IEEE 802.3bj Test Points and Parameters
100 Gb/s copper cable

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Purpose

- **Baseline proposals for 802.3bj test point specifications and parameters for 100 Gb/s copper cable applicable for both PAM-2 and PAM-4.**

- **Baseline proposal for PAM-2 channel insertion loss budget.**

Supporters

- Vittal Balasubramanian - FCI
- Tom Palkert, Jay Neer, Mark Bugg - Molex
- Marc Dupuis, Megha Shanbhag, Nathan Tracy – TE Connectivity
- Ali Ghiasi - Broadcom
- Bernd Jansen, Cattalen Pelard - LEONI Cables & Systems
- Valerie Maguire - Siemon Company
- Olindo Savi - Hitachi Cable Manchester, Inc.
- Adee Ran - Intel
- Rick Rabinovich - Alcatel-Lucent
- Pavel Zivny, Tektronix
- Merrick Moeller, Amphenol TCS

802.3bj test point specifications

- **Adopt Figure 85-2 and Table 85-4 as baseline for 802.3bj with applicable changes for naming transmit and receive functions and figure and clause numbering.**

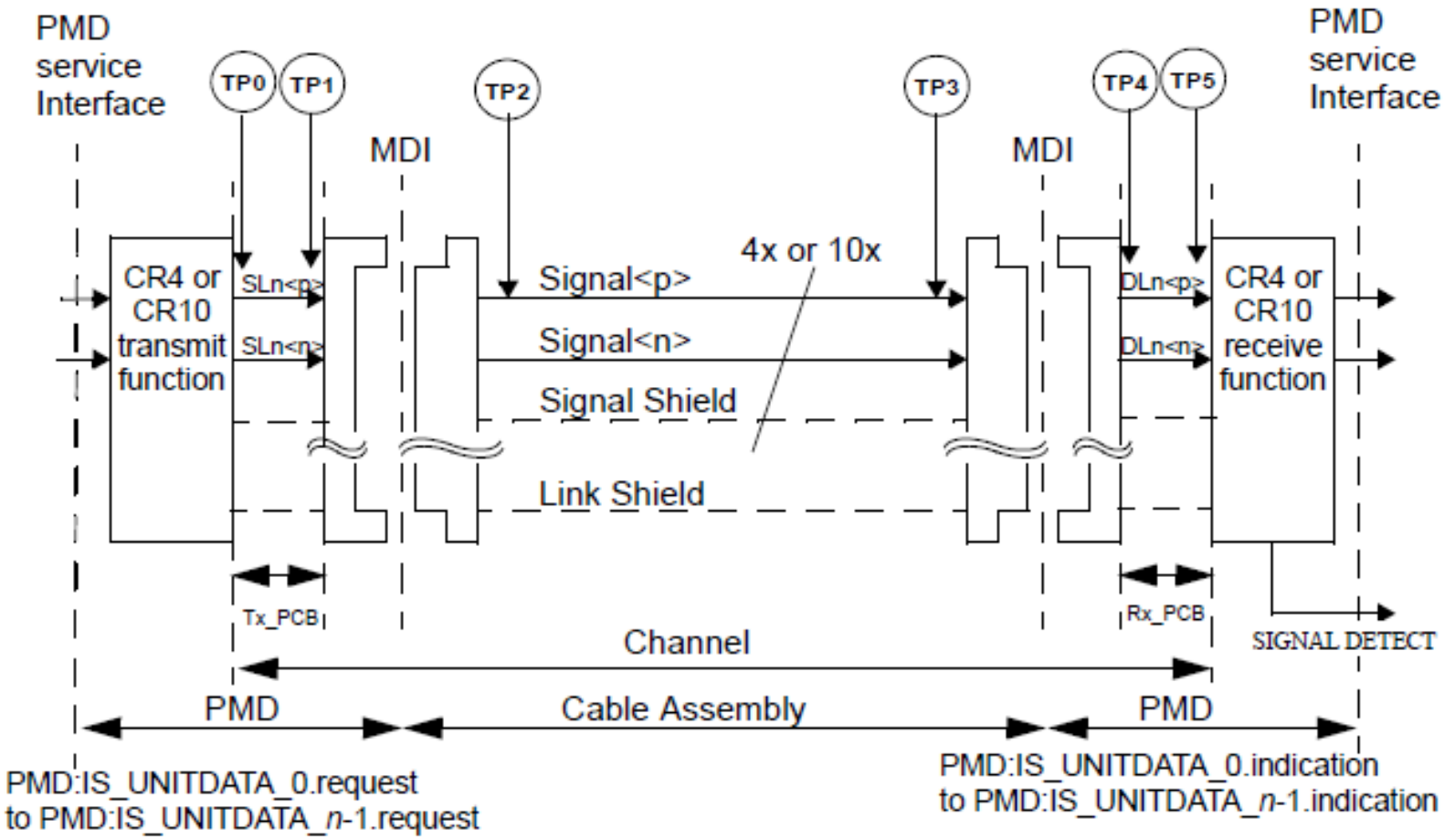


Figure 85–2—40GBASE-CR4 or 100GBASE-CR10 link (half link is illustrated)

