Signal Integrity specs: Proposal for baseline

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Outline

1. Introduction
2. Specifying channels
3. Tx at host compliance point
4. Tx part
5. Rx at host compliance point
6. Rx part

Introduction

This is a draft of proposed baseline for signal integrity specifications in IEEE802.3bj. It is either complete or nearly complete in general form and outline, although I will listen to proposed improvements, but many specific specs and values need refinement. I intend to have continuations of the consensus building discussions which helped form this presentation to further refine it and ask the task force, either at the March or May meeting, to accept it as a baseline for writing the draft spec.

This proposal is heavily leveraged from IEEE802.3ap and IEEE802.3ba and some slides are specifically based on tables or equations from these prior specs. On those slides I have highlighted in yellow specs which changed just because the data rate has increased by 2.5 times in. Specs which I have added or changed but have only tentative values or no values at all are highlighted in green Values I am certain of are marked red.

Specifying channels

Use method described in moore_01_0311 with improvements, rather than Clause 85.9, Clause 85.10, and Annex 69B Most likely this will require a new annex. Some parameters may be described within the annex others specified for specific uses. Method used in:

1. Specifying backplane (informative?)
2. Specifying Cable (normative)
3. Specifying host trace (informative)
4. Specifying overall cable channel (informative)
5. Specifying various test channels

Method returns values for:

1. Dibit gain
2. Fitting coefficients
3. Channel noise
4. ICN
5. S/N

Various values are used in various specifications

Tx Specification at host compliance point (cable channel only)

Use method described in Clause 85.8.3 “Transmitter characteristics” except

1 Change Table 85.5 as shown on slide 6

2 Change Table 85.6 as shown on slide 9

3 Change equation 85.1 (return loss) as shown in slides 7 and 8

. Note: equation 85.1 will be used in finding re-reflection noise so we will have some rational basis for choice.

4 Possibly change values in Clause 85.8.3.3.2 “Coefficient step size”

5 Possibly change values in Clause 85.8.3.3.2 “Coefficient range”

Transmitter characteristics at TP2 summary

Parameter	Subclause reference	Value	Units
Signaling rate, per lane	85.8.3.8	25.78125±100ppm	GBd
Unit interval nominal	85.8.3.8	38.78788	ps
Differential peak-to-peak output voltage (max) with Tx disabled	85.8.3.3	30	mV
Common-mode voltage limits	72.7.1.4	0-1.9	V
Differential output return loss (min)	85.8.3.1	See Modified equation	dB
Common-mode output return loss (min)		See Modified equation	dB
Common-mode AC output voltage (max., RMS)		30	mV
Amplitude peak-to-peak (max)	72.7.1.4	1200	mV
Transmitter DC amplitude	85.8.3.3	340 min 600 max	mV
Linear fit pulse (min)	85.8.3.3	0.54 x Transmitter DC amplitude	mV
Transmitted waveform max normalized error(linear fit) abs coefficient step size minimum precursor fullscale range minimum post cursor fullscale range	 85.8.3.3 85.8.3.3.2 85.8.3.3.2 85.8.3.3.2	 0.037 0.0083 min, 0.05 max 1.54 4	
Far-end transmit output noise (max) Low insertion loss channel High insertion loss channel	85.8.3.2	 2 See Equation (85–2) 1 See Equation (85–3)	mV
Max output jitter (peak-to-peak) Random jitter Duty Cycle Distortion Total jitter excluding data dependent jitter		 0.15 0.035 0.25	 UI UI UI

Transmitter characteristics at TP2

Differential output return loss (min)

$$\text{Return\_loss(f)} = 10 \cdot \log_{10}\left(\frac{\Gamma_{01}^2 + (f/f_1)^2}{1 + (f/f_1)^2}\right) - 2 * \frac{f}{F_2} \qquad f < 15\text{GHz}$$

