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# Considerations for NGOATH SG Copper Twinaxial Cables Reach Objectives

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# Purpose

- Considerations for copper twinaxial cables reach objectives consistent with adopted objectives
  - Define single-lane 50 Gb/s PHYs for operation
    - copper twinaxial cables.
    - printed circuit board backplane.
    - MMF with lengths up to at least 100m.
    - SMF with lengths up to at least 2km.
    - SMF with lengths up to at least 10km
  - Define 200 Gb/s PHYs for operation
    - copper twinaxial cables.
    - printed circuit board backplane.
    - MMF with lengths up to at least 100m.
  - Provide physical layer specifications which support 200 Gb/s operation over
    - At least 2 km SMF
    - At least 2 km SMF
  - Define a two lane 100 Gb/s PHY for operation over copper twinaxial cables.
  - Define a two lane 100 Gb/s PHY for operation over a printed circuit board backplane.
  - Define a two fiber 100 Gb/s PHY for operation over MMF with lengths up to at Least 100m

Source: [http://www.ieee802.org/3/50G/public/objectives\\_50G\\_NGOATH\\_01a\\_0116.pdf](http://www.ieee802.org/3/50G/public/objectives_50G_NGOATH_01a_0116.pdf)

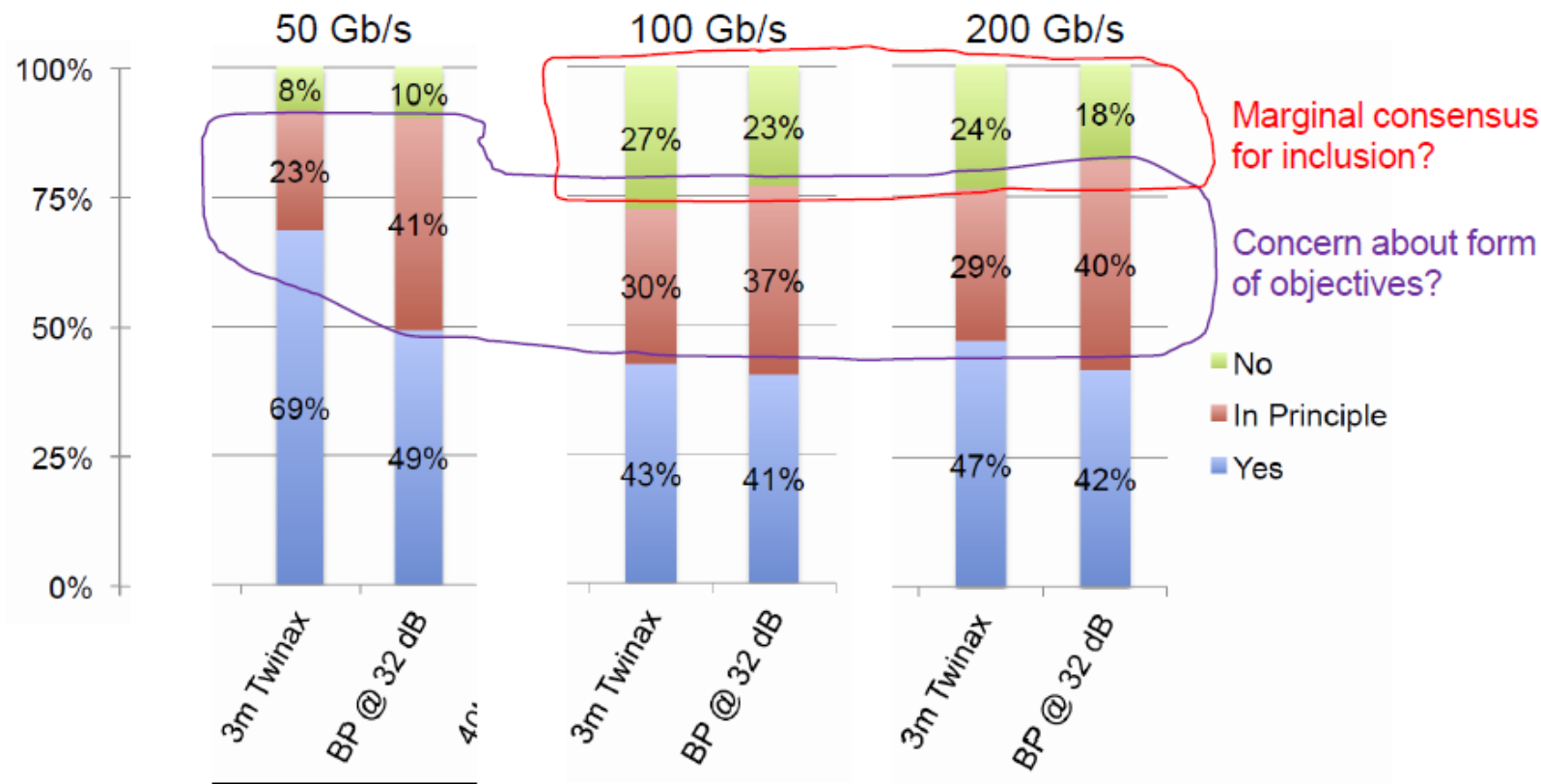
# Supporters

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- Erdem Matoglu – Amphenol
- Jon Lewis – Dell
- Scott Sommers – Molex

# Consensus survey monkey

- Survey monkey results were published from Mark Nowell.



from: [http://www.ieee802.org/3/50G/public/adhoc/archive/nowell\\_010616\\_50GE\\_NGOATH\\_adhoc.pdf](http://www.ieee802.org/3/50G/public/adhoc/archive/nowell_010616_50GE_NGOATH_adhoc.pdf)

# Consensus survey comments

<p><b>3m Twinax</b> → 50Gb/s no-FEC option for low-latency applications. → We should be open to a slightly shorter reach to ensure practicality. → need confirmation of technical feasibility</p> <p><b>Backplane</b> → The numbers 32 and 12.9 are wrong. Nyquist frequency for the likely encoding is approx. 13.3 GHz. The work done in OIF suggests that an insertion loss of 27-28 dB is the limit for reasonable PAM4 transceivers at this rate, far less than 32 dB. &lt;snip&gt; I intend to propose an objective for "PCB backplane consistent with a total insertion loss equivalent to 3m of Twinax cable". → Need technical feasibility data → I think an insertion loss in the range of 28 to 30dB is more realistic. → More detailed work on Channel loss → uncertain of the 32 dB limit.</p>	50 Gb/s
<p><b>3m Twinax</b> → need BMP data → We should be open to a slightly shorter reach to ensure practicality. → Only reach should be defined. Strongly recommend to consider high performance computing applications where latency is critical and Active cable may be needed.</p> <p><b>Backplane</b> → Adoption of a backplane objective is fine. It is not clear what an appropriate insertion loss target should be. → With serial 100 Gb/s not technically feasible it does not make sense to define 2x50G Cu → technical feasibility and should mirror 50G objective. → uncertain of the 32 dB limit.</p>	100 Gb/s
<p><b>3m Twinax</b> → I see no reason to define a 200G copper PMD at this point in time. The primary purpose for such PMDs would be to connect servers to TOR switches... → We should be open to a slightly shorter reach to ensure practicality. → Only reach should be defined. Strongly recommend to consider high performance computing applications where latency is critical and Active cable may be needed.</p> <p><b>Backplane</b> → The numbers 32 and 12.9 are wrong. Nyquist frequency for the likely encoding is approx. 13.3 GHz. The work done in OIF suggests that an insertion loss of 27-28 dB is the limit for reasonable PAM4 transceivers at this rate, far less than 32 dB. &lt;snip&gt; I intend to propose an objective for "PCB backplane consistent with a total insertion loss equivalent to 3m of Twinax cable". → Same reason as above. I see no need for a 200GE backplane interface at this point in time → I think an insertion loss in the range of 28 to 30dB is more realistic. → More detailed work on Channel loss → uncertain of the 32 dB limit.</p>	200 Gb/s

Observation: Common theme is concern for choice of backplane insertion loss number.

