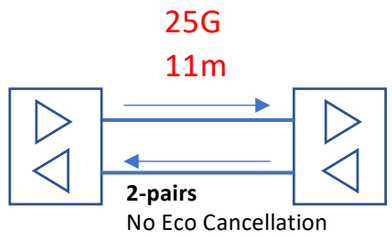
–> “No echo”

Calculated Values	Upstream	Downstream
Theoretical Slicer SNR [dB]:	28.03	28.03
Estimated Slicer SNR [dB]:	22.03	22.03
Required Slicer SNR [dB]:	17.78	17.78
SNR Margin [dB]:	4.25	4.25
Nyquist Frequency [GHz]:	6.90	6.90
Insertion Loss @ Nyquist [dB]:	36.70	36.70

Excellent

25G @ 11m has <u>MORE</u> margin than 10G @ 15m!!

Symmetrical operation – 1-pair Vs 2-pairs



Cable Model	1-pair Echo Cancellation SNR Margin (dB)	2-pairs - No Echo Cancellation SNR Margin (dB)
eq149-18	-3.2	4.25
mueller_3cy_01_10_14_20_target	0.91	6.54
boyer_3cy_01_10_14_20_c1	1.61	9.06
patel_3cy_01_0920	-1.13	6.32

2-pair operation has robust margin at 11 meters with all the above channels "hard" connectors used on the analysis (4 total)

Asymmetrical operation – Echo Cancellation Vs TDD

Cable model - eq149-18

	Upstream	Downstream
Requrements		
Data Rate [Gbps]:	10	10
Target RS-FEC output BER:	1.00E-12	1E-12
Cable Length [m]:	15	15
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%
Transmit Signal		
PSD-mask:	PSD_brick	PSD_brick
Transmit Power [dBm]:	0	0
Design Tradeoff		
Impulse Error Rate:	1.00E-04	1.00E-04
AFE-noise [dB/Hz]:	-150	-150
EC cancelation [dB]:	5	5
EC Connector cancelation [%]:	100%	100%
Implementation Loss [dB]:	6	6
Simulation Parameters		
Cable Model:	eq149-18	
Connector Echo Model:	hard	
Max Simulation Frequency:	9.00E+09	

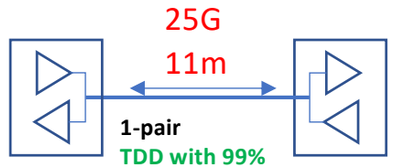
Calculated Values	Upstream	Downstream
Theoretical Slicer SNR [dB]:	24.98	24.98
Estimated Slicer SNR [dB]:	18.98	18.98
Required Slicer SNR [dB]:	17.78	17.78
SNR Margin [dB]:	1.20	1.20
Nyquist Frequency [GHz]:	2.76	2.76
Insertion Loss @ Nyquist [dB]:	29.47	29.47

Feasible

	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%
Transmit Signal		
PSD-mask:	PSD_brick	PSD_brick
Transmit Power [dBm]:	0	0
Design Tradeoff		
Impulse Error Rate:	1.00E-04	1.00E-04
AFE-noise [dB/Hz]:	-150	-150
EC cancelation [dB]:	5	5
EC Connector cancelation [%]:	100%	100%
Implementation Loss [dB]:	6	6
Simulation Parameters		
Cable Model:	eq149-18	
Connector Echo Model:	hard	
Max Simulation Frequency:	9.00E+09	

Calculated Values	Upstream	Downstream
Theoretical Slicer SNR [dB]:	20.58	20.58
Estimated Slicer SNR [dB]:	14.58	14.58
Required Slicer SNR [dB]:	17.78	17.78
SNR Margin [dB]:	-3.20	-3.20
Nyquist Frequency [GHz]:	6.90	6.90
Insertion Loss @ Nyquist [dB]:	36.70	36.70

Not Feasible



	99%	99%
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:	99%	99%
Transmit Signal		
PSD-mask:	PSD_brick	PSD_brick
Transmit Power [dBm]:	0	0
Design Tradeoff		
Impulse Error Rate:	1.00E-04	1.00E-04
AFE-noise [dB/Hz]:	-150	-150
EC cancelation [dB]:	100	100
EC Connector cancelation [%]:	100%	100%
Implementation Loss [dB]:	6	6
Simulation Parameters		
Cable Model:	eq149-18	
Connector Echo Model:	hard	
Max Simulation Frequency:	9.00E+09	

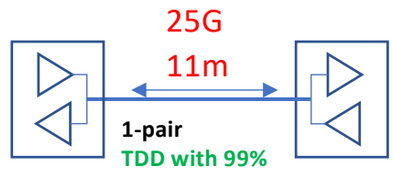
–> “No echo”

Calculated Values	Upstream	Downstream
Theoretical Slicer SNR [dB]:	27.80	27.80
Estimated Slicer SNR [dB]:	21.80	21.80
Required Slicer SNR [dB]:	17.78	17.78
SNR Margin [dB]:	4.02	4.02
Nyquist Frequency [GHz]:	6.97	6.97
Insertion Loss @ Nyquist [dB]:	36.84	36.84

Excellent

25G @ 11m has <u>MORE margin</u> than 10G @ 15m!!

Asymmetrical operation – Echo Cancellation Vs TDD



Cable Model	1-pair Echo Cancellation SNR Margin (dB)	1-pair – TDD 99% Downstream SNR Margin (dB)
eq149-18	-3.2	4.02
mueller_3cy_01_10_14_20_target	0.91	6.31
boyer_3cy_01_10_14_20_c1	1.61	8.82
patel_3cy_01_0920	-1.13	6.08

1-pair operation with TDD has robust margin at 11 meters with all the above channels with "hard" connectors.

In the data presented for TDD, Upstream BW would be up to 1% of 25 Gbps = 250 Mbps

Power and Design complexity

- **Power consumption**
  - 2-pair power consumption will be significantly lower than 1-pair echo cancellation PHY
  - 1-pair TDD power consumption will be lower than 1-pair echo cancellation PHY

- **Design complexity**
  - 2-pair design complexity is significantly lower than 1-pair echo cancellation PHY
  - 1-pair TDD design complexity is significantly lower than 1-pair echo cancellation PHY

- Choose same base design (PAM levels, FEC etc.) for both modes
- With that, same PHY can operate in 2-pair sym mode or 1-pair asym mode (TDD)

Conclusions

- Echo-cancellation is the fundamental bottleneck in achieving 11 m operation
- Echo-cancellation can be avoided by adopting 2-pair for symmetrical operation and TDD for 1-pair asymmetrical operation
- One 25G PHY that operates in 2-pair sym and 1-pair asym mode has the following benefits
  - Meets 11 m objective in both cases
  - Better power consumption
  - Lower design complexity
  - Better SNR margin

Thank You

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