Baseline Proposal for “100 Gb/s, 200 Gb/s, and 400 Gb/s Chip-to-Module Attachment Unit Interface (100GAUI-1, 200GAUI-2, and 400GAUI-4)”

IEEE 802.3ck Task Force
Vancouver-March 2019

Mike Peng Li, Intel
Jane Lim, Cisco
Ali Ghiasi, Ghiasi Quantum
Karthik Gopalakrishnan, Inphi
Ilya Lyubomirsky , Inphi
Piers Dawe, Mellanox
Ed Frlan, Semtech
Mark Kimber, Semtech

Purpose

- Present a baseline specification proposal for 100GAUI-1, 200GAUI-2, and 400GAUI-4 C2M electrical interface in support of the 100 Gb/s, 200 Gb/s, and 400 Gb/s Electrical Interfaces Task Force to fulfill its objective of:

  - Define a single-lane 100 Gb/s Attachment Unit interface (AUI) for chip-to-module applications, compatible with PMDs based on 100 Gb/s per lane optical signaling
  - Define a two-lane 200 Gb/s Attachment Unit interface (AUI) for chip-to-module applications, compatible with PMDs based on 100 Gb/s per lane optical signaling.
  - Define a four-lane 400 Gb/s Attachment Unit interface (AUI) for chip-to-module applications, compatible with PMDs based on 100 Gb/s per lane optical signaling.

Technology Choice Highlights 1

- Channel target/requirement based on the following equation:
  - $\text{ILmax} = \begin{cases} 0.05 + 1.8\sqrt{f} + 0.2513f & 0.01 \le f \le 26.56, f\ in\ GHz \\ -12.4192 + 1.07f & 26.56 < f \le 53.125 \end{cases}$
  - ILmax at Nyquist (26.56 GHz) is 16 dB

    as the informative insertion loss
- Channel equalization is based on “set and forget” outputs, and inputs having autonomous CTLE + 5 tap FFE (1 main, 4 post)
  - TX output FIR and Rx DFEs are not specified in host or module transceivers. (allowed, but not mandated.)
  - 4 tap TX FIR with 2 pre-cursor has been studied
  - Strong DFE taps should be avoided considering risk of burst errors.

Technology Choice Highlights 2

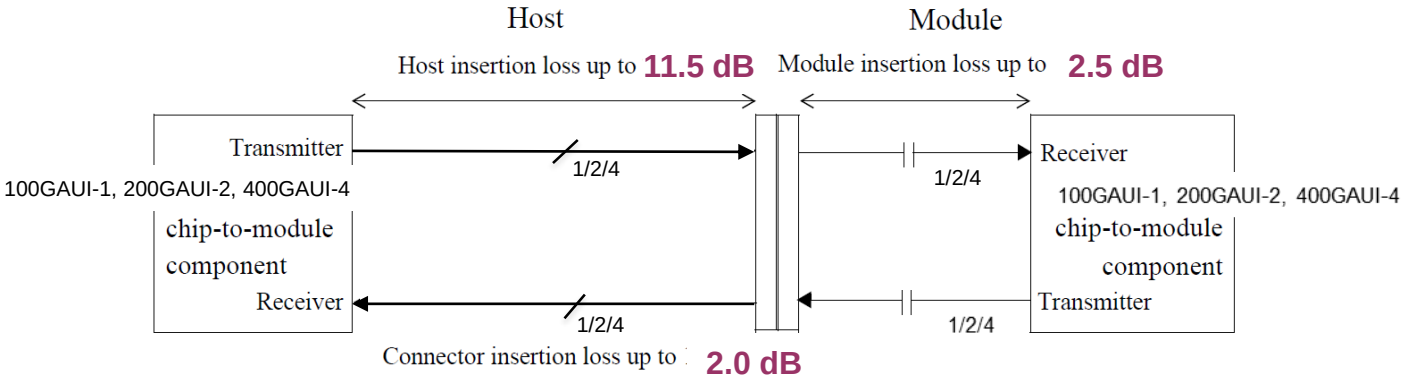
- Raw BER of 100GAUI-1, 200GAUI-2, and 400GAUI-4 c2m links to be < 1e-5; FEC brings link system BER to < 1e-13 (200, 400GAUI) and 1e-12 (100GAUI) at the MAC
  - FEC is in the hosts, protecting C2M and optical link, as for 400GAUI-8 C2M (Annex 120E).

Technology Choice Highlights 3

- Leverage the CEI-112G-VSR-PAM4 current draft specification[1] using one data rate:
  - 53.1256 GBd
- Gray-code specified
- C2M link operate with end-end RS (544, 514) FEC without the need to terminate the FEC in the module
- Pre-coding not assumed
- Reuse 200GAUI-4, 400GAUI-8 c2m Tx and Rx methodologies for specifying electrical characteristics and corresponding tests
  - Diff and CM RLs and compliance point definitions
  - HCB/MCB method for channel compliance
  - Oscilloscope and reference equalizer and CRU for assessing signals.