802.3bj test point specifications

- **Table 85-4**

Table 85–4—40GBASE-CR4 and 100GBASE-CR10 test points

Test points	Description
TP0 to TP5	The 40GBASE-CR4 and 100GBASE-CR10 channels including the transmitter and receiver differential controlled impedance printed circuit board insertion loss and the cable assembly insertion loss.
TP1 to TP4	All cable assembly measurements are to be made between TP1 and TP4 as illustrated in Figure 85–2. The cable assembly test fixture of Figure 85–13 or its functional equivalent, is required for measuring the cable assembly specifications in 85.10 at TP1 and TP4.
TP0 to TP1 TP4 to TP5	A mated connector pair has been included in both the transmitter and receiver specifications defined in 85.8.3 and 85.8.4. The maximum insertion loss from TP0 to TP2 or TP3 to TP5 including the test fixture is specified in 85.8.3.4.
TP2	Unless specified otherwise, all transmitter measurements and tests defined in Table 85–5 are made at TP2 utilizing the test fixture specified in 85.8.3.5.
TP3	Unless specified otherwise, all receiver measurements and tests defined in 85.8.4 are made at TP3 utilizing the test fixture specified in 85.8.3.5.

802.3bj Channel definition and test points

- **Adopt 85A 40GBASE-CR4 and 100GBASE-CR10 TP0 and TP5 test point parameters as baseline for 802.3bj channel parameters.**

- **Extend frequency and adjust limits as necessary to meet objectives.**

TP0 to TP5	The 40GBASE-CR4 and 100GBASE-CR10 channels including the transmitter and receiver differential controlled impedance printed circuit board insertion loss and the cable assembly insertion loss.

- 85A.2 Transmitter characteristics at TP0 [RL]
- 85A.3 Receiver characteristics at TP5 [RL]
- 85A.4 Transmitter and receiver differential printed circuit board trace loss
- 85A.5 Channel insertion loss
- 85A.6 Channel return loss
- 85A.7 Channel insertion loss deviation (ILD)
- 85A.8 Channel integrated crosstalk noise (ICN)

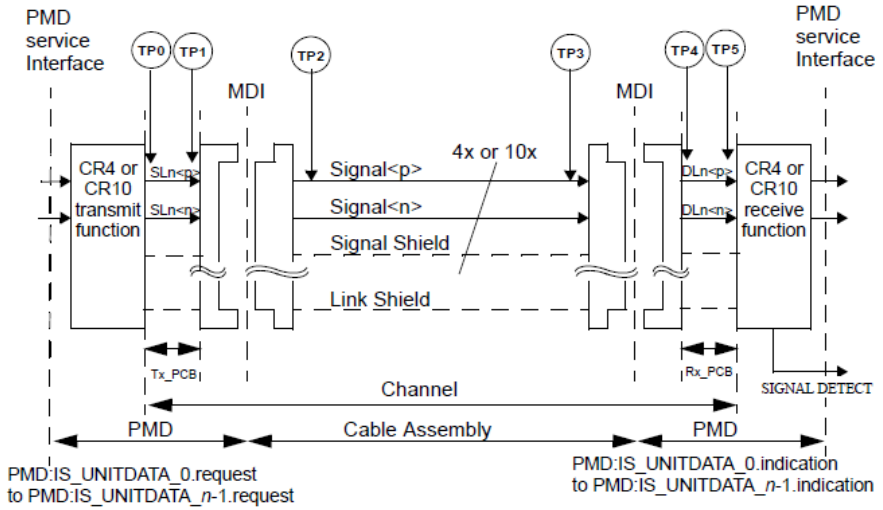


Figure 85–2—40GBASE-CR4 or 100GBASE-CR10 link (half link is illustrated)

802.3bj cable assembly characteristics and test points

- **Adopt Table 85-9 and 85.10.1 cable characteristic parameter set as baseline for 802.3bj cable characteristic parameter set.**

- **Extend frequency and adjust limits as necessary to meet objectives.**

TP1 to TP4	All cable assembly measurements are to be made between TP1 and TP4 as illustrated in Figure 85–2. The cable assembly test fixture of Figure 85–13 or its functional equivalent, is required for measuring the cable assembly specifications in 85.10 at TP1 and TP4.

