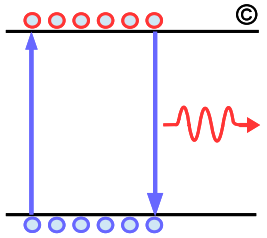


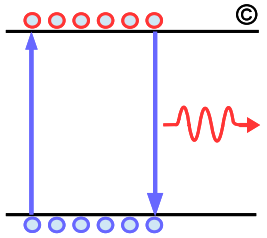
C2M AUI and Cu MDI Options

Ali Ghiasi
Ghiasi Quantum LLC

IEEE 802.3
100GEL Task Force Interim Meeting

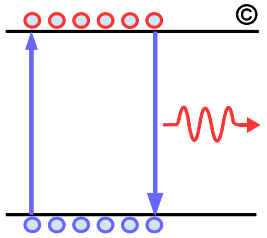
May 24, 2018

List of Supporters



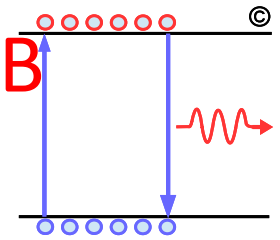
- Christophe Metivier – Arista Network
- Rob Stone – Broadcom
- David Piehler - Dell
- Brian Taylor – Facebook
- Zuowei Shen - Google
- Xinyuan Wang – Huawei
- Hong Feng - Huawei

Overview



- **This contribution is an update to adhoc presentation ghiasi_100GEL_adhoc_01_050918.pdf**
  - Considers host channel via loss and MCB/HCB min/nom/max loss
  - Historically these 2nd order effects have been ignored but at 26.55 GHz becoming substantive
- **This contribution in addition to symmetric also explores asymmetric and dual port types, where all 3 schemes may support 2 m Cu cables**
  - Symmetric – single port type
    - Define a common port with 10.4 dB for C2M and host Cu-MDI
  - Asymmetric – single port type switch-NIC ports
    - Defines max 14 dB loss for switch Cu MDI/C2M
    - Defines max 10.4 dB loss for NIC Cu MDI/C2M
  - Symmetric – dual port types
    - Define max loss of 10.4 dB for symmetric dual-port type to support Cu cable and optics/AOC
    - Define max loss of 15 dB for C2M ports supporting AOC/Optics/Active DAC
- **A symmetric-single port type with 10.4 dB loss will have substantial power-cost penalty on high port counts ASICs!**

Lim Proposal Ball-Ball Loss Needs to be Reduced to 28 dB Based on 100GEL Objective



http://www.ieee802.org/3/100GEL/public/18_03/lim_100GEL_01b_0318.pdf

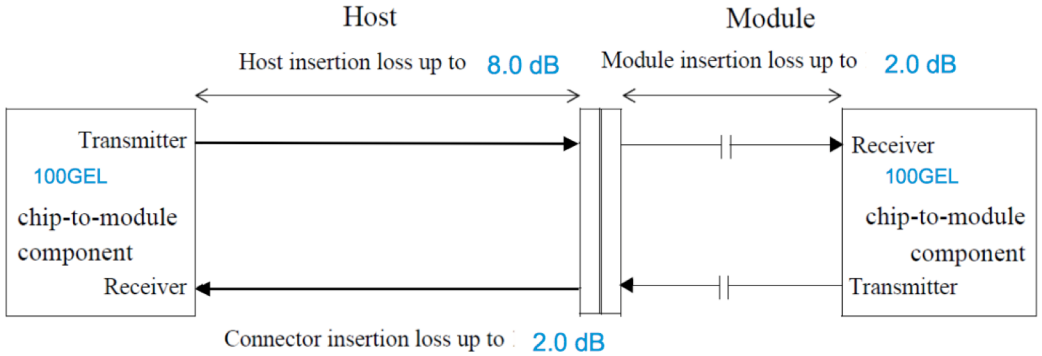


Figure 1: 100GEL C2M insertion loss budget at 26.56 GHz

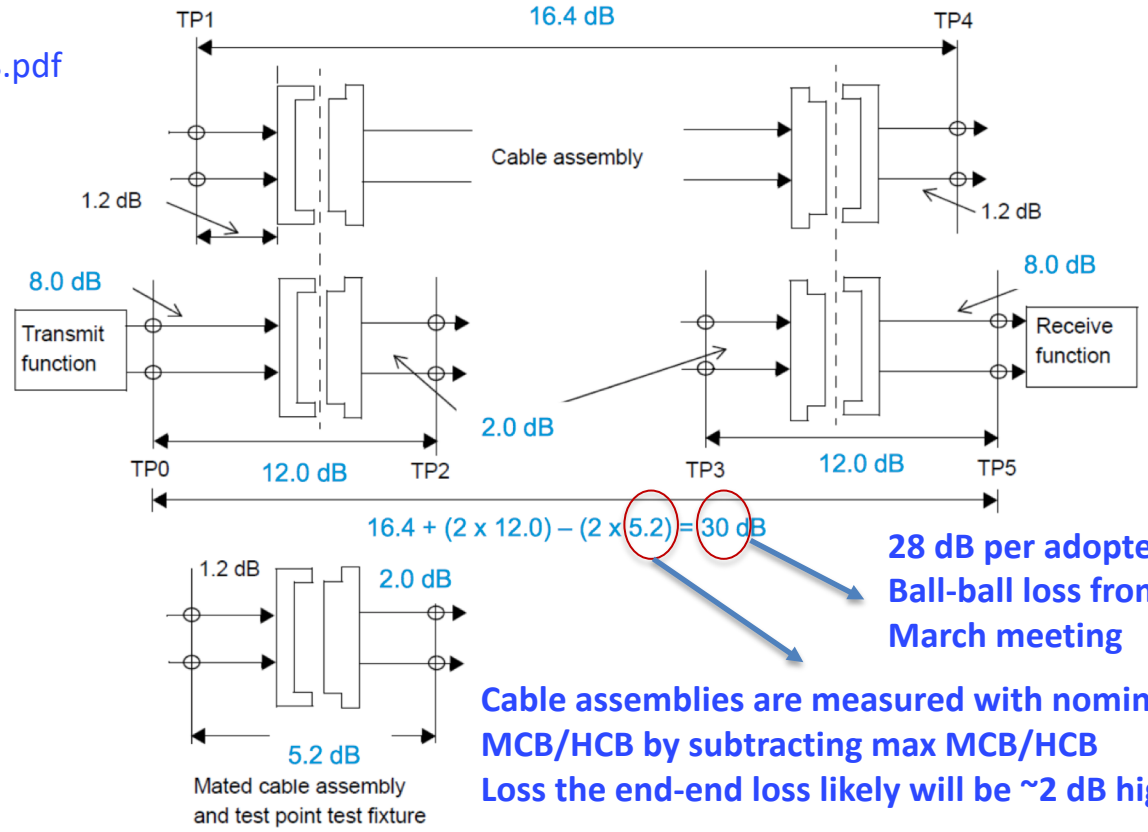
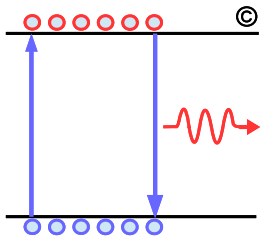