from: [http://www.ieee802.org/3/50G/public/adhoc/archive/nowell\\_010616\\_50GE\\_NGOATH\\_adhoc.pdf](http://www.ieee802.org/3/50G/public/adhoc/archive/nowell_010616_50GE_NGOATH_adhoc.pdf)

# Copper twinaxial cables objectives

- Considerations for copper twinaxial cables reach objectives consistent with adopted objectives
  - Define single-lane 50 Gb/s PHYs for operation over
    - copper twinaxial cables.
  - Define a two lane 100 Gb/s PHY for operation over copper twinaxial cables.
  - Define 200 Gb/s PHYs for operation over
    - copper twinaxial cables.
- 802.3by Adopted and approved Objective
  - Define a single-lane 25 Gb/s PHY for operation over links consistent with copper twin axial cables, with lengths up to at least 3m
- Considerations for copper twinaxial cables reach objectives consistent with adopted objectives
  - Define single-lane 50 Gb/s PHYs for operation over links consistent with copper twin axial cables with lengths up to at least 3 m.
  - Define two-lane 100 Gb/s PHYs for operation over links consistent with copper twin axial cables with lengths up to at least 3 m.
  - Define four-lane 200 Gb/s PHYs for operation over links consistent with copper twin axial cables with lengths up to at least 3 m.

# Copper twinaxial cables objectives

- Length considerations predicated on development of channel insertion loss budget
- Example 802.3by insertion loss

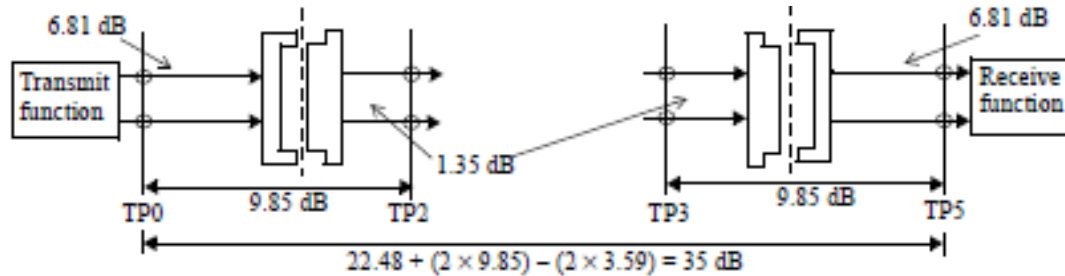


Table 110A-1—Cable insertion loss budget values at 12.8906 GHz

Parameter	CA-25G-L	CA-25G-S	CA-25G-N	Units
$IL_{Clmax}$	35	29	28.02	dB
$IL_{Curmax}$	22.48	16.48	15.50	dB
$IL_{Ch0.5m}$	20.52			dB
$IL_{Curin}$	8			dB
$IL_{Host}$	9.85			dB
$IL_{MatedITF}$	3.59			dB

# 8 x 50 Gb/s PAM-4

- Leverage of industry investment

Technology	Nomenclature	Description	Status
Backplanes	100GBASE-KP4 & KR4 CEI-56G-LR-PAM4	4 x 25 Gb/s backplane 56 Gb/s PAM4	IEEE 802.3bj Published Straw Ballot
Chip-to-Module	CDAUI-8 CEI-56G-VSR-PAM4	8 x 50 Gb/s PAM4 60 Gb/s PAM4	IEEE P802.3bs in Task Force Rev Straw Ballot
Chip-to-Chip	CDAUI-8 CEI-56G-MR-PAM4	8 x 50 Gb/s PAM4 60 Gb/s PAM4	IEEE P802.3bs in Task Force Rev Straw Ballot
SMF Optical	400GBASE-FR8 & LR8 400GBASE-DR4	8 x 50 Gb/s PAM4 4 x 100 Gb/s PAM4	IEEE P802.3bs in Task Force Review
Module Form Factor	SFP56	1 x 50 Gb/s	Extension to Summary Document SFF-8402
	QSFP56	4 x 50 Gb/s	Extension to Summary Document SFF-8665

[http://www.ieee802.org/3/cfi/1115\\_1/CFI\\_01\\_1115.pdf](http://www.ieee802.org/3/cfi/1115_1/CFI_01_1115.pdf)



# CAUI/CDAUI chip-to-module interfaces

- CAUI-4 signaling rate for each lane is 25.78125 GBd<sup>1</sup>.

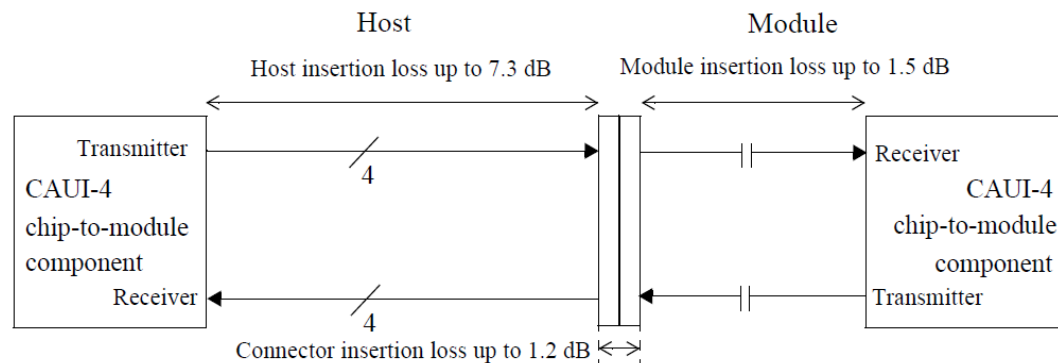


Figure 83E-2—Chip-to-module insertion loss budget at 12.89 GHz

- CDAUI-8 signaling rate for each lane is 26.5625 GBd<sup>2</sup>

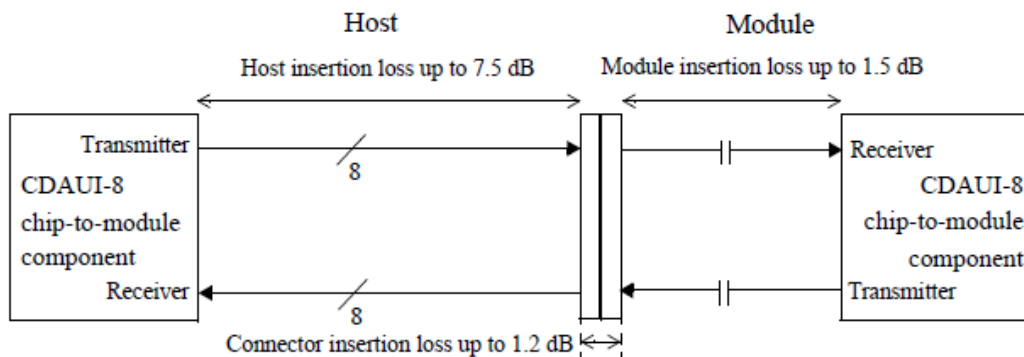


Figure 120E-2—Chip-to-module insertion loss budget at 13.28 GHz

[1] using spec similar to CEI-28G-VSR, [2] using spec similar to CEI-56G-VSR-PAM

# Host Channels

- CAUI-4 signaling rate for each lane is 25.78125 GBd<sup>1</sup>.