f in Hz

$f_1 = 3.2 \cdot 10^{10}$

$f_2 = 1.29 \cdot 10^{10}$

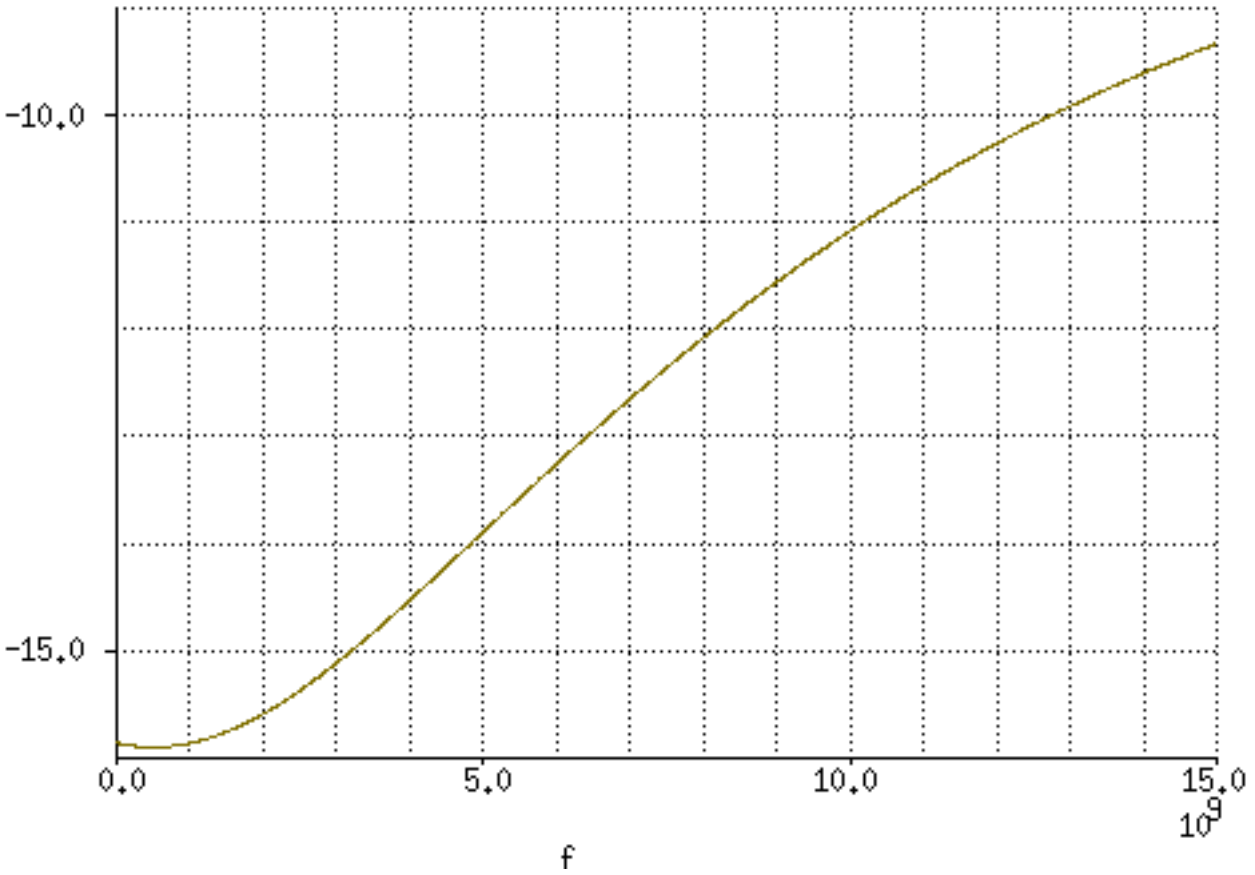
$\Gamma_{01} = 0.161$

Common-mode output return loss (min)

$$\text{Return\_loss} = TBD \qquad f < 15\text{GHz}$$

Transmitter characteristics at TP2

Differential output return loss (min)



Transmitter characteristics at TP2: Normalized transmit pulse template

Description	Symbol	Value	Units
Linear fit pulse length	N_p	11	UI
Linear fit pulse delay	D_p	3	UI
Equalizer length	N_w	11	UI
Equalizer delay	D_w	3	UI

Fixtures for testing receiver and transmitter

We can no longer test as though the tester is connected directly to the part, the effects of losses in the channel connecting the part under test and the tester must be taken into account. This was done in IEEE802.3ba, Clause 85 for both the receiver and the transmitter but the channel, the host trace, was part of what was measured. For IEEE802.3bj we will need to specify the PHY by itself so to test the Rx and Tx we will need a specified test fixture and a spec which takes fixture loss into account. The test fixture is described in another presentation given by Pavel Zivny. The spec given below apply at the points called TP0A and TP5A.