Figure 2: 100GEL CR 30dB insertion loss budget at 26.56 GHz

Striplines Via Insertion Loss



- **Typical C2M stripline traces will have two vias, result below are for 112 mils deep via on a 129 mils board**
  - For 6 ps skew via loss @ 26.55 could be ~1 dB and even higher for smaller drill size!
  - For this analysis will assume 3.5 ps skew and the via loss of ~0.5 dB @26.55 GHz!

Tradeoffs between tightly and loosely coupled differential vias for multi-Gbps design, Clement Luk, Designcon 2016.

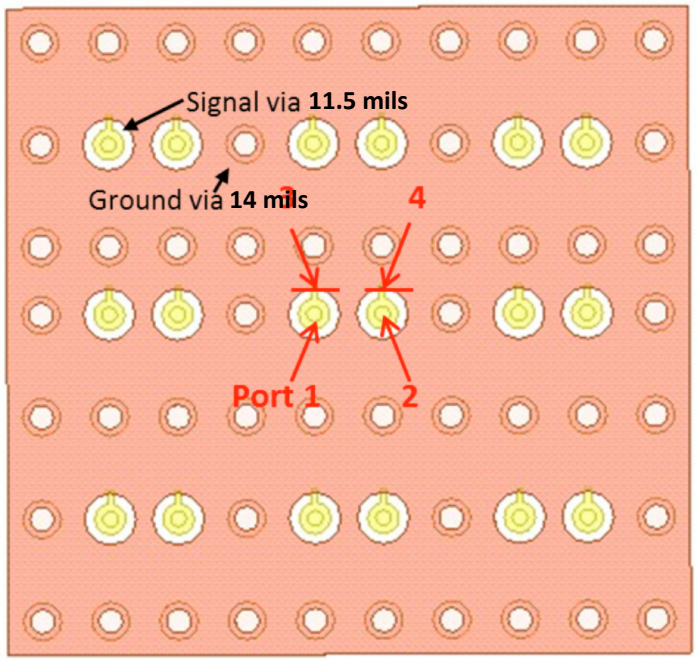


Figure 18. Tightly-coupled via design.

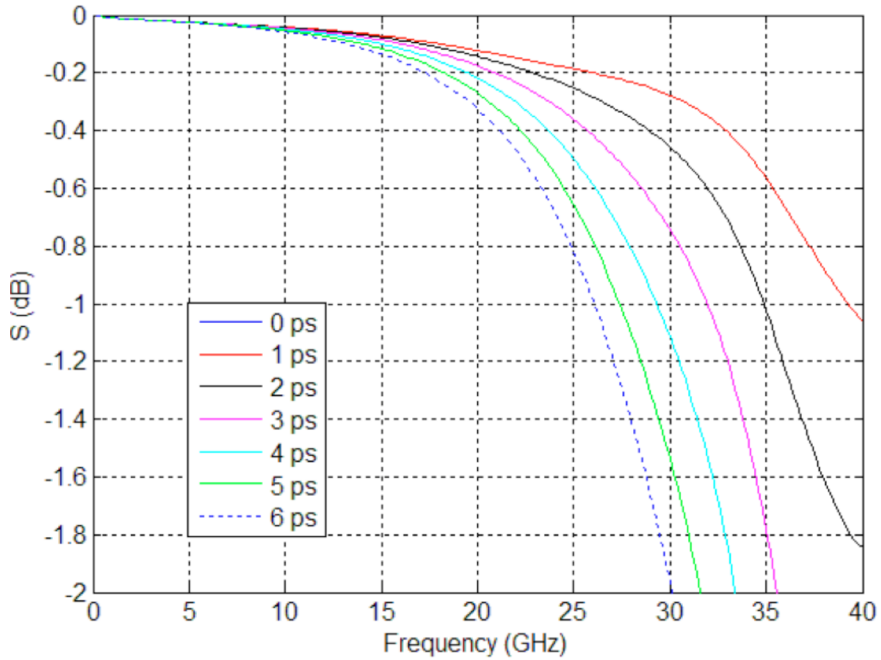
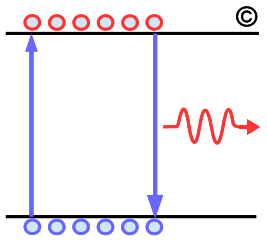


Figure 23. Sensitivity of SDD12 to skew for tightly-coupled vias.

Skew (ps)	IL (dB)
1	0.19
2	0.25
3	0.36
4	0.50
5	0.66
6	0.82

Table 1. Differential IL of tightly coupled vias vs. skew at 25GHz.