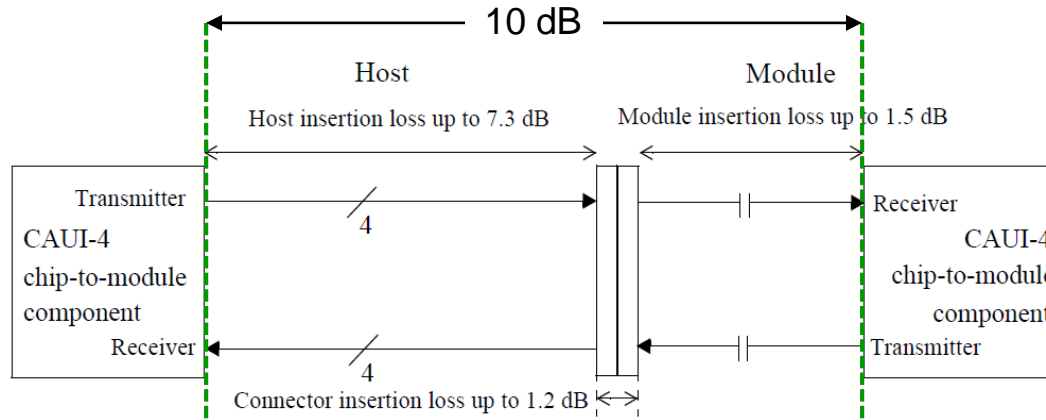


Figure 83E-2—Chip-to-module insertion loss budget at 12.89 GHz

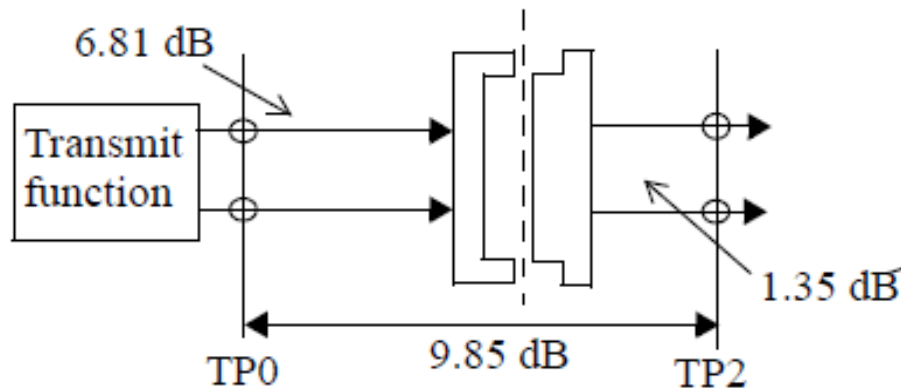
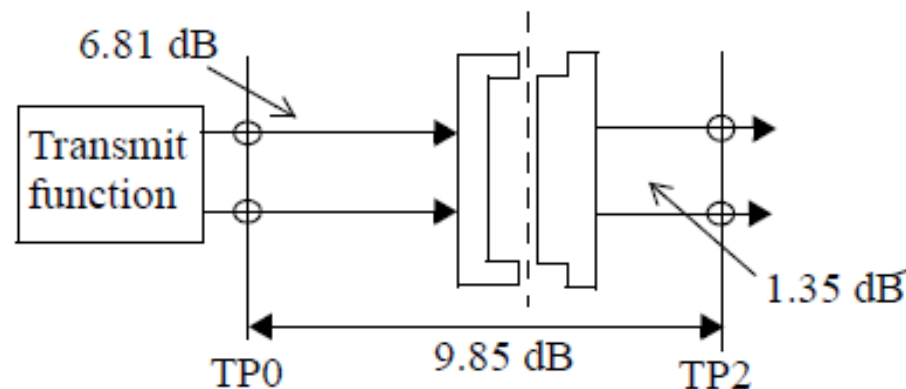


Figure 110A-1—Host Loss budget at 12.8906 GHz

[1] using spec similar to CEI-28G-VSR, [2] using spec similar to CEI-56G-VSR-PAM

# Tx/RX PCB and Test Fixture PCB - Baseline

- Transmitter and receiver differential printed circuit board trace loss (with IL @ 13.28GHz)
  - Specified in 92A.4 EQ(92A-1 and 92A-2)– referenced 110A.4
- Test fixture printed circuit board reference insertion loss (with IL @ 13.28 GHz)
  - Specified in 92.11 EQ(92-35) – referenced 110B.1.1



Host Loss budget at 12.8906 GHz

# Transmitter and receiver differential PCB IL

- IL @ 13.28 GHz

$$IL_{PCB}(f) \leq IL_{PCBmax}(f) = 0.5(0.0694 + 0.4248\sqrt{f} + 0.9322f) \quad (dB) \quad (1)$$

for  $0.01 \text{ GHz} \leq f \leq 19 \text{ GHz}$ .

$$IL @ 12.89 \text{ GHz} = 6.81 \text{ dB}$$

$$IL @ 13.28 \text{ GHz} = 7.00 \text{ dB}$$

where

$f$  is the frequency in GHz

$IL_{PCB}(f)$  is the insertion loss for the transmitter and receiver PCB

$IL_{PCBmax}(f)$  is the recommended maximum insertion loss for the transmitter and receiver PCB

$$IL_{PCB}(f) \geq IL_{PCBmin}(f) = 0.086(0.0694 + 0.4248\sqrt{f} + 0.9322f) \quad (dB)$$

for  $0.01 \text{ GHz} \leq f \leq 19 \text{ GHz}$ .

$$IL @ 12.89 \text{ GHz} = 1.17 \text{ dB}$$

$$IL @ 13.28 \text{ GHz} = 1.20 \text{ dB}$$

where

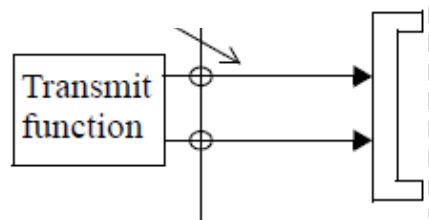
$f$  is the frequency in GHz

$IL_{PCB}(f)$  is the insertion loss for the transmitter and receiver PCB

$IL_{PCBmin}(f)$  is the minimum insertion loss for the transmitter and receiver PCB

$$IL @ 12.89 \text{ GHz} = \text{Max } 6.81 \text{ dB}$$

$$= \text{Min } 1.17 \text{ dB}$$



# Test fixtures PCB insertion loss

$$IL_{tfr_{ref}}(f) = -0.00144 + 0.13824\sqrt{f} + 0.06624 f \quad (\text{dB})$$

for  $0.01 \leq f \leq 25$  GHz

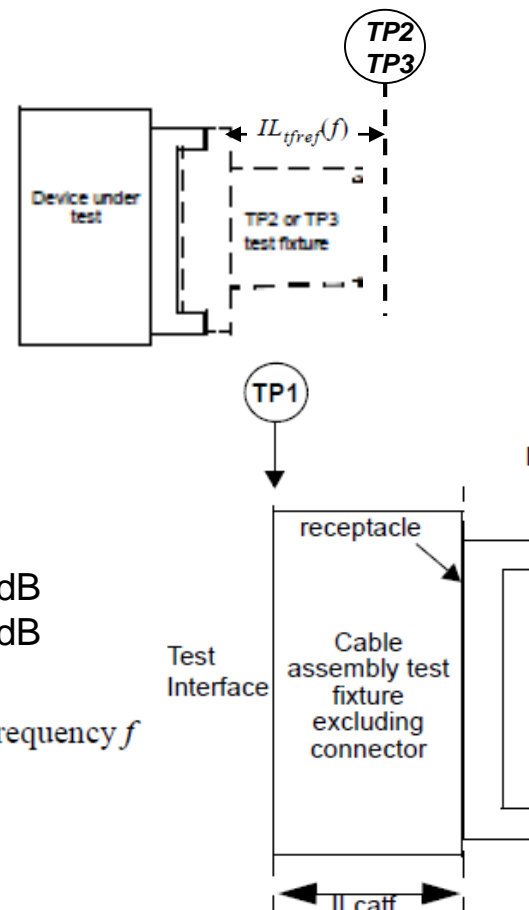
IL @ 12.89 GHz = 1.35 dB

where

IL @ 13.28 GHz = 1.38 dB

$f$  is the frequency in GHz

$IL_{tfr_{ref}}(f)$  is the reference test fixture PCB insertion loss at frequency  $f$



$$IL_{catf}(f) = -0.00125 + 0.12\sqrt{f} + 0.0575f \quad (\text{dB})$$

for  $0.01 \text{ GHz} \leq f \leq 25 \text{ GHz}$

where

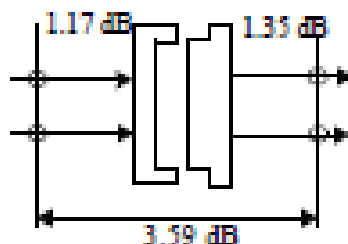
IL @ 12.89 GHz = 1.17 dB

IL @ 13.28 GHz = 1.20 dB

$f$  is the frequency in GHz

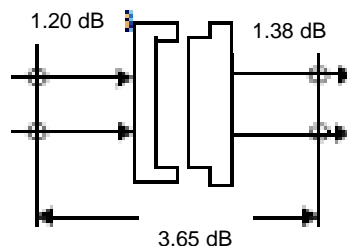
$IL_{catf}(f)$  is the reference test fixture printed circuit board insertion loss at frequency  $f$

