Specifying receiver and transmitter for 100GCu.

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Outline

1. Introduction
2. Tx at host compliance point
3. Tx part on test board (TP0A)
4. Rx at host compliance point
5. Rx part on test board (TP5A)

Introduction

This is a proposed baseline for signal integrity specifications in IEEE802.3bj. It is either complete or nearly complete in general form and outline but many specific specs and values need refinement. I intend to ask the task force to accept it as a baseline for writing the initial 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. Some values have been changed to take into account the increased data rate and some have been marked TBD. New tests have been added to the receiver to take into account operation relying on FEC.

Many values are not marked as TBD but are intended only as examples of what could be done. These are are highlighted in green and if this presentation is used as a baseline for an initial draft standard, they should be changed to TBD in the draft.

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 7

2 Change Table 85.6 as shown on slide 9

3 Change equation 85.1 (return loss) as shown in slide 8

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

Transmitter characteristics at TP2 summary

Parameter	Subclause reference	Value	Units
Signaling rate, per lane	85.8.3.8	25.78125±100ppm	GBd
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 Steady State Amplitude	85.8.3.3	TBD min 600 max	mV
Linear fit pulse (min)	85.8.3.3	TBD 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 TBD	 UI UI UI

Transmitter characteristics at TP2

Differential output return loss (min)

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

Common-mode output return loss (min)

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

Transmitter characteristics at TP2: Normalized transmit pulse template

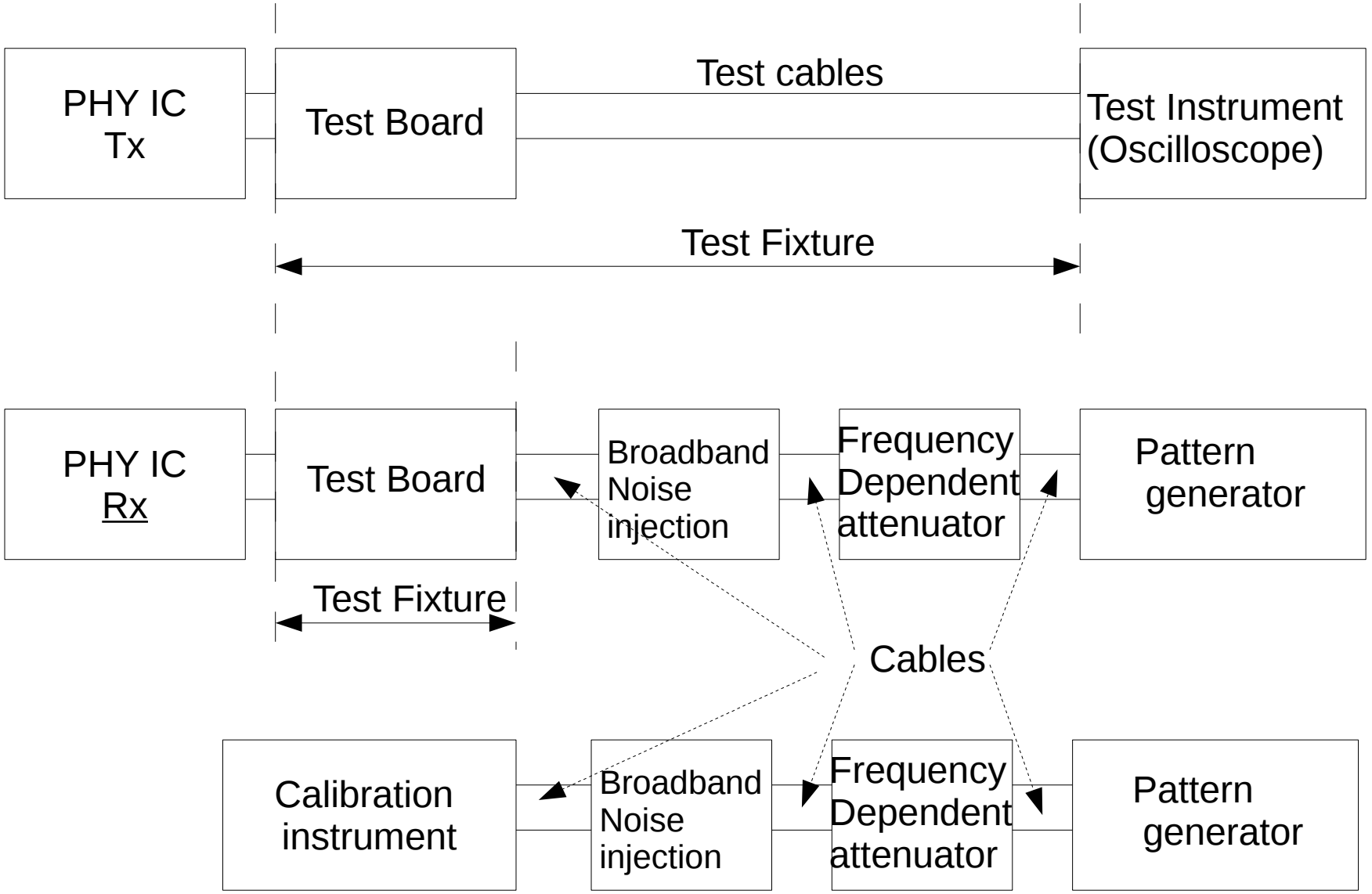
Description	Symbol	Value	Units
Linear fit pulse length	N_p	11	UI
Linear fit pulse delay	D_p	3	UI
Equalizer length	N_w	11	UI
Equalizer delay	D_w	3	UI

