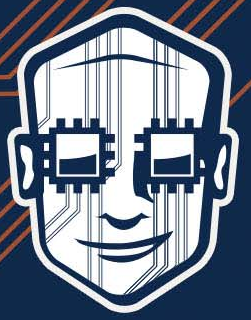
DesignCon® 2015



100 GB/S ETHERNET - 100GBASE-CR4 TEST POINTS AND TEST FIXTURES

UBM

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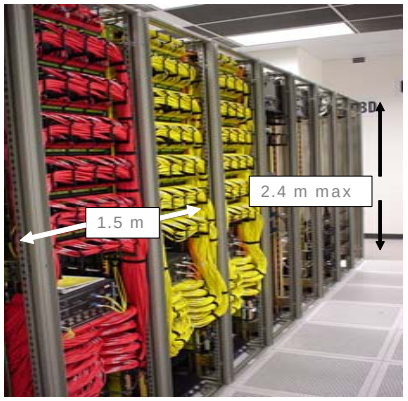
IEEE 802.3bj – 100GBASE-CR4

- IEEE Standard for Ethernet Amendment 2: Physical Layer Specifications and Management Parameters for 100 Gb/s Operation Over Backplanes and Copper
- 100 Gb/s backplane and copper cable port type 100GBASE-CR4
- Passive twinaxial copper cable assemblies of lengths up to at least 5 meters
- Interconnection of switches and server's in equipment racks within the data center, computer room, and central office environments.

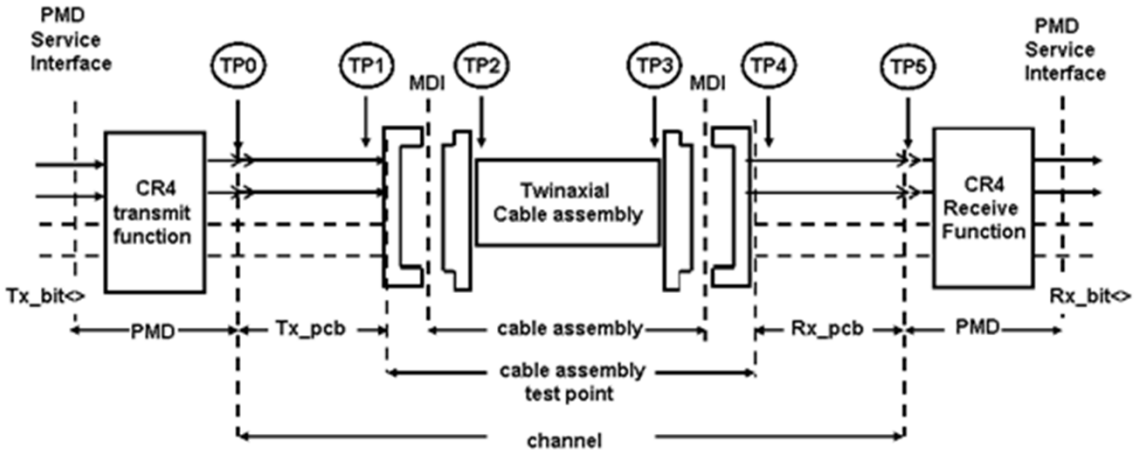


Abstract

- Overview 100GBASE-CR4 test point specifications and test fixtures for testing;
  - transmitter and receiver signals
  - twinaxial copper cable assemblies
- Demonstration of achievability of conformance to the 100GBASE-CR4 test fixture s-parameter specifications;
  - HFSS models
  - vector network analyzer measurements

Channel and link Definitions

- The channel is defined between the transmitter and receiver blocks to include the transmitter and receiver differential controlled impedance printed circuit board and the cable assembly.
- The Media dependent interfaces (MDIs) refer to the connector interfaces. 100GBASE-CR4 specifies the quad small form factor pluggable (QSFP28) plug and receptacle.



Test Points and Descriptions

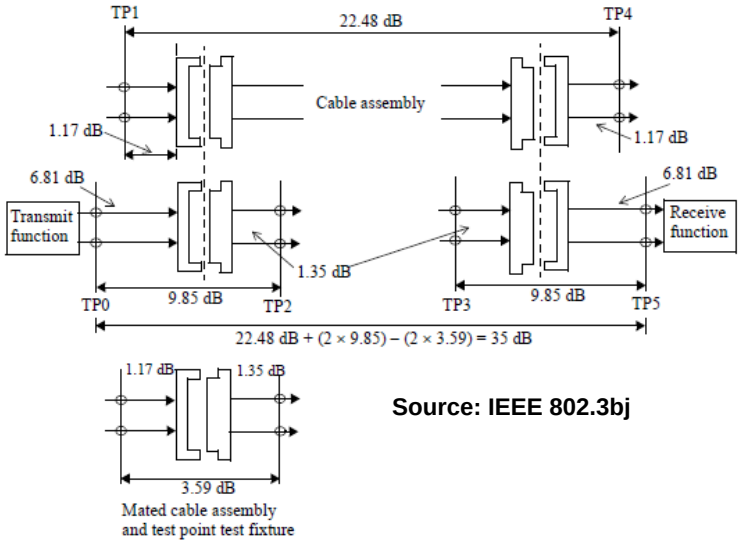
- For conformance testing five test points are standardized.

Test Points	Description
TP0 to TP5	The channel is defined between the transmitter and receiver blocks to include the transmitter and receiver differential controlled impedance printed circuit board and the cable assembly.
TP1 to TP4	All cable assembly measurements between TP1 and TP4. are performed with the test fixtures specified in 100GBASE-CR4.
TP0 to TP2 TP3 to TP5	A mated connector pair is included in both the transmitter and receiver specifications.
TP2	Transmitter parameters are measured at TP2 utilizing the test fixture specified in 100GBASE-CR4.
TP3	Receiver parameters are measured at TP3 utilizing the test fixture specified in 100GBASE-CR4.

Channel Parameters and Insertion Loss Budgets

- TP0 and TP5 may not be accessible in an implemented system
- Information (not required for conformance) of channel transmission characteristics and insertion loss budgets provided in Annex's.

Parameter description	f(GHz)	Unit
Transmitter and receiver differential printed circuit board trace loss (host PCB insertion loss 6.81 dB @12.89 GHz)	0.05≤f≤19	dB
Channel Insertion Loss (6.81 dB @12.89 GHz)	0.05≤f≤19	dB
Maximum channel insertion Loss (35 dB @12.89 GHz)	0.05≤f≤19	dB
Minimum channel insertion loss (x dB @12.89 GHz)	0.05≤f≤19	dB
Channel operating margin (3 dB)		dB