Tx PHY Specification in test fixture
Normative for backplane
Informative for cable

Use method used in Clause 85.8.3 “Transmitter characteristics” except

1 Change Table 85.5 as shown in slide 12 for NRZ or slide 16 for PAM4

2 Change Table 85.6 as shown in slide 15 for NRZ or slide 20 for PAM4

3 Change equation 85.1 (return loss) as shown in slide 13 and 14 for NRZ or slides 18 and 19 for PAM4.

Note: equation 85.1 will be used in finding re-reflection noise so we will have some rational basis for choice.

4 Possibly change values in Clause 85.8.3.3.2 “Coefficient step size”

5 Possibly change values in Clause 85.8.3.3.2 “Coefficient range”

6 Values in 1-3 may different from specifications at host compliance point

NRZ Transmitter characteristics at Test interface summary

Parameter	Subclause reference	Value	Units
Signaling rate, per lane	85.8.3.8	25.78125±100ppm	GBd
Unit interval nominal	85.8.3.8	38.78788	ps
Differential peak-to-peak output voltage (max) with Tx disabled	85.8.3.3	30	mV
Common-mode voltage limits	72.7.1.4	0-1.9	V
Differential output return loss (min)	85.8.3.1	See Modified equation	dB
Common-mode output return loss (min)		See Modified equation	dB
Common-mode AC output voltage (max., RMS)		30	mV
Amplitude peak-to-peak (max)	72.7.1.4	1200	mV
Transmitter DC amplitude	85.8.3.3	480 min 600 max	mV
Linear fit pulse (min)	85.8.3.3	0.64 x Transmitter DC amplitude	mV
Transmitted waveform max normalized error(linear fit) abs coefficient step size minimum precursor fullscale range minimum post cursor fullscale range	 85.8.3.3 85.8.3.3.2 85.8.3.3.2 85.8.3.3.2	 0.025 0.0083 min, 0.05 max 1.54 4	
Far-end transmit output noise (max) Low insertion loss channel High insertion loss channel	85.8.3.2	 2 See Equation (85–2) 1 See Equation (85–3)	mV
Max output jitter (peak-to-peak) Random jitter Duty Cycle Distortion Total jitter excluding data dependent jitter		 0.15 0.035 0.25	 UI UI UI

NRZ Transmitter characteristics at Test interface

Differential output return loss (min)

$$\text{Return\_loss(f)} = 10 \cdot \log_{10}\left(\frac{\Gamma_{01}^2 + (f/f_1)^2}{1 + (f/f_1)^2}\right) \qquad f < 15\text{GHz}$$