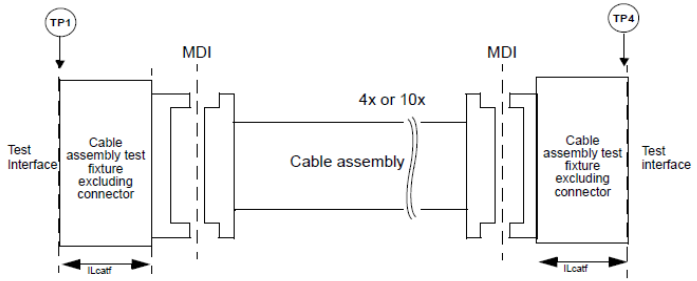


Figure 85–13—Cable assembly test fixtures

Table 85–9—Cable assembly differential characteris

Description	Reference	Value	Unit
Maximum insertion loss at 5.15625 GHz	85.10.2	17.04	dB
Minimum insertion loss at 5.15625 GHz		3	dB
Insertion loss deviation at 5.15625 GHz	85.10.3	max = 1.73 min = –1.73	dB
Minimum return loss at 5.15625 GHz	85.10.4	6.66	dB
MDNEXT loss	85.10.5	Equation (85–26)	dB
MDFEXT loss	85.10.6	Equation (85–27)	dB
Maximum integrated crosstalk noise	85.10.7	Equation (85–33)	mV

85.10.1 Characteristic impedance and reference impedance

The nominal differential characteristic impedance of the cable assembly is 100 Ω. The differential reference impedance for cable assembly specifications shall be 100 Ω.

802.3bj Transmitter and Receiver measurements and test points

- **Adopt transmitter parameters in Table 85-5 as baseline for 802.3bj transmitter parameters.**
- **Adopt receiver parameters in 85.7 and 85.8.4.2 Receiver interference tolerance test as baseline for 802.3bj Receiver interference tolerance test.**
- **Extend frequency and adjust limits as necessary to meet objectives.**

Table 85–5—Transmitter characteristics at TP2 summary

Parameter	Subclause reference	Value	Units
Signaling rate, per lane	85.8.3.8	10.3125 ± 100 ppm	GBd
Unit interval nominal	85.8.3.8	96.969697	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 to 1.9	V
Differential output return loss (min)	85.8.3.1	See Equation (85–1)	dB
Common-mode output return loss (min)		See Equation (72–6) and Equation (72–7)	dB
Common-mode AC output voltage (max., RMS)		30	mV
Amplitude peak-to-peak (max)	72.7.1.4	1200[a]	mV
Transmitter DC amplitude[b]	85.8.3.3	0.34 min, 0.6 max	V
Linear fit pulse (min)[c]	85.8.3.3	0.63 × Transmitter DC amplitude	V
Transmitted waveform max normalized error(linear fit), "e" abs coefficient step size minimum precursor fullscale range minimum post cursor fullscale range	 85.8.3.3 85.8.3.3.2 85.8.3.3.3 85.8.3.3.3	 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[d] Duty Cycle Distortion[e] Total jitter excluding data dependent jitter[f]		 0.15 0.035 0.25	 UI UI UI

TP2	Unless specified otherwise, all transmitter measurements and tests defined in Table 85–5 are made at TP2 utilizing the test fixture specified in 85.8.3.5.
TP3	Unless specified otherwise, all receiver measurements and tests defined in 85.8.4 are made at TP3 utilizing the test fixture specified in 85.8.3.5.

Table 85–7—Receiver characteristics at TP3 summary

Parameter	Subclause reference	Value	Units
Bit error ratio	85.8.4.3	10^{-12} or better	
Signaling rate, per lane	85.8.4.4	10.3125 ± 100 ppm	GBd
Unit interval (UI) nominal	85.8.4.4	96.969697	ps
Differential peak-to-peak input amplitude tolerance (max)	72.7.2.4	1200	mV
Differential input return loss (min)[a]	85.8.4.1	Equation (85–17)	dB
Differential to common-mode input return loss		10 min from 10 MHz to 10 GHz	dB

[a]Relative to 100 Ω differential.

802.3bj Receiver interference tolerance test and parameters

- **Adopt Receiver interference tolerance test as baseline for 802.3bj.**
- **Extend frequency and adjust limits as necessary to meet objectives.**

Table 85–8—10GBASE-CR4 and 10GBASE-CR10 interference tolerance parameters

Parameter	Test 1 values	Test 2 values	Units
Target BER	10^{-12}	10^{-12}	
Maximum fitted insertion loss coefficients	$a_1 = 2.15$ $a_2 = 0.78$ $a_4 = 0.03$	$a_1 = 6.04$ $a_2 = 0.94$ $a_4 = 0.08$	dB/√GHz dB/GHz dB/GHz^2
Applied SJ[a] (min peak-to-peak)	0.115	0.115	UI
Applied RJ[b] (min peak-to-peak)	0.13	0.13	UI
Applied DCD (min peak-to-peak)	0.035	0.035	UI
Calibrated far-end crosstalk (min RMS) Calibrated ICN (min, RMS) – σ_{nx}	6.3 3.7	2.2 3.7	mV mV

[a]Applied SJ frequency >15 MHz, specified at TP0.
[b]Applied random jitter at TP0 is specified at 10^{-12}.