100GAUI-1,200GAUI-2, and 400GAUI-4 Chip-to-Module Links

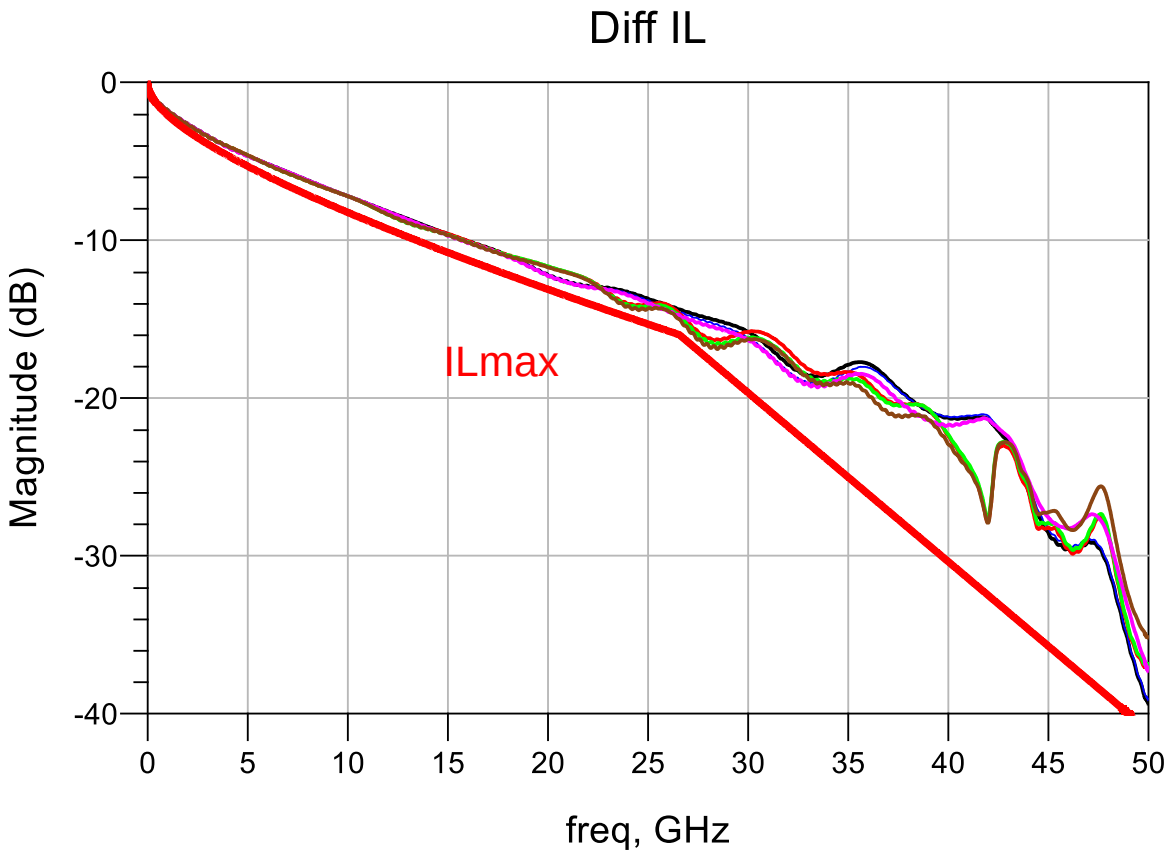
Modulation	PAM4 (Gray coded)
Nominal Signaling Rate (each lane)	53.1256 GBd +/-100 ppm
Unit Interval	18.8235 ps
Loss Budget, max	16 dB at 26.5628 GHz
Pre-FEC BER	1e-5
Post FEC BER	1e-13 (200GAUI-2, 400GAUI-4) 1e-12 (100GAUI-1)



- Parameters in purple needs further study/ confirmation through out this doc

Figure 1: 100GAUI-1, 200GAUI-2, and 400GAUI-4 C2M **TP0-TP1a** insertion loss budget at 26.56 GHz

100GAUI-1, 200GAUI-2, 400GAUI-4 C2M PAM4 Channel Insertion Loss Limit



– IL limit derived from IEEE 802.3bs (Annex 120E)

$$\text{ILmax} = \begin{cases} 0.05 + 1.8\sqrt{f} + 0.2513f & 0.01 \le f \le 26.56, f \text{ in } GHz \\ -12.4192 + 1.07f & 26.56 < f \le 53.125 \end{cases}$$

100GAUI-1,200GAUI-2, and 400GAUI-4 Host Output (at TP1a)

Parameters	Min	Max	Units
Signaling rate per lane (range)	53.125-100 ppm	53.125+100 ppm	GBd
Differential Voltage TX disabled TX enabled		 35 880	mV
DC Common Mode output Voltage	-0.3	2.8	V
AC Common Mode output Noise (rms)		17.5	mV
Single-ended output voltage	-0.4	3.3	V
ESMW (eye symmetry mask width)	TBD	TBD	UI
Eye height, differential	TBD		mV
Vertical Eye Closure (VEC)		TBD	dB
Differential return loss		See S12	dB
Common to diff MC return loss		See S13	dB
Differential termination mismatch		10	%
Eye linearity	90		%
Transition time (20-80%)	TBD		ps

100GAUI-1,200GAUI-2, and 400GAUI-4 Module Output (at TP4)

Parameters	Min	Max	Units
Signaling rate per lane (range)	53.125-100 ppm	53.125+100 ppm	GBd
Differential Voltage		900	mV
DC Common Mode output Voltage	-0.3	2.8	V
AC Common Mode output Noise (rms)		17.5	mV
Near-End ESMW (eye symmetry mask width)	TBD	TBD	UI
Near-end Eye height, differential	TBD		mV
Far-end ESMW (eye symmetry mask width)	TBD	TBD	UI
Far-end Eye height, differential	TBD		mV
Differential return loss		See S12	dB
Common to diff MC return loss		See S13	dB
Differential termination mismatch		10	%
Near-end Eye linearity	90		%
Near-end Transition time (20-80%)	TBD		ps

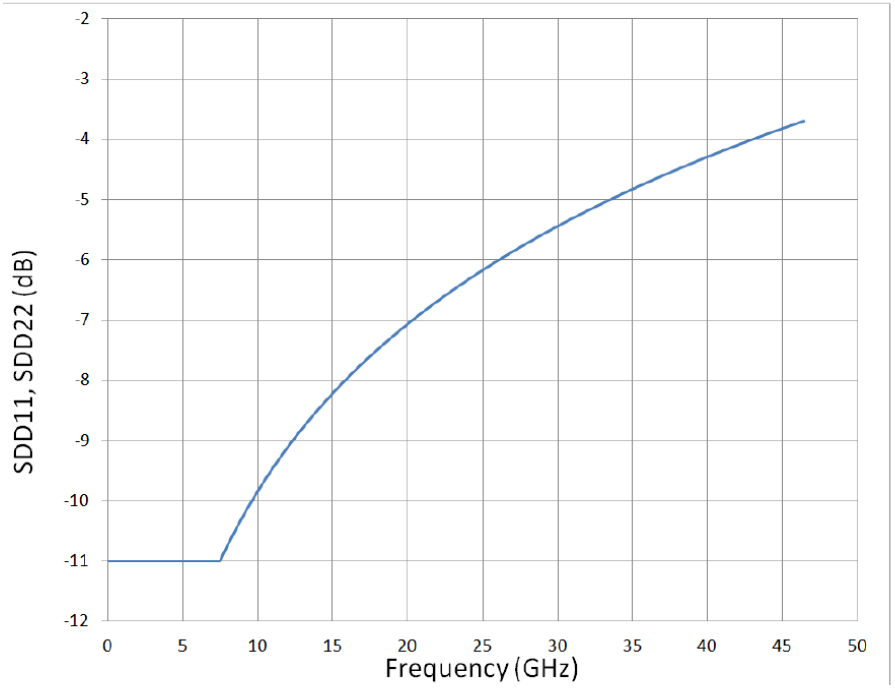
100GAUI-1,200GAUI-2, and 400GAUI-4 Module Input