f in Hz

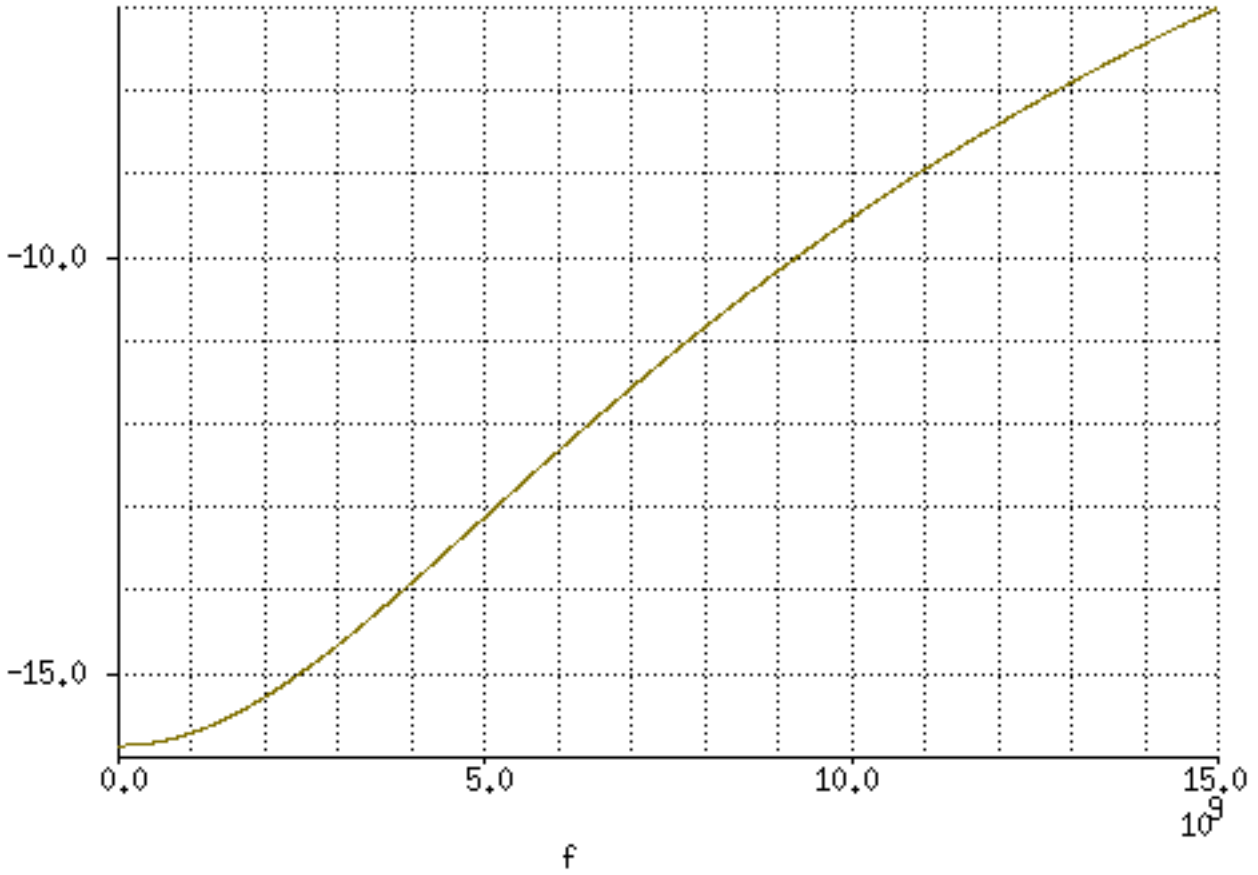
$f_1 = 3.2 \cdot 10^{10}$

$\Gamma_{01} = 0.161$

Common-mode output return loss (min)

$$\text{Return\_loss} = TBD \qquad f < 15\text{GHz}$$

NRZ Transmitter characteristics at Test interface
Differential output return loss (min)



NRZ Transmitter characteristics at test interface: Normalized transmit pulse template

Description	Symbol	Value	Units
Linear fit pulse length	N_p	8	UI
Linear fit pulse delay	D_p	2	UI
Equalizer length	N_w	8	UI
Equalizer delay	D_w	2	UI

Or use same values as used at TP2 for convenience

PAM4 Transmitter characteristics at Test interface summary

Parameter	Subclause reference	Value	Units
Signaling rate, per lane	85.8.3.8	12.8906±100ppm	GBd
Unit interval nominal	85.8.3.8	77.6758	ps
Differential peak-to-peak output voltage (max) with Tx disabled	85.8.3.3	30	mV
Common-mode voltage limits	72.7.1.4	0-1.9	V
Differential output return loss (min)	85.8.3.1	See Modified equation	dB
Common-mode output return loss (min)		See Modified equation	dB
Common-mode AC output voltage (max., RMS)		30	mV
Amplitude peak-to-peak (max)	72.7.1.4	1200	mV
Transmitter DC amplitude	85.8.3.3	480 min 600 max	mV
Linear fit pulse (min)	85.8.3.3	0.80 x Transmitter DC amplitude	mV
Transmitted waveform PAM4 DAC linearity max normalized error(linear fit) abs coefficient step size minimum precursor fullscale range minimum post cursor fullscale range	(new clause) 85.8.3.3 85.8.3.3.2 85.8.3.3.2 85.8.3.3.2	 0.05 0.025 0.0083 min, 0.05 max 1.54 4	
Far-end transmit output noise (max) Low insertion loss channel High insertion loss channel	85.8.3.2	 2 See Equation (85–2) 1 See Equation (85–3)	mV
Max output jitter (peak-to-peak) Random jitter Duty Cycle Distortion Total jitter excluding data dependent jitter		 0.08 0.018 0.13	 UI UI UI

PAM4 will require additions to the Tx test to allow DAC linearity measurement. I would like to work with a PAM4 proponent on defining the test.

