QSFP-DD SMT MCB/HCB Performance vs. 802.3ck D1.2

Alex Haser (alex.haser@molex.com)
17 June 2020

molex®
one company › a world of innovation

Overview:

- OBJECTIVE: To evaluate DDQ SMT (1x1) performance against the 802.3ck D1.2 MCB/HCB limits
  - Several parameters have not yet been defined
  - The data presented will be used to determine a proposal for these undefined parameters
- Both simulated and measured data sets are presented
  - Simulated data captures the performance of the entire connector
  - Measured data is more realistic, but only “proof of concept” (POC, partially populated) results are available, so the data set is incomplete

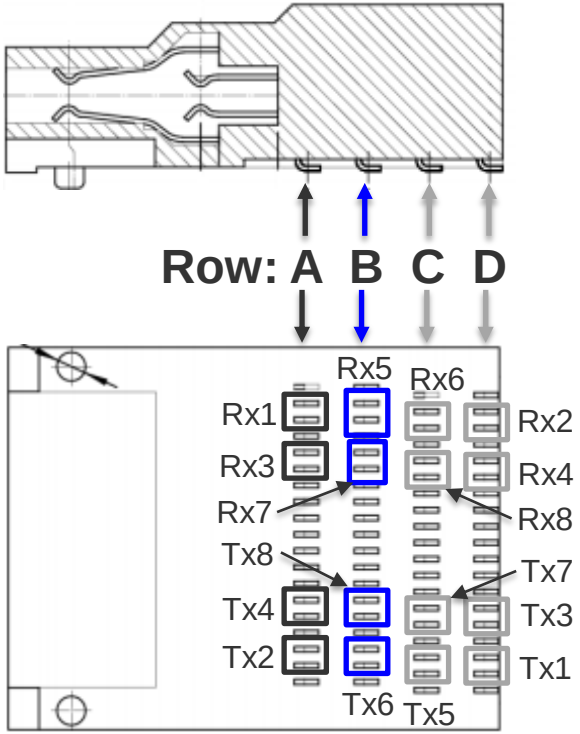
molex

Notes About Data:

- Simulated Data:
  - The connector model was concatenated with trace models & RF connector model
- Measured Data: (see figures at right)
  - Molex test boards are lossier than what is specified in the spec
    - Measured data were fully de-embedded using AFR, then concatenated with simulated MCB/HCB traces & RF connectors
  - Physical connectors are proof of concept (POC) parts and are only partially populated
    - For crosstalk analysis, some pairs were doubled to better approximate full crosstalk response
    - See slide 19 for more information

Legacy Pairs
DD Pairs
Unpopulated

Measured Data:

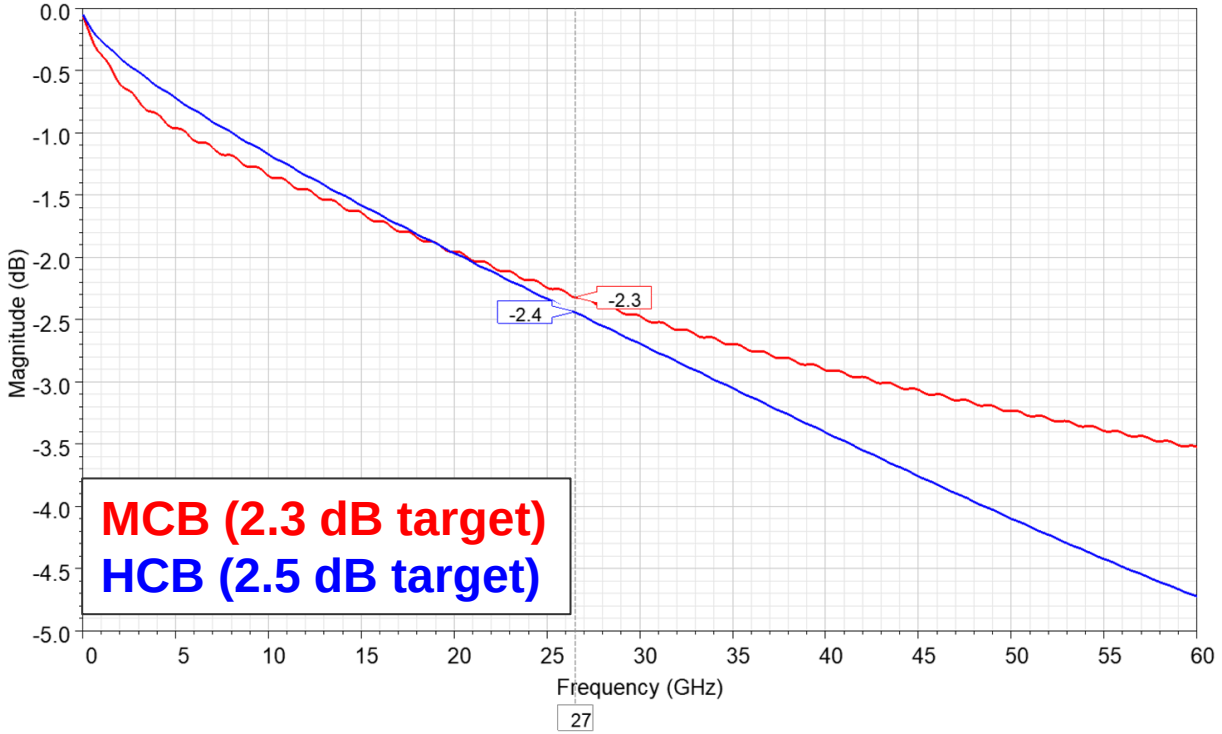


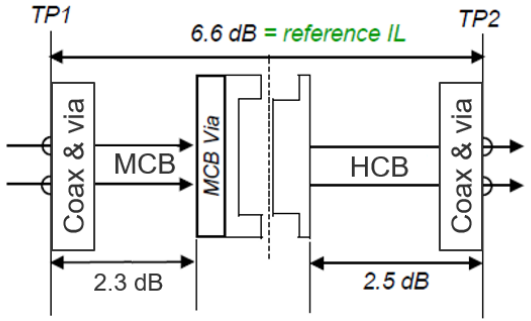
Bottom of connector

molex

Simulated Data: Traces

NOTE: These simulated traces were used with both simulated and measured data sets





Note: 2.3 d.3 dB MCB PCB includes test point IL and Md MCB Via allowance is 0.2 dB

Notes on the Following Slides:

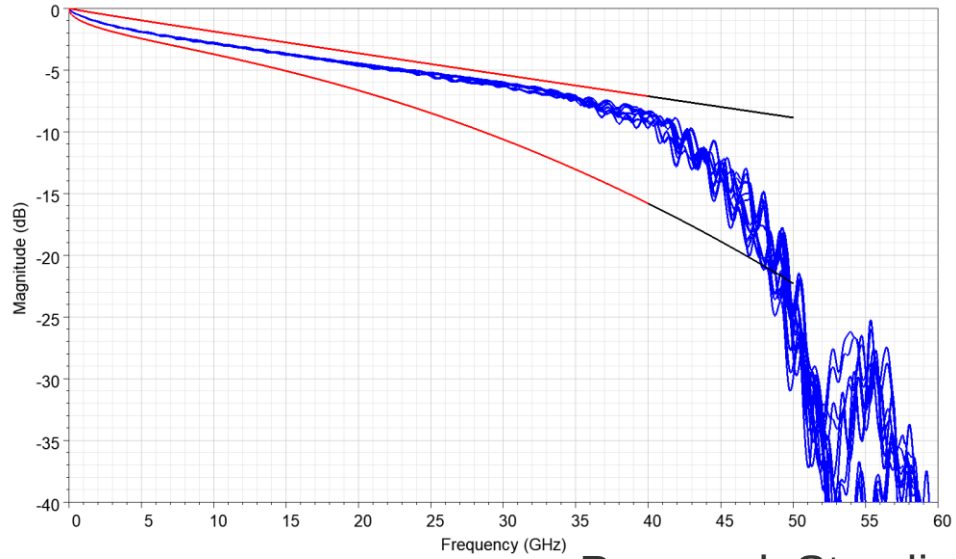
- Different stop frequencies due to data availability
  - Simulated data goes up to 60 GHz
  - Measured data goes up to 50 GHz
- High frequency passivity issues in measured data are due to de-embedding
- Limit lines:
  - **Black** lines show the current 802.3ck D1.2 limits
  - **Red** lines show the proposed limits