Parameters	Min	Max	Units/Test Point
Signaling rate per lane (range)	53.125-100 ppm	53.125+100 ppm	GBd/TP1
Differential pk-pk input voltage tolerance	900		mV/TP1a
Differential input return loss	See S12		dB/TP1
Differential to common mode input return loss	See S13		dB/TP1
Differential termination mismatch		10	%/TP1
Single-ended voltage tolerance range	-0.4	3.3	mV/TP1a
DC Common Mode Voltage	-0.35	2.85	mV/TP1
Module Stress Input (rows below)			TP1a
ESMW (eye symmetry mask width)	TBD	TBD	UI/TP1a
Eye Width		TBD	UI/TP1a
Applied pk-pk sinusoidal jitter	TBD		UI/TP1a
Eye height, differential		TBD	mV/TP1a

100GAUI-1,200GAUI-2, and 400GAUI-4 Host Input

Parameters	Min	Max	Units/Test Point
Signaling rate per lane (range)	53.125-100 ppm	53.125+100 ppm	GBd/TP4a
Differential pk-pk input voltage tolerance	900		mV/TP4
Differential input return loss	See S12		dB/TP4a
Differential to common mode input return loss	See S13		dB/TP4a
Differential termination mismatch		10	%/TP4a
Common Mode Voltage	-0.30	2.8	mV/TP4a
Host Stress Input (rows below)			-/TP4
Far-End ESMW (eye symmetry mask width)	TBD	TBD	UI/TP4
Far-End Eye Width		TBD	UI/TP4
Applied pk-pk sinusoidal jitter	See		UI/TP4
Far-End Eye height, differential		TBD	mV/TP4

100GAUI-1,200GAUI-2, and 400GAUI-4 C2M Tx & Rx Differential Return Loss Spec

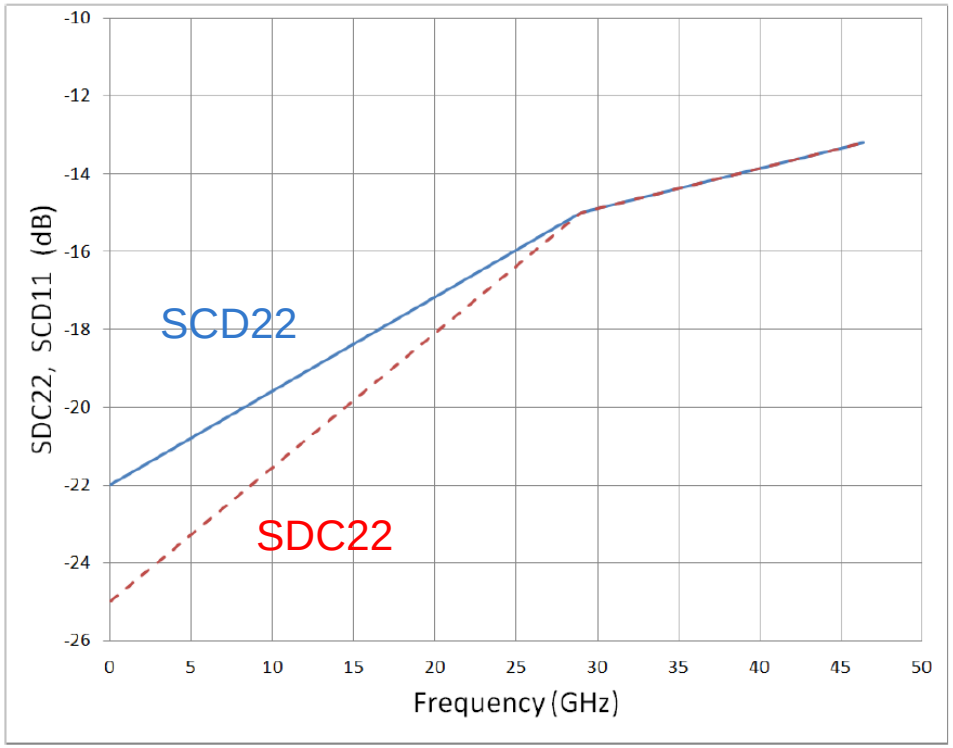


$$\text{SDD11, SDD22} < \text{-11 dB} \qquad \text{for} \quad 0.05 \le \text{f} \le \frac{f_b}{7.5}$$

$$\text{SDD11, SDD22} < \text{-6.0+9.2*log}_{10}\left(\frac{15}{7}\frac{\text{f}}{f_b}\right)\text{dB} \qquad \text{for} \quad f_b/7.5 < \text{f} < 0.8\,f_b$$

From CEI-112G-VSR-PAM4[1], but fb=53.125 GBd for 802.3ck

100GAUI-1,200GAUI-2, and 400GAUI-4 C2M Tx Common-Mode to Differential & Rx Differential to Common-Mode Return Loss Specs



$SCD11 < -22+14*(f/f_b)$ dB for $0.05 < f < f_b/2$

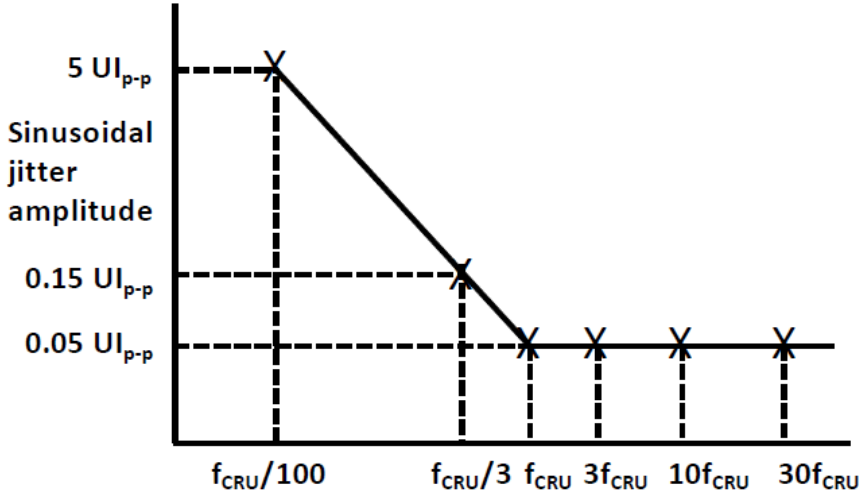
$SCD11 < -18+6*(f/f_b)$ dB for $f_b/2 < f < 0.8\,f_b$

$SDC22 < -25+20*(f/f_b)$ dB for $0.05 < f < f_b/2$

$SDC22 < -18+6*(f/f_b)$ dB for $f_b/2 < f < 0.8\,f_b$

From CEI-112G-VSR-PAM4[1], but fb=53.125 GBd for 802.3ck

100GAUI-1,200GAUI-2, and 400GAUI-4 C2M Host and Module Stress Input Jitter Tolerance Mask