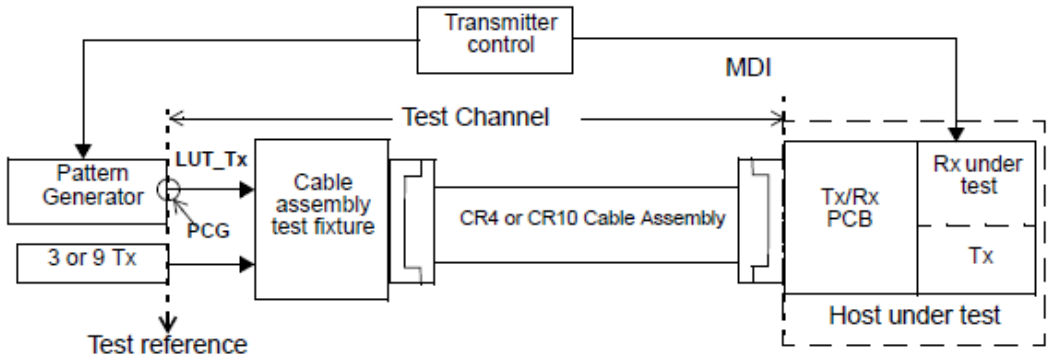


Figure 85–7—Interference tolerance test setup

802.3bj Test fixtures; test points and parameters

- **Adopt 85.10.8 Cable assembly test fixture parameters as baseline for 802.3bj Cable assembly test fixture parameters.**

- **Extend frequency and adjust limits as necessary to meet objectives.**

TP1 to TP4	All cable assembly measurements are to be made between TP1 and TP4 as illustrated in Figure 85–2. The cable assembly test fixture of Figure 85–13 or its functional equivalent, is required for measuring the cable assembly specifications in 85.10 at TP1 and TP4.

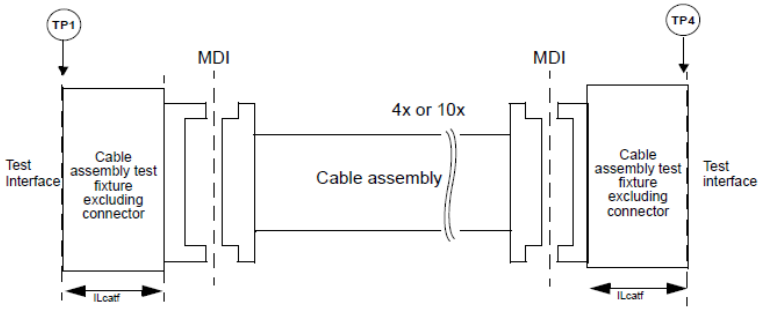


Figure 85–13—Cable assembly test fixtures

- 85.10.8 Cable assembly test fixture
- 85.10.9 Mated test fixtures
- 85.10.9.1 Mated test fixtures insertion loss
- 85.10.9.2 Mated test fixtures return loss
- 85.10.9.3 Mated test fixtures common-mode return loss
- 85.10.9.4 Mated test fixtures common-mode conversion loss
- 85.10.9.5 Mated test fixtures integrated crosstalk noise

802.3bj Test fixtures; test points and parameters

- **Adopt 85.8.3.5 Test fixture parameters as baseline for 802.3bj test fixture parameters for measuring the transmitter specifications at TP2 and the receiver specifications at TP3.**

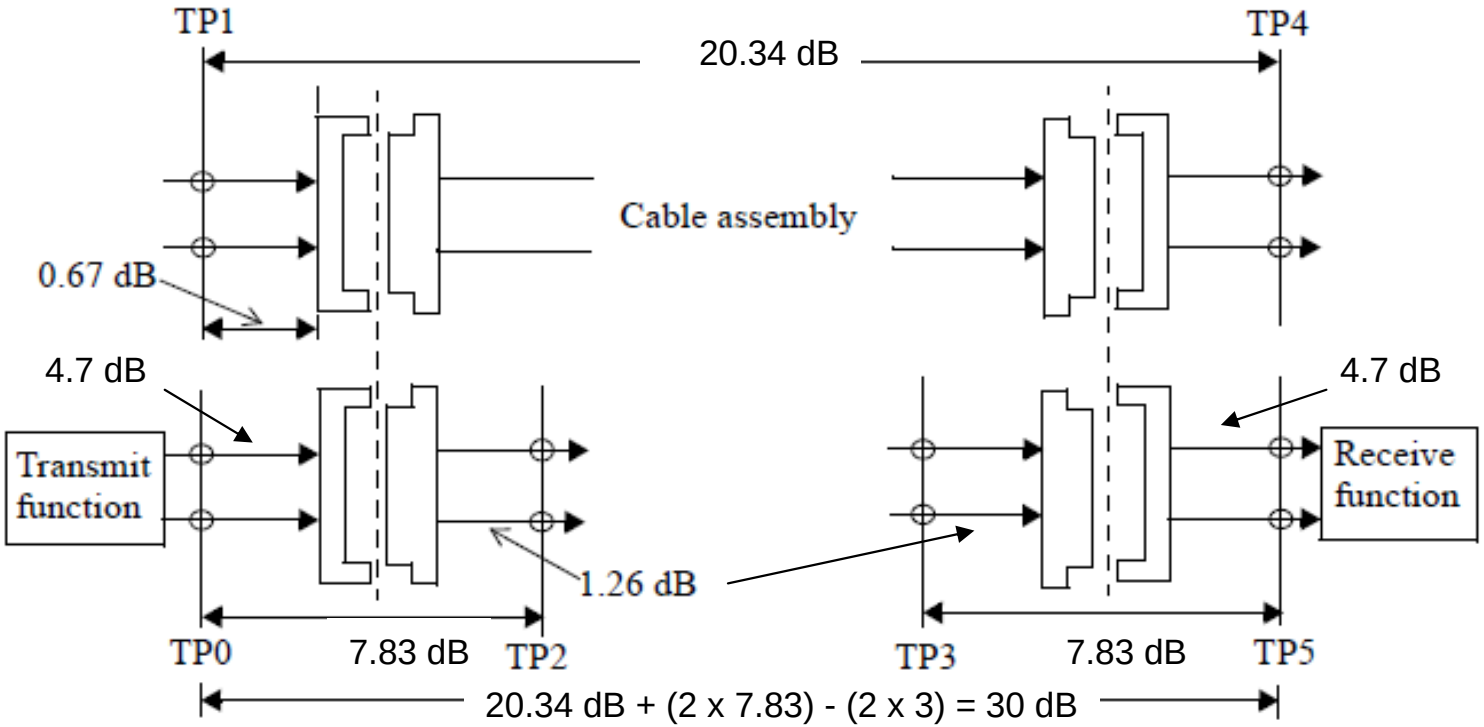
- **Extend frequency and adjust limits as necessary to meet objectives.**