IL @ 12.89 GHz



Mated cable assembly  
and test point test fixture

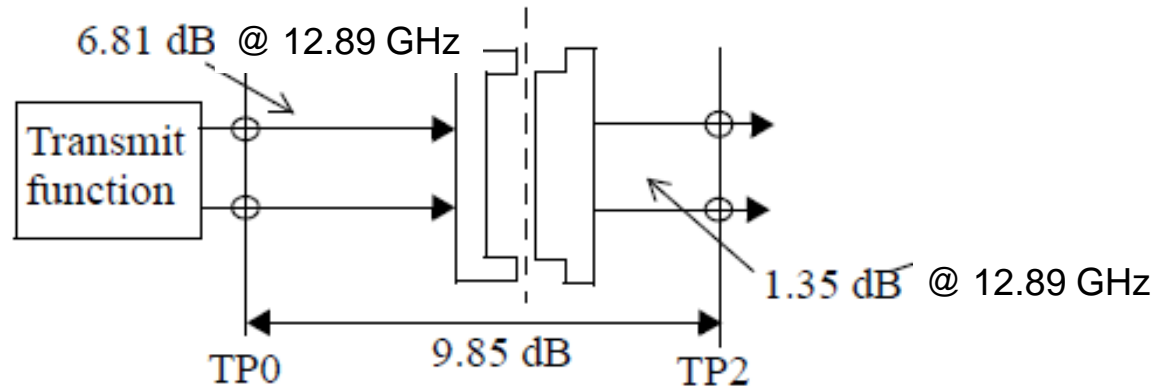
IL @ 13.28 GHz



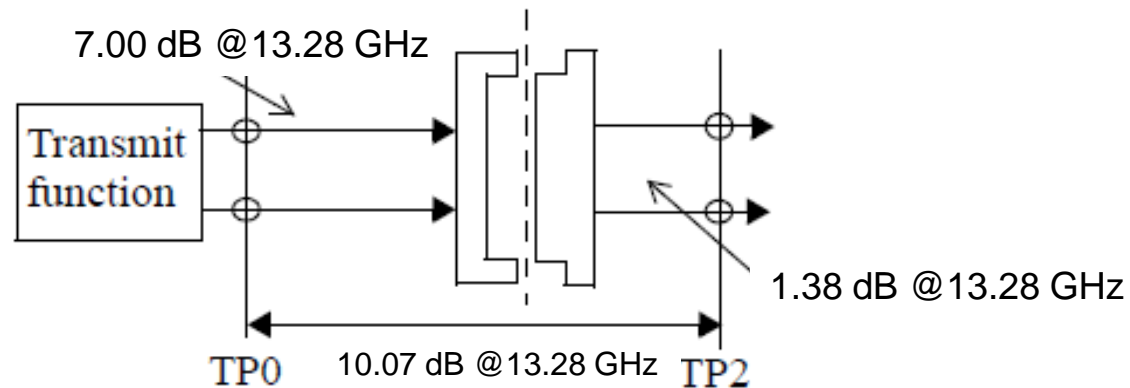
Mated cable assembly  
and test point test fixture

NOTE—The connector insertion loss is 1.07 dB for the mated test fixture. The host connector is allocated 0.62 dB of additional margin.

# Host Channel – Baseline



NOTE—The connector insertion loss is 1.07 dB for the mated test fixture. The host connector is allocated 0.62 dB of additional margin. IL host connector @ 12.89 GHz =  $9.85 - 6.81 - 1.35 = 1.69$  dB



# IEEE 802.3bj: 100GBASE-CR4 Specifications

## Host Tx and Rx PCB losses

- Transmitter and receiver differential printed circuit board trace loss

GHz	dB/in
1	0.1856
6.5	0.8971
7	0.9557
12.89	1.5924
14	1.702

Attenuation* (dB/in) at:	1 GHz	6.5 GHz	7 GHz	12.89 GHz	14 GHz
Meg6_LowSR – Wide	0.0951	0.4159	0.4433	0.7562	0.8127
Meg6_LowSR – Narrow	0.1466	0.5849	0.6205	1.0152	1.0847
Meg6_HighSR – Wide	0.1175	0.5960	0.6367	1.0891	1.1688
Meg6_HighSR – Narrow	0.1856	0.8971	0.9557	1.5924	1.7020
ImpFR4_LowSR – Wide	0.1202	0.6096	0.6541	1.1772	1.2734
ImpFR4_LowSR – Narrow	0.1717	0.7794	0.8323	1.4410	1.5512
ImpFR4_HighSR – Wide	0.1427	0.7904	0.8484	1.5158	1.6367
ImpFR4_HighSR – Narrow	0.2106	1.0930	1.1692	2.0283	2.1813

\*using Algebraic Model v2.02a – see backup slides for values entered in Model

PROPOSED PARAMETERS;  
GRAPHS ON PREVIOUS SLIDE

Proposal for Defining  
Material Loss

26-Jan 12

Elizabeth  
Kochuparambil  
Joel Goergen

Cisco

[http://www.ieee802.org/3/bj/public/jan12/kochuparambil\\_01a\\_0112.pdf](http://www.ieee802.org/3/bj/public/jan12/kochuparambil_01a_0112.pdf)

12

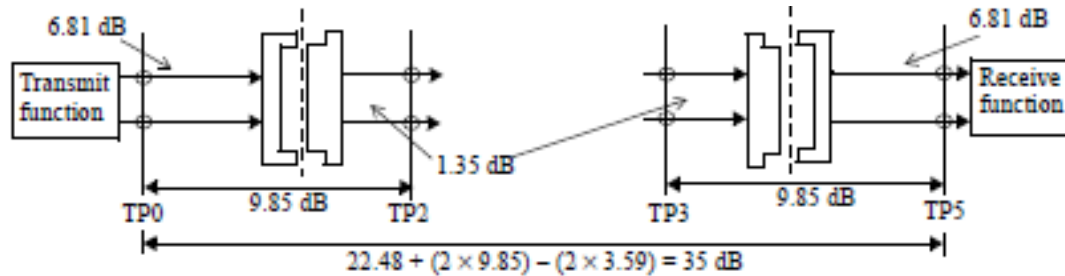
802.3bj Cu specifications

[http://www.ieee802.org/3/bj/public/may12/diminico\\_01a\\_0512.pdf](http://www.ieee802.org/3/bj/public/may12/diminico_01a_0512.pdf)

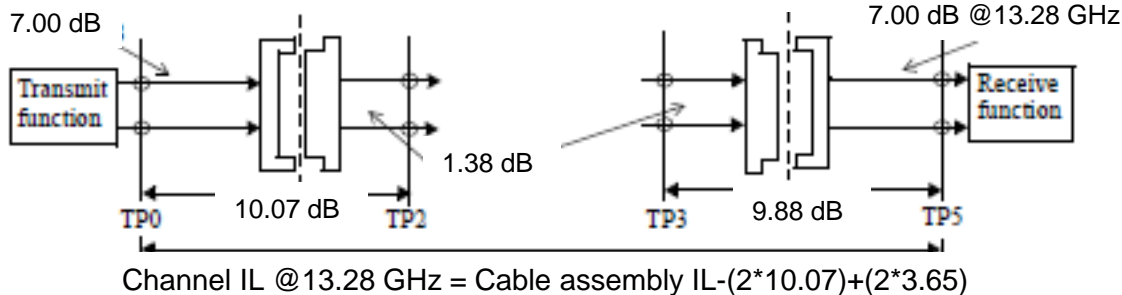
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# Channel Insertion Loss



Channel IL @ 12.89 GHz = Cable assembly IL - (2\*9.85) + (2\*3.59)



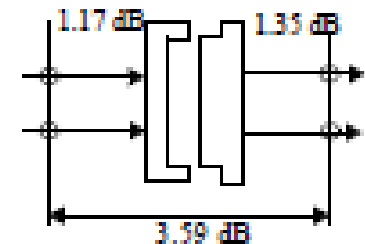
Channel IL @ 13.28 GHz = Cable assembly IL - (2\*10.07) + (2\*3.65)

NOTE—The connector insertion loss is 1.07 dB for the mated test fixture. The host connector is allocated 0.62 dB of additional margin.