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 IC by itself so to test the Rx and Tx we will need a specified test fixture and a spec which takes the 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.

Expected test fixture characteristics at NRZ data rates

Test channel	Dibit gain (Alternative 1)	Insertion loss at Nyquist (Alternative 2)	Noise less Tx-Rx re-reflection noise
Transmitter test board plus cable	0.800- 0.820	2.2 dB- 2.5 dB	<14 mV
Receiver test board only	0.880- 0.900	1.0 dB 1.3 dB	<14 mV



Tx and Rx test fixtures

Tx PHY IC 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 14 for NRZ or slide 18 for PAM4

2 Change Table 85.6 as shown in slide 17 for NRZ or slide 22 for PAM4

3 Change equation 85.1 (return loss) as shown in slide 15 and 16 for NRZ or slides 20 and 21 for PAM4.

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

4 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
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 Steady State Amplitude	85.8.3.3	TBD min 600 max	mV
Linear fit pulse (min)	85.8.3.3	TBD 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	 0.035 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 TBD	 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

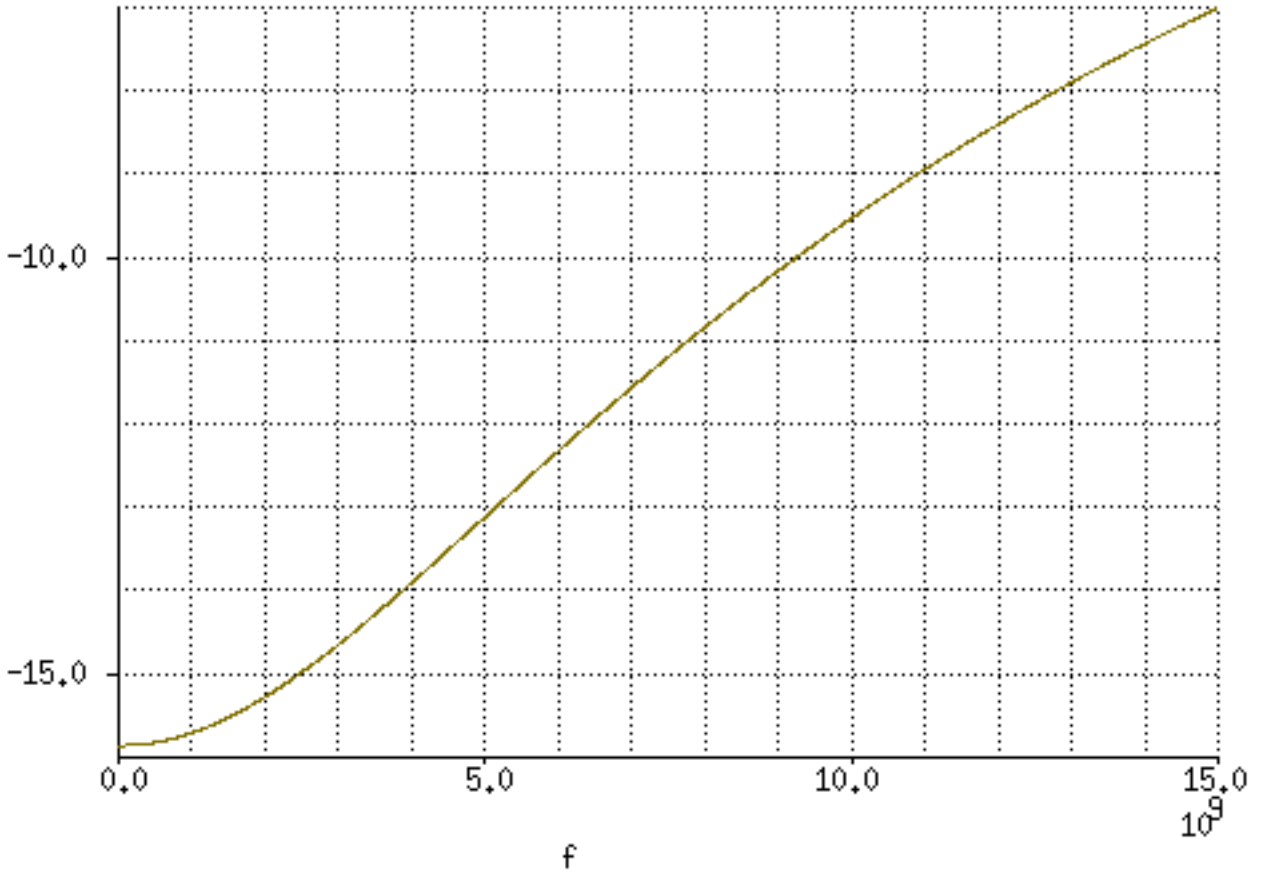
$f_1 = 3.2 \cdot 10^{10}$

$\Gamma_{01} = 0.161$

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	TBD±100ppm	GBd
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 Steady State Amplitude	85.8.3.3	TBD min 600 max	mV
Linear fit pulse (min)	85.8.3.3	TBD 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	 0.06 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		 0.075 0.01 0.13	 UI UI UI

To determine PAM4 code linearity use the method described in bliss_01_0911.pdf pages 4 and 5. This method consists of measuring a stair step of the 4 allowed codes, with each code repeated often enough to allow the value to settle. Linearity is defined in terms of ratios and differences among the 4 values.

