Recommendation for Module Plug Board Losses

Addressing comments: 118 and 128

Ali Ghiasi – Ghiasi Quantum
Frank Chang – Source Photonics
Jim Theodoras – HG Genuine
Rangchen Yu – Innolight
David Cassan – Alphawave Semi
Vasu Parthasarathy – Broadcom
Phil Sun – Credo
Sridhar Ramesh - Maxlinear

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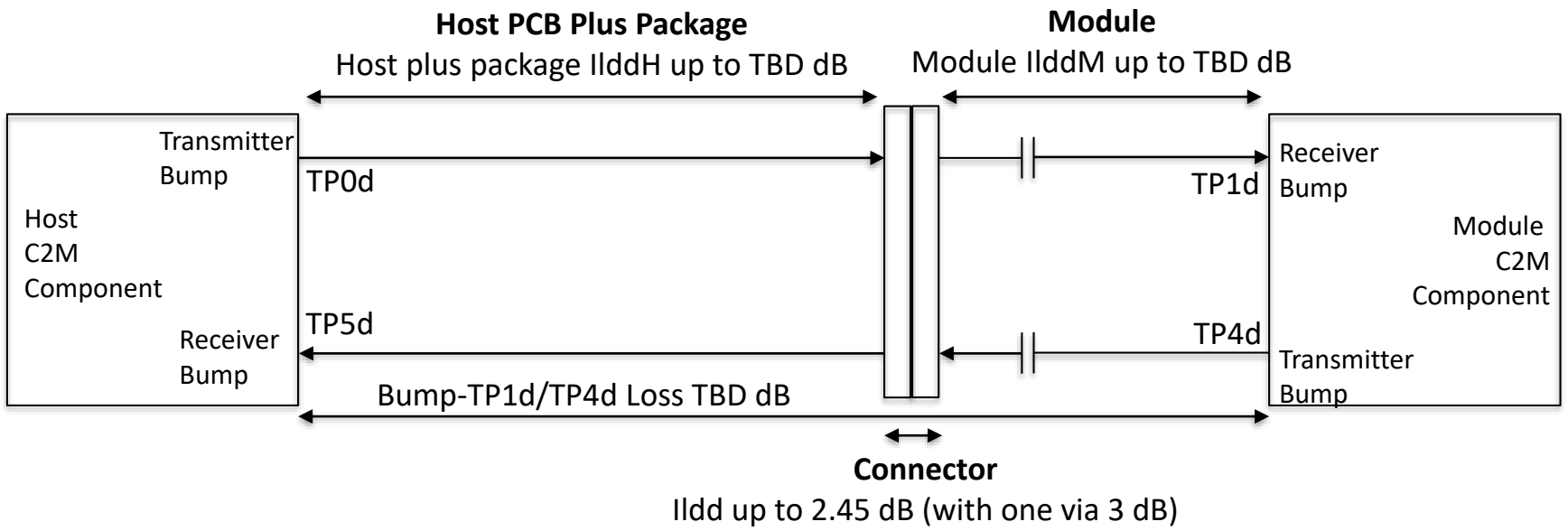
Overview

- **C2M applications**
- **Advance module packaging**
  - mSAP construction
  - Module DC blocks
  - Simulation of module plug board losses
- **Bottom-up module plug board loss**
- **AUI C2M Application Reference Model**
- **Summary.**

Module Loss

- **Contribution addresses module/plug loss IlddM based on bottom-up analysis by considering following implementations**
  - mSAP (modified Semi Additive Package) – Trend
  - Conventional small core-less package – let's not rule out 1st level package.