Table 110A-1—Cable insertion loss budget values at 12.8906 GHz

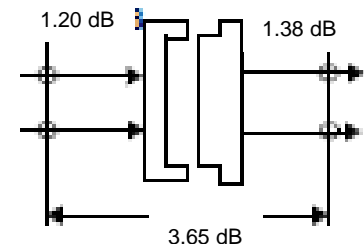
Parameter	CA-25G-L	CA-25G-S	CA-25G-N	Units
$IL_{Climax}$	35	29	28.02	dB
$IL_{Cmin}$	22.48	16.48	15.50	dB
$IL_{Ch0.5m}$		20.52		dB
$IL_{Cmin}$		8		dB
$IL_{Host}$		9.85		dB
$IL_{MatedITF}$		3.59		dB

IL @ 12.89 GHz



Mated cable assembly and test point test fixture

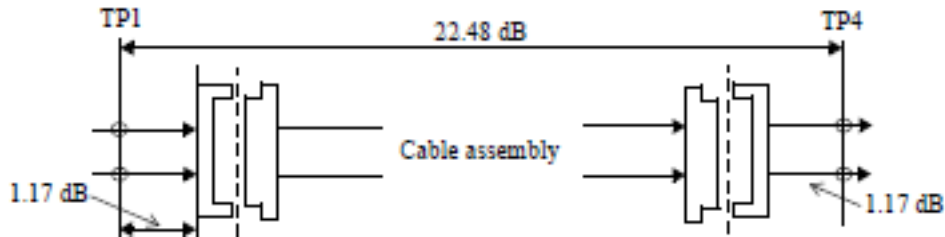
IL @ 13.28 GHz



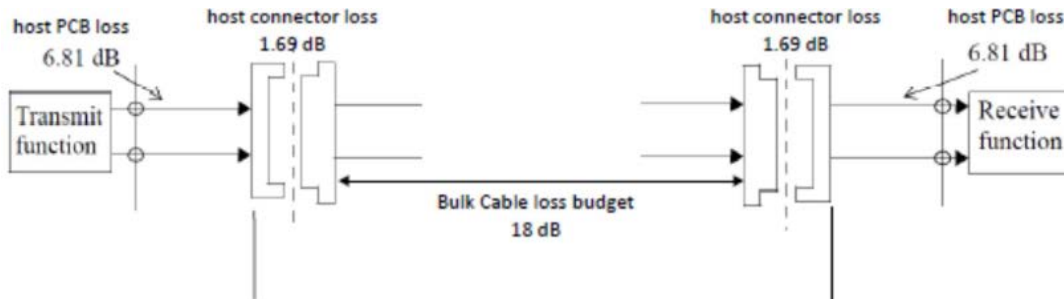
Mated cable assembly and test point test fixture



# Cable Assembly Insertion Loss



Bulk cable assumed = Cable assembly IL - (2\*1.17) + (2\*1.07)



Bulk cable assumed = Channel IL - (2\*6.81) + (2\*1.69)

□

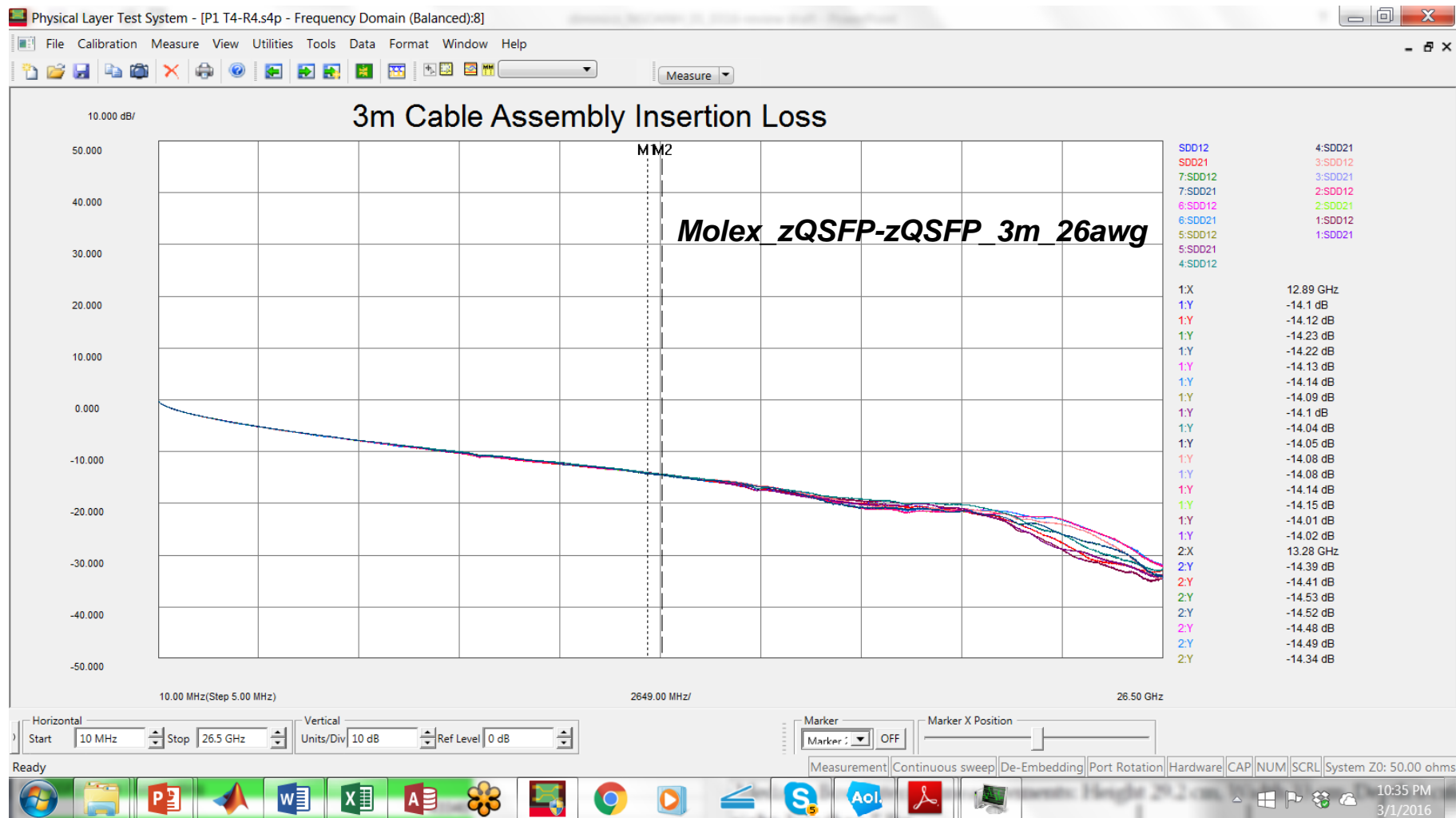
NOTE—The connector insertion loss is 1.07 dB for the mated test fixture. The host connector is allocated 0.62 dB of additional margin.