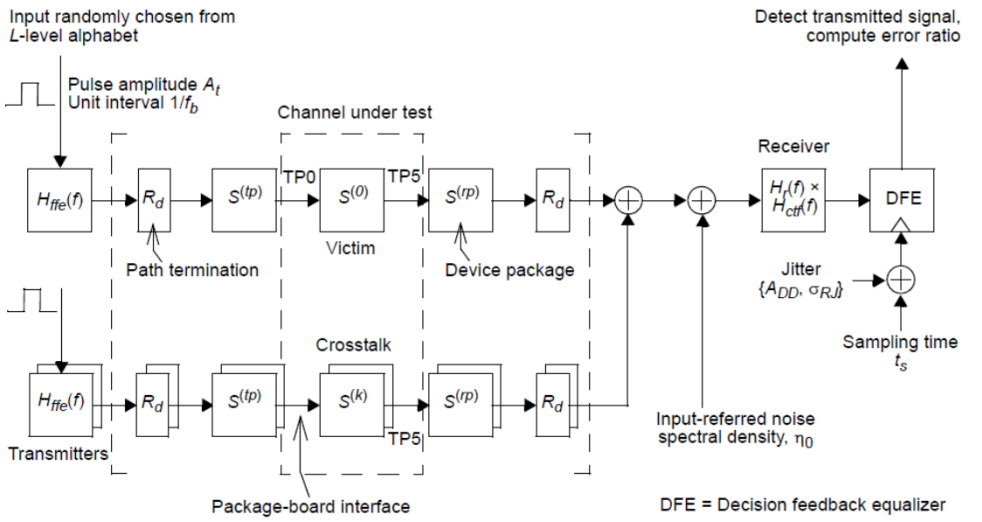


Source: IEEE 802.3bj

Insertion loss budget @ 12.89 GHz

The Channel Operating Margin (COM)

- A figure of merit for a channel derived from a measurement of its scattering parameters. COM is related to the ratio of a calculated signal amplitude to a calculated noise amplitude; channel operating margin (3 dB).

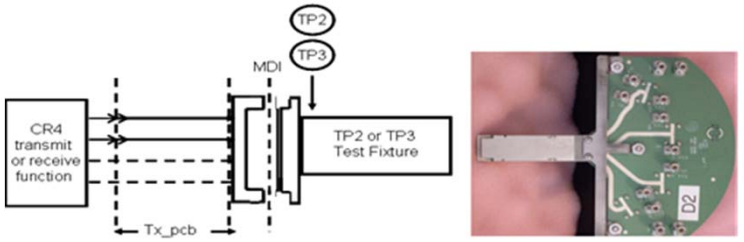


Source: IEEE 802.3bj

Parameter	Symbol	Value	Units
Signaling rate	f_b	25.78125	GBd
Maximum start frequency	f_{min}	0.05	GHz
Maximum frequency step	Δf	0.01	GHz
Device package model Single-ended device capacitance Transmission line length, Test 1 Transmission line length, Test 2 Single-ended package capacitance at package-to-board interface	C_d z_p z_p C_p	2.5×10^{-4} 12 30 1.8×10^{-4}	nF mm mm nF
Single-ended reference resistance	R_0	50	Ω
Single-ended termination resistance	R_d	55	Ω
Receiver 3 dB bandwidth	f_c	$0.75 \times f_b$	GHz
Transmitter equalizer, minimum cursor coefficient	$c(0)$	0.62	—
Transmitter equalizer, pre-cursor coefficient Minimum value Maximum value Step size	$c(-1)$	 −0.18 0 0.02	 — — —
Transmitter equalizer, post-cursor coefficient Minimum value Maximum value Step size	$c(1)$	 −0.38 0 0.02	 — — —
Continuous time filter, DC gain Minimum value Maximum value Step size	g_{DC}	 −12 0 1	 dB dB dB
Continuous time filter, zero frequency	f_z	$f_b / 4$	GHz
Continuous time filter, pole frequencies	f_{p1} f_{p2}	$f_b / 4$ f_b	GHz
Transmitter differential peak output voltage Victim Far-end aggressor Near-end aggressor	A_v A_{fe} A_{ne}	 0.4 0.4 0.6	 V V V
Number of signal levels	L	2	—
Level separation mismatch ratio	R_{LM}	1	—
Transmitter signal-to-noise ratio	SNR_{TX}	27	dB
Number of samples per unit interval	M	32	—
Decision feedback equalizer (DFE) length	N_b	14	UI
Normalized DFE coefficient magnitude limit, for $n = 1$ to N_b	$b_{max}(n)$	1	—
Random jitter, RMS	σ_{RJ}	0.01	UI
Dual-Dirac jitter, peak	A_{DD}	0.05	UI
One-sided noise spectral density	η_0	5.2×10^{-8}	V^2/GHz
Target detector error ratio	DER_0	10^{-5}	—

Transmitter and Receiver Parameters TP2/TP3

- The electrical transmit signals is defined at the output end of the mated connector (TP2) and all receiver measurements and tests are made at the input end of the mated connector (TP3).



Parameter	Subclause reference	Value	Units
Receiver input amplitude tolerance	92.8.4.1	1200 mV as measured at TP2	mV
Differential input return loss (min)	92.8.4.2	Equation (92–20)	dB
Differential to common-mode input return loss	92.8.4.3	Equation (92–21)	dB
Interference Tolerance	92.8.4.4	Table 92–8	—
Signaling rate, per lane	92.8.4.6	25.78125 ± 100 ppm	GBd
Unit interval (UI) nominal	92.8.4.6	38.787879	ps

Receiver characteristics at TP3 summary

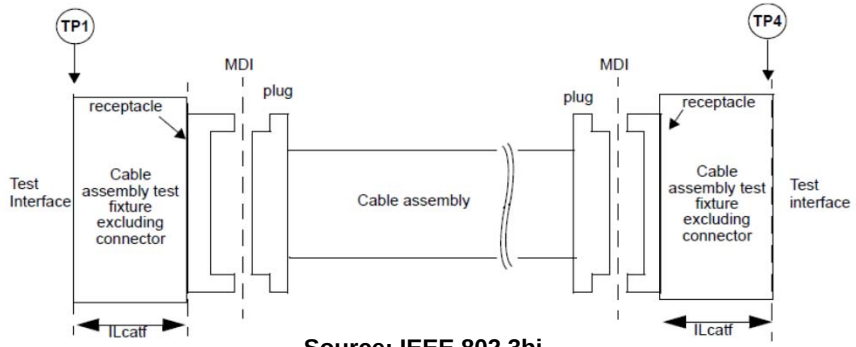
Parameter	Subclause reference	Value	Units
Differential peak-to-peak output voltage (max.) with Tx disabled	92.8.3.1	35	mV
DC common-mode voltage (max.)	92.8.3.1	1.9	V
AC common-mode output voltage, v_{cmi} (max., RMS)	92.8.3.1	30	mV
Differential peak-to-peak voltage, v_{di} (max.)	92.8.3.1	1200	mV
Differential output return loss (min.)	92.8.3.2	See Equation (92–1)	dB
Common-mode to differential mode output return loss (min.)	92.8.3.3	See Equation (92–2)	dB
Common-mode to common-mode output return loss (min.)	92.8.3.4	See Equation (92–3)	dB
Transmitter steady-state voltage, v_f (min.) Transmitter steady-state voltage, v_f (max.)	92.8.3.5.2	0.34 0.6	V
Linear fit pulse peak (min.)	92.8.3.5.2	0.45 × v_f	V
Transmitted waveform abs coefficient step size (min.) abs coefficient step size (max.) minimum precursor full-scale ratio minimum post cursor full-scale ratio	 92.8.3.5.4 92.8.3.5.4 92.8.3.5.5 92.8.3.5.5	 0.0083 0.05 1.54 4	
Signal-to-noise-and-distortion ratio (min.)	92.8.3.7	26	dB
Output jitter (max.) Even-odd jitter, peak-to-peak Effective bounded uncorrelated jitter, peak-to-peak Effective total uncorrelated jitter, peak-to-peak	 92.8.3.8.1 92.8.3.8.2 92.8.3.8.2	 0.035 0.1 0.18	 UI UI UI
Signaling rate, per lane	92.8.3.9	25.78125±100 ppm	GBd
Unit interval nominal	92.8.3.9	38.787879	ps