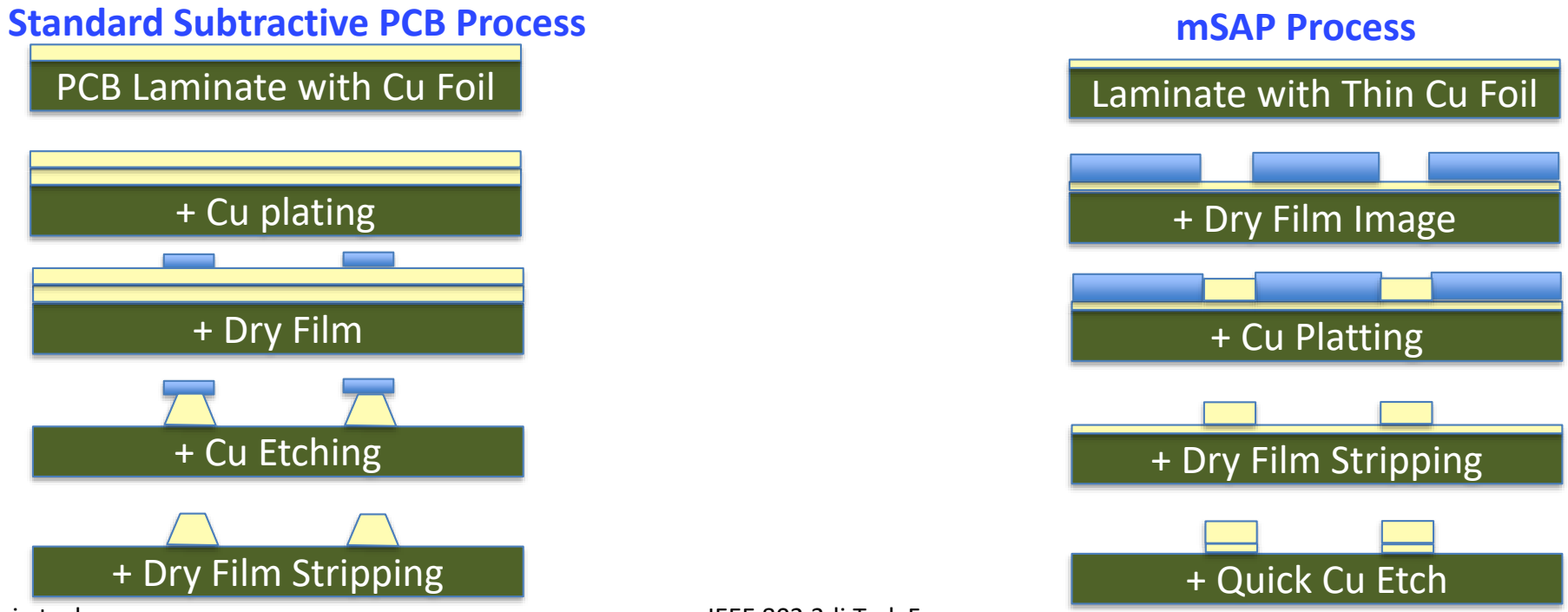


mSAP is Mainstream for Optical Modules Today

- **mSAP was developed in the last 7-10 years in support of smart phones and watches**
- **The primary reason optical modules are using advance mSAP packaging are:**
  - Several 53 GBd and 113 GBd optical DSPs drive EML/laser directly from the DAC
    - A DSP DAC when driving few mm long transmission line doesn't require double termination
    - Eliminating a driver saves power and cost
    - Specially at 113 GBd integrated driver with die on board improves signal integrity and lower power at expense of complexity and mSAP lead time
  - Several 53 GBd optical DSP suppliers have had integrated TIA offering
    - Due to noise sensitivity the PD must be bumped or wire bounded on the same substrate/PCB
    - Integrating TIA can save power and cost but complicates PD integration
- **Advance optical modules are using mSAP to save cost, power, and SI**
  - At 106/113 GBd some CDR/DSP suppliers are only offering dies
  - With increase speed to 106/113 GBd most modules (if not all) will use mSAP to reduce transmission lines to save power
    - But we can't rule out use of small core-less CDR package.