PAM4 Transmitter characteristics at Test interface

Differential output return loss (min)

$$\text{Return\_loss(f)} = 10 \cdot \log_{10}\left(\frac{\Gamma_{01}^2 + (f/f_1)^2}{1 + (f/f_1)^2}\right) \qquad f < 8\text{GHz}$$

f in Hz

$f_1 = 1.6 \cdot 10^{10}$

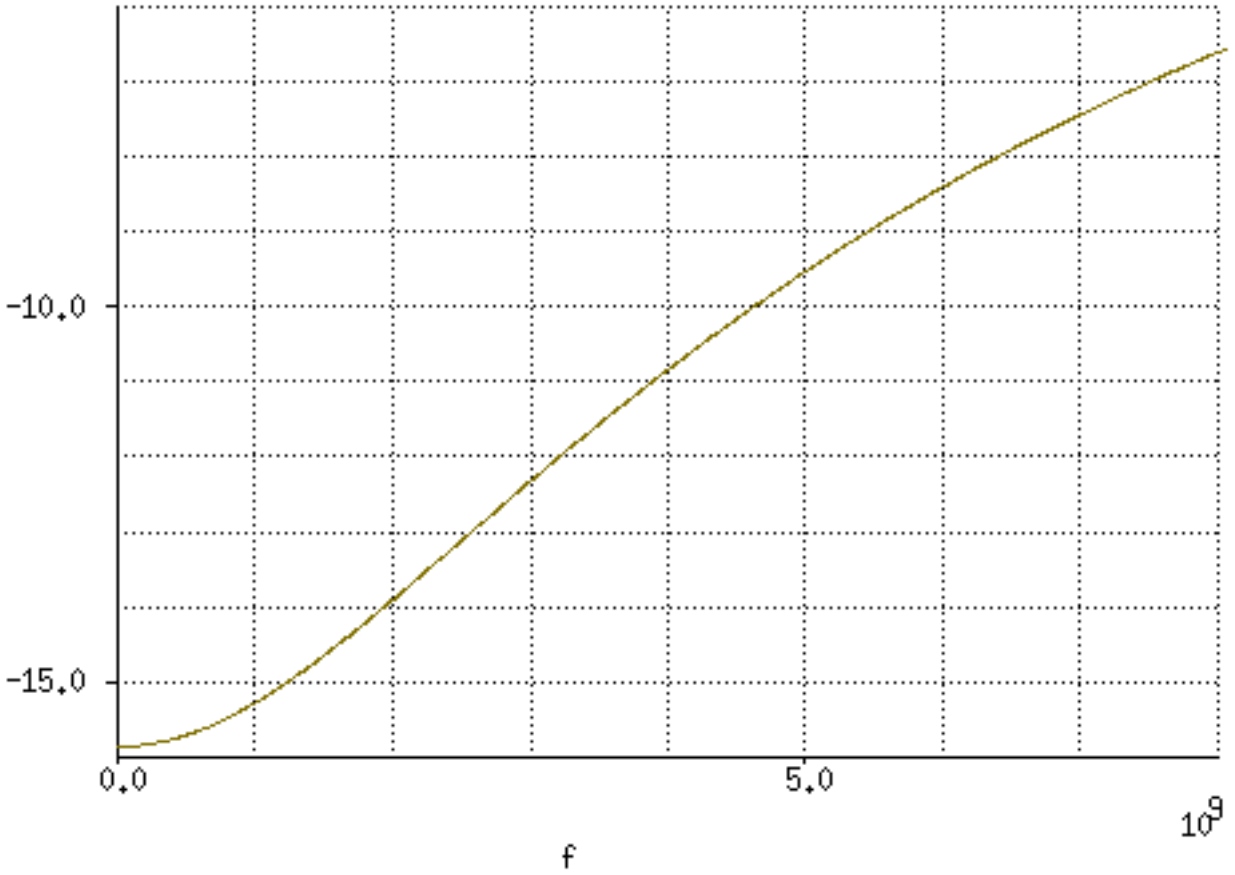
$\Gamma_{01} = 0.161$

Common-mode output return loss (min)

$$\text{Return\_loss} = TBD \qquad f < 15\text{GHz}$$

NRZ Transmitter characteristics at Test interface

Differential output return loss (min)