- fCRU = fb/13280
- fb = 53.125 GBd

Table 23-7. Sinusoidal jitter frequency for TP4 and TP1a testing

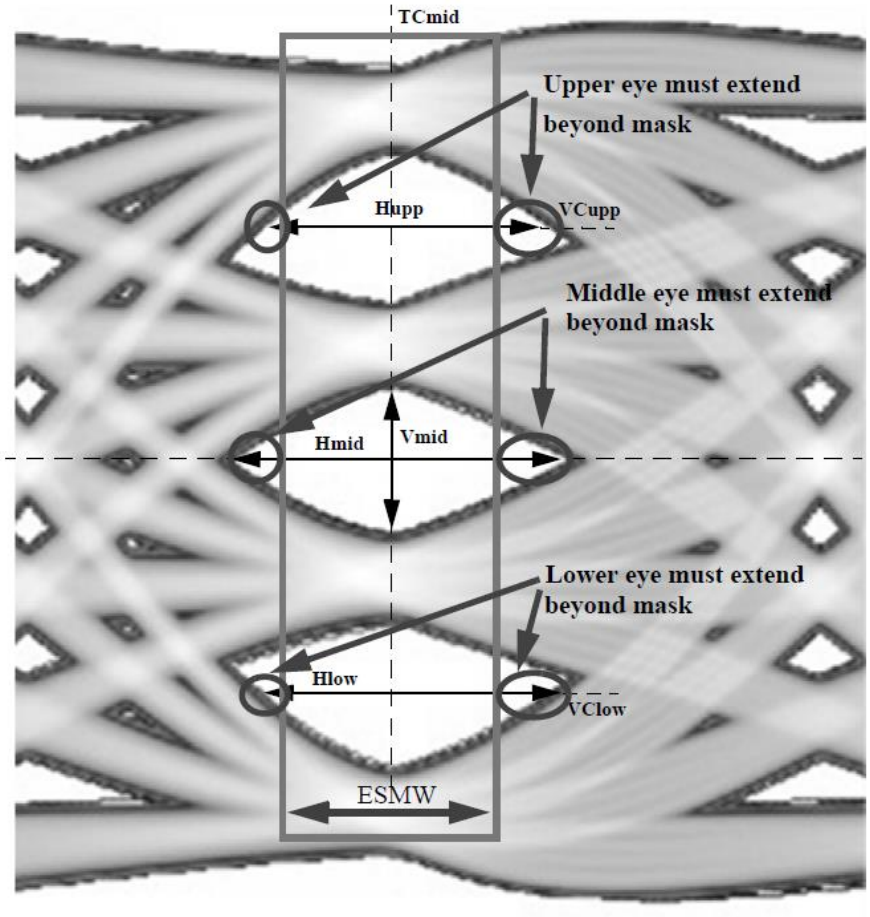
Frequency	Sinusoidal jitter, peak-to-peak (UI)
$f_{CRU}/100$	5
$f_{CRU}/3$	0.15
f_{CRU}	0.05
$3f_{CRU}$	0.05
$10f_{CRU}$	0.05
$30f_{CRU}$	0.05

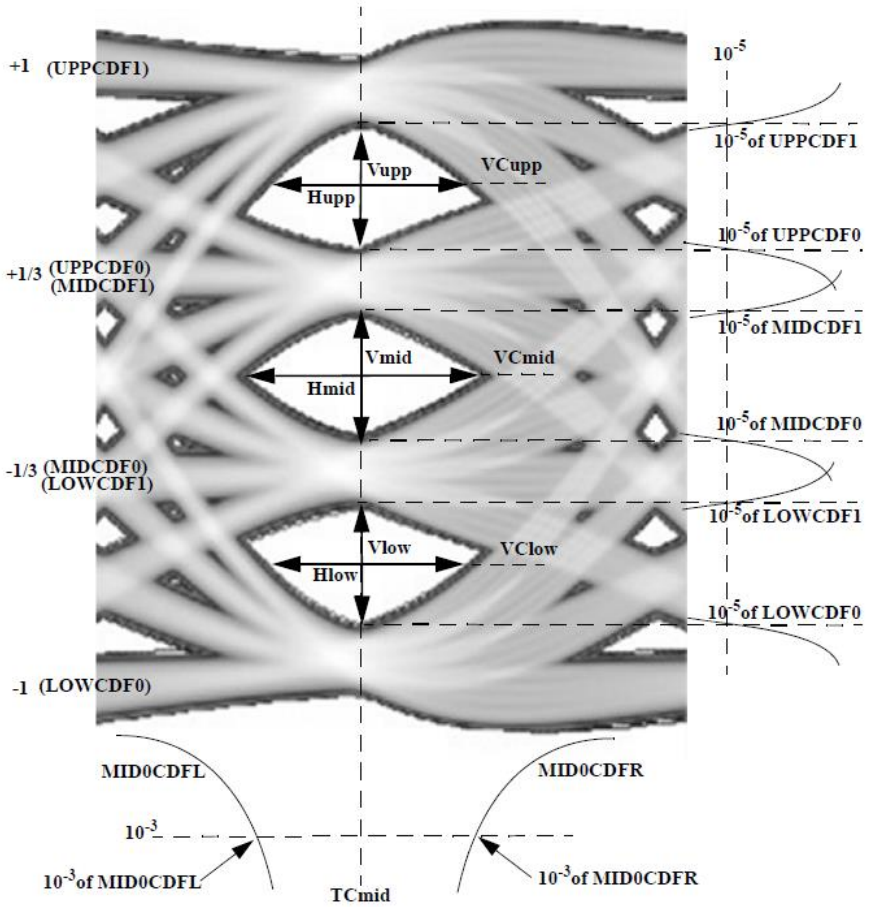
From CEI-112G-VSR-PAM4[1], but fb=53.125 GBd for 802.3ck

100GAUI-1,200GAUI-2, and 400GAUI-4 C2M Test Patterns

- 100GAUI-1, 200GAUI-2, and 400GAUI-4 PMA will reuse test pattern defined in clause 120.5.11.2
  - PRBS13Q for output
  - PRBS31Q for input