C2M Channel Reach



- **PCB loss estimate assumptions and tools for calculation**
  - Rogers Corp impedance calculator (free download but require registration) https://www.rogerscorp.com/acm/technology/index.aspx
  - The IEEE tool if updated could be another option to estimate channel reach http://www.ieee802.org/3/bj/public/tools/Reference__DkDf_AlegbraicModel_v2.04.pdf
  - Stripline ~ 50 Ω, trace width is 5.5 mils, and with ½ oz Cu
  - Isola 408HR DK=3.65, DF=0.0095, RO=2.5 um, Meg-6 DK=3.4, DF=0.005, RO 1.2 µm, Tachyon100 DK=3.02, DF=0.0021, RO=1.2 µm
  - To support equivalent PCB traces for C2M need at least 14.5-15 dB end-end channel loss consistent with tracy_100GEL_01a_0118
  - Assumed loss for two vias is 1 dB@26.55 GHz.

Host Trace Length (in)	Total Loss (dB)	Via Loss (dB)	Host PCB Loss(dB) - 2 via loss	Isola 408HR	Megtron 6	Tachyhon100	
Nominal PCB Loss/in at 5.15 GHz	N/A	0.05	N/A	0.65	0.52	0.46	
Nominal PCB Loss/in at 13 GHz	N/A	0.15	N/A	1.27	0.98	0.83	
Nominal PCB Loss/in at 27 GHz	N/A	0.5	N/A	2.18	1.60	1.28	
10GSFP+ with one connector & HCB	6.5	N/A	4.9	7.5	9.4	10.7	✓
28G-VSR + stack connector *	10.5	N/A	6.51	5.1	6.6	7.8	✓
Lim symetric proposal adj for 28 dB **	10.4	N/A	5.4	2.5	3.4	4.2	✗
Asymetric NIC port with SMT connector ***	8	N/A	4	1.8	2.5	3.1	✓
Asymetric Switch with Stacked connector ****	14	N/A	9	4.1	5.6	7.0	✓
C2M with Stacked connector ****	15	N/A	10	4.6	6.3	7.8	✓

Reach Inches Too Short

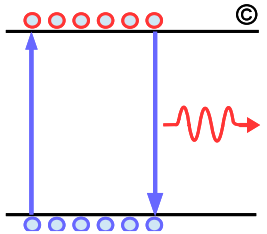
* Assumes connector loss is 1.69 dB and HCB loss is 2.0 dB at 12.89 GHz

** Assumes 2 dB to support stacked connectors, 2 dB for HCB, 1 dB for 2 vias at 26.55 GHz, and the budget adjust based on 28 dB ball-ball.

*** Assumes 1 dB to SMT connector, 2 dB for HCB loss at 26.55 GHz, and 1 dB for 2 vias at 26.55 GHz.

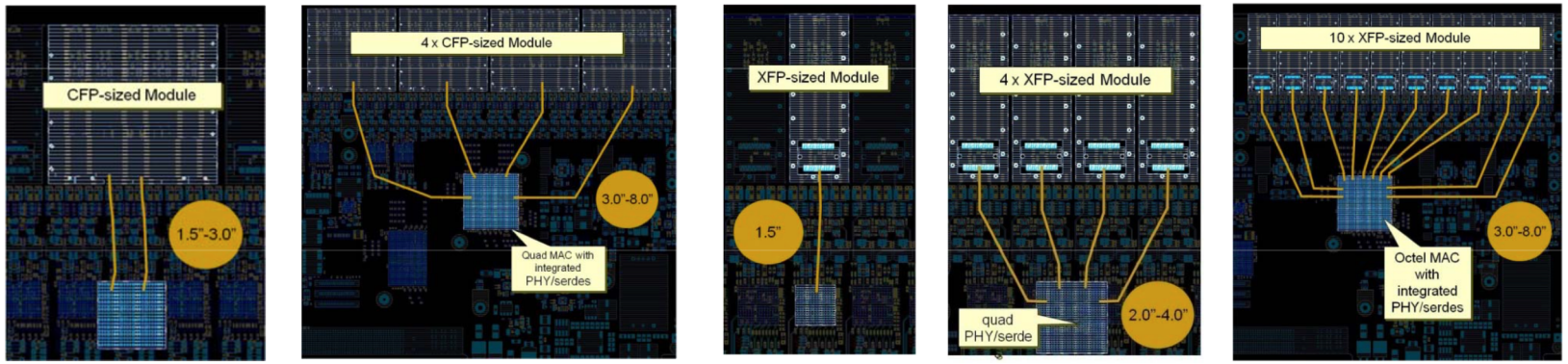
**** Assumes 2 dB to support stacked connectors, 2 dB for HCB, and 1 dB for 2 vias at 26.55 GHz.

nicholl_01_1111_NG100GOPTX States an Octal XFP Ports Requires 3-8”



- **Symmetric proposal based on 28 dB ball-ball loss with 2 m Cu support the host PCB is limited to 4.2” only**
- **4.2” is length of PCB trace necessary typically for a Quad PHY!**

- Distances for nAUI/nPPI were primarily driven out of nicholl_01_0708



1 port CFP | 4 port CFP | 1 port ‘XFP’ | 4 port ‘XFP’ | 8/10 port ‘XFP’

CFP sized module (Retimed)

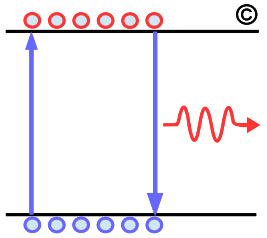
1 port: 1.5” - 3”
4 port: 3.0” - 8.0”

CXP/QSFP sized module (Unretimed)

1 port: 1.5”
4 port: 2.0” - 4.0”
8 port: 3.0” - 8.0”

- In keeping with the ‘Quad Phy’ rule-of-thumb, 802.3ba targeted 8” for nAUI (retimed) and 4” for nPPI (unretimed)