TP2	Unless specified otherwise, all transmitter measurements and tests defined in Table 85–5 are made at TP2 utilizing the test fixture specified in 85.8.3.5.
TP3	Unless specified otherwise, all receiver measurements and tests defined in 85.8.4 are made at TP3 utilizing the test fixture specified in 85.8.3.5.

- 85.8.3.5 Test fixture (TP2 or TP3)
- 85.8.3.6 Test fixture impedance
- 85.8.3.7 Test fixture insertion loss

Channel insertion loss budget – 30 dB @ 12.89 GHz

Channel insertion loss budgets at 12.89 GHz

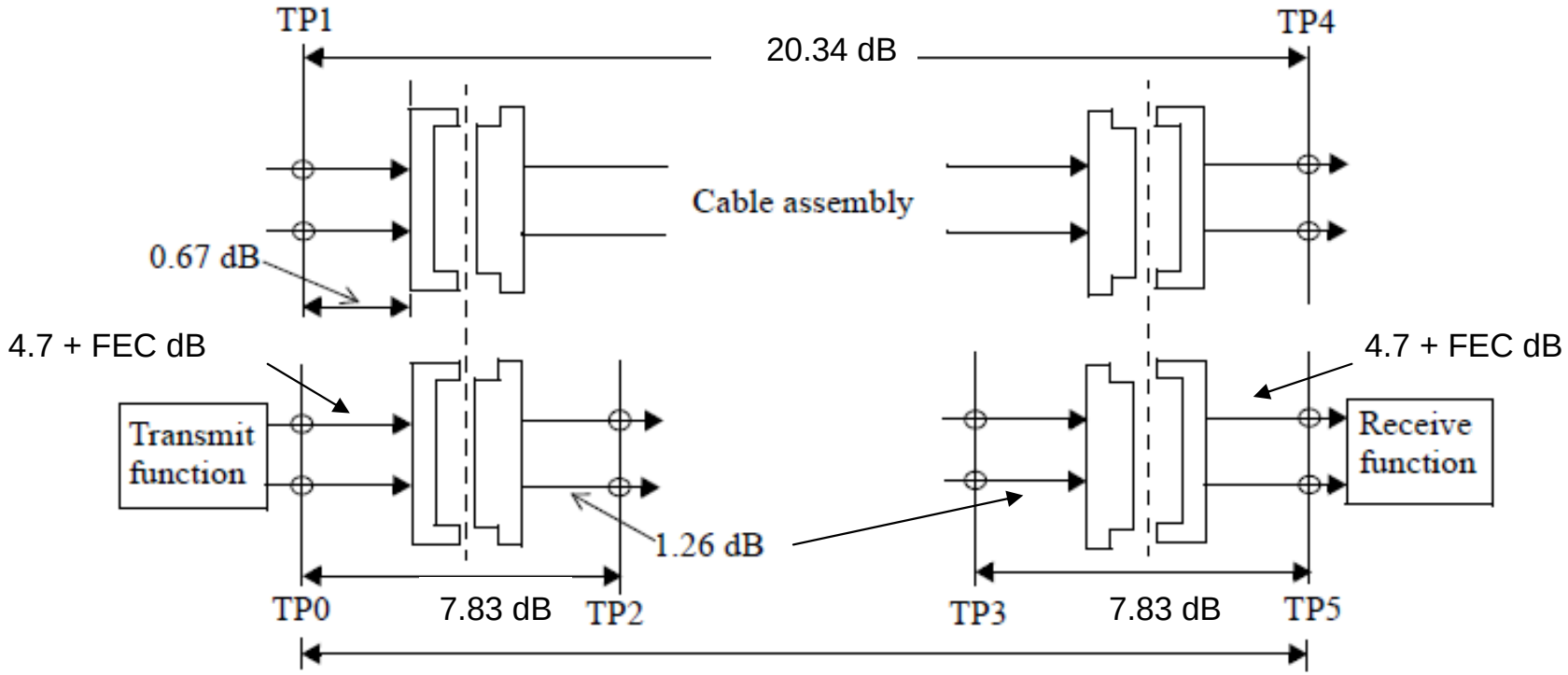


5 meter cable	3.2 dB/m	16 dB
Connector*	1.5 dB	3 dB
CA-TF loss	.67 dB	1.34 dB
cable assembly		20.34 dB
Tx/Rx PCB	4.7 dB	9.4 dB

- **Adopt channel insertion loss budget as baseline for 802.3bj 30 dB channel insertion loss budget.**

Channel insertion loss budget >30 dB @ 12.89 GHz

Channel insertion loss budgets at 12.89 GHz



5 meter cable	3.2 dB/m	16 dB
Connector*	1.5 dB	3 dB
CA-TF loss	.67 dB	1.34 dB
cable assembly		20.34 dB
Tx/Rx PCB	4.7 + FEC dB	9.4 + FEC dB

•Adopt channel insertion loss budget as baseline for 802.3bj >30 dB channel insertion loss budget.

Conclusion

- **Baseline proposals for 802.3bj test point specifications and parameters for 100 Gb/s copper cable applicable for both PAM-2 and PAM-4.**