Transmitter characteristics at TP2 summary

Source: IEEE 802.3bj

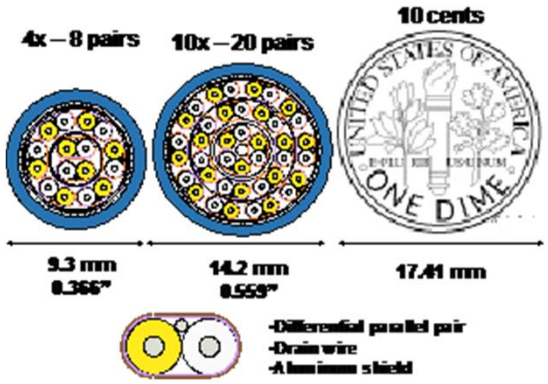
Cable Assembly Characteristics TP1/TP4

- The twinaxial copper cable assembly consists of shielded signal pairs utilized for differential signaling at 25 Gb/s per differential signal pair.



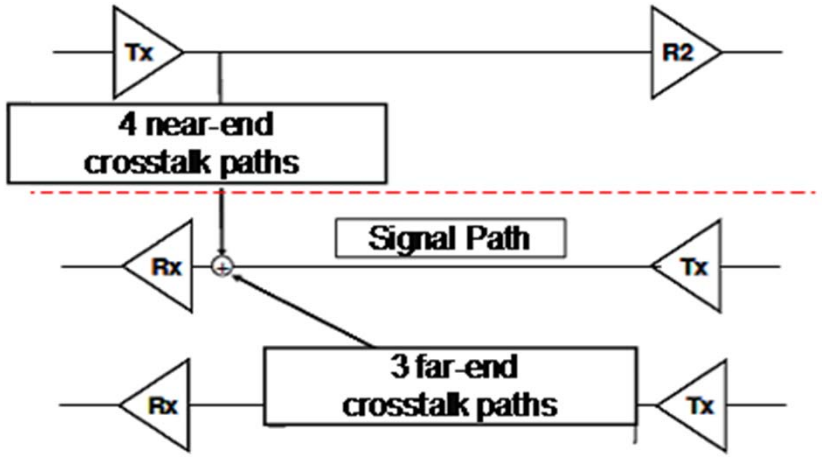
Source: IEEE 802.3bj

Parameter description	f(GHz)	Unit
Maximum Insertion Loss (22.48 dB)	@12.89 GHz	dB
Minimum Insertion Loss (8 dB @ 12.89 GHz	0.05≤f≤19	dB
Minimum Return Loss	0.05≤f≤19	dB
Differential to common-mode return loss	0.05≤f≤19	dB
Differential to common-mode conversion loss	0.05≤f≤19	dB
Common-mode to common –mode return loss	0.05≤f≤19	dB
Common-mode to common –mode return loss	0.05≤f≤19	dB
Cable assembly Channel Operating Margin (3 dB)		dB



Cable Assembly Channel (COM)

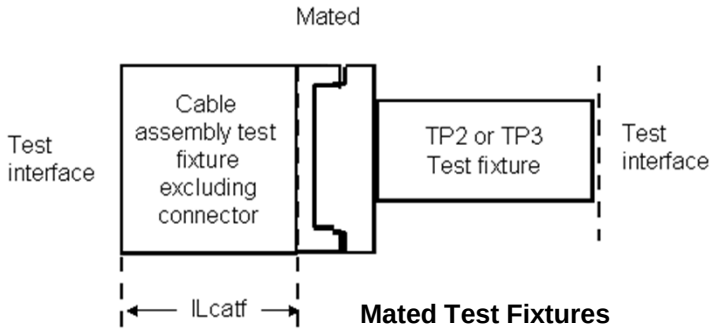
- The cable assembly Channel Operating Margin (COM) for each victim signal path (receive lane) is derived from measurements of the cable assembly victim signal path, the four individual near-end crosstalk paths, and the three far-end crosstalk paths that can couple into a victim signal path.



Cable assembly signal paths and crosstalk paths for COM

Test Fixture Specifications

- Test fixtures specified in a mated state used for testing the transmitter, the receiver and cable assembly measurements
  - The TP2/TP3 test fixture also known in the industry as Host Compliance Board (HCB) is required for measuring the transmitter specifications at TP2 and the receiver return loss at TP3.
  - The cable assembly test fixture also known in the industry as Module Compliance Board (MCB) is required for measuring the cable assembly specifications at TP1 and TP4.

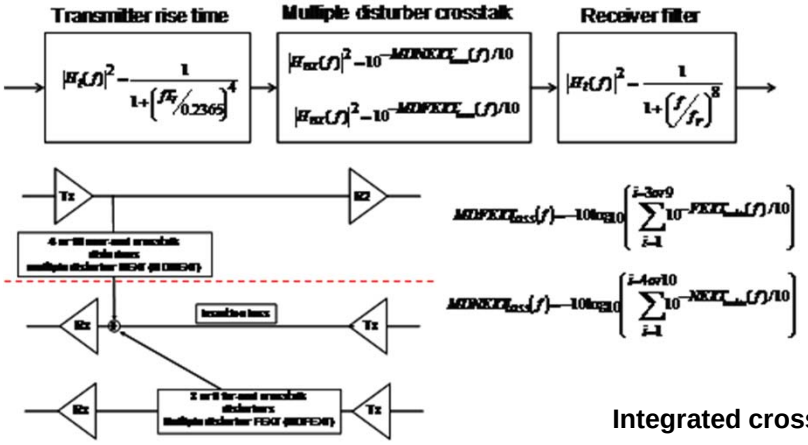


Mated Test Fixtures

Mated Test Fixtures Parameters

Parameter description	f(GHz)	Unit
Maximum insertion Loss	0.01≤f≤25	dB
Minimum Insertion Loss	0.01≤f≤25	dB
Minimum Return Loss	0.01≤f≤25	dB
Common-mode conversion insertion loss	0.01≤f≤25	dB
Common-mode return loss	0.01≤f≤25	dB
Common-mode to differential –mode return loss	0.01≤f≤25	dB
Integrated crosstalk noise		

Mated test fixtures parameters



Description	Symbol	Value	Units
Symbol rate	f_b	25.78125	GBd
Near-end disturber peak differential output amplitude	A_{nt}	600	mV
Far-end disturber peak differential output amplitude	A_{ft}	600	mV
Near-end disturber 20% to 80% rise and fall times	T_{nt}	9.6	ps
Far-end disturber 20% to 80% rise and fall times	T_{ft}	9.6	ps

Source: IEEE 802.3bj

Integrated crosstalk noise (ICN)