10G SFP+

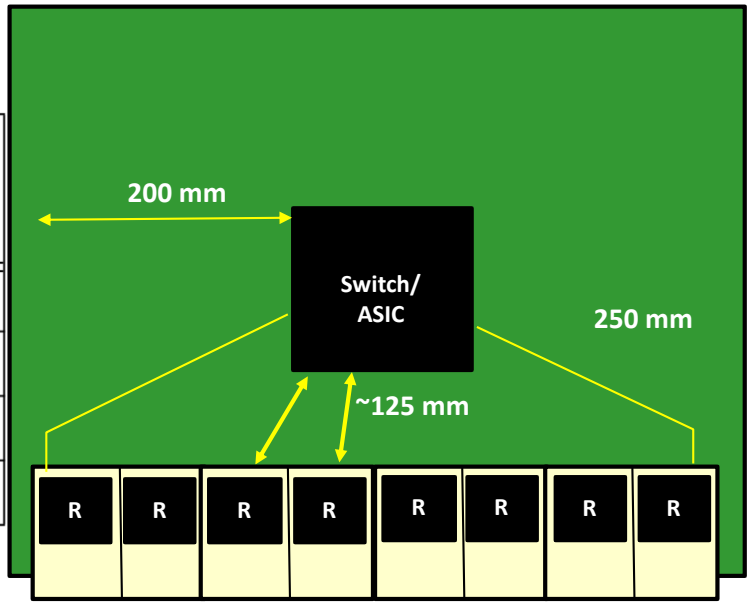


- **10G SFP+ was the first Ubiquitous port supporting optical and passive Cu**
  - 10G SFP+ supported 200-300 mm of host PCB trace on mid-grade material
  - 10GSFP+ Cu DAC did not burden or reduce the host PCB trace
  - lim_100GEL_01b_0318.pdf in order to support Cu cable even with best material Megtron 7NE PCB limited to 4.2” after adjusting for 28 dB ball-ball loss, via loss, and mated board loss adjustment.

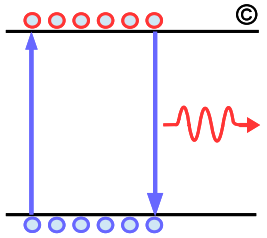
Table 2 Host Board Achievable Trace Length (SFP+)

Type	*Material*	*Trace Width (mm)*	*Loss Tangent*	*Copper Thickness (oz) see 1*	*Copper Thickness (µm)*	*Trace Length (mm)*
Microstrip	FR4-6/8	0.3	0.022	1	35	200
	Nelco 4000-13	0.3	0.016	1	35	300
Stripline	FR4-6/8	0.125	0.022	0.5	17.5	150
	Nelco 4000-13	0.125	0.016	0.5	17.5	200

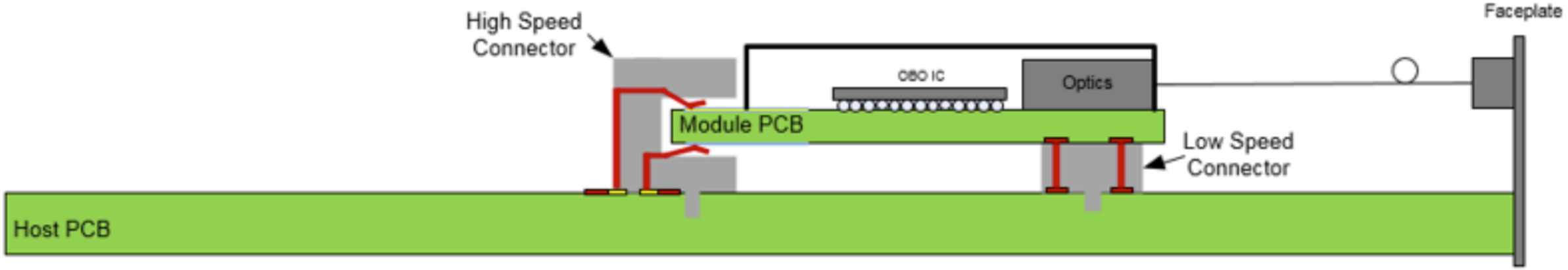
1. Copper (oz) is defined as an ounce of copper over one square foot of laminate.