What is mSAP

- **mSAP borrows from both package substrate and PCB manufacturing, but the construction is more like PCB but uses package substrate additive metallization**
  - Generally, mSAP can support non-advance bump pitch of 150/130 μm with ~ 1 mil linewidth
  - Generally, mSAP support core-less, multi-layer up to ~ 10 layers, ~1x laser via construction
  - Several material including ABF can be used for mSAP construction
- **Example process flow for standard subtractive PCB and mSAP shown below:**



Suitable DC Blocks for Optical Modules

- **Following companies have ultra-broadband DC blocks with following loss property that may be suitable for optical module DC blocks**
  - Vendor A offer RF/Microwave ceramic 0.1 μF in 0201 size with loss of <0.6 dB up to 60 GHz
  - Vendor B offers silicon 0.047 μF in 0201 with loss of 0.3 dB up to 60 GHz
  - Vendor C offer ceramic 0.1 μF in 0201 and 0402 size with loss of <0.5 dB up to 50 GHz
- **Capacitors suppliers above offer specialized broadband DC blocks for optical modules**
  - Based on the above 3 suppliers offering DC blocks estimated loss for 802.3dj PMDs is < 0.6 dB up to Nyquist frequency
  - Some of the capacitors offered operate up to 110 GHz
  - Recommend doubling low frequency corner frequency from current 50 kHz which require 0.1 μF and will limit supply option using smaller size caps.

mSAP Loss

- **Most module use 1 mm PCB except OSFP-XD that uses 1.2 mm plug PCB**
  - Typical mSAP module traces constructions are ~3 mils wide
  - mSAP trace losses at 53 GHz would be similar to lim_3dj_02_2307 (Class A) skip layer losses 0.15 dB/mm.

Comparison of Key Design/Material Characteristics of "Class A" vs "Class B" PKGs

Package	"Class A"	"Class B"
ABF (Ajinomoto build-up film) material	GL107 Like	NA
Cross-section	8-2-8, or 10-2-10	6-2-6, to 9-2-9
Core thickness	~1000 µm	800-1200 µm
Trace routing lengths	33 mm max	30-40 mm max
Surface treatment	CZ8401 Like	NA
BGA ball pitch	0.8 mm	> 1.0 mm
Skip Layer	Yes (x%)	No
Trace line / space	~30 / 60 / 30 µm	27-45-27 µm
Trace line / space (Skip Layer)	~80 / 80 / 80 µm	NA
Impedance	~87.5 ohms	90-92 ohms
ABF height	35 µm	40 µm