TP2/TP3 (HCB) HFSS Model

- TP2/TP3 (HCB) test fixture insertion loss specification of 1.35 dB @12.89 GHz yields an insertion loss of approximately 0.3 dB/in @12.89 GHz.
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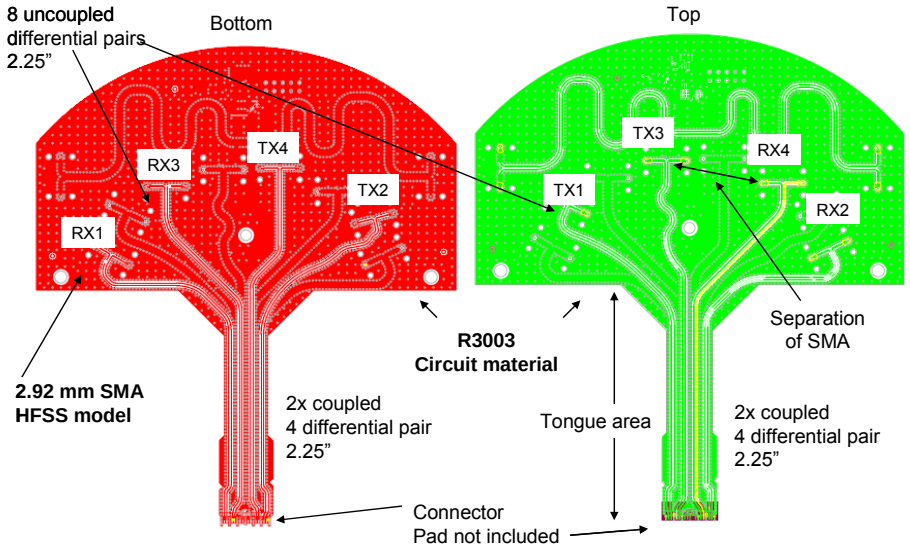
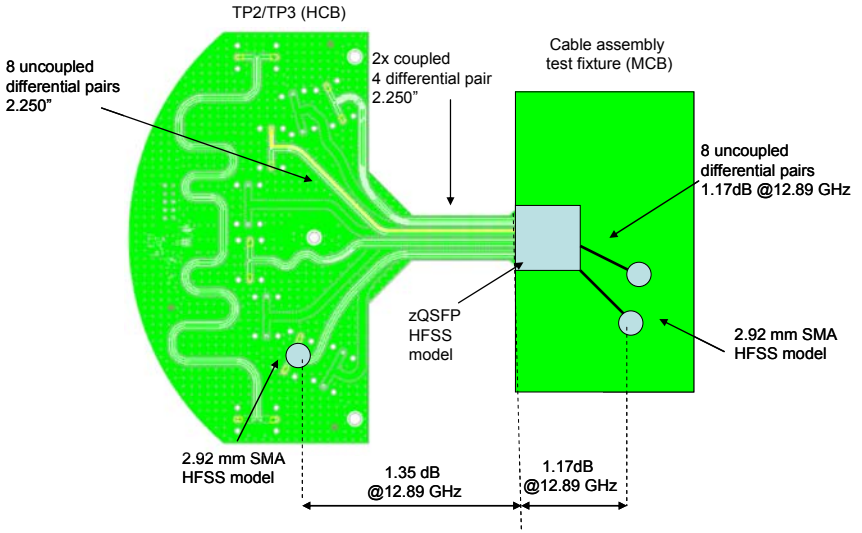
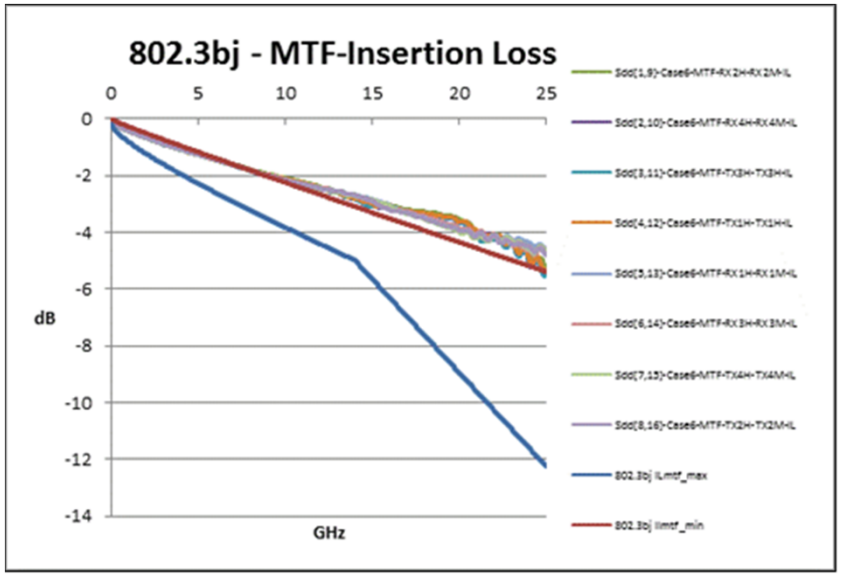
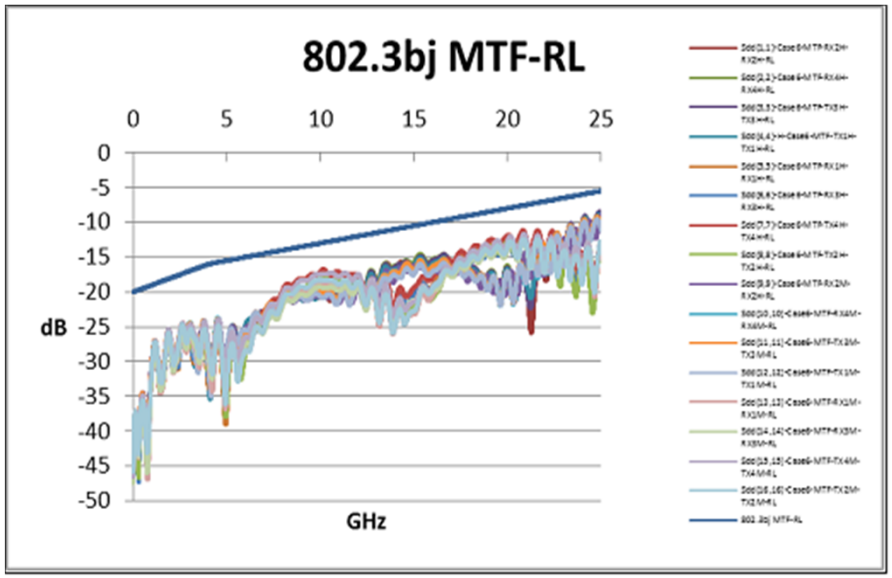