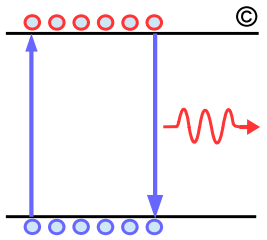
COBO – Uses VSR Specifications



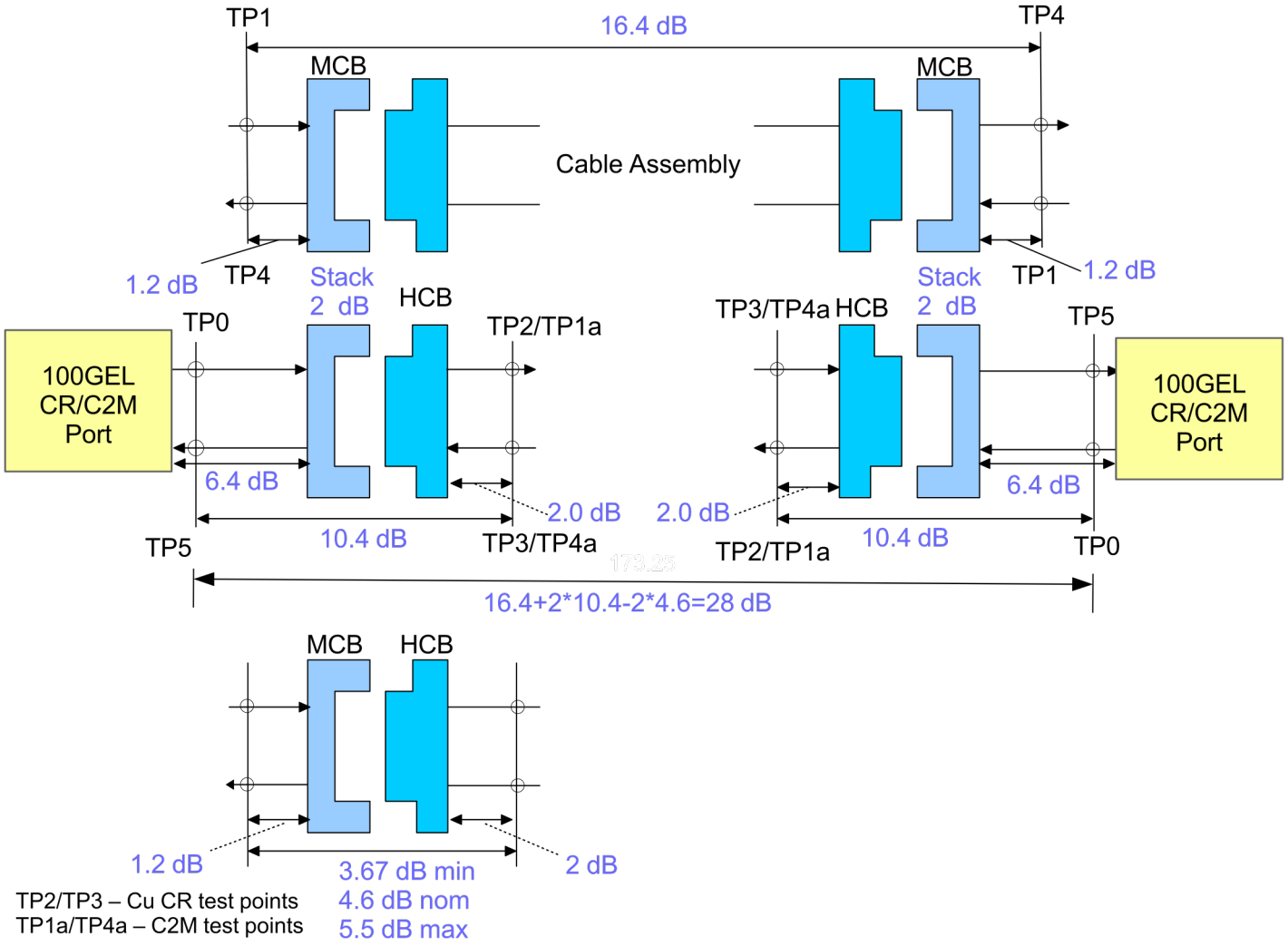
- **COBO (on board optics) electrical interface is based on VSR given the PCB trace length**
  - In order to support 36 Cobo modules from single ASIC ~9” of host PCB is required
  - XSR specifications based on 4.2 dB would have offered lower power dissipation but XSR supporting only 50 mm host PCB trace would have required 2nd retimer on the line card
  - If Cobo requires >8” how do we expect that 5-6” is enough for pluggable modules!



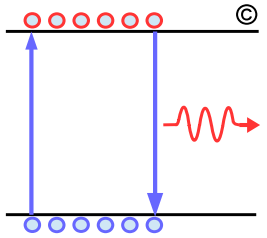
Option I: Symmetric-Single Port Type Specifications



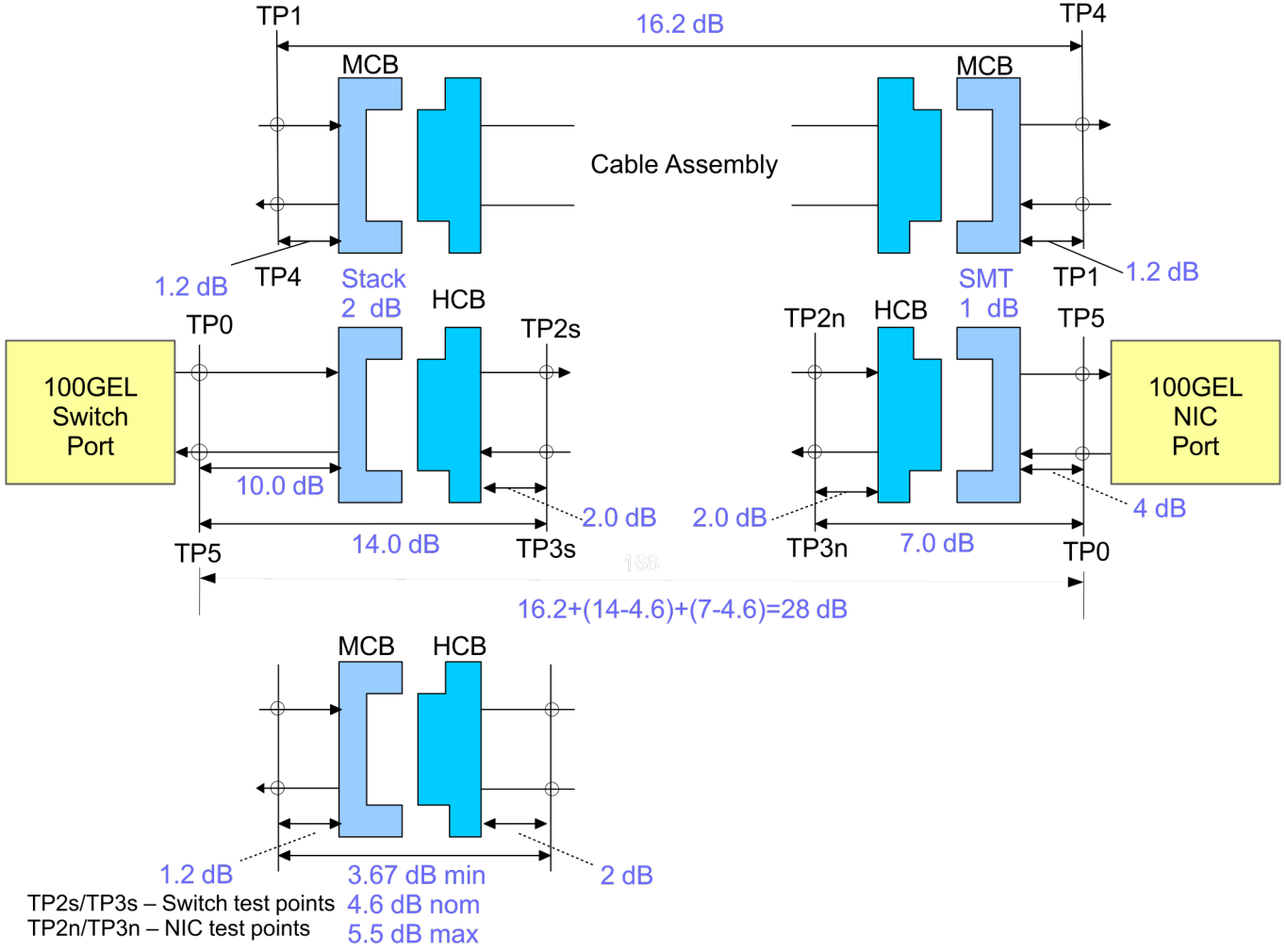
- **Symmetric-single port type with common host budget supporting both optical module/AOC and passive Cu cable**
  - Proposed symmetric-single port type budget assumes 28 dB ball-ball to support 2 m passive Cu cable but the host-MDI loss is only 10.4 dB
  - Cable assembly loss is 16.4 dB
  - Switch PCB loss 6.4 dB and only 5.4 dB after accounting for 2 vias
  - Host connectors assumed loss is 2 dB to support stack connectors
    - Application using SMT connector may use ~ 1 dB loss reduction for additional host loss
  - 5.4 dB host PCB only supports 4.2"!