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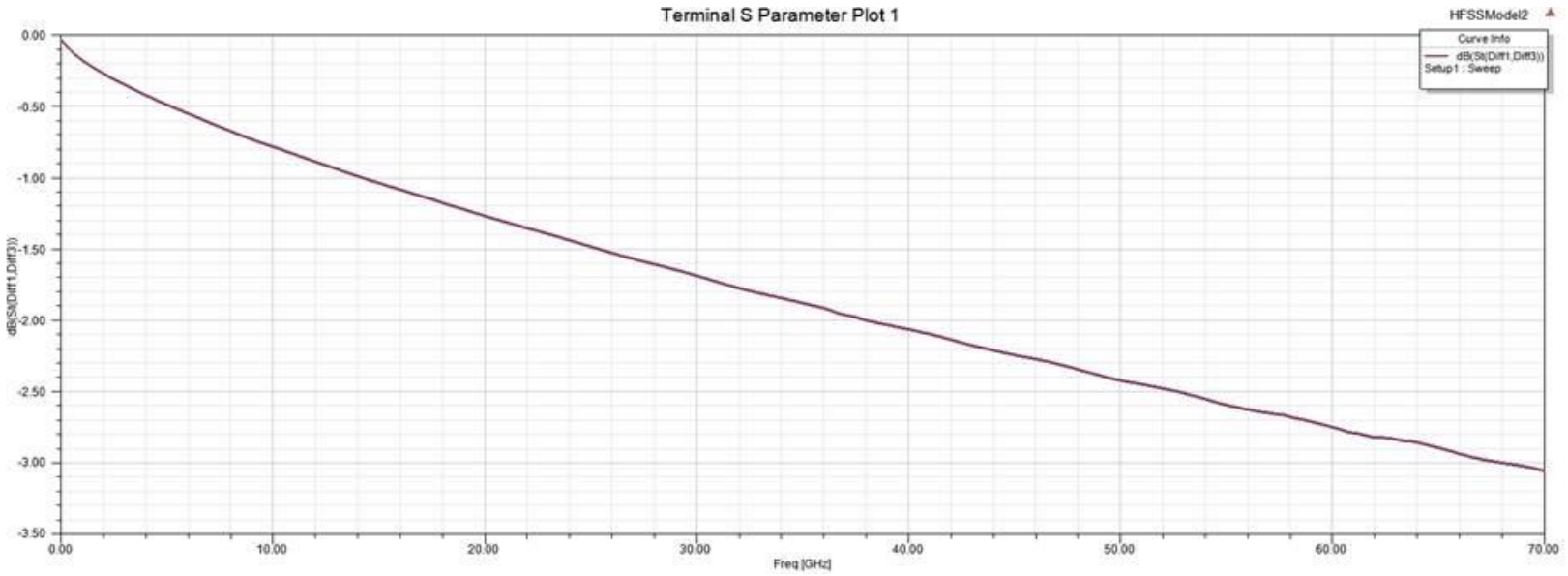
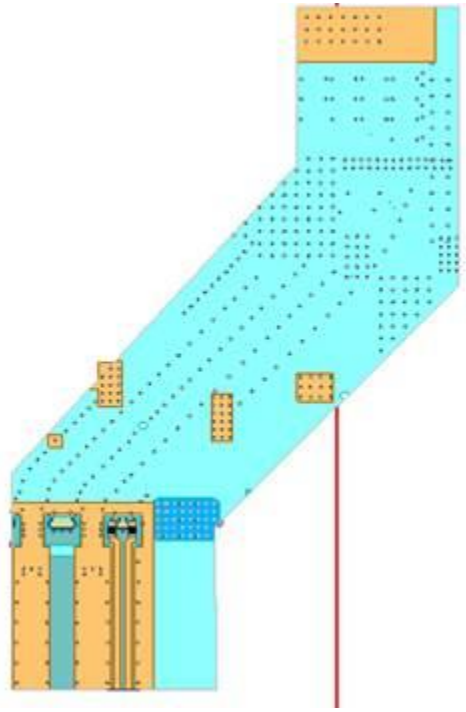
106 GBd Module Plug Implementation

- **This mSAP example module plug board including DC block at 56 GHz for 113 GBd module has a loss of just 2.6 dB!**





Bottom-Up Module Plug Losses

- **Most module use 1 mm PCB except OSFP-XD that uses 1.2 mm plug PCB**
  - Typical module plug PCB/mSAP trace lengths expect to be < 20 mm
  - Proposing **3.8 dB** for plug board which will support both mSAP and conventional PCB construction
  - Conventional construction and mSAP losses are about the same but conventional PCB will have additional degradation not reflected in the loss.

Module Trace Ranges	Loss (Class A) (dB/mm)	Loss (dB)	DC Block Loss (dB)	Total Loss (dB)
15 mm	0.15	2.25	0.5	2.8
20 mm	0.15	3.0	0.5	3.6
22.0 mm	0.15	3.3	0.5	3.8