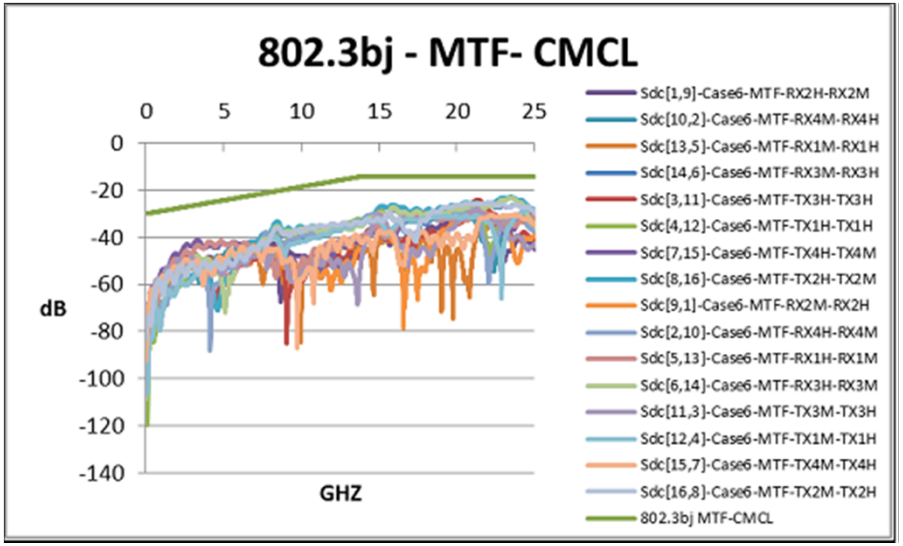
Mated test fixture HFSS model

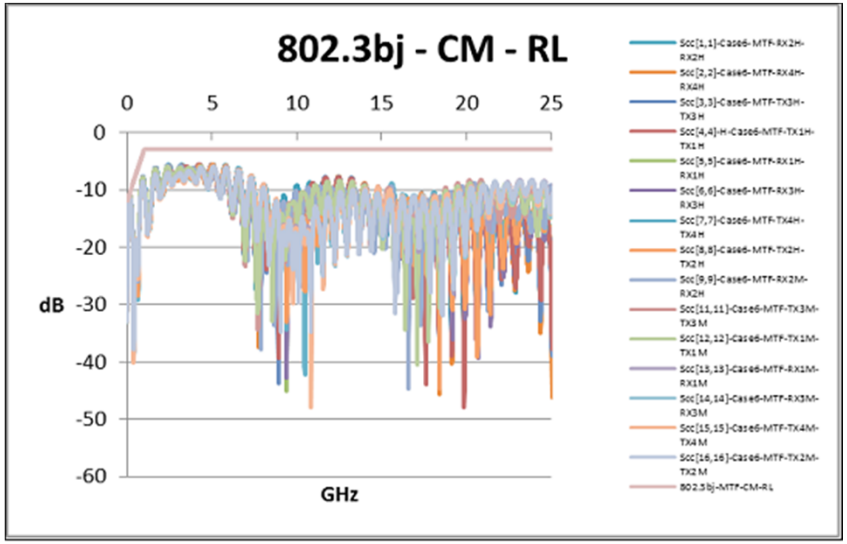
Mated Test Fixture – HFSS Model



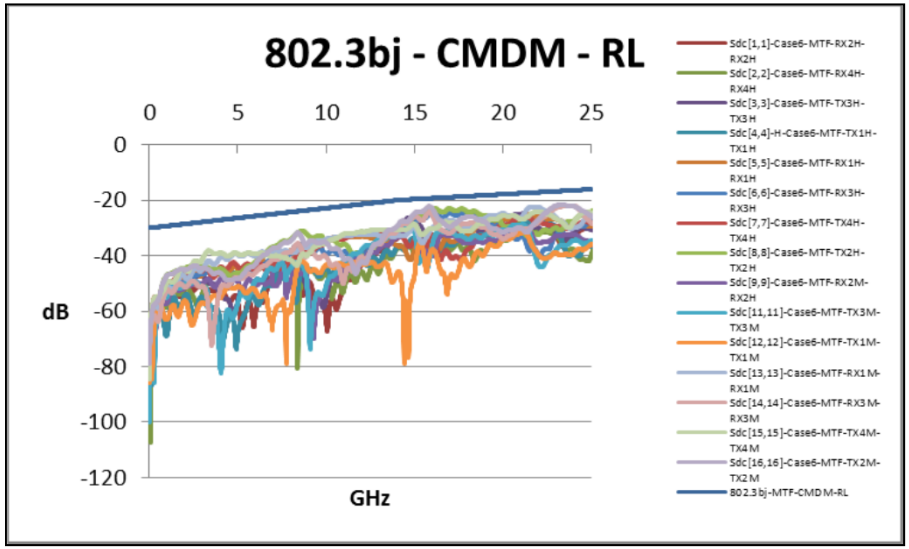


Mated Test Fixture – HFSS Model

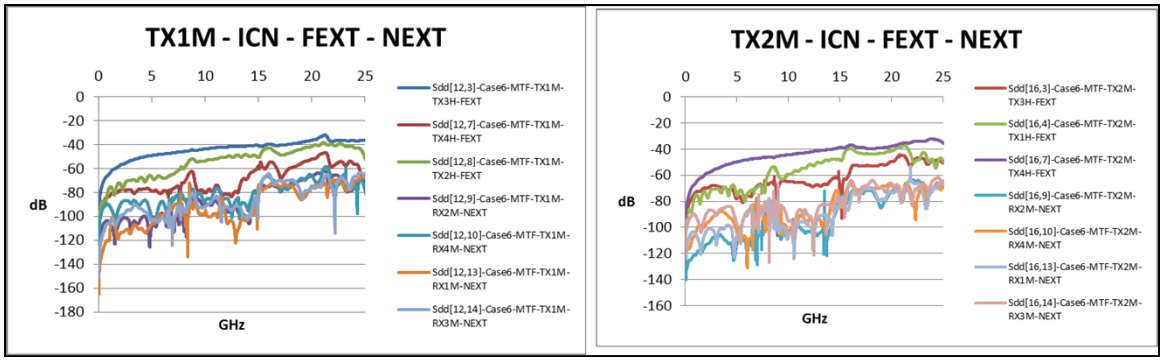


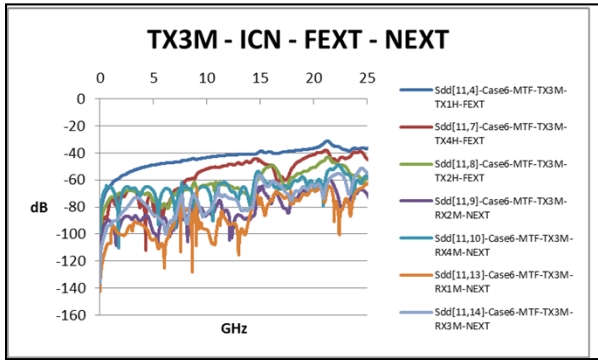


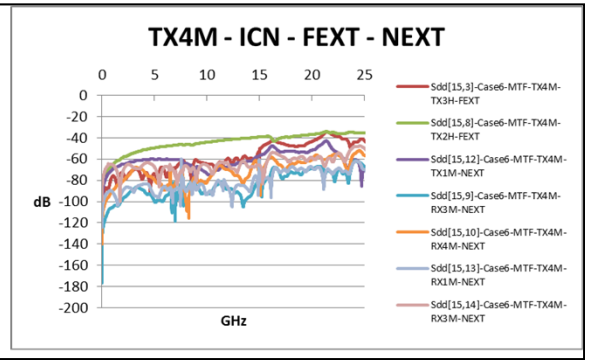
Mated Test Fixture – HFSS Model



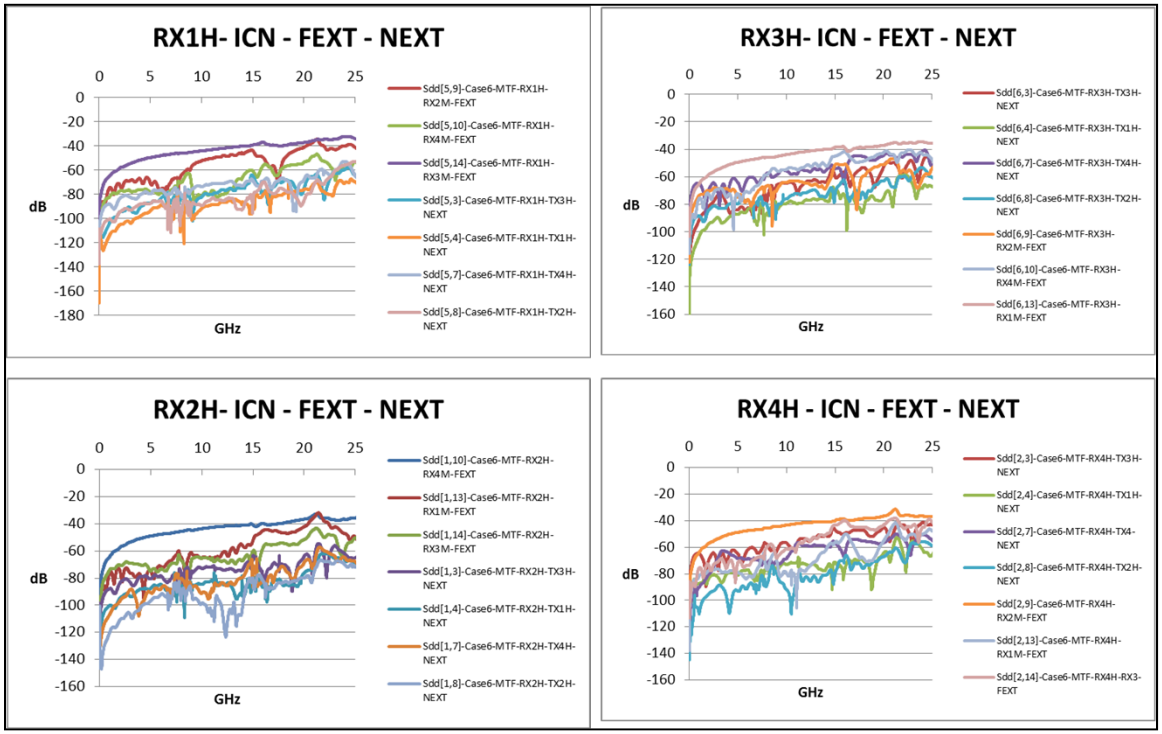
Mated Test Fixture – HFSS Model

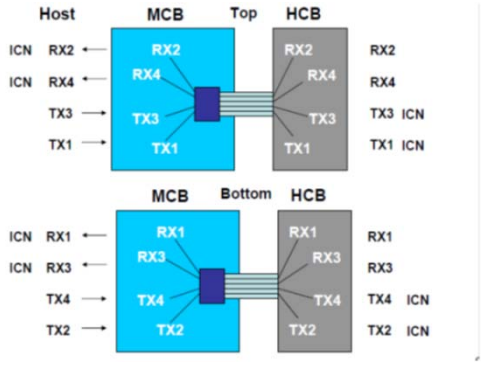






Mated Test Fixture – HFSS Model