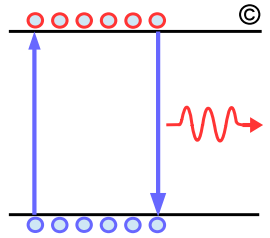
Option II: Asymmetric-Single Port Type Specifications



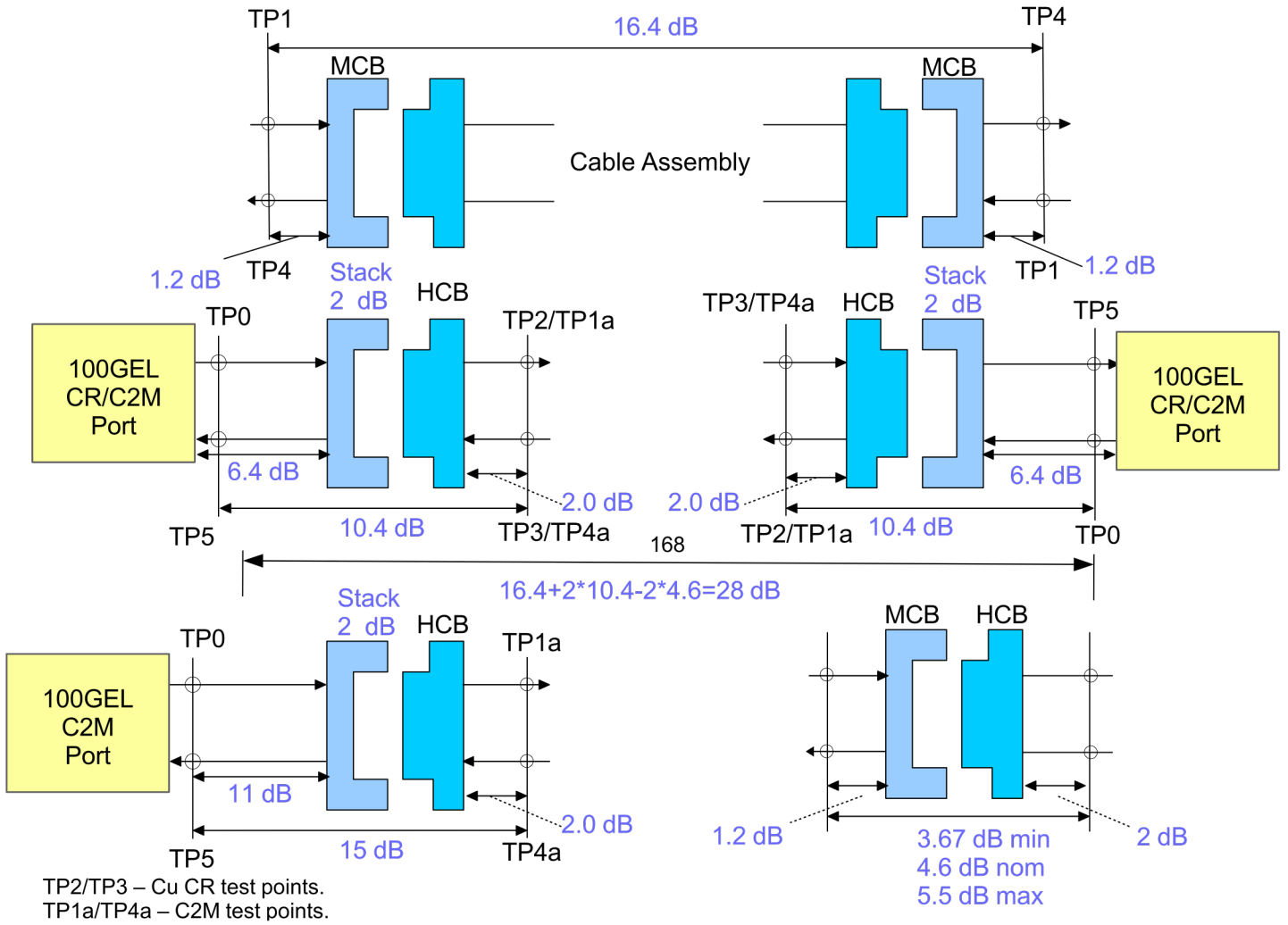
- **Asymmetric-single port type with common switch and NIC budget supports both passive Cu cable and optical module/AOC on all ports**
  - Proposed asymmetric link budget assumes 28 dB ball-ball to support 2 m of passive Cu cable
  - Cable assembly loss is 16.2 dB
  - Switch PCB loss is ~9 dB after accounting for 2 vias with 1 dB loss supports 7” PCB
    - Switch connector assumed stacked with 2 dB loss
  - NIC PCB loss is ~3 dB after accounting for 2 vias with 1 dB loss supports 3” PCB
    - NIC connector assumed to be SMT with 1 dB loss
- **Asymmetric-single port type require introducing 2 additional test points to support NIC test poits**
  - TP2s and TP3s for switch output/input
  - TP2n and TP3s for NIC output/input.