molex

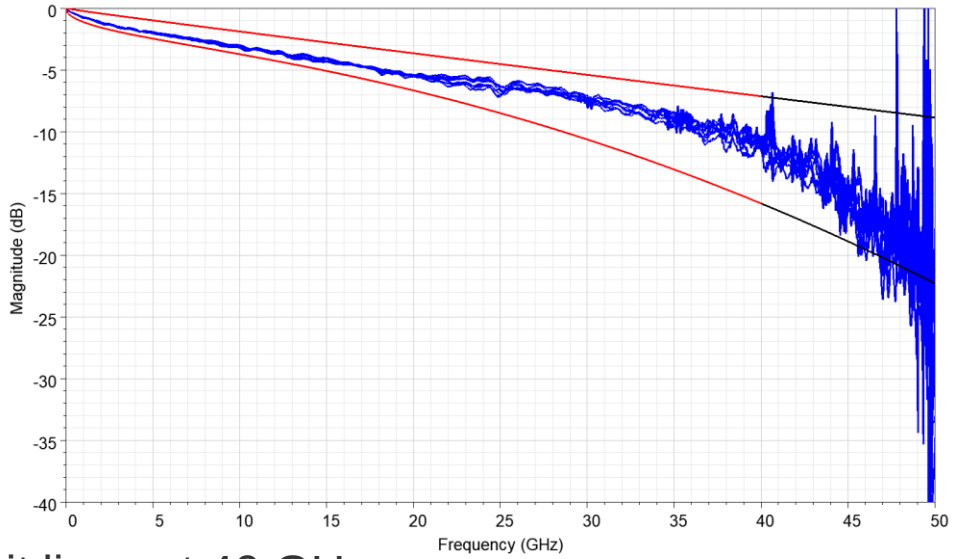
SDD21:

Key:
BLACK = 802.3ck D1.2
RED = Proposal

Simulated Data:



Measured Data:



Proposal: Stop limit lines at 40 GHz

molex

FOM_{ILD}:

Parameter	Value
f_b	53.125 GHz
T_r	**6.16 ps**
f_r	0.75 x fb
f_{start}	**0.05 GHz***
f_{stop}	40 GHz
FOM_{ILD} Limit	**0.18 dBrms**

* The current D1.2 specification identifies f_{start} = 0.01 GHz (see next slide for more information)

Key:
Legacy Pair
DD Pair
Proposed Value

Pair	Simulated	Measured
1 (Tx1)	0.040	
2 (Tx3)	0.042	
3 (Tx5)	0.046	
4 (Tx7)	0.053	
5 (Tx6)	0.040	0.132
6 (Tx8)	0.045	0.121
7 (Tx2)	0.072	0.099
8 (Tx4)	0.064	0.093
9 (Rx4)	0.043	
10 (Rx2)	0.040	
11 (Rx8)	0.051	
12 (Rx6)	0.047	
13 (Rx7)	0.047	0.110
14 (Rx5)	0.042	0.133
15 (Rx3)	0.062	0.118
16 (Rx1)	0.069	0.114
MAX	**0.072**	**0.133**

molex

FOM_{ILD}: Start frequency

- Start frequency for FOM_{ILD} calculation is unrealistic
- Most VNAs with the necessary frequency range (50+ GHz) cannot measure below 0.05 GHz
- Additionally, changing the start frequency has a negligible effect on the results since low frequency IL is well behaved (see chart)
- NOTE: Calculation parameters (except for the start frequency) are the same as what's shown on the previous slide

Key:
Legacy Pair
DD Pair

	Simulated	
Pair	f_{start} = 0.01 GHz	f_{start} = 0.05 GHz
1 (Tx1)	0.041	0.040
2 (Tx3)	0.042	0.042
3 (Tx5)	0.047	0.046
4 (Tx7)	0.053	0.053
5 (Tx6)	0.041	0.040
6 (Tx8)	0.045	0.045
7 (Tx2)	0.072	0.072
8 (Tx4)	0.065	0.064
9 (Rx4)	0.044	0.043
10 (Rx2)	0.041	0.040
11 (Rx8)	0.052	0.051
12 (Rx6)	0.047	0.047
13 (Rx7)	0.047	0.047
14 (Rx5)	0.042	0.042
15 (Rx3)	0.063	0.062
16 (Rx1)	0.070	0.069
MAX	**0.072**	**0.072**

A Note on the FOM_{ILD} Value Proposed:

- FOM_{ILD} values for measured data are significantly worse than those predicted by simulation
- The worst measured FOM_{ILD} value for the available, limited data set is 0.133 dBrms
- Therefore, a limit of 0.18 dBrms is proposed
- **Proposal:**
  - T_r = 6.16 ps
  - f_{start} = 0.05 GHz
  - f_{stop} = 40 GHz
  - FOM_{ILD} Limit = 0.18 dBrms

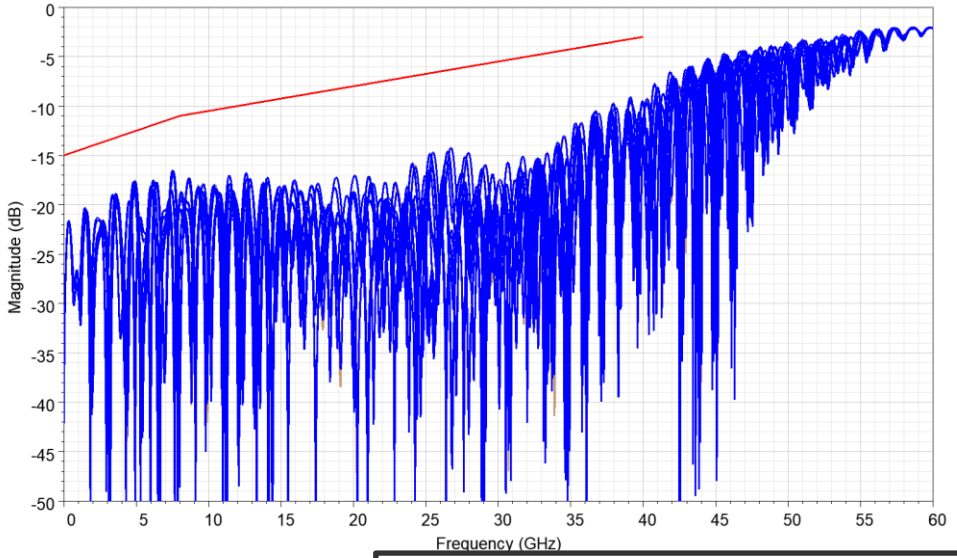
molex

SDD11:

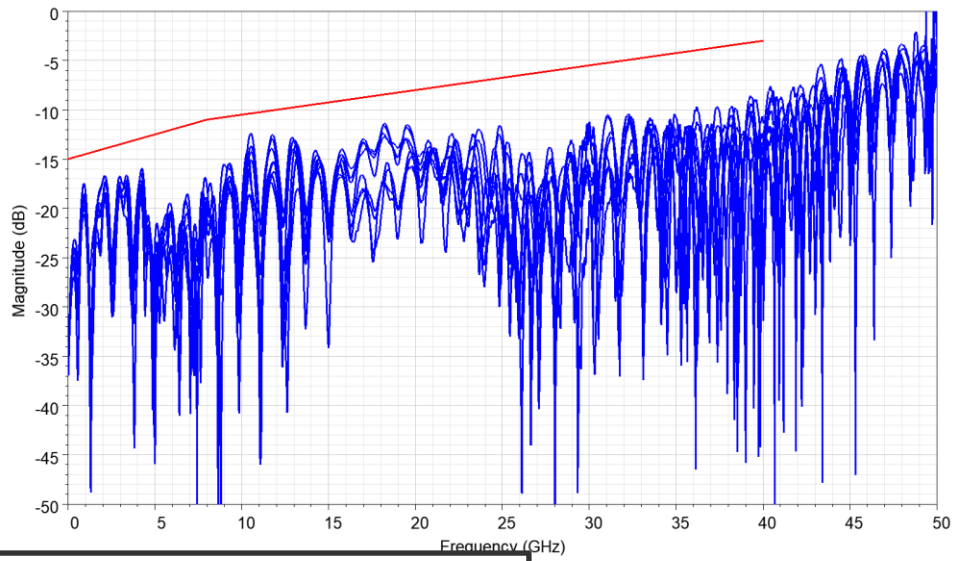
NOTE: 802.3ck D1.2 does not include a limit line for this parameter

Key:
BLACK = 802.3ck D1.2
RED = Proposal

Simulated Data:



Measured Data:



Proposal:

$$15 - 0.5f \qquad f < 8\ GHz$$
$$13 - 0.25f \qquad 8\ GHz \leq f \leq 40\ GHz$$

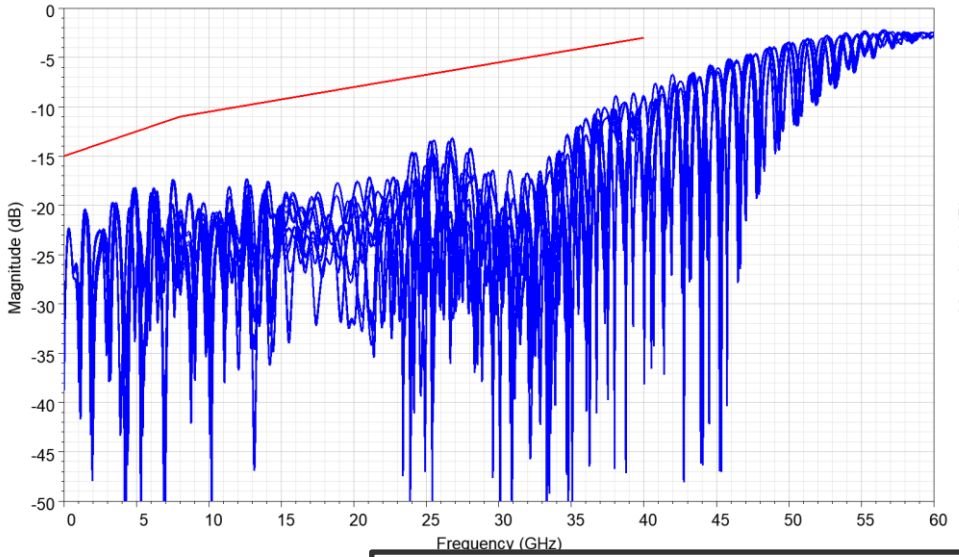
molex

SDD22:

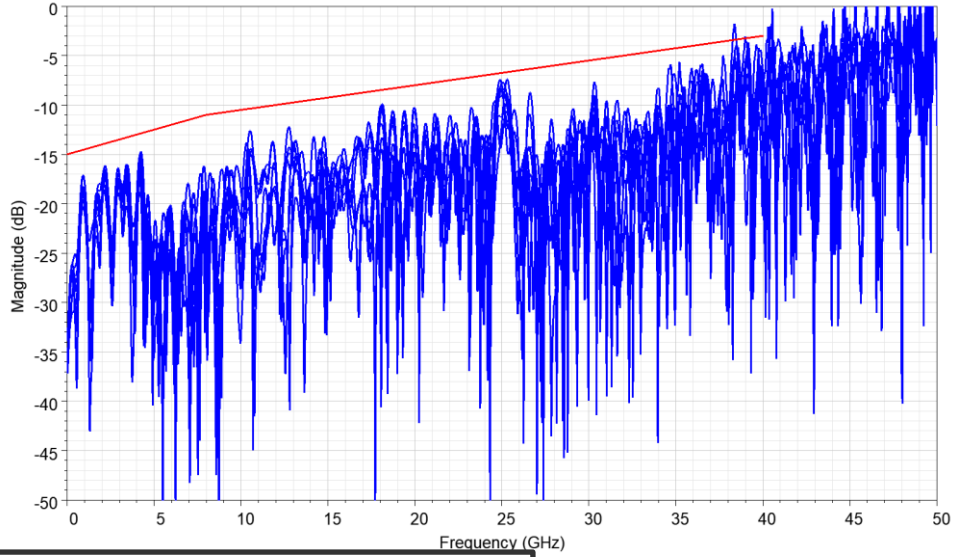
NOTE: 802.3ck D1.2 does not include a limit line for this parameter

Key:
BLACK = 802.3ck D1.2
RED = Proposal

Simulated Data:



Measured Data:



Proposal:

$$15 - 0.5f \qquad f < 8\ GHz$$
$$13 - 0.25f \qquad 8\ GHz \leq f \leq 40\ GHz$$

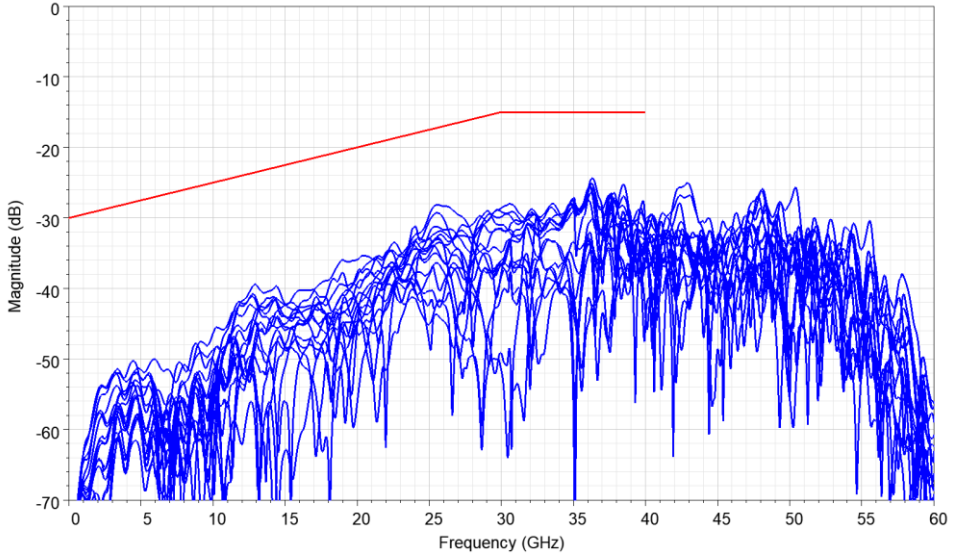
molex

SDC12:

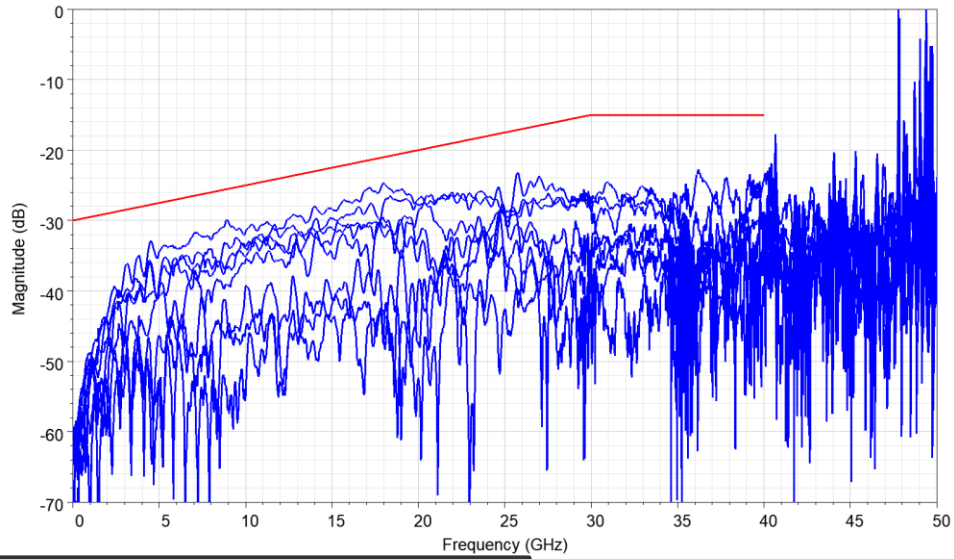
NOTE: 802.3ck D1.2 does not include a limit line for this parameter

Key:
BLACK = 802.3ck D1.2
RED = Proposal

Simulated Data:



Measured Data:



Proposal: $30 - 0.5f$ for $f < 30\ GHz$; 15 for $30\ GHz \leq f \leq 40\ GHz$

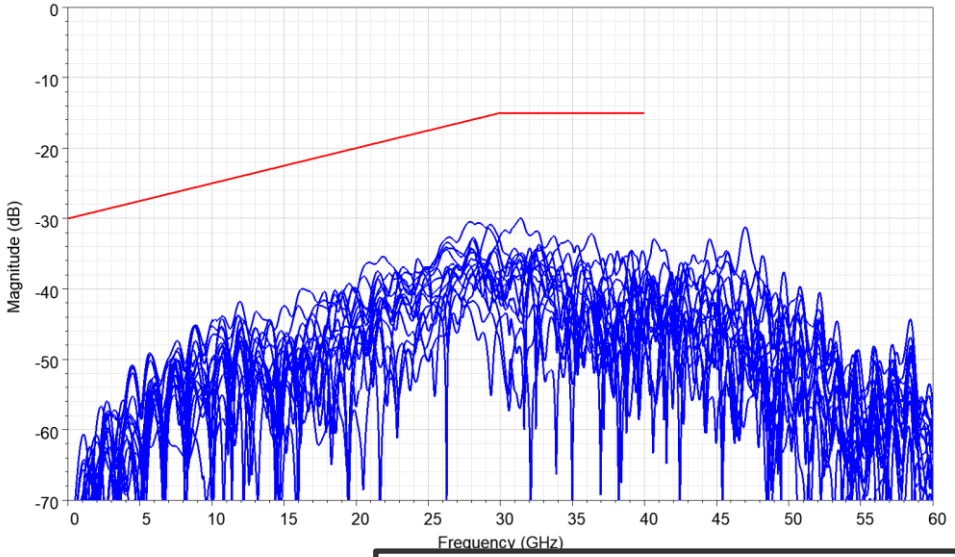
molex

SDC21:

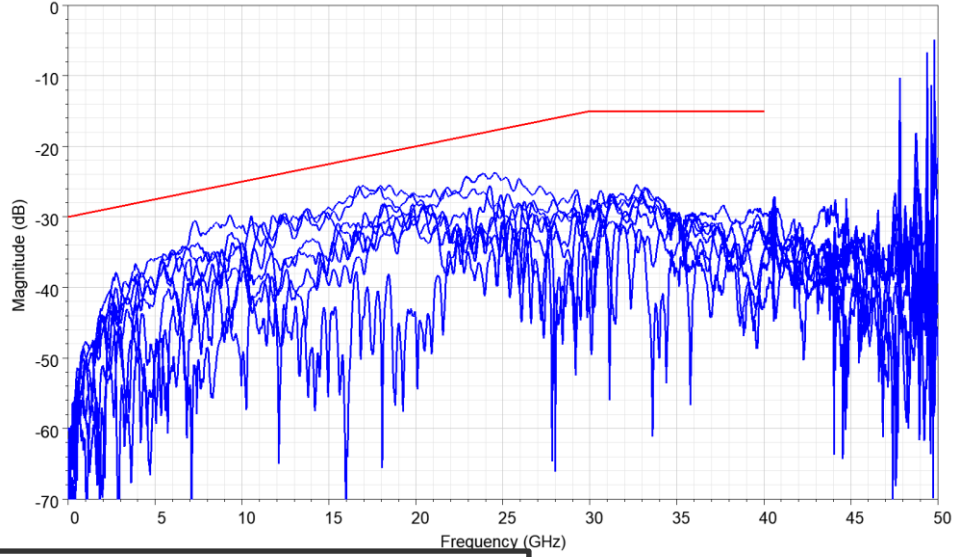
NOTE: 802.3ck D1.2 does not include a limit line for this parameter

Key:
BLACK = Proposal
RED = 802.3ck D1.2

Simulated Data:



Measured Data:



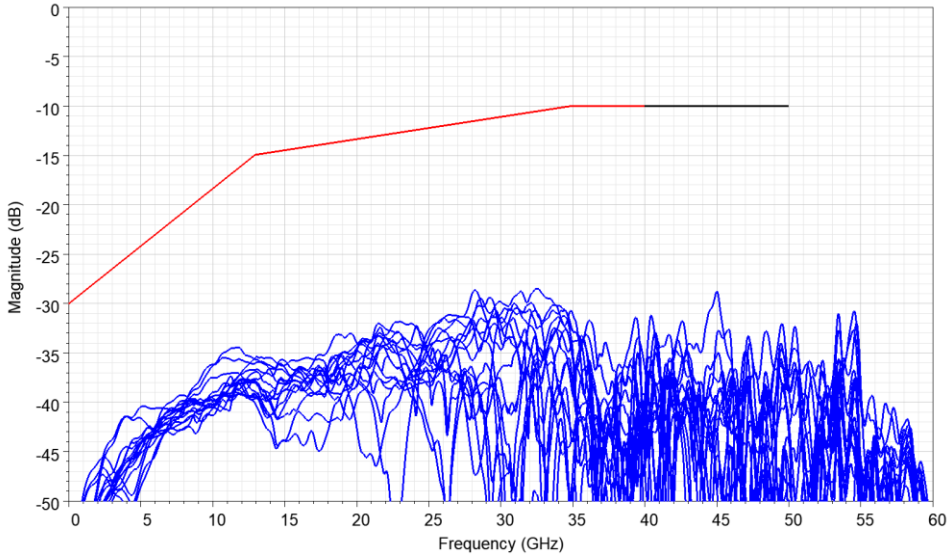
Proposal: $30 - 0.5f$ for $f < 30\ GHz$; 15 for $30\ GHz \leq f \leq 40\ GHz$

molex

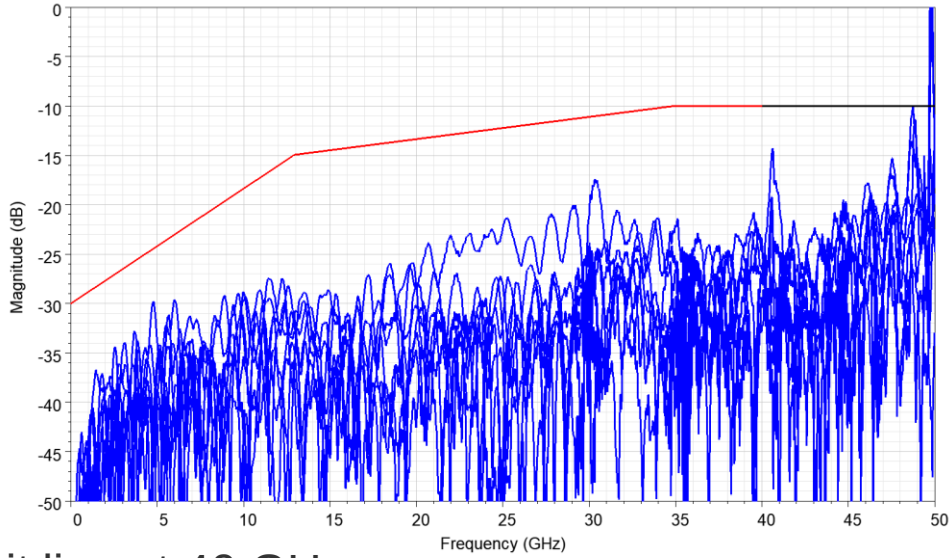
SDC11:

Key:
BLACK = 802.3ck D1.2
RED = Proposal

Simulated Data:



Measured Data:



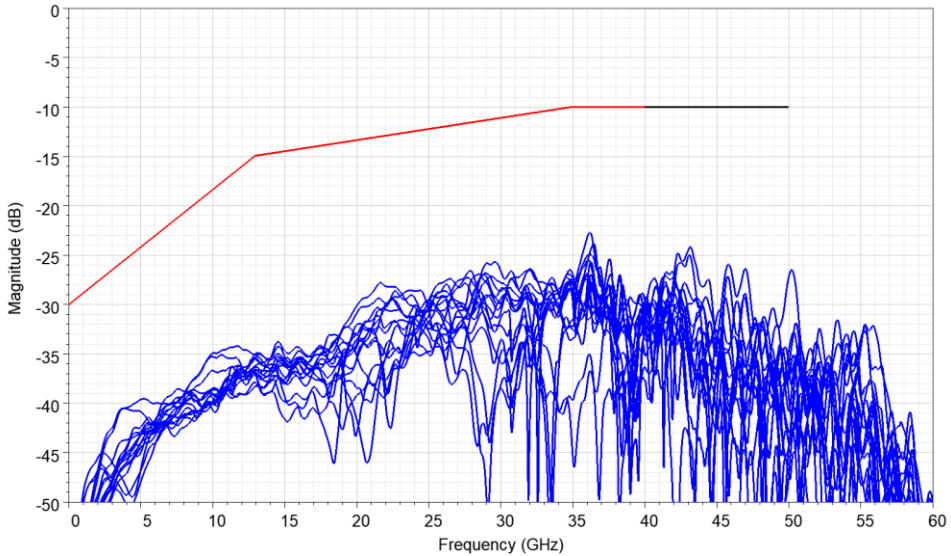
Proposal: Stop limit line at 40 GHz

molex

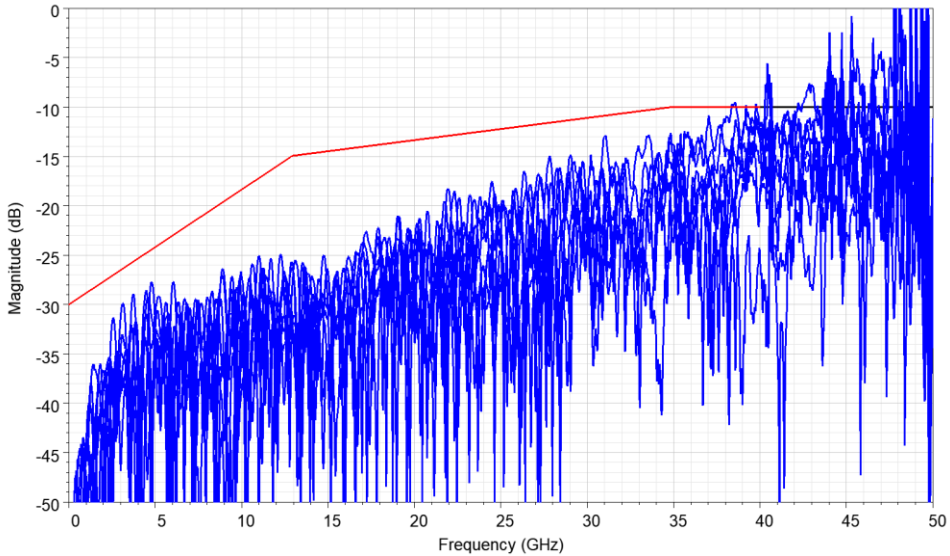
SDC22:

Key:
BLACK = 802.3ck D1.2
RED = Proposal

Simulated Data:



Measured Data:



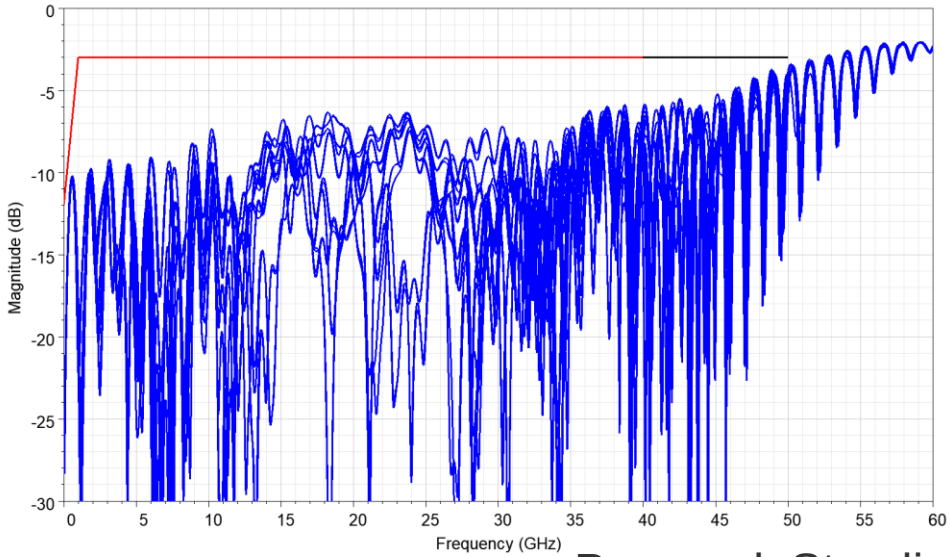
Proposal: Stop limit line at 40 GHz

molex

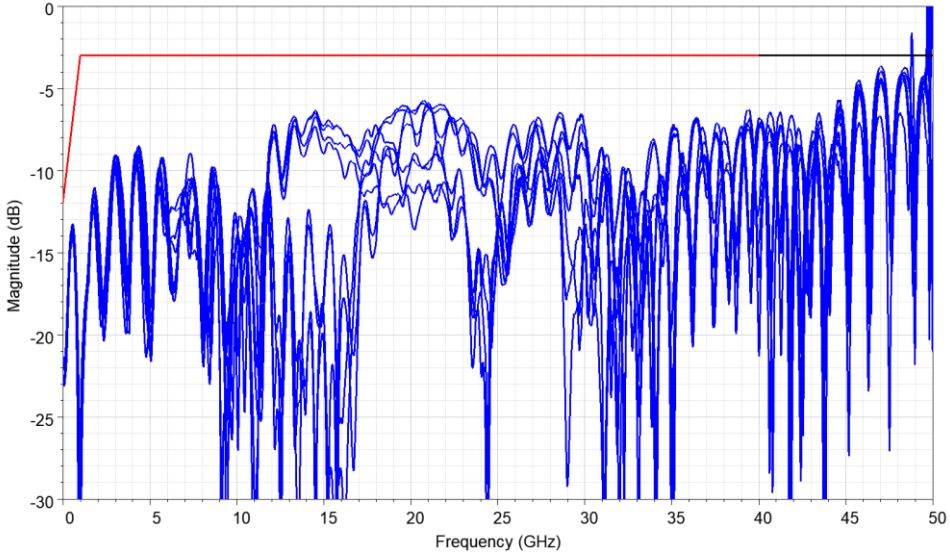
SCC11:

Key:
BLACK = 802.3ck D1.2
RED = Proposal

Simulated Data:



Measured Data:



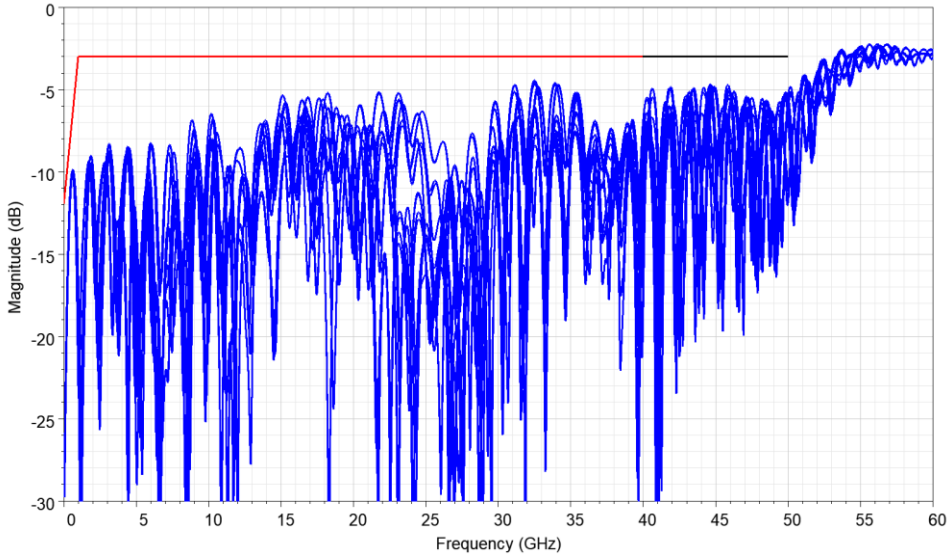
Proposal: Stop limit line at 40 GHz

molex

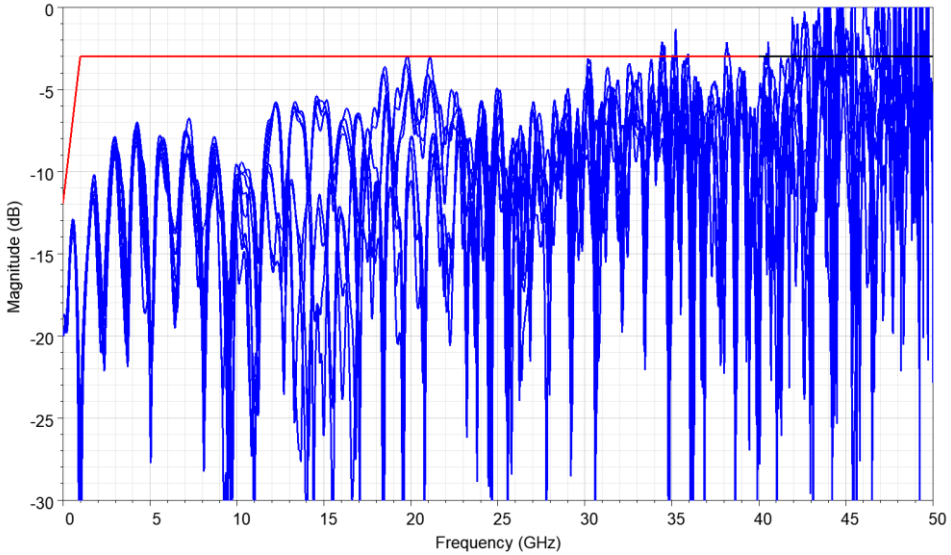
SCC22:

Key:
BLACK = 802.3ck D1.2
RED = Proposal

Simulated Data:



Measured Data:



Proposal: Stop limit line at 40 GHz

molex

Crosstalk: Measured Data

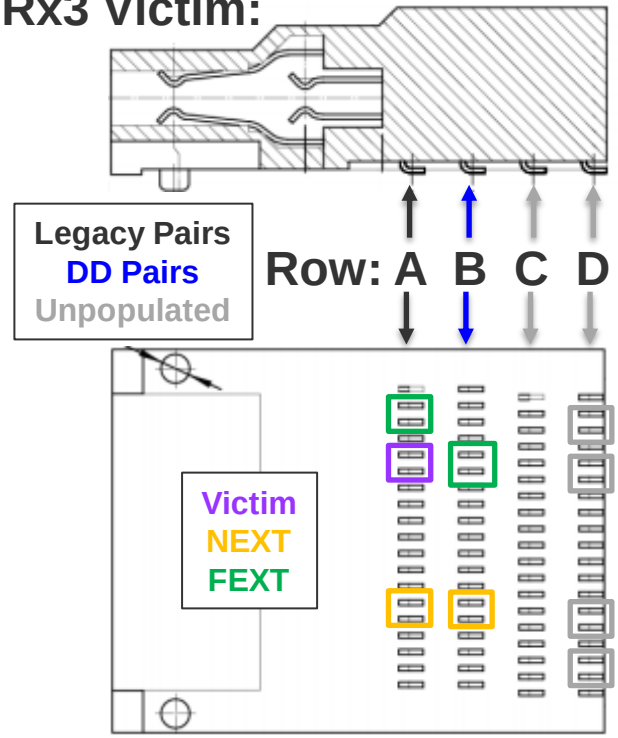
- Due to the nature of the POC connectors, full crosstalk results were not available
- Some crosstalk measurements were duplicated to simulate crosstalk in Row C
- See next slide for pinout information

molex

Crosstalk: Measured Data

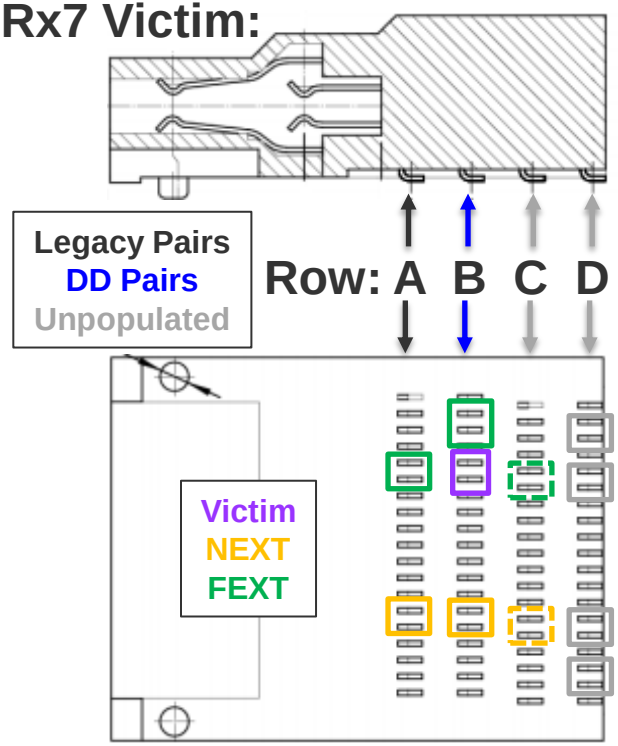
SOLID = Measured data
D-A-S-H-E-D = “Simulated” data

Rx3 Victim:



Bottom of connector

Rx7 Victim:



Bottom of connector

molex

Correction:

- In previous versions of this presentation, the reported MCB/HCB ICN values for QSFP-DD POC connectors were incorrect
- The error occurred in both simulated and measured data sets
- ICN values on the next slide are the corrected values (also see slides 32 & 33)
- The proposed values for the ICN have not changed

molex

ICN Stop Frequency:

Max Values	Simulated			Measured		
Victim	ICN_{NEXT}	ICN_{FEXT}	ICN_{Total}	ICN_{NEXT}	ICN_{FEXT}	ICN_{Total}
f_{stop} = 40 GHz	1.031	3.072	3.188	0.973	3.840	3.961
f_{stop} = 50 GHz	1.108	3.138	3.293	1.019	3.857	3.989

Parameter	Value
f_b	53.125 GHz
f_r	0.75 x fb
f_{min}	**0.05 GHz**
f_{max}	**40 GHz**
A_{nt}, A_{ft}	600 mV
T_{nt}, T_{ft}	**6.16 ps**
ICN_{NEXT} Limit	**1.5 mV***
ICN_{FEXT} Limit	**4.2 mV***
ICN_{Total} Limit	**4.4 mV***

- The ICN values calculated with a 40 GHz stop frequency are roughly the same as those calculated with a 50 GHz stop frequency
- This is due to the decay of the weighting function over this frequency band
- Calculating ICN all the way to 50 GHz has a minimal impact on the results
- Recommendation: For ICN, f_{stop} = 40 GHz
- NOTE: 0.75 x f_b = 39.84 GHz

* No change from 802.3cd spec

molex

ICN Proposal Summary:

- **Input parameters:**
  - f_{start} = 0.50 GHz
  - f_{stop} = 40 GHz
  - T_{nt}, T_{ft} = 6.16 ps
- **Limits:**
  - ICN_{NEXT} Limit = 1.50 mV (same as 802.3cd)
  - ICN_{FEXT} Limit = 4.20 mV (same as 802.3cd)
  - ICN_{Total} Limit = 4.40 mV (same as 802.3cd)

molex

Summary:

- Proposal to change all existing frequency domain limits to stop at 40 GHz (see diminico_3ck_01_0120)
- Frequency domain limits were proposed for RL & Thru Mode Conversion
- FOM_{ILD} & ICN parameters and limits were proposed

molex

Proposal Summary:

- f_{stop} = 40 GHz for all frequency domain limits
- FOM_{ILD}:
  - T_r = 6.16 ps
  - f_{start} = 0.05 GHz
  - f_{stop} = 40 GHz
  - FOM_{ILD} Limit = 0.18 dBrms
- SDD11 / SD22 =

$$\begin{matrix} 15 - 0.5f & f < 8\ GHz \\ 13 - 0.25f & 8\ GHz \leq f \leq 40\ GHz \end{matrix}$$

- SDC12 / SDC21 =

$$\begin{matrix} 30 - 0.5f & f < 30\ GHz \\ 15 & 30\ GHz \leq f \leq 40\ GHz \end{matrix}$$

- ICN:
  - f_{start} = 0.05 GHz
  - f_{stop} = 40 GHz
  - T_{nt}, T_{ft} = 6.16 ps
  - ICN_{NEXT} Limit = 1.50 mV
  - ICN_{FEXT} Limit = 4.20 mV
  - ICN_{Total} Limit = 4.40 mV