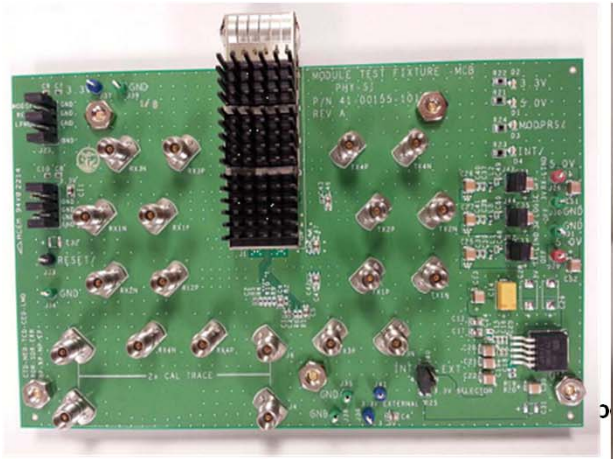


Parameter	100GBASE-CR4	Units
MDNEXT integrated crosstalk noise voltage	less than 1.8	mV
MDFEXT integrated crosstalk noise voltage	less than 4.8	mV

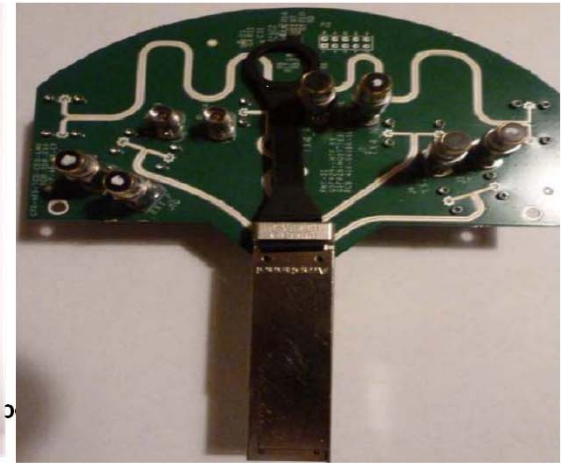
	RX1	RX2	RX3	RX4
MDNEXT ICN (mV)	0.11	0.10	0.73	0.81
MDFEXT ICN (mV)	2.91	2.80	2.95	3.01

	TX1	TX2	TX3	TX4
MDNEXT ICN (mV)	0.07	0.07	0.30	0.30
MDFEXT ICN (mV)	2.90	2.94	2.99	2.84

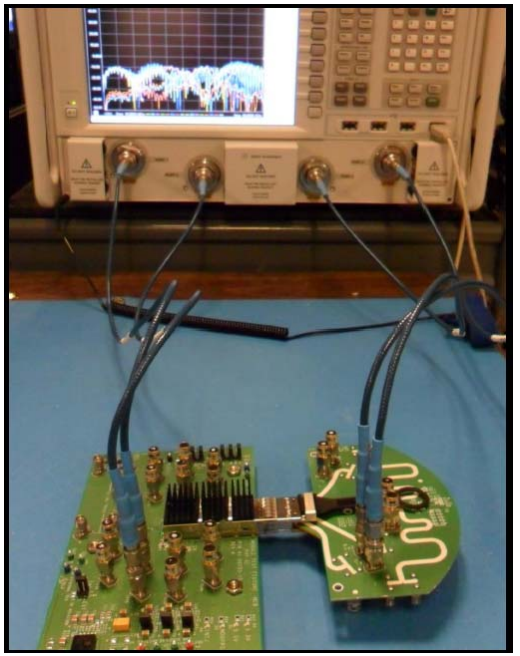
Test Fixtures



Module compliance board (MCB)
- •Cable assembly test fixture
- •Module test fixture
- •TP1 to TP4 test fixture