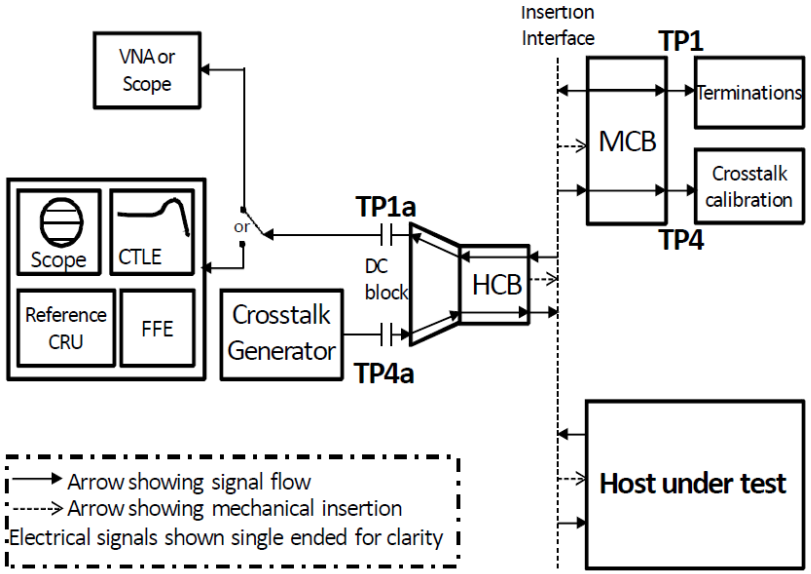
100GAUI-1,200GAUI-2, and 400GAUI-4 c2m PAM4 Jitter and Eye Height Parameters

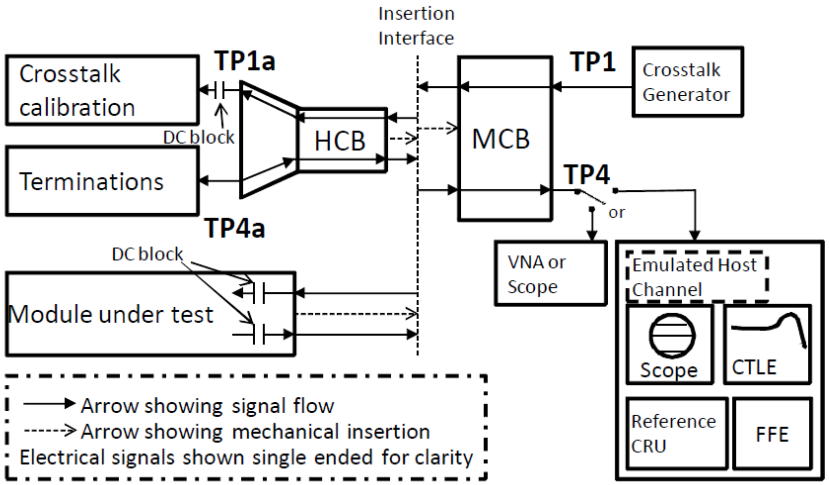




Host / Module Output Waveform Test

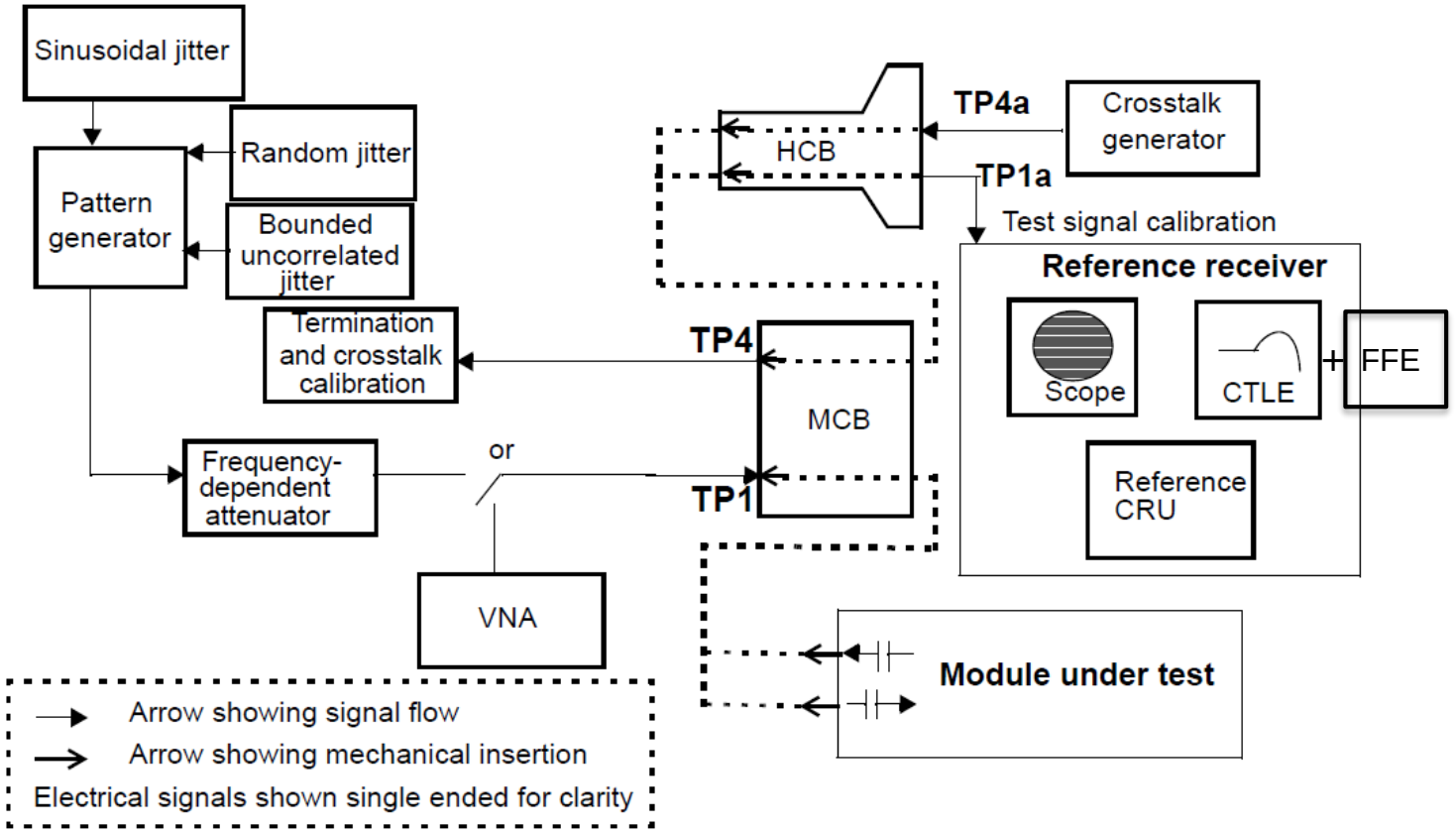
- Same test configuration as Annex 120E
  - FFE added to the ref EQ, in addition to CTLE
  - CRU corner frequency: see slide 14