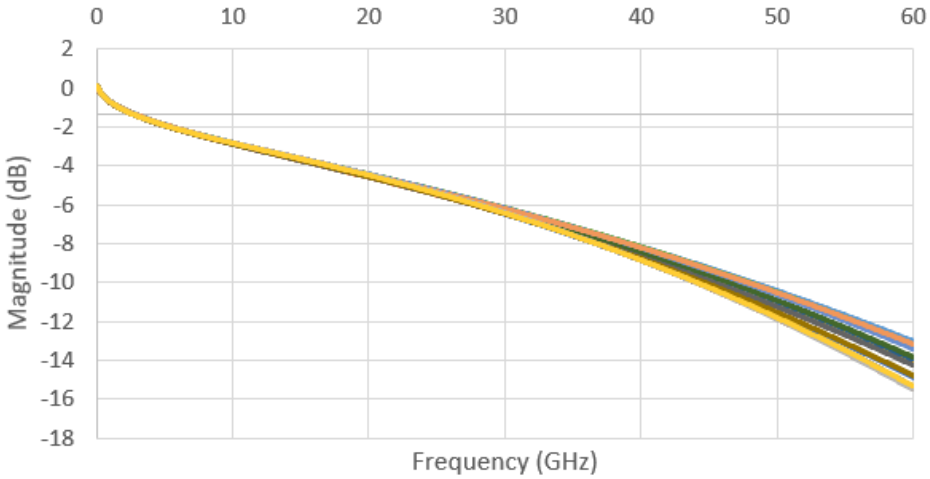
molex

molex®

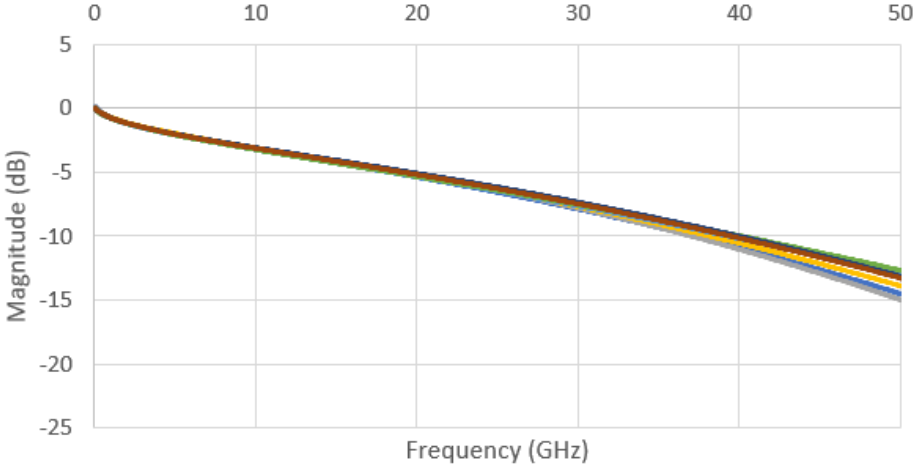
These plots are included for reference

IL_{fit}: f_{stop} = 40 GHz

Simulated Data:



Measured Data:

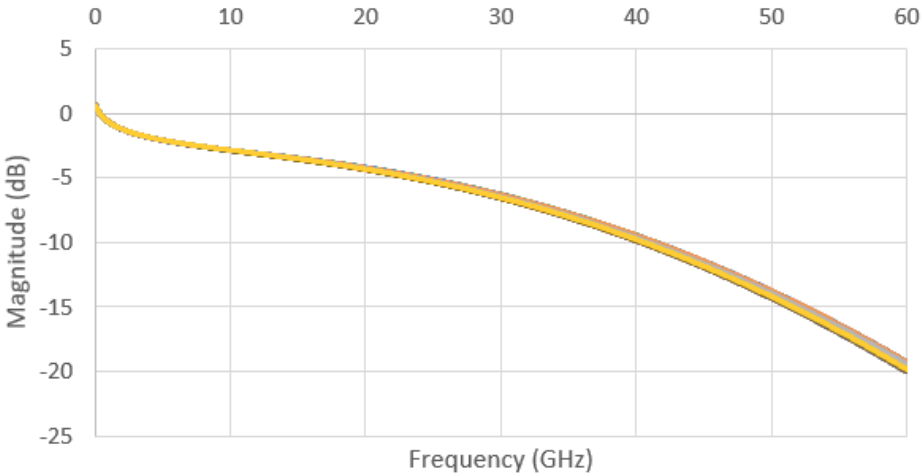


molex

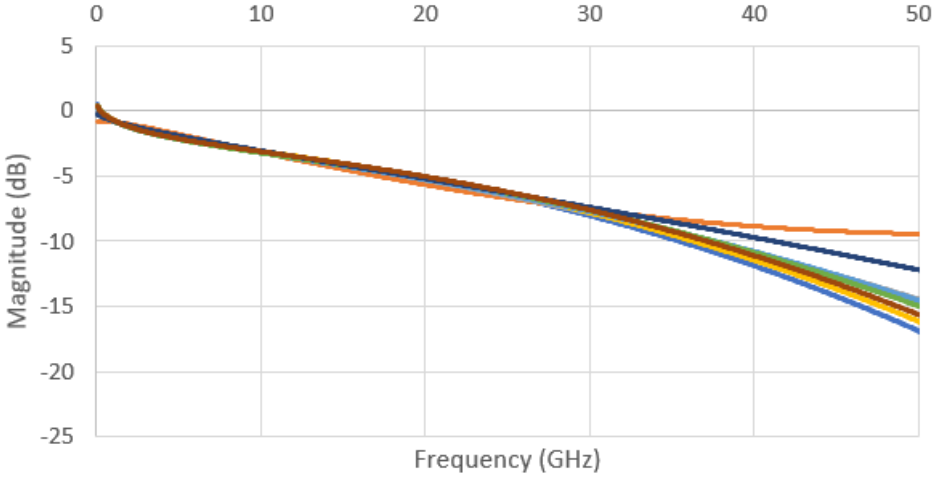
These plots are included for reference

IL_{fit}: f_{stop} = 50 GHz

Simulated Data:



Measured Data:



molex

Simulated ILD: Coefficients

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
f_{stop} = 40 GHz	a_0	-0.331	-0.283	-0.318	-0.352	-0.250	-0.295	-0.406	-0.425	-0.293	-0.334	-0.353	-0.311	-0.310	-0.260	-0.421	-0.399
	a_1	1.134	1.066	1.094	1.135	0.990	1.050	1.220	1.245	1.079	1.136	1.136	1.083	1.071	1.004	1.242	1.212
	a_2	-0.066	-0.043	-0.056	-0.067	-0.025	-0.043	-0.094	-0.104	-0.047	-0.066	-0.067	-0.052	-0.049	-0.029	-0.104	-0.092
	a_4	0.003	0.002	0.003	0.003	0.002	0.002	0.003	0.003	0.002	0.003	0.003	0.002	0.002	0.002	0.003	0.003
f_{stop} = 50 GHz	a_0	-1.052	-1.088	-1.092	-1.135	-1.166	-1.211	-1.047	-1.048	-1.095	-1.050	-1.141	-1.105	-1.209	-1.157	-1.017	-1.055
	a_1	2.065	2.108	2.089	2.142	2.167	2.226	2.045	2.042	2.117	2.062	2.149	2.105	2.228	2.155	2.004	2.056
	a_2	-0.329	-0.337	-0.335	-0.349	-0.355	-0.372	-0.325	-0.326	-0.340	-0.327	-0.350	-0.339	-0.373	-0.351	-0.316	-0.328
	a_4	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007

Measured ILD: Coefficients

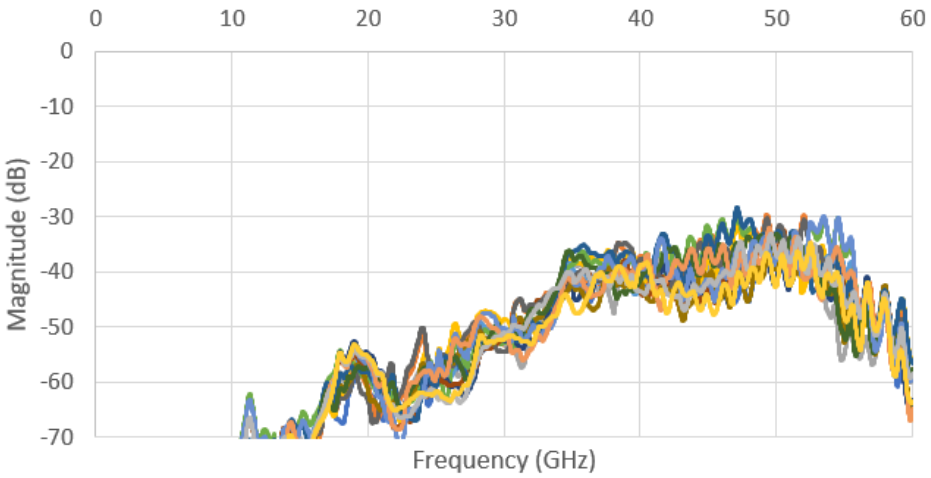
		5	6	7	8	13	14	15	16
f_{stop} = 40 GHz	a_0	-0.369	-0.211	-0.427	-0.232	-0.215	-0.179	-0.295	-0.298
	a_1	1.148	0.936	1.237	0.938	0.943	0.911	1.044	1.044
	a_2	-0.039	0.023	-0.079	0.007	0.025	0.035	-0.022	-0.014
	a_4	0.003	0.002	0.004	0.003	0.002	0.002	0.003	0.003
f_{stop} = 50 GHz	a_0	-0.867	0.964	-0.183	-0.755	-0.554	-0.753	0.098	-0.830
	a_1	1.815	-0.552	0.938	1.627	1.392	1.662	0.558	1.747
	a_2	-0.233	0.432	0.001	-0.191	-0.104	-0.179	0.108	-0.218
	a_4	0.007	-0.004	0.003	0.006	0.004	0.005	0.001	0.006