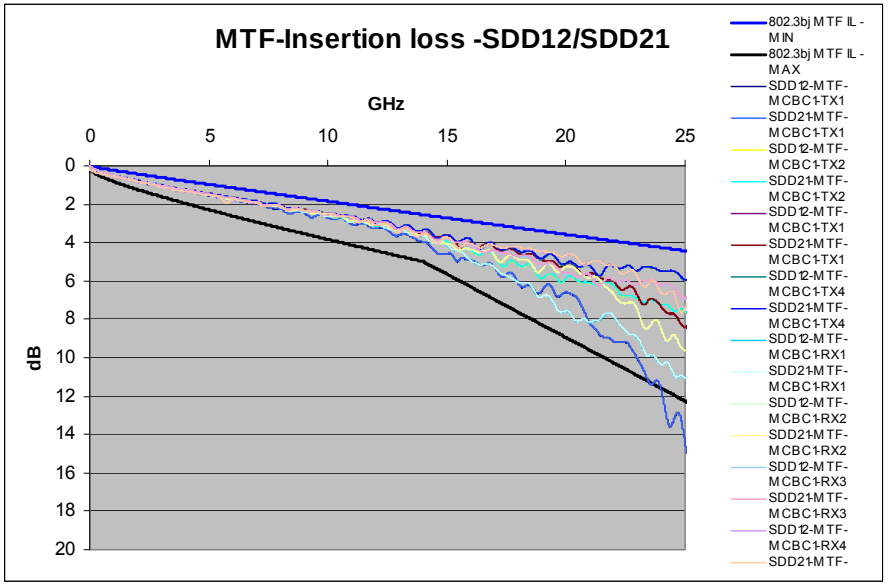


Host compliance board (HCB)
- •TP2 or TP3 Test Fixture



PHY-SI Mated test fixtures measured at University of New Hampshire Interoperability Test Lab (UNH-IOL)

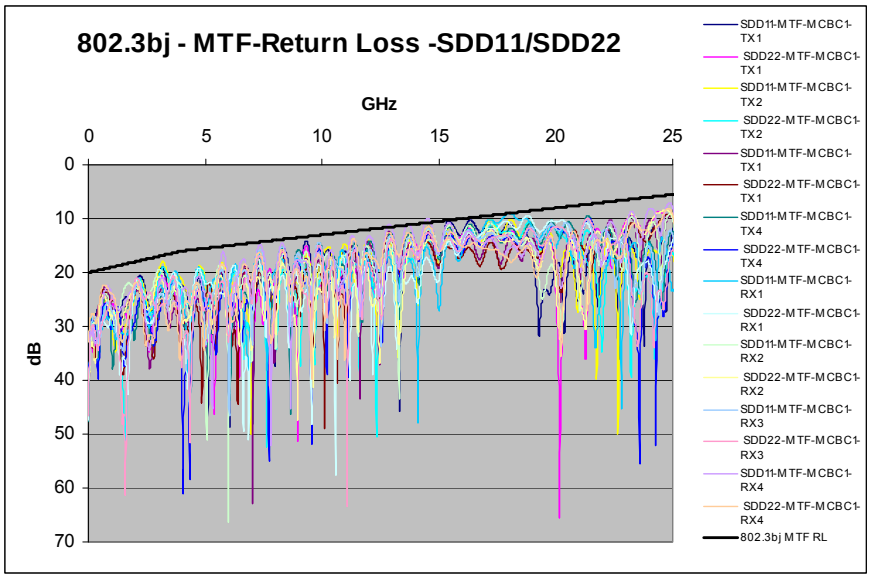
Mated Test Fixture – Measurements

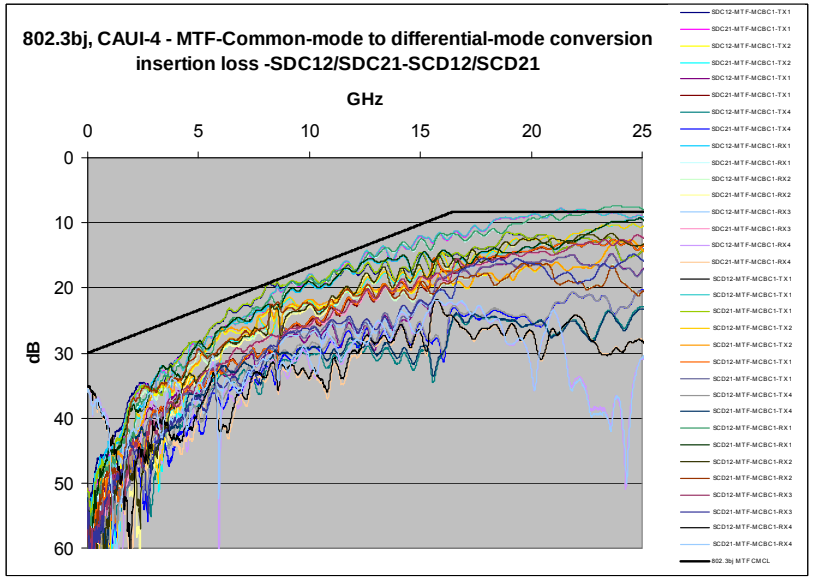


FOM_{ILD} is calculated according to 93A.4 with f_b=25.78125 GHz, T_t=9.6 ps, and f_r=0.75 × f_b. The fitted insertion loss and insertion loss deviation are computed over the range f_{min}=0.01 GHz to f_{max}=25 GHz. FOM_{ILD} shall be less than 0.13 dB.

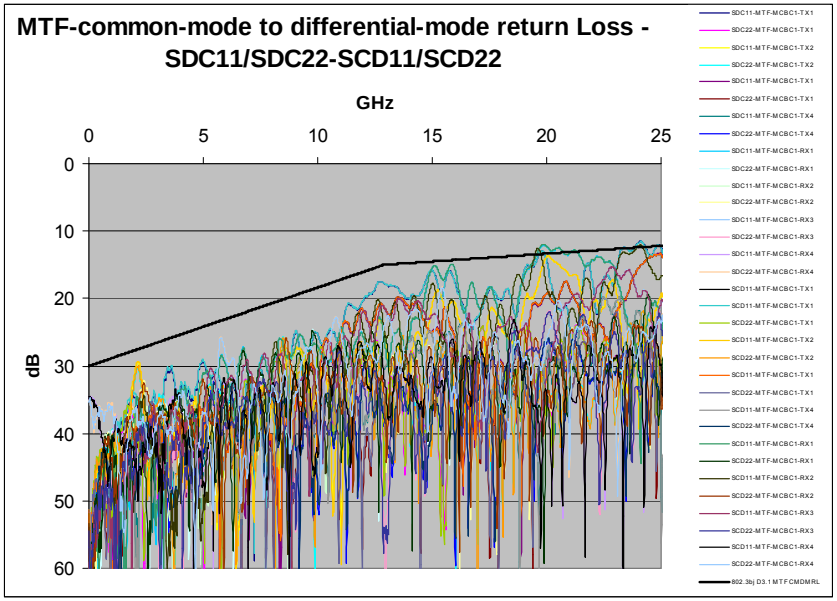
Lane	FOM_{ILD} (dB)
TX1	0.075
TX2	0.045
TX3	0.039
TX4	0.044
RX1	0.067
RX2	0.046
RX3	0.042
RX4	0.053