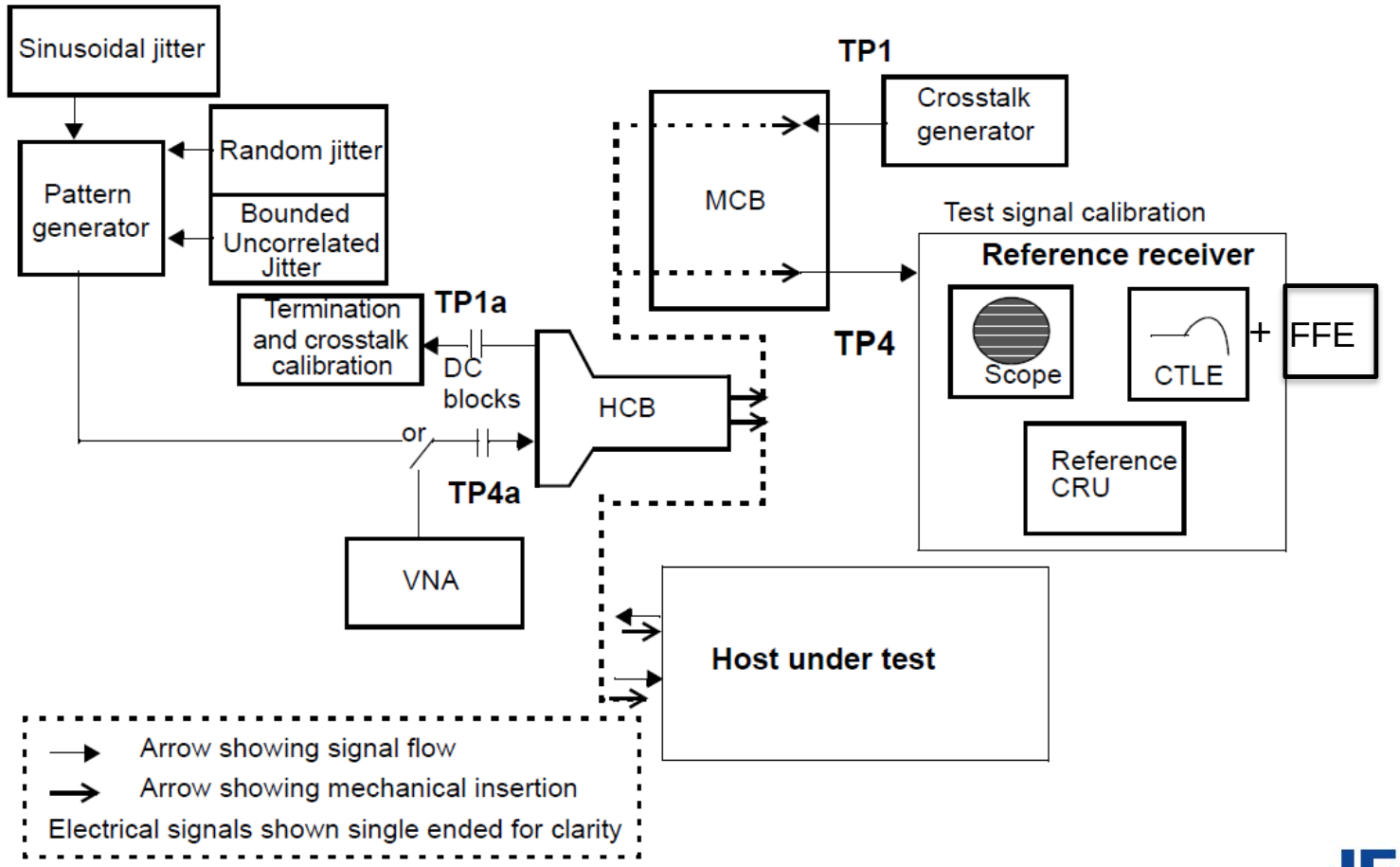
Module Stressed Receiver Test

- Same test configuration as Annex 120E
  - FFE added to the ref EQ, in addition to CTLE
  - CRU and SIJT corner frequencies: see slide 14

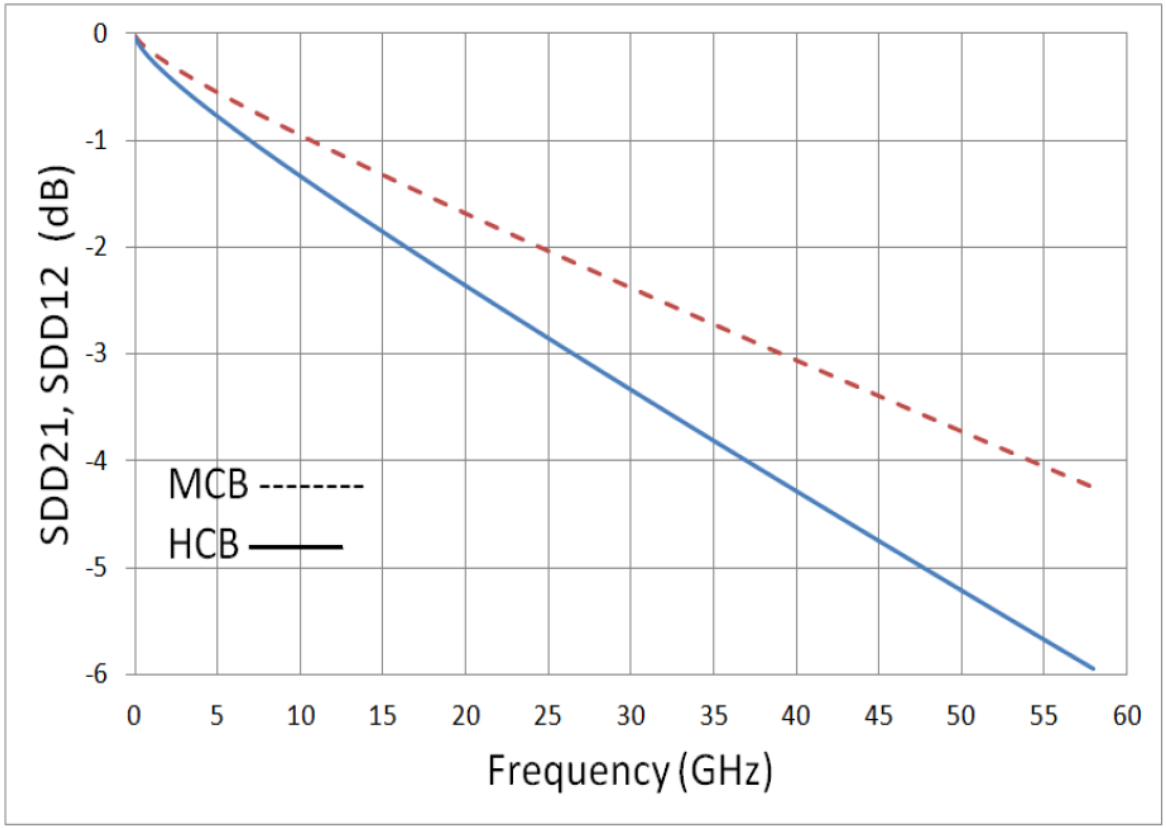


Host Stressed Receiver Test

- Same test configuration as Annex 120E
  - FFE added to the ref EQ, in addition to CTLE
  - CRU and SIJT corner frequencies: see slide 14