molex®

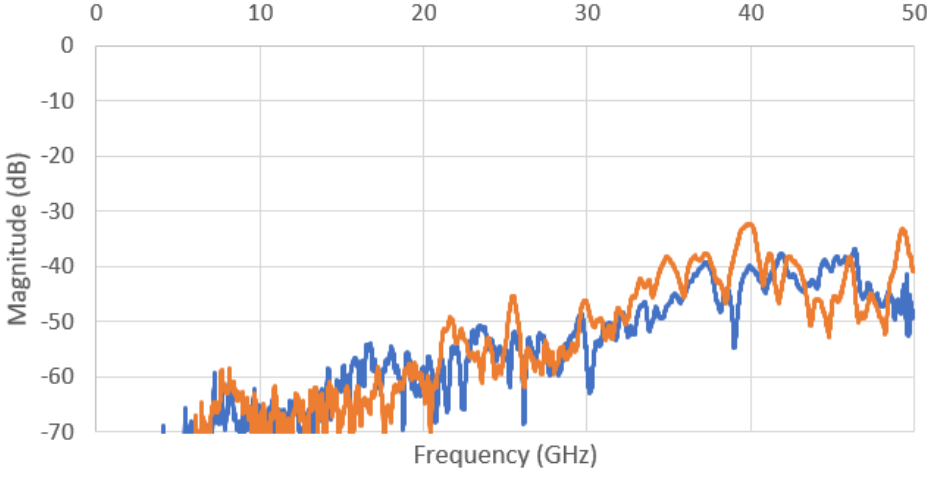
These plots are included for reference

PSNEXT:

Simulated Data:



Measured Data:

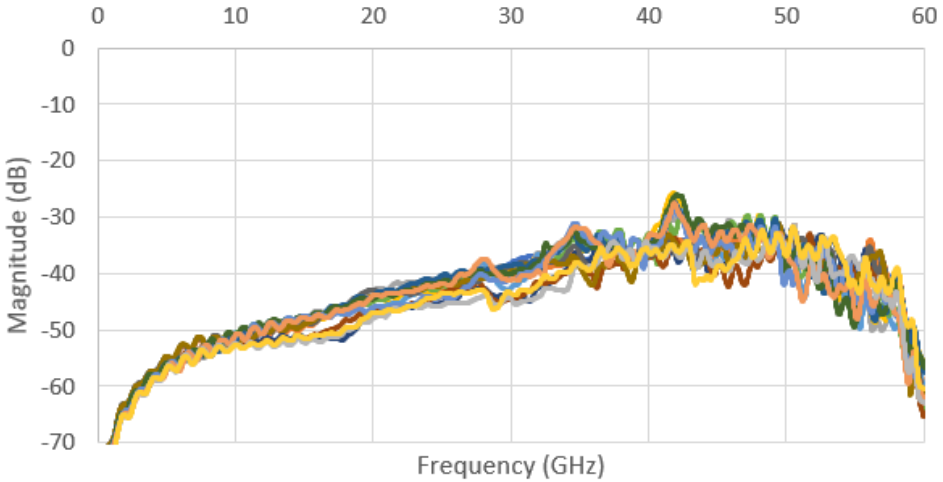


molex

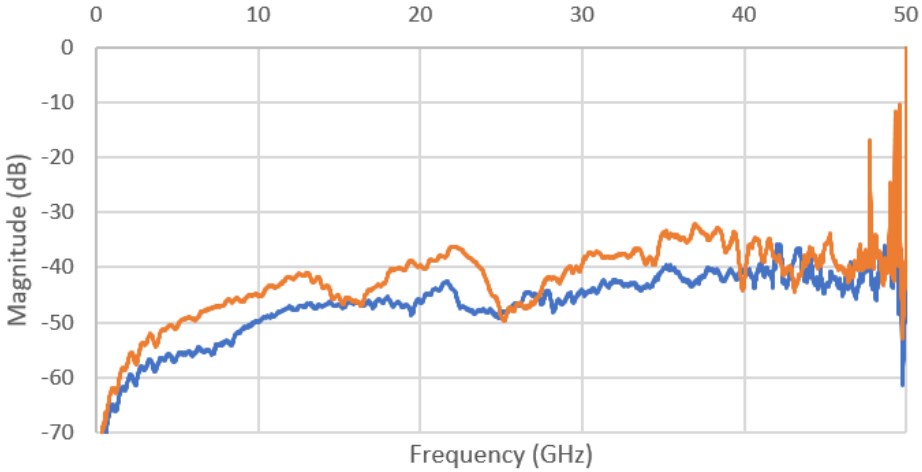
These plots are included for reference

PSFEXT:

Simulated Data:



Measured Data:



molex

ICN:

Corrected values (see slide 20)

Key:
Legacy Pair
DD Pair
Proposed Value

Parameter	Value
f_b	53.125 GHz
f_r	0.75 x fb
f_{min}	**0.05 GHz**
f_{max}	**40 GHz**
A_{nt}, A_{ft}	600 mV
T_{nt}, T_{ft}	**6.16 ps**
ICN_{NEXT} Limit	**1.5 mV***
ICN_{FEXT} Limit	**4.2 mV***
ICN_{Total} Limit	**4.4 mV***

* No change from 802.3cd spec

NOTE: 0.75 x f_b = 39.84 GHz

	Simulated			Measured		
Victim	ICN_{NEXT}	ICN_{FEXT}	ICN_{Total}	ICN_{NEXT}	ICN_{FEXT}	ICN_{Total}
1 (Tx1)	0.698	2.788	2.874			
2 (Tx3)	0.879	2.566	2.713			
3 (Tx5)	0.809	3.072	3.176			
4 (Tx7)	0.989	2.821	2.990			
5 (Tx6)	0.807	2.779	2.893			
6 (Tx8)	0.906	2.789	2.932			
7 (Tx2)	0.687	2.009	2.123			
8 (Tx4)	0.783	2.015	2.162			
9 (Rx4)	0.920	2.787	2.935			
10 (Rx2)	0.674	2.616	2.701			
11 (Rx8)	1.031	3.017	3.188			
12 (Rx6)	0.901	2.913	3.049			
13 (Rx7)	0.823	2.686	2.809	0.973	3.840	3.961
14 (Rx5)	0.740	2.897	2.990			
15 (Rx3)	0.788	1.848	2.009	0.691	2.087	2.199
16 (Rx1)	0.654	1.998	2.102			
MAX	**1.031**	**3.072**	**3.188**	**0.973**	**3.840**	**3.961**

ICN:

Corrected values (see slide 20)

Key:
Legacy Pair
DD Pair
Proposed Value

Parameter	Value
f_b	53.125 GHz
f_r	0.75 x fb
f_{min}	**0.05 GHz**
f_{max}	**50 GHz**
A_{nt}, A_{ft}	600 mV
T_{nt}, T_{ft}	**6.16 ps**
ICN_{NEXT} Limit	**1.5 mV***
ICN_{FEXT} Limit	**4.2 mV***
ICN_{Total} Limit	**4.4 mV***

* No change from 802.3cd spec

NOTE: 0.75 x f_b = 39.84 GHz

	Simulated			Measured		
Victim	ICN_{NEXT}	ICN_{FEXT}	ICN_{Total}	ICN_{NEXT}	ICN_{FEXT}	ICN_{Total}
1 (Tx1)	0.734	2.828	2.922			
2 (Tx3)	0.925	2.612	2.771			
3 (Tx5)	0.864	3.138	3.255			
4 (Tx7)	1.041	2.950	3.128			
5 (Tx6)	0.844	2.861	2.983			
6 (Tx8)	0.991	2.852	3.019			
7 (Tx2)	0.731	2.049	2.176			
8 (Tx4)	0.807	2.054	2.207			
9 (Rx4)	0.964	2.822	2.982			
10 (Rx2)	0.697	2.655	2.745			
11 (Rx8)	1.108	3.101	3.293			
12 (Rx6)	0.960	3.028	3.176			
13 (Rx7)	0.881	2.756	2.893	1.019	3.857	3.989
14 (Rx5)	0.796	2.979	3.084			
15 (Rx3)	0.813	1.891	2.058	0.730	2.103	2.226
16 (Rx1)	0.687	2.037	2.150			
MAX	**1.108**	**3.138**	**3.293**	**1.019**	**3.857**	**3.989**