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

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

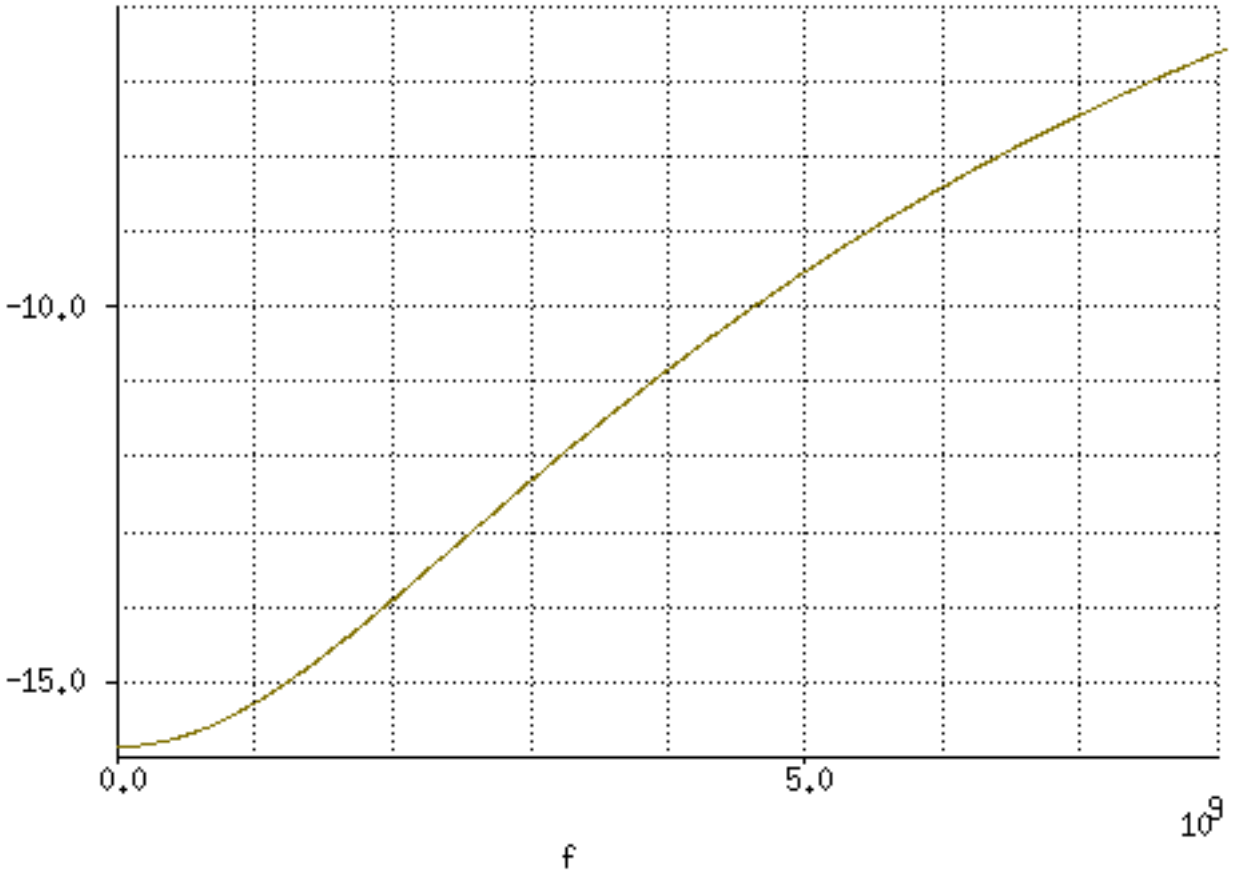
$\Gamma_{01} = 0.161$

Common-mode output return loss (min)

$$\text{Return\_loss} = TBD \qquad f < 8\text{GHz}$$

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

Normative 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 24
2. Change Table 85.8 as shown in slide 26
3. Change equation 85.17 (return loss) as shown in slide 25. 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 26 Defines test channel in terms of dibit gain (alternative 1) or Channel loss at Nyquist, 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
Differential peak-to-peak amplitude tolerance	72.7.2.4	1200	mV
Differential input return loss (min)	85.8.4.1	See Modified equation	
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)

$$\text{Return\_loss}(f) = \text{TBD}$$

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)