PAM4Transmitter characteristics at test interface:
Normalized transmit pulse template

Description	Symbol	Value	Units
Linear fit pulse length	N_p	8	UI
Linear fit pulse delay	D_p	2	UI
Equalizer length	N_w	8	UI
Equalizer delay	D_w	2	UI

Rx Specification at host compliance point
Cable channel only

Use method described in Clause 85.8.4 “Receiver characteristics at TP3 summary” except:

1. Change Table 85.7 as shown in slide 22
2. Change Table 85.8 as shown in slide 24
3. Change equation 85.17 (return loss) as shown in slide 23. Note equation 85.1 will be used in finding re-reflection noise so we will have some rational basis for choice.
4. Remove references to CR10

Note: Slide 20 Defines test channel in terms of dibit gain, near and far end crosstalk and limits on fitting parameters. It also prescribes multiple test, some with BER targets of 10-12 some with a higher BER (perhaps 10^{-5}) for channels which will require significant FEC.

Receiver characteristics at TP3 summary

Parameter	Subclause reference	Value	Units
Bit error ratio after ECC	85.8.4.3	10^{-12} max	
Signaling rate, per lane	85.8.4.4	25.78125±100ppm	GBd
Unit interval (UI) nominal	85.8.4.4	77.6758	ps
Differential peak-to-peak amplitude tolerance	72.7.2.4	1200	mV
Differential input return loss (min)	85.8.4.1	See Modified equation	2
Differential to common-mode input return loss		10 min from 10 MHz to 25 GHz	dB

Receiver characteristics at TP3

Differential output return loss (min)

$$\text{Return\_loss(f)} = 10 \cdot \log_{10}\left(\frac{\Gamma_{01}^2 + (f/f_1)^2}{1 + (f/f_1)^2}\right) - 2 * \frac{f}{F_2} \qquad f < 15\text{GHz}$$

f in Hz

$f_1 = 3.2 \cdot 10^{10}$

$f_2 = 1.29 \cdot 10^{10}$

$\Gamma_{01} = 0.161$

(see plot on slide 8)

Common-mode output return loss (min)

$$\text{Return\_loss} = TBD \qquad f < 15\text{GHz}$$

Interference tolerance parameters for test at TP3

Parameter	Test 1 values	Test 2 values	Test 3 values	Test 4 values	Units
Type of test	short	long	Long Noisy	Very long	
Bit error ratio before ECC max (BER < 10^{-12} after ECC)	10^{-12}	10^{-12}	10^{-5}	10^{-5}	
Dibit gain, max Real part of a0 min Real part of a2 min Real part of a4 min	0.320 -0.100 -3.0×10^{-11} -2.5×10^{-21}	0.160 -0.100 -5.0×10^{-11} -3.5×10^{-21}	0.160 -0.100 -5.0×10^{-11} -3.5×10^{-21}	0.110 -0.100 -5.0×10^{-11} -5.0×10^{-21}	 GHz^{-1} GHz^{-2}
Approximate loss at 12.89 GHz	15	24	24	31	dB
Applied SJ (min peak-to-peak at >100MHz)	0.115	0.115	0.115	0.115	UI
Applied RJ (min peak-to-peak)	0.13	0.13	0.13	0.13	UI
Applied DCD (min peak-to-peak)	0.035	0.035	0.035	0.035	UI
Calibrated far-end crosstalk (min RMS) Calibrated ICN (min, RMS) $-\sigma_{nx}$	6.3 3.7	3.2 3.7	6.4 3.7	2.0 3.7	mV

For all test channels: maximum a0=0.1, maximum for a1, a2, a4 is 0

Rx PHI Specification in test fixture
Normative for backplane
Informative for cable

Use method described in Annex 69A “Interference tolerance testing” except:

1. Test channels defined in terms of maximum dibit gain and limits on fitting parameters.
2. Signal and noise defined at test interface rather than chip
3. Multiple test, some with BER targets of 10-12 some with a higher BER (10-5) and channels which will require significant FEC.
4. Informative tests for receivers used in cable systems are given in slide 26.
5. Normative tests for NRZ receivers used in back planes are given in slide 27.
6. Normative tests for PAM4 receivers used in back planes are given in slide 28.