Channel IL (dB)@ 12.98 GHz	Cable assembly IL (db)@ 12.89 GHz	Bulk cable dB @ 12.89 GHz
27.0	14.48	10.00
27.5	14.98	10.50
28.0	15.48	11.00
28.02	15.50	11.02
28.5	15.98	11.50
29.0	16.48	12.00
29.5	16.98	12.50
30.0	17.48	13.00
30.5	17.98	13.50
31.0	18.48	14.00
31.5	18.98	14.50
32.0	19.48	15.00
32.5	19.98	15.50
33.0	20.48	16.00
33.5	20.98	16.50
34.0	21.48	17.00
34.5	21.98	17.50
35.0	22.48	18.00

Table 110A-1—Cable insertion loss budget values at 12.8906 GHz

Parameter	CA-25G-L	CA-25G-S	CA-25G-N	Units
$IL_{Channel}$	35	29	28.02	dB
$IL_{Cable}$	22.48	16.48	15.50	dB
$IL_{Ch0.5m}$	20.52			dB
$IL_{Cablein}$	8			dB
$IL_{Host}$	9.85			dB
$IL_{MatedITF}$	3.59			dB

# NGOATH Contributed Channel Data



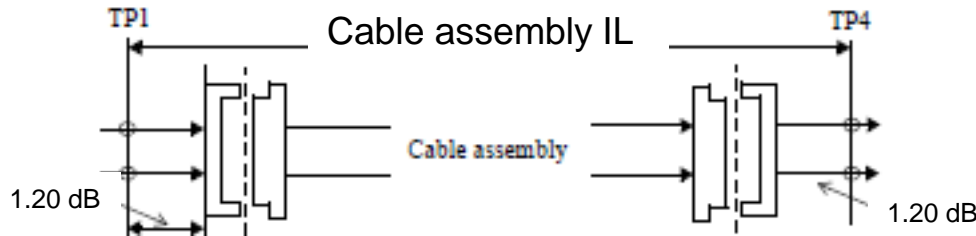
<http://www.ieee802.org/3/50G/public/channel/index.html>

Molex\_zQSFP-zQSFP\_3m\_26awg

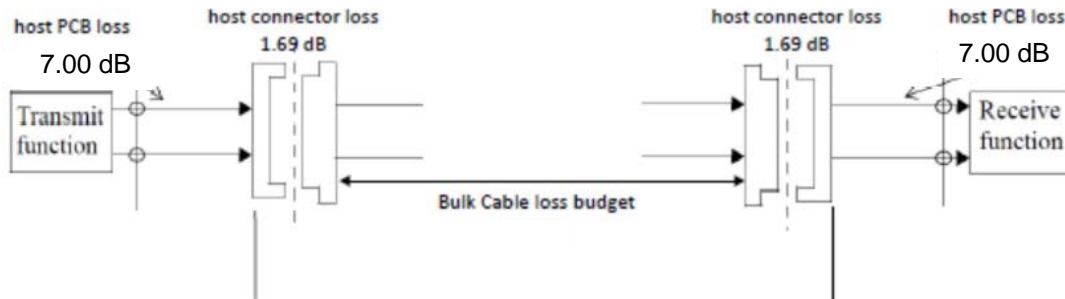
802.3 NGOATH Study Group

# Objectives Proposal - starting point (3 m cable assembly)

- Consistent with technical feasibility copper channel loss budget presentations NGOATH/OIF
- Consistent with NGOATH contributed channel data



Bulk cable assumed @ 13.28 GHz = Cable assembly IL - (2\*1.20) + (2\*1.07)



Bulk cable assumed @ 13.28 GHz = Channel IL - (2\*7) + (2\*1.69)

Bulk cable assumed @ 13.28 GHz = Channel IL - (2\*7) + (2\*1.69)

NOTE—The connector insertion loss is 1.07 dB for the mated test fixture. The host connector is allocated 0.62 dB of additional margin.

Channel IL (dB) @ 13.28 GHz	Cable assembly IL (db) @ 13.28 GHz	Bulk cable dB @ 13.28 GHz
27.0	14.16	9.62
27.5	14.66	10.12
28.0	15.16	10.62
28.5	15.66	11.12
29.0	16.16	11.62
29.5	16.66	12.12
30.0	17.16	12.62
30.5	17.66	13.12
31.0	18.16	13.62
31.5	18.66	14.12
32.0	19.16	14.62
32.5	19.66	15.12
33.0	20.16	15.62
33.5	20.66	16.12
34.0	21.16	16.62
34.5	21.66	17.12
35.0	22.16	17.62

# Cable Assembly – Baseline

- Cable assembly - consistent with CL92 and CL110 – referenced parameters @ 13.28 GHz

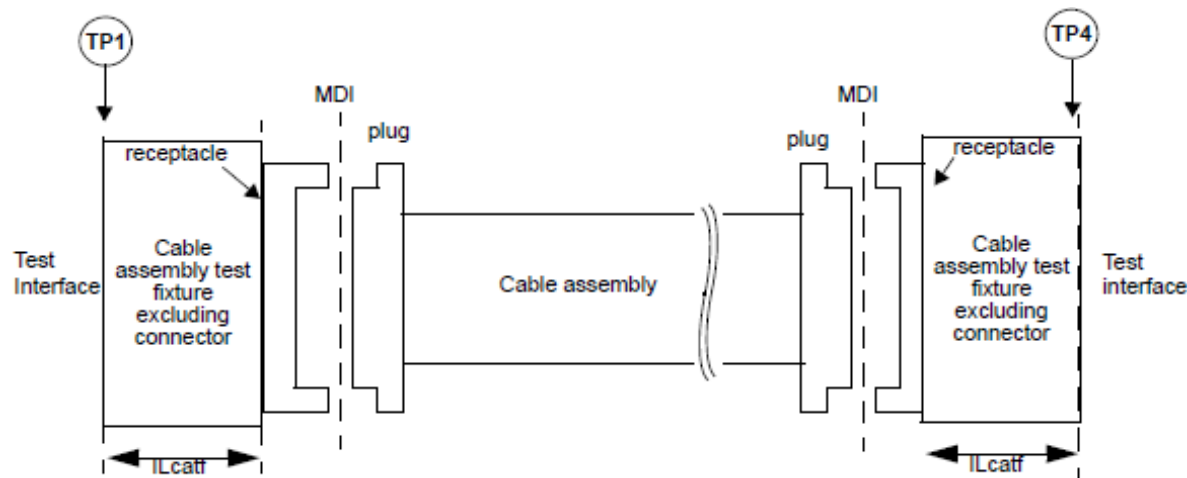
Table 92–10—Cable assembly differential characteristics summary

Description	Reference	Value	Unit
Maximum insertion loss at 12.8906 GHz	92.10.2	22.48	dB
Minimum insertion loss at 12.8906 GHz	92.10.2	8	dB
Minimum return loss at 12.8906 GHz	92.10.3	6	dB
Differential to common-mode return loss	92.10.4	Equation (92–28)	dB
Differential to common-mode conversion loss	92.10.5	Equation (92–29)	dB
Common-mode to common-mode return loss	92.10.6	Equation (92–30)	dB

Table 110–10—Cable assembly characteristics summary

Description	Reference	CA-25G-L	CA-25G-S	CA-25G-N	Unit
Maximum insertion loss at 12.8906 GHz	110.10.2	22.48	16.48	15.5	dB
Minimum insertion loss at 12.8906 GHz	110.10.2	8			dB
Minimum differential return loss at 12.8906 GHz	110.10.3	6			dB
Differential to common-mode return loss	110.10.4	Equation (92–28)			dB
Differential to common-mode conversion loss	110.10.5	Equation (92–29)			dB
Common-mode to common-mode return loss	110.10.6	Equation (92–30)			dB
COM	110.10.7	See Table 110–11			dB

from  $[0.01/0.05/0.2] \leq f \leq 19$  GHz



# COM- Baseline

- COM - consistent with methodology CL92 and CL110
- COM parameter values TBD

Table 110-11—COM parameter values

Parameter	Symbol	CA-25G-N	CA-25G-S	CA-25G-L <sup>a</sup>	Units
Signaling rate	$f_b$	25.78125			GBd
Maximum start frequency	$f_{min}$	0.05			GHz
Maximum frequency step <sup>b</sup>	$\Delta f$	0.01			GHz
Device package model					
Single-ended device capacitance	$C_d$	$2.5 \times 10^{-4}$			nF
Transmission line length, Test 1	$z_p$	12			mm
Transmission line length, Test 2	$z_p$	30			mm
Single-ended package capacitance at test board interface	$C_p$	$1.5 \times 10^{-4}$			nF
Single-ended reference resistance	$R_0$	50			$\Omega$
Single-ended termination resistance	$R_d$	50			$\Omega$
Receiver 3 dB bandwidth		$f_b/4$			GHz
Transmitter equalizer, minimum cursor coefficient	$c(0)$	0.62			
Transmitter equalizer, pre-cursor coefficient	$c(-1)$				
Minimum value		-0.18			
Maximum value		0			
Step size		0.02			
Transmitter equalizer, post-cursor coefficient	$c(1)$				
Minimum value		-0.38			
Maximum value		0			
Step size		0.02			
Continuous time filter, DC gain	$g_{DC}$				
Minimum value		-16	-12	-12	dB
Maximum value		0	0	0	dB
Step size		1	1	1	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