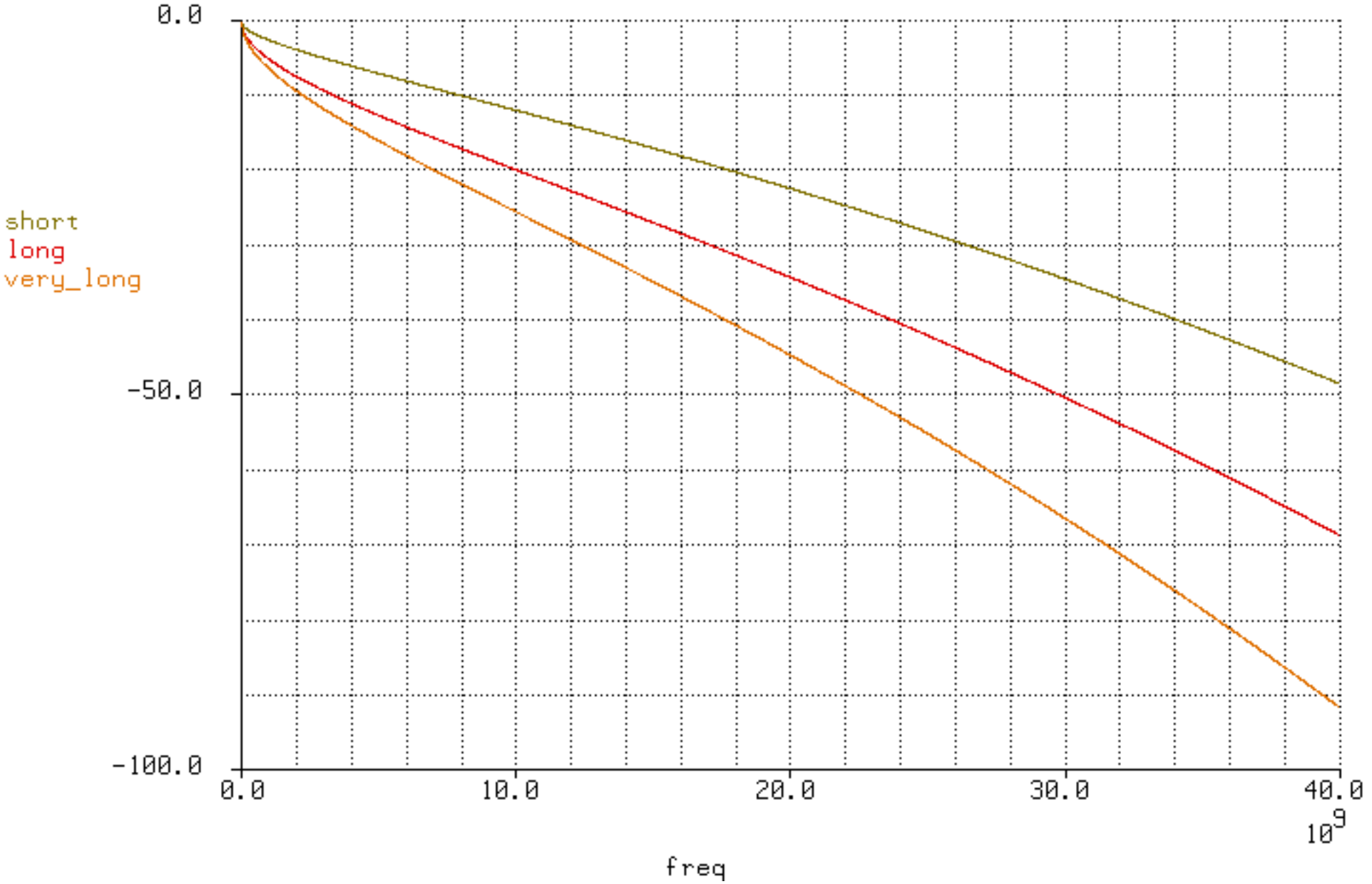
Common-mode output return loss (min)

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

Conditions for interference tolerance 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 (alternative 1) Loss at 12.89 GHz (alternative 2) Real part of a0 min Real part of a1 min Real part of a2 min Real part of a4 min	0.320 15 -0.100 No min -8.0×10^{-11} -2.5×10^{-21}	0.160 24 -0.100 No min -8.0×10^{-11} -3.5×10^{-21}	0.160 24 -0.100 No min -8.0×10^{-11} -3.5×10^{-21}	0.110 31 -0.100 No min -8.0×10^{-11} -5.0×10^{-21}	dB $Hz^{-1/2}$ Hz^{-1} Hz^{-2}
Channel Noise minus Tx-Rx re-reflection noise	0.0	0.0	0.0	0.0	mV
Applied SJ (min peak-to-peak at >100MHz)	0.115	0.115	0.115	0.115	UI
Applied RJ (peak-to-peak at BER=10^{-12})	0.15	0.15	0.15	0.15	UI
Applied DCD (peak-to-peak)	0.035	0.035	0.035	0.035	UI
Calibrated far-end crosstalk (RMS) Calibrated ICN (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



Loss curves for 3 test channels used in interference tolerance test at TP3

Rx PHI IC 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 or channel loss at Nyquist and limits on fitting parameters.
2. Signal and noise defined at test interface rather than IC
3. Multiple test, some with BER targets of 10^{-12} some with a higher BER (10^{-5} to $3x10^{-4}$) and channels which will require significant FEC.
4. Informative tests for receivers used in cable systems are given in slide 29.
5. Normative tests for NRZ receivers used in back planes are given in slide 30.
6. Normative tests for PAM4 receivers used in back planes are given in slide 31.