- **Baseline proposal for PAM-2 channel insertion loss budget.**

Backup

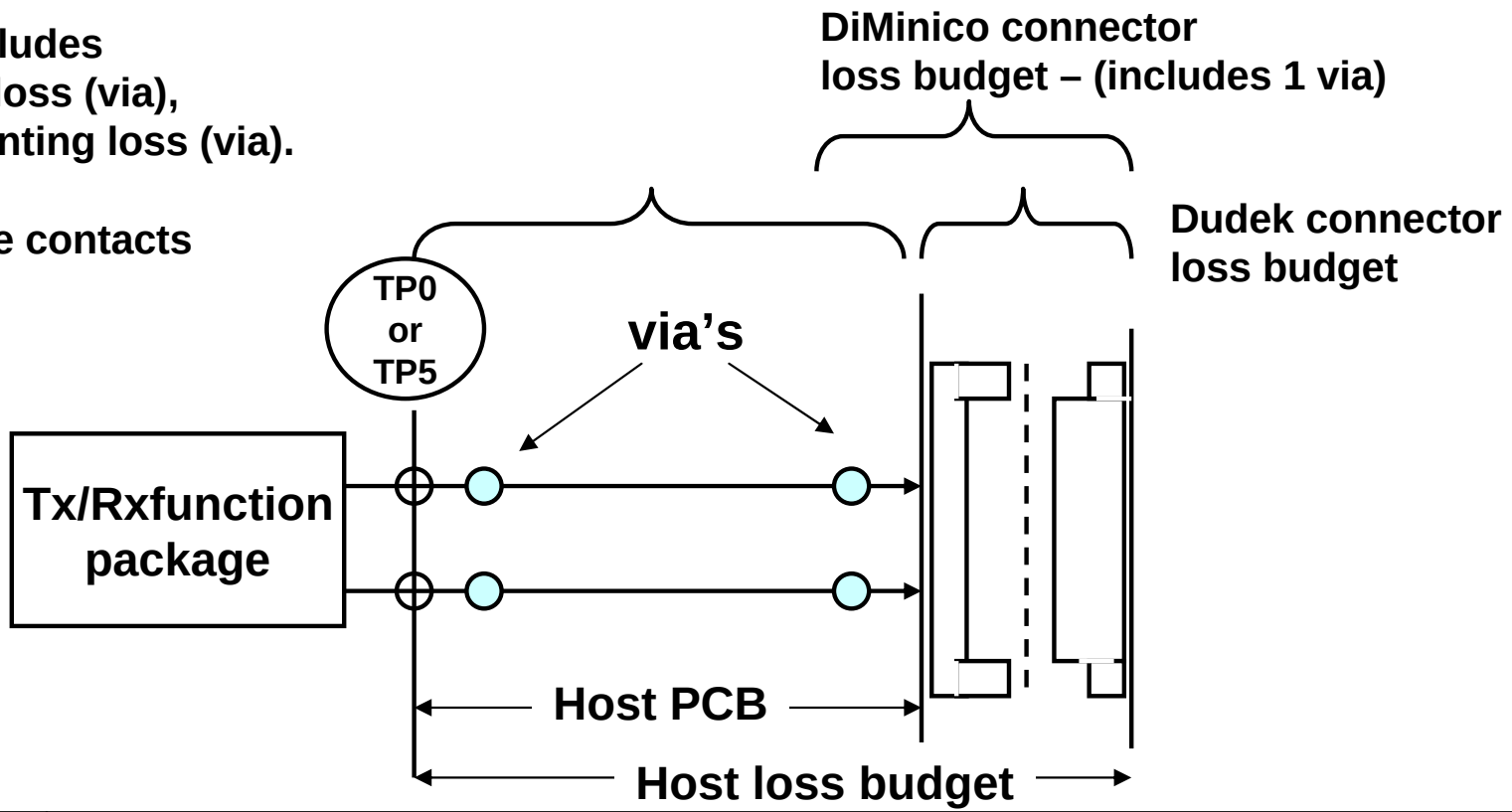
Loss budget examples

	Next generation signal integrity	
Uncoded rate, Gb/s	25.0	25.0
Line code	NRZ	4-PAM
Signaling rate, GBd	25.7813	12.8913
SNR for BER ≤ 10^{-12} , dB [1]	17.0	26.6
Cable length, m	5	7
Host TX PCB (4") [2], dB	4.70 [3]	2.54 [3]
TX Connector, dB	2.30	1.63 [5]
Bulk cable, dB	16.00 [4]	14.5 [6]
RX Connector, dB	2.30	1.63 [5]
Host RX PCB (4"), dB	4.70 [3]	2.54 [3]
Total insertion loss, dB	30.00	22.84

[1] Assumes fixed transmitter peak-to-peak differential output voltage.
[2] Losses are defined at the fundamental frequency for the cited signaling rate.
[3] Tx PCB-4" from Megtron4 measurements-OIF2010.132.01.pdf =4*(0.0838*fGHz+0.0944)
[4] Measured cable pair 24 AWG 3.2 dB/m (+13% from measurement)
[5] Derived as 2.3 x sqrt(6.4453/12.8913)