HCB, MCB Insertion Loss

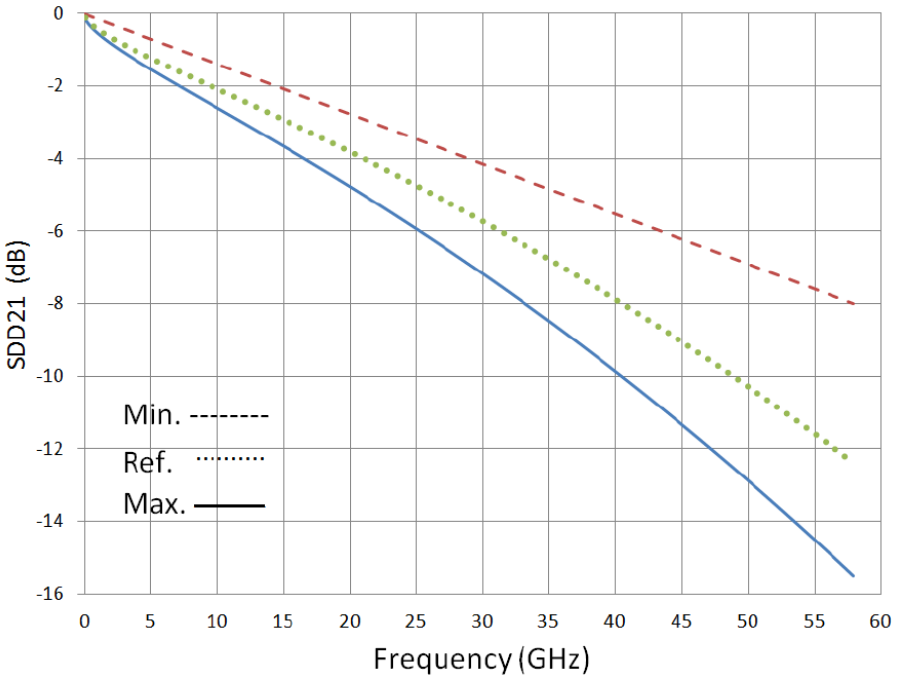


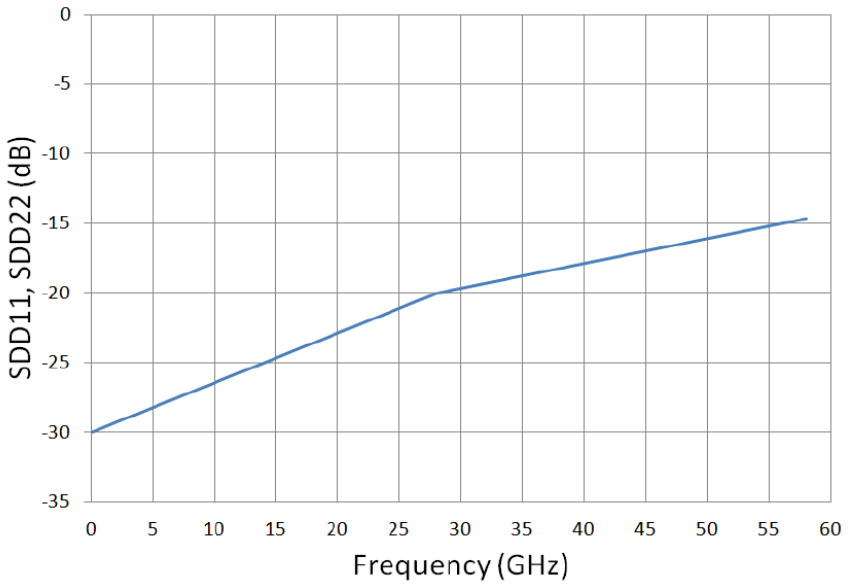
HCB ref SDD21= 1.75 *(0.001 - 0.096 * sqrt(f) - 0.046*f) dB

MCB ref SDD21= 1.25*(0.001-0.096*sqrt(f)-0.046*f) dB

From CEI-112G-VSR-PAM4[1]

Mated HCB,MCB S-Parameters (I)





IL mated min (f) = -0.138*f dB for 1 MHz < f < 56 GHz

Min SDD11, SDD22 = -25.012+0.179*f dB for 28 GHz < f < 58 GHz

IL mated max (f) = 0.899*(0.471*sqrt(f)+0.1194*f+0.02*f^2 dB for 1 MHz < f < 56 GHz

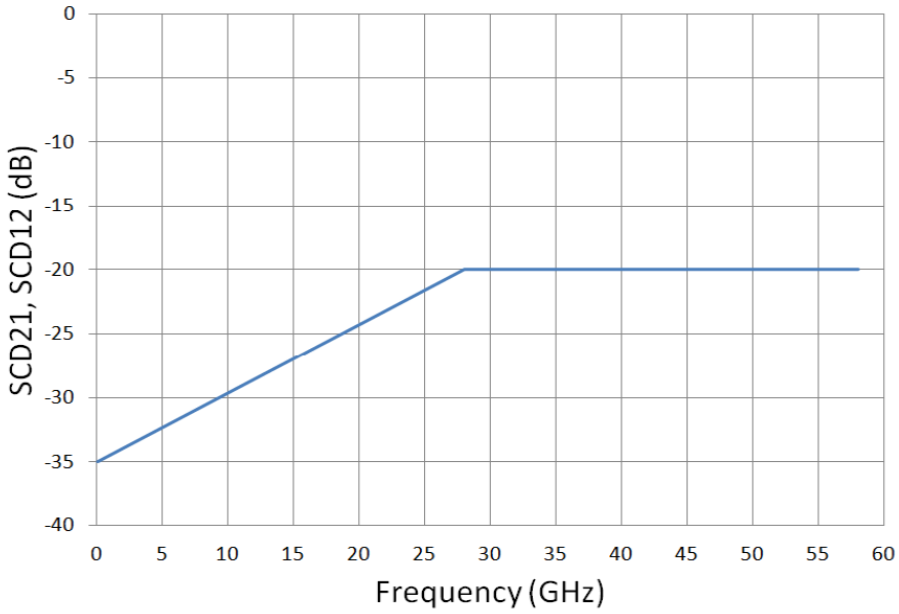
Min SDD11, SDD22 = -30+0.357*f dB for f < 28 GHz