Conditions for informative interference tolerance test of cable PHY receivers tested at test interface

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 (alternative 1) Loss at 12.89 GHz (alternative 2) Real part of a0 min Real part of a1 min Real part of a2 min Real part of a4 min	0.290 16 -0.100 No min -3.0×10^{-11} -2.5×10^{-21}	0.120 30 -0.100 No min -5.0×10^{-11} -3.5×10^{-21}	0.120 30 -0.100 No min -5.0×10^{-11} -3.5×10^{-21}	0.100 34 -0.100 No min -5.0×10^{-11} -5.0×10^{-21}	dB $Hz^{-1/2}$ Hz^{-1} Hz^{-2}
Channel Noise minus Tx-Rx re-reflection noise	0.0	0.0	0.0	0.0	mV
Applied SJ (min peak-to-peak) at > 100 MHz	0.115	0.115	0.115	0.115	UI
Applied RJ (peak-to-peak at BER=10^{-12})	0.15	0.15	0.15	0.15	UI
Applied DCD (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

Conditions for normative interference tolerance test of NRZ backplane PHY

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 (alternative 1) Loss at 12.89 GHz (alternative 2) Real part of a0 min Real part of a1 min Real part of a2 min Real part of a4 min	0.300 16 -0.100 -1.2×10^{-5} No min -2.5×10^{-21}	0.135 30 -0.100 -1.2×10^{-5} No min -3.5×10^{-21}	0.135 30 -0.100 -1.2×10^{-5} No min -3.5×10^{-21}	0.110 30 -0.100 -1.2×10^{-5} No min -5.0×10^{-21}	dB $Hz^{-1/2}$ Hz^{-1} Hz^{-2}
Channel Noise minus Tx-Rx re-reflection noise	0.0	0.0	0.0	0.0	mV
Applied SJ (min peak-to-peak) at > 100 MHz	0.115	0.115	0.115	0.115	UI
Applied RJ (peak-to-peak at BER=10^{-12})	0.15	0.15	0.15	0.15	UI
Applied DCD peak-to-peak)	0.035	0.035	0.035	0.035	UI
Broad band Noise (RMS)	10.0	5.0	8.2	6.6	mV

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

Conditions for normative interference tolerance test of PAM4 backplane PHY

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}	$3x10^{-4}$	$3x10^{-4}$	
Dibit gain (alternative 1) Loss at 7.0 GHz (alternative 2) Real part of a0 min Real part of a1 min Real part of a2 min Real part of a4 min	0.330 15 -0.100 $-1.2x10^{-5}$ No min $-2.5x10^{-21}$	0.250 19 -0.100 $-1.2x10^{-5}$ No min $-3.5x10^{-21}$	0.250 19 -0.100 $-1.2x10^{-5}$ No min $-3.5x10^{-21}$	0.135 32 -0.100 $-1.5x10^{-5}$ No min $-5.0x10^{-21}$	dB $Hz^{-1/2}$ Hz^{-1} Hz^{-2}
Channel Noise minus Tx-Rx re-reflection noise	0.0	0.0	0.0	0.0	mV
Applied SJ (peak-to-peak) at > 50 MHz	0.058	0.058	0.058	0.058	UI
Applied RJ (peak-to-peak at BER=10^{-12})	0.075	0.075	0.075	0.075	UI
Applied DCD (peak-to-peak)	0.01	0.01	0.01	0.01	UI
Broad band Noise (RMS)	5.8	4.4	8.8	4.6	mV

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