[6] Measured cable pair 24 AWG 2.07 dB/m (+13% from measurement)

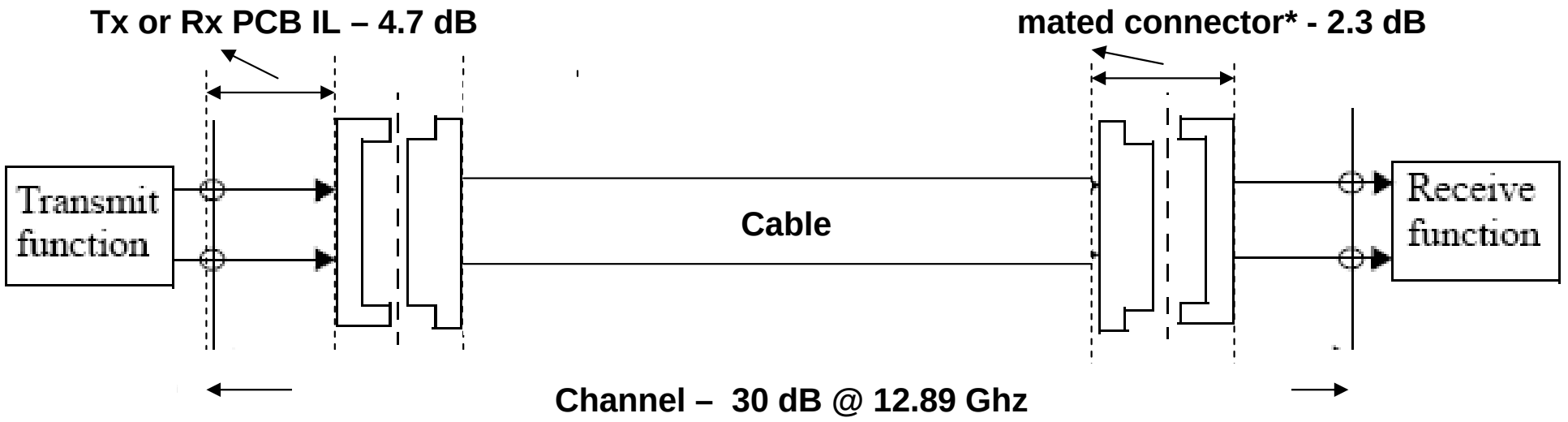
Host Loss budget

Host loss budget includes
- **Chip/ball mounting loss (via),**
- **MDI receptacle mounting loss (via).**
- **MDI receptacle**
- **Plug connector edge contacts**



Reference	Host PCB	Mated Connector	Host loss budget - 12.89 GHz	Host loss budget – 14 GHz
diminico_01_1111.pdf, diminico_01_0511.pdf	4.70 dB @ 12.89 GHz (1.175 dB/in) 5.07 dB @ 14.00 GHz (1.268 dB/in) (4" Megtron 4) – no via	1.87 dB @ 12.89 GHz 2.30 db @ 14.00 GHz (includes connector via)	6.57 dB	7.37 dB
CEI-28G-VSR Nov11	7.3 dB 14 GHz (PCB+2 via's) (2 via's[0.5 dB] + host trace[6.8 dB]) (4" N4000-13 or slightly worse material (up to 1.7dB/in) at 14GHz	1.2 dB @ 14 GHz		8.50 dB
Dudek_01a_1111..pdf	8.0 dB 12.89 GHz (PCB+2 via's)	1.2 dB @ 12.89 GHz	9.20 dB	9.20 dB