Mated Test Fixture – Measurements

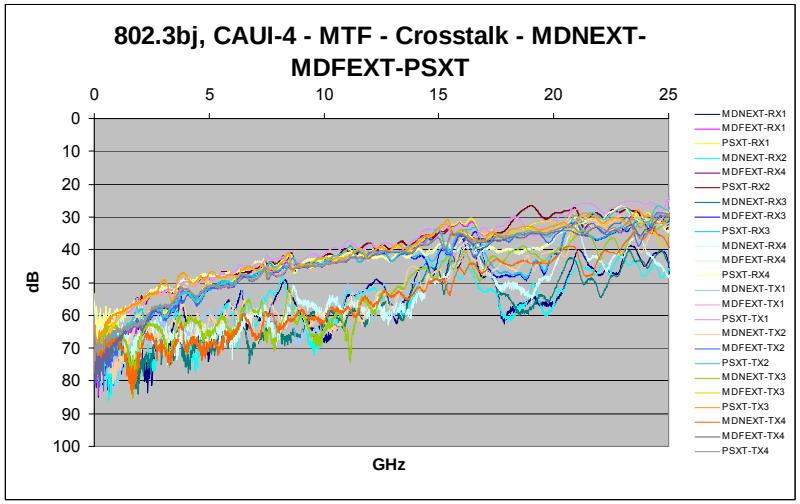


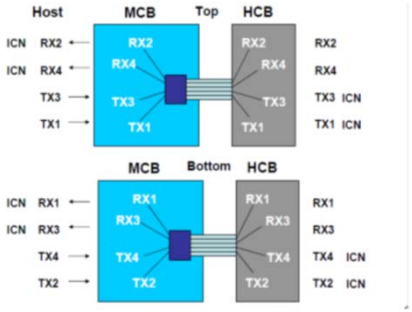


Mated Test Fixture – Measurements



Mated Test Fixture – Measurements





Description	Symbol	Value	Units
Symbol rate	f_b	25.78125	GBd
Near-end disturber peak differential output amplitude	A_{nt}	600	mV
Far-end disturber peak differential output amplitude	A_{ft}	600	mV
Near-end disturber 20% to 80% rise and fall times	T_{nt}	9.6	ps
Far-end disturber 20% to 80% rise and fall times	T_{ft}	9.6	ps

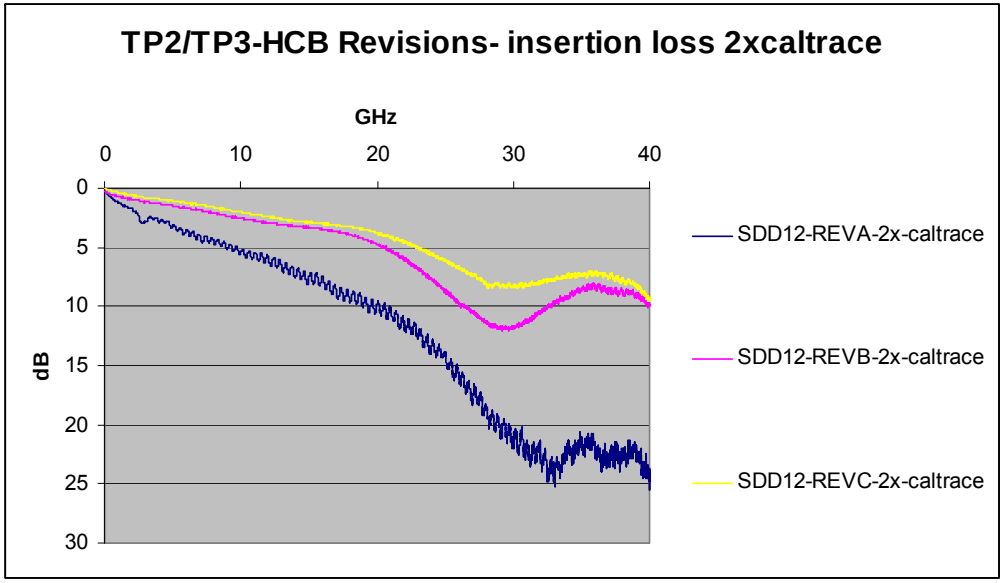
Parameter	100GBASE-CR4	Units
MDNEXT integrated crosstalk noise voltage	less than 1.8	mV
MDFEXT integrated crosstalk noise voltage	less than 4.8	mV

	RX1	RX2	RX3	RX4
MDNEXT ICN (mV)	1.08	0.95	1.00	0.95
MDFEXT ICN (mV)	3.72	4.09	2.77	3.01

	TX1	TX2	TX3	TX4
MDNEXT ICN (mV)	1.39	1.13	1.11	0.81
MDFEXT ICN (mV)	4.17	3.19	3.74	3.00

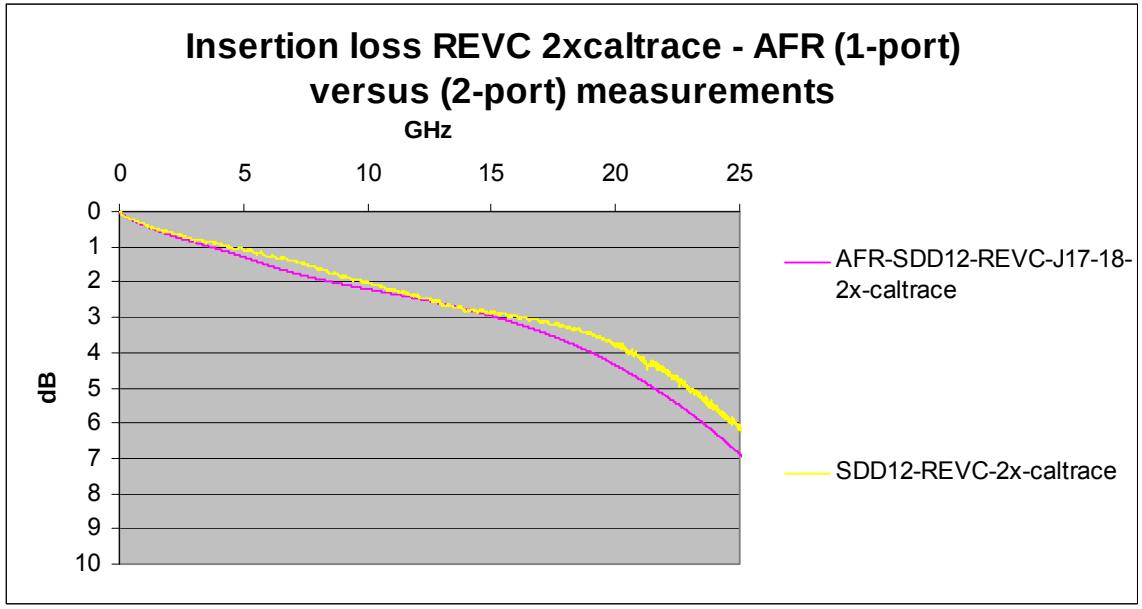
2x Calibration Trace – Measurements

- Three revisions of the PHY-SI TP2/TP3 HCB test fixture improvements; transmission line structure, PCB materials, plating over copper, differential and ground trace geometries, ground plane stitching symmetry, proximity of solder mask to differential trace placement and tightly controlled PCB fabrication tolerances.



Automatic Fixture Removal (AFR) Software

- Viability of open ended test fixture measurements (i.e., tested in an unmated state) was explored using Keysight's physical layer test software (PLTS) automatic fixture removal (AFR) software.



Summary

- Overview 100GBASE-CR4 test point specifications and test fixtures
- The achievability of meeting the 100GBASE-CR4 test fixture s-parameter specifications was demonstrated in HFSS models as well as by vector network analyzer measurements
- Test fixture measurement results were presented and compared to the s-parameter specification limits.
- Revisions of the PHY-SI TP2/TP3 HCB test fixture design depicting insertion loss improvements based on design attributes were illustrated.
- Considerations for the viability of open ended test fixture measurements (i.e., tested in an unmated state) was explored using Keysight's physical layer test software (PLTS) automatic fixture removal (AFR) software.

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