Table 110-11—COM parameter values (continued)

Parameter	Symbol	CA-25G-N	CA-25G-S	CA-25G-L <sup>a</sup>	Units
Transmitter differential peak output voltage					
Victim	$A_v$	0.4			V
Far-end aggressor	$A_{fe}$	0.6			V
Near-end aggressor	$A_{ne}$	0.6			V
Number of signal levels	$L$	2			
Level separation mismatch ratio	$R_{LSM}$	1			
Transmitter signal-to-noise ratio	$SNR_{TX}$	26		27	dB
Number of samples per unit interval		3			
Decision feedback equalizer (DFE) length	$N_b$				
Normalized DFE coefficient magnitude limit, for $n = 1$ to $N_b$	$b_{max}(n)$	0.35	0.5	1	—
Random jitter, RMS	$\sigma_{RJ}$	0.01			UI
Dual-Dirac jitter, peak	$A_{DD}$	0.05			UI
One-sided noise spectral density	$\eta_0$	$5.2 \times 10^{-8}$			V <sup>2</sup> /GHz
Target detector error ratio	$DER_0$	$10^{-12}$	$10^{-8}$	$10^{-5}$	—
Channel Operating Margin (min.)	COM	3 <sup>c</sup>	3	3	dB

<sup>a</sup>The parameters for CA-25G-L are the same as those for 100GBASE-CR4 (Table 93-8), except for  $A_{fe}$ .

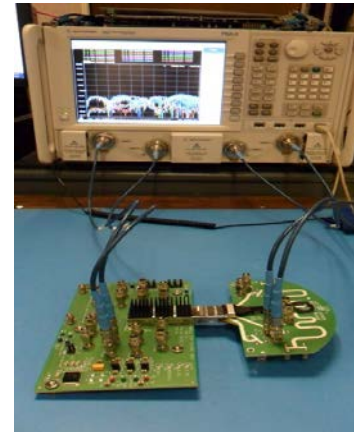
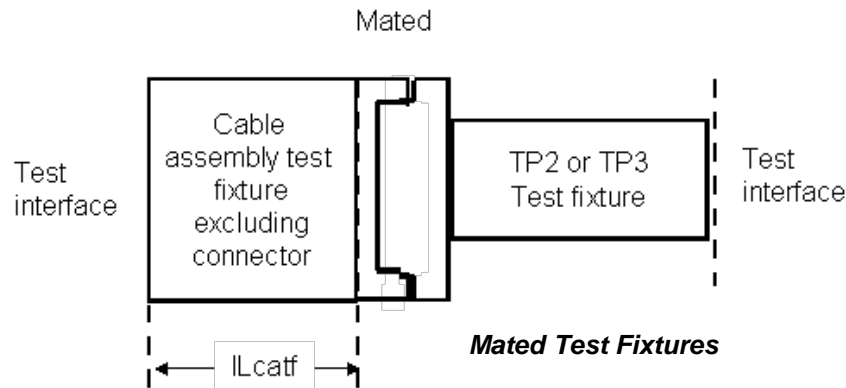
<sup>b</sup>For cable lengths greater than 4 m, a frequency step ( $\Delta f$ ) no larger than 5 MHz is recommended.

<sup>c</sup>For CA-25G-N cable assemblies with insertion loss at 12.8906 GHz greater than 12 dB, the minimum COM is relaxed to 2.2 dB.

Consider: <http://www.ieee802.org/3/bs/public/adhoc/elect/index.shtml>  
 COM update for Annex 120D (CDAUI-8 C2C) 12-Jan-16 (2157k)  
 config\_com\_ieee8023\_93a=CDAUI-8-C2C\_D1p1\_mellitz\_01\_0116.xls

# Test Fixtures

- Test Fixture specifications - consistent with CL92 and CL110
- 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.



# Test Fixtures - Baseline

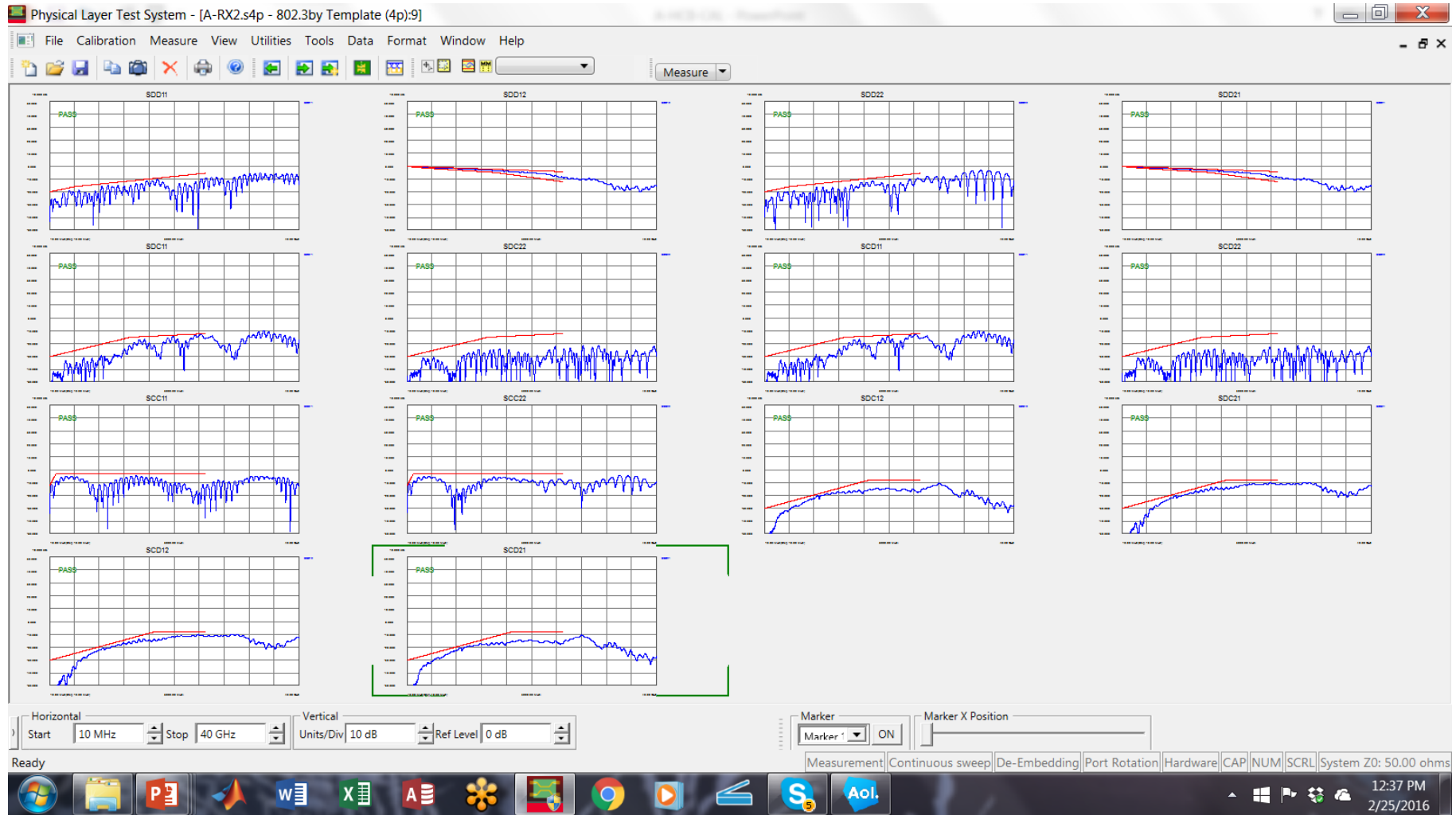
- Test Fixture specifications - consistent with CL92 and CL110