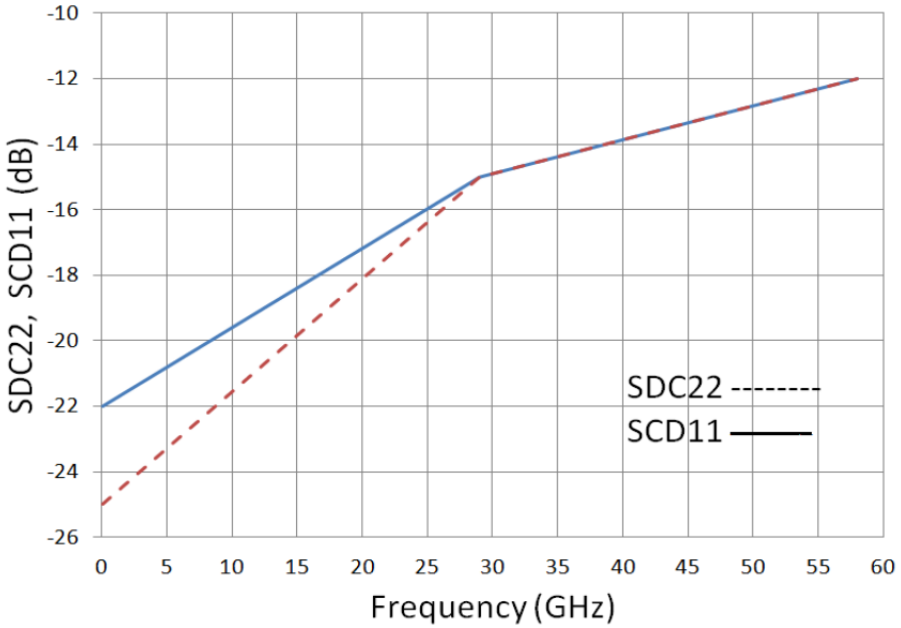
$$RefILmated(f) = (0.8)(a_1\sqrt{f} - a_2 f - a_4 f^2)$$

$a_1 = 0.423$ $a_2 = 0.107$ $a_4 = 0.0018$

From CEI-112G-VSR-PAM4[1]

Mated HCB,MCB S-Parameters (II)





SCD21, SCD12 ≤ -35+(15/28)*f dB for 50 MHz < f < 28 GHz

SCD21, SCD12 ≤ -20 dB for 28 GHz < f < 0.85*fb GHz

SCD11, SDC11 ≤ -22+(1/4)f dB

SCD22, SDC22 ≤ -25+(5/14)f dB

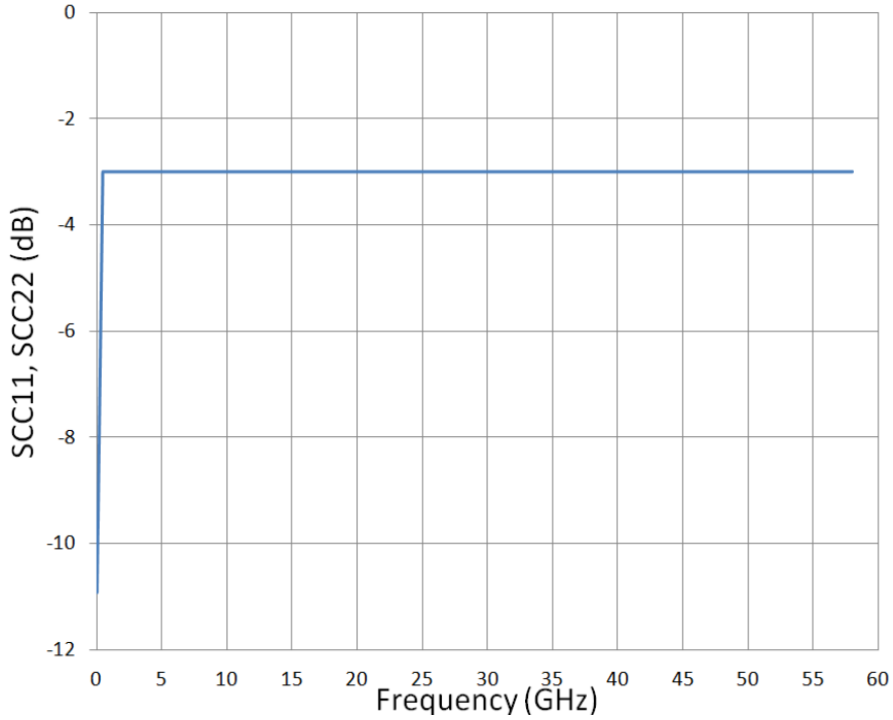
for 50 MHz < f < 28 GHz

SCD11, SCD22, SDC11, SDC22 ≤ -18+(3/28)f dB

for 28 GHz < f < 56 GHz

From CEI-112G-VSR-PAM4[1]

Mated HCB,MCB S-Parameters (III)



SCC11 and SCC22 ≤ -12+(18)f dB for 50 MHz < f < 500 MHz

SCC11 and SCC22 ≤ 3 dB for 500 MHz < f < 56 GHz

- FOM_{ILD} (50 MHZ – 42 GHz) < 0.1 dB
- MDNEXT < 1.35 mV RMS
- MDFEXT < 3.6 mv RMS
- ICN < 3.9 mv RMS
- ICN, MDFEXT, MDNEXT estimation using method defined in 92.11.3
  - Voltage amplitude and transition time from slide 10

From CEI-112G-VSR-PAM4[1]

Summary

- Baseline proposal using PAM4 signaling for a 100GAUI-1, 200GAUI-2, and 400GAUI-4 C2M electrical interface specification:
  - Supports 100GAUI-1, and 200GAUI-2, and 400GAUI-4 C2M channels
  - Reuses test setup in Annex 120E
  - Leverage and is consistent with CEI-112G-VSR-PAM4 current specification document
    - A synergy desired by the industry when possible

References

[1] oif.2017.346.07, www.oiforum.com (This document was provided as an attachment to the January, 3, 2019 liaison from OIF to IEEE 802.3 see http://ieee802.org/3/minutes/jan19/index.html . The liaison and its attachments can be found in the IEEE P802.3ck Task Force private area). Note that authors of this presentation are also the authors contributed to the 1st draft which was adopted as CEI-112G-VSR-PAM4 (oif.2017.346.xx).