Channel insertion loss - 12.89 GHz – 5 m assembly

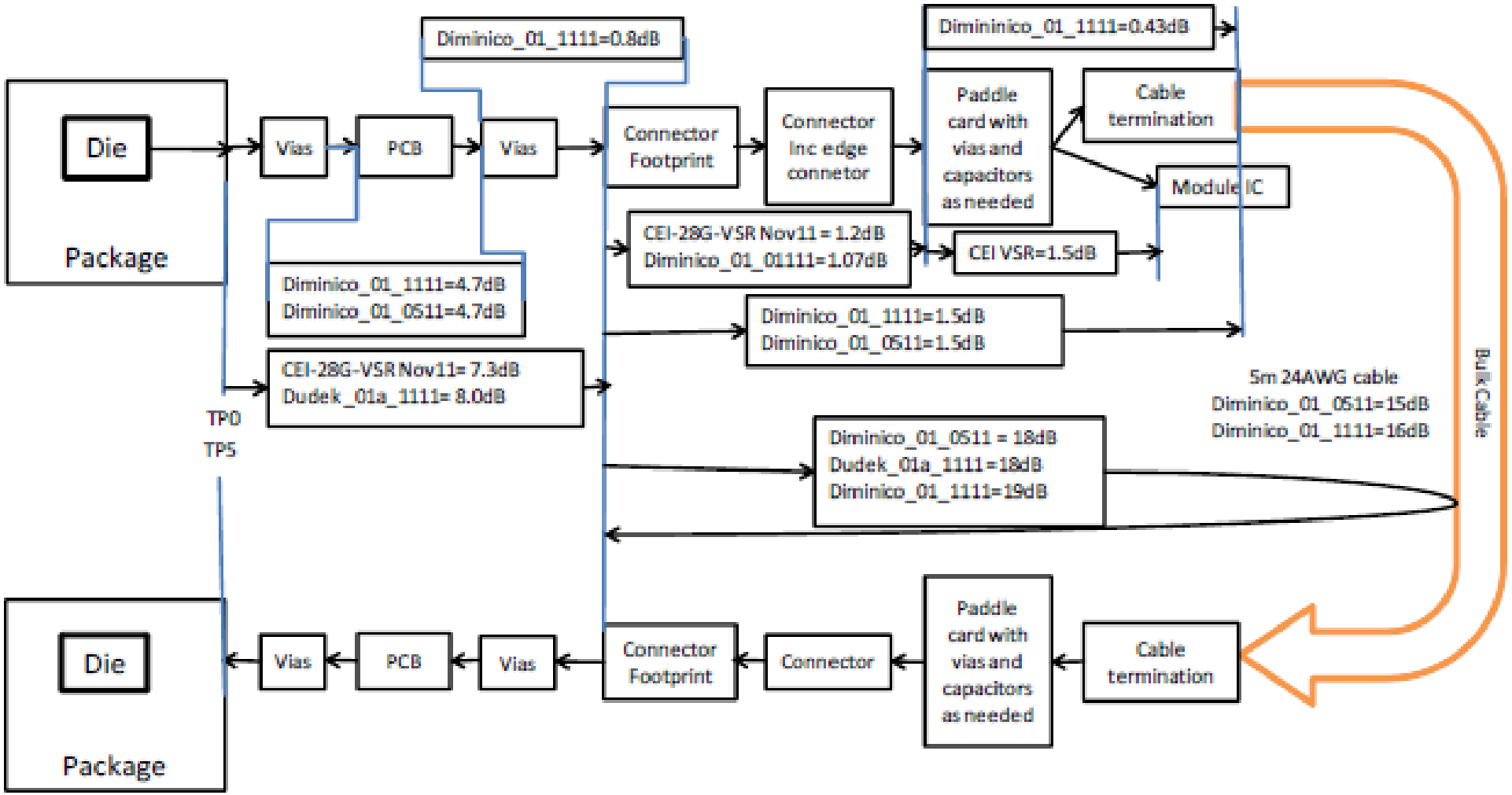


***mated connector loss including paddle card and wire termination**

Channel IL= 2 x 4.70 dB (PCB) + 2 x 2.3 dB mated connector + 16.00 dB cable = 30 dB

Channel components	Total 30 dB @ 12.89
Tx PCB-4” from Megtron4 measurements (1.175 dB/in)	OIF2010.132.01.pdf =4*(0.0838*fGHz+0.0944)= 4.7 dB
Connector loss including paddle card termination	0.641*sqrt(fGHz) = 2.3 dB
Cable 5 m 24 AWG	3.2 dB/m = 16 dB
Connector loss including paddle card termination	0.641*sqrt(fGHz) = 2.3 dB
Rx PCB-4” from Megtron4 measurements (1.175 dB/in)	OIF2010.132.01.pdf =4*(0.0838*fGHz+0.0944)= 4.7 dB

Detailed differences in channel loss budget references



Source: Mike Dudek, QLogic Corporation