Informative interference tolerance parameters for test at test interface for testing cable receivers

Parameter	Test 1 values	Test 2 values	Test 3 values	Test 4 values	Units
Type of test	short	long	Long Noisy	Very long	
Bit error ratio before ECC max (BER < 10^{-12} after ECC)	10^{-12}	10^{-12}	10^{-5}	10^{-5}	
Dibit gain, max Real part of a0 min Real part of a1 min Real part of a2 min Real part of a4 min	0.290 -0.100 No min -3.0×10^{-11} -2.5×10^{-21}	0.145 -0.100 No min -5.0×10^{-11} -3.5×10^{-21}	0.145 -0.100 No min -5.0×10^{-11} -3.5×10^{-21}	0.100 -0.100 No min -5.0×10^{-11} -5.0×10^{-21}	 GHz^{-1} GHz^{-2}
Approximate loss at 12.89 GHz	16	27	27	33	dB
Applied SJ (min peak-to-peak) at > 100 MHz	0.115	0.115	0.115	0.115	UI
Applied RJ (min peak-to-peak)	0.13	0.13	0.13	0.13	UI
Applied DCD (min peak-to-peak)	0.035	0.035	0.035	0.035	UI
Broad band Noise (RMS)	10.0	5.0	8.2	6.2	mV

For all test channels: maximum a0=0.1, maximum for a1, a2, a4 is 0

Normative interference tolerance parameters for test at test interface for testing NRZ backplane receivers

Parameter	Test 1 values	Test 2 values	Test 3 values	Test 4 values	Units
Type of test	short	long	Long Noisy	Very long	
Bit error ratio before ECC max (BER < 10^{-12} after ECC)	10^{-12}	10^{-12}	10^{-5}	10^{-5}	
Dibit gain, max Real part of a0 min Real part of a1 min Real part of a2 min Real part of a4 min	0.290 -0.100 No min -3.0×10^{-11} -2.5×10^{-21}	0.145 -0.100 No min -5.0×10^{-11} -3.5×10^{-21}	0.145 -0.100 No min -5.0×10^{-11} -3.5×10^{-21}	0.100 -0.100 No min -5.0×10^{-11} -5.0×10^{-21}	 GHz^{-1} GHz^{-2}
Approximate loss at 12.89 GHz	16	29	29	38	dB
Applied SJ (min peak-to-peak) at > 100 MHz	0.115	0.115	0.115	0.115	UI
Applied RJ (min peak-to-peak)	0.13	0.13	0.13	0.13	UI
Applied DCD (min peak-to-peak)	0.035	0.035	0.035	0.035	UI
Broad band Noise (RMS)	10.0	5.0	8.2	6.2	mV

For all test channels: maximum a0=0.1, maximum for a1, a2, a4 is 0

Normative interference tolerance parameters for test at test interface for testing PAM4 backplane receivers

Parameter	Test 1 values	Test 2 values	Test 3 values	Test 4 values	Units
Type of test	short	long	Long Noisy	Very long	
Bit error ratio before ECC max (BER < 10^{-12} after ECC)	10^{-12}	10^{-12}	10^{-5}	10^{-5}	
Dibit gain, max Real part of a0 min Real part of a1 min Real part of a2 min Real part of a4 min	0.450 -0.100 No min -3.0×10^{-11} -2.5×10^{-21}	0.320 -0.100 No min -5.0×10^{-11} -3.5×10^{-21}	0.320 -0.100 No min -5.0×10^{-11} -3.5×10^{-21}	0.250 -0.100 No min -5.0×10^{-11} -5.0×10^{-21}	 GHz^{-1} GHz^{-2}
Approximate loss at 6.45GHz	10	14	14	19	dB
Applied SJ (min peak-to-peak) at > 50 MHz	0.058	0.058	0.058	0.058	UI
Applied RJ (min peak-to-peak)	0.07	0.07	0.07	0.07	UI
Applied DCD (min peak-to-peak)	0.018	0.018	0.018	0.018	UI
Broad band Noise (RMS)	7.5	3.7	6.1	4.6	mV

For all test channels: maximum a0=0.1, maximum for a1, a2, a4 is 0