## Mated test fixtures parameters

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

# QSFP28-Mated Test Fixture – 802.3bj/802.3by Specification

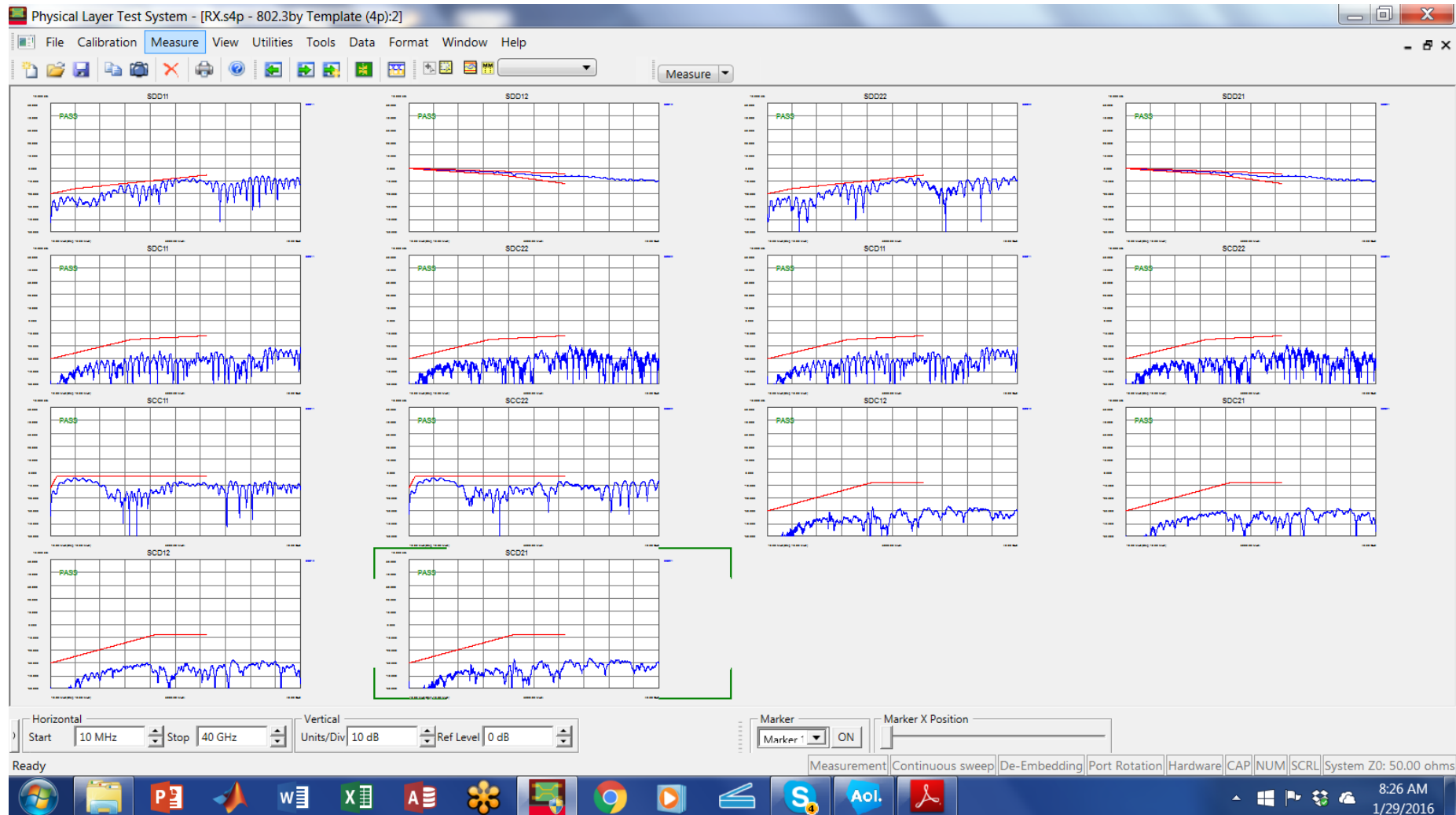
- Measurements 10 MHz-40 GHz





# SFP28-Mated Test Fixture – 802.3bj/802.3by Specification

- Measurements 10 MHz-40 GHz



# QSFP28 MTF – Figure of merit – ILD

$FOM_{ILD}$  is calculated according to 93A.4 with  $f_b=25.78125$  GHz,  $T_t=9.6$  ps, and  $f_r=0.75 \times f_b$ . 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

[http://www.ieee802.org/3/bm/public/jul14/plenary/diminico\\_01\\_0714\\_optx.pdf](http://www.ieee802.org/3/bm/public/jul14/plenary/diminico_01_0714_optx.pdf)

# SFP28 - Mated test fixture specifications - ICN

Table 110B–2—Mated test fixture integrated near-end crosstalk noise parameters

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

Table 110B–1—Mated test fixtures integrated near-end crosstalk noise

Parameter	Value	Units
Integrated near-end crosstalk noise voltage	Less than 1.8	mV

25.78125 GBd	MCB-TD-MCB-RD	HCB-TD-HCB-RD
NEXT ICN (mV)	0.945	0.926
26.5625 GBd	MCB-TD-MCB-RD	HCB-TD-HCB-RD
NEXT ICN (mV)	0.976	0.962

# QSFP28 - Mated test fixture specifications - ICN

Table 92–14—Mated test fixture integrated crosstalk noise 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

Table 92–13—Mated test fixtures integrated crosstalk noise

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

25.78125 GBd /26.5625 GBd

	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)	1.39/1.47	1.13	1.11	0.81
MDFEXT ICN (mV)	4.17/4.27	3.19	3.74	3.00

# Copper cable reach objective

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Motion: Adopt the following objectives

- Define single-lane 50 Gb/s PHYs for operation over links consistent with copper twin axial cables with lengths up to at least 3 m.
- Define two-lane 100 Gb/s PHYs for operation over links consistent with copper twin axial cables with lengths up to at least 3 m.
- Define four-lane 200 Gb/s PHYs for operation over links consistent with copper twin axial cables with lengths up to at least 3 m.

Y:

N:

A:

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# BACKUP

# CAUI-4/CDAUI-10 chip-to-module interfaces

- CAUI-4 signaling rate for each lane is 25.78125 GBd<sup>1</sup>.

$$Insertion\_loss(f) \leq \left\{ \begin{array}{ll} 1.076(0.075 + 0.537\sqrt{f} + 0.566f) & 0.01 \leq f < 14 \\ 1.076(-18 + 2f) & 14 \leq f < 18.75 \end{array} \right\} \quad (\text{dB}) \quad (83\text{E-1})$$

where

$f$  is the frequency in GHz  
 $Insertion\_loss(f)$  is the CAUI-4 chip-to-module insertion loss

- CDAUI-8 signaling rate for each lane is 26.5625 GBd<sup>2</sup>

$$Insertion\_loss(f) \leq 1.076(0.0801 + 0.5736\sqrt{f} + 0.6046f) \quad (\text{dB}) \quad (120\text{E-1})$$

for  $0.01 \leq f \leq 28.05$

where

$f$  is the frequency in GHz  
 $Insertion\_loss(f)$  is the CDAUI-8 chip-to-module insertion loss

[1] using spec similar to CEI-28G-VSR, [2] using spec similar to CEI-56G-VSR-PAM

# CAUI-4/CDAUI-10 chip-to-module interfaces