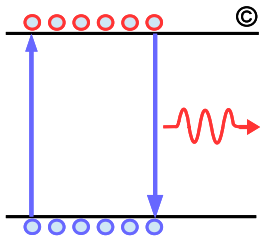
Option III: Symmetric Dual-Port Type



- **Symmetric dual-port type allow building a superset port supporting passive Cu cable and optical port/AOC or build an optical/AOC/Active Cu ports if passive Cu cable support not required**
- **Symmetric dual-port type with common host budget supports both C2M and Cu MDI**
  - Proposed symmetric dual-port type budget assumes 28 dB ball-ball to support 2 m of passive Cu cable with loss of 16.4 dB
  - Superset port supporting passive Cu and optical/AOC max channel loss is 10.4 dB
    - Cu host channel loss based on 6.4 dB or 5.4 after accounting for 2 vias, which supports
  - C2M ports supporting optical/AOC max loss is 15 dB
    - C2M host channel loss based on 11 dB or 10 dB after accounting for 2 vias supports
  - Host connectors assumed loss is 2 dB to support stack connectors
    - Application using SMT connector may use ~ 1 dB loss reduction for additional host loss
- **C2M budget in symmetric dual-port type is not tight to Cu cable end-end loss.**

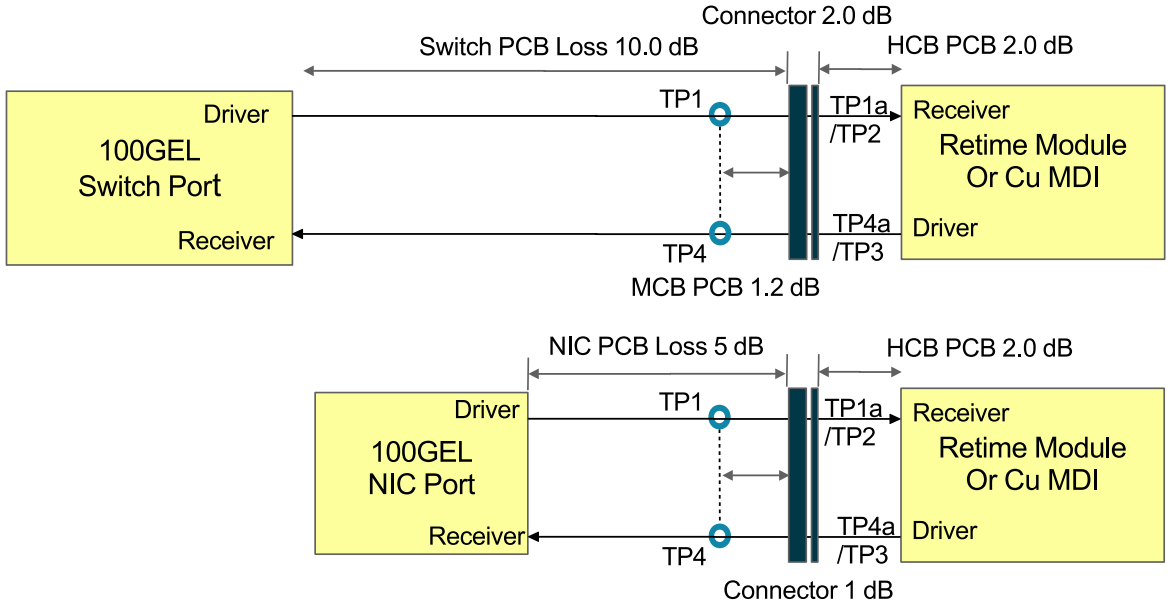


Overview of Symmetric and Asymmetric Port Types

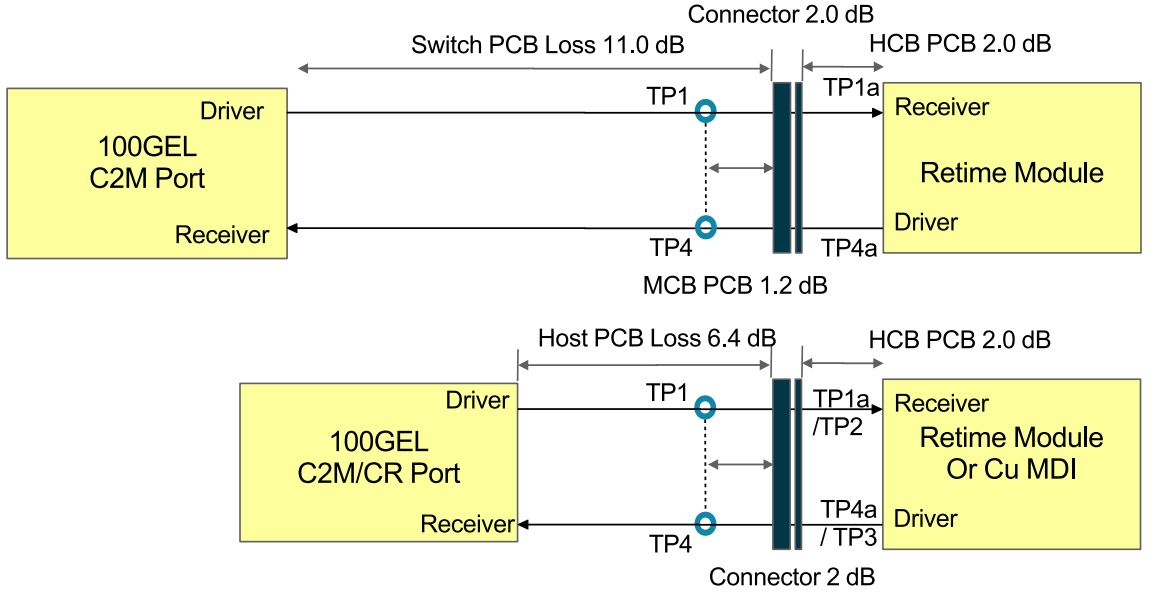


- **Symmetric single-port type**
  - Supports Cu cables on all port types (diagram similar to lower right)
  - Not viable due extra short ~4.2” host PCB trace
- **Asymmetric single-port type**
  - Supports Cu cables on all switch-NIC port but not on switch-switch
- **Symmetric dual-port types**
  - Supports passive Cu cable on superset ports having max loss of 10.4 dB loss.

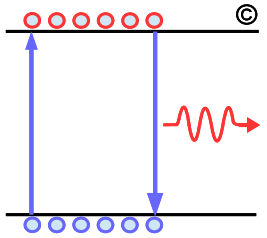
Asymmetric Single Port-Type



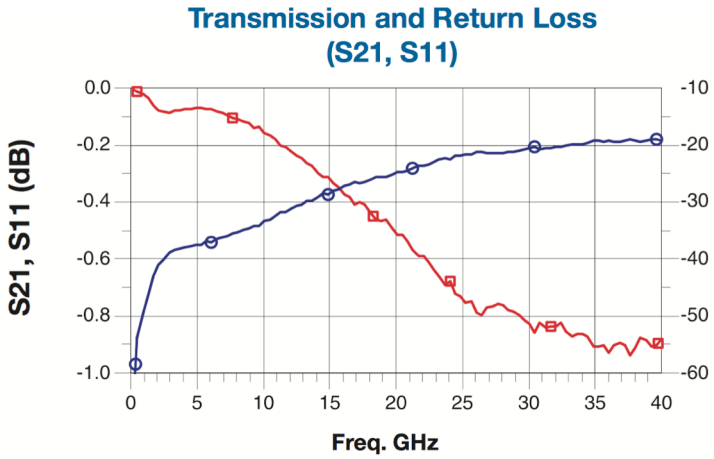
Symmetric Dual-Port Type



Building Cu Cable Assembly Loss from Ground Up



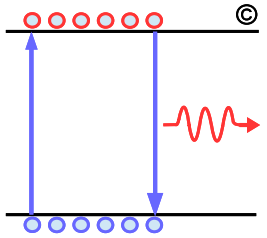
- **Assuming 2 m objective can only be met with 26 AWG**
  - More likely deployment will be 1.5 m on 28 AWG
- **QSFP Cu cable loss estimate are 5.05 dB/m for 26 AWG and 7.6 dB for 28 AWG, see**
  - http://www.ieee802.org/3/100GEL/public/18_03/palkert_100GEL_01a_0318.pdf
- **Key assumed cable assembly losses:**
  - DC block 0.8 dB one of
  - Plug PCB loss 1 dB 2 of
  - MCB connector 1 dB 2 of
  - MCB PCB board 1.2 dB 2 of
  - Analysis does not include any via loss associated with QSFP-dd rear contacts
- **Symmetric dual port-type Cu cable budget can be increased to allow supporting 1.5 m 28 AWG Cu cables by reducing the Cu host channel.**



Presidio Microwave
Broadband DC Block
MBB0502X104MGP5C8

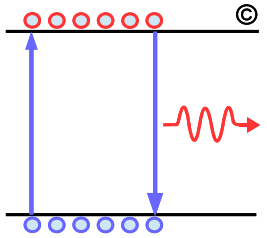
Cable assembly elements	2 m 26 AWG	1.5 m 28 AWG
Cable loss dB/m	5.05	7.60
Cable loss (dB)	10.1	11.4
Nominal MCB PCB loss 2 of (dB)	2.0	2.0
MCB connector loss 2 of (dB)	2.0	2.0
Cable plug PCB loss 2 of (dB)	2.0	2.0
DC block (dB)	0.8	0.8
Cable assembly end-end loss (dB)	16.9	18.2

Options Moving Forward



Options	Applications Supported	PHY-Less Support on High Radix Switch	Supports ~2 m Cu	C2M Applications
I- Symmetric port type -10.4 dB	Switch-Switch, and Switch-NIC	No (~2/3 of ports require retimers)	Yes	Penalized by Cu cable by forcing retimers on ~ 2/3 of ports on a system never using Cu cable!
II- Asymmetric- Single Port Type 14.0 dB switch 7.0 dB NIC	Switch-NIC	Yes	Yes	Not penalized by the Cu cable
III- Symmetric Dual-Port Types Cu ports 10.4 dB C2M ports 15 dB	Switch-Switch, and Switch-NIC (Superset ports with 10.4 dB support both Cu/optics but C2M with 15 dB only optics/AOC)	Optional (If Cu cable support required then ~2/3 of ports need retimers to implement superset port)	Yes (on the superset ports)	Not penalized by the Cu cable

Summary



- **The proposed lim_01b_0318.pdf based on 30 dB symmetric single port-type proposal adjusted for 28 dB ball to ball loss**
  - After considering via loss and difference between MCB connector loss vs stacked host connector symmetric single port-type host PCB loss is only 5.4 dB or about 4.2”
  - If we need to support 2 m Cu cabling symmetric single port-type is not a viable option
- **This contributions investigates**
  - Option I - Symmetric single port-type based on ~10.4 dB loss
  - Option II - Asymmetric single port-type based on 14.0 dB for switch and 8.0 dB for NIC loss
  - Option III – Symmetric dual port-type based on 10.4 dB for CR/C2M superset ports and 15 dB for C2M
- **Asymmetric single port-type offers passive Cu cable support on every switch-NIC ports but not on switch-switch ports**
  - Asymmetric budget is getting tight with NIC PCB allocation limited to 4 dB only
- **Symmetric dual-port types allocates higher host PCB loss for C2M but lower host PCB loss for superset Cu host-MDI/C2M ports and offer a more robust path to support 2 m of Cu Cable**
  - Symmetric dual-ports offers more generous budget for C2M and the budget isn’t locked to 28 dB CR ball-ball loss
- **The 100GEL task force need to investigate further option III symmetric dual port-types and option II asymmetric single port type**
  - Option III offers more generous budget without the complications associated with asymmetric port definition
  - Option II can also work but the budget for switch and NIC PCB traces are getting tight
- **Area of further study: better understanding of MCB/HCB loss, better way to account the difference between cable measured with SMT MCB vs host using stack connectors, technical feasibility of 28 dB ball-ball loss to support 2 m Cu cable, better understanding of C2M equalizer and channels.**