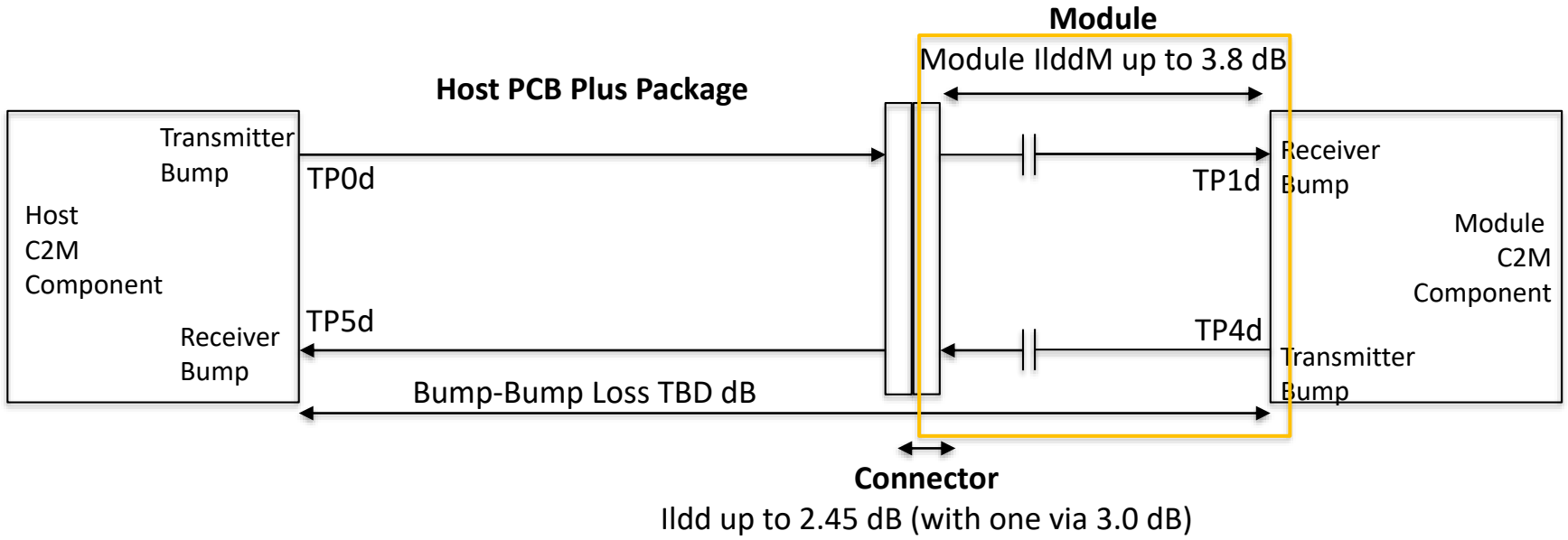
mSAP Construction

Module Trace Ranges	PC Loss (dB/in)	Loss (dB)	DC Block Loss (dB)	Loss (Class B) (dB/mm)	CDR PKG Trace (mm)	CDR PKG Loss (dB)	Total Loss (dB)
15 mm	1.5	0.9	0.5	0.195	10	1.95	3.35
20 mm	1.5	1.2	0.5	0.195	10	1.95	3.65
23.0 mm	1.5	1.35	0.5	0.195	10	1.95	3.8

Conventional Construction

AUI C2M Application Reference Model

- **Maximum module IlddM is 3.8 dB including DC blocks**
- **mSAP module construction – device attaches directly to the substrate trace without 1st level package**
  - Transmission line (PCB) model based on Class A package model, see Table 176E-5
    - Zp2=0, Zc2=NA
    - As long as channel S4P include module PCB then mSAP trace should nulled and device is cascaded directly to the S4P
- **Conventional module construction – conventional HDI board with 1st level package**
  - Coreless package (4-10 mm) based on Class B package transmission line model, see Table 176E-5
    - Zp2,3,4=0, Zc2,3,4=NA
    - As long as channel S4P include module PCB then small core-less package should be cascaded without any added PCB to the S4P.



Summary

- **Most common 106/113 GBd module implementation will mSAP without using 1st level CDR/DSP**
- **This consensus proposal recommends allocating 3.8 dB loss for the plug board to support varity of advanced mSAP implementation as well as conventional implementations with 1st level package**
  - The 3.8 dB plug board loss include DC blocks
  - 1st level package trace of 4-10 mm expect to cover 1x-16x module applications
- **The 3.8 dB module plug loss is equal to HCB loss of 3.8 dB**
  - HCB loss equal to plug loss allow measuring at TP1d device bump equivalent directly
- **If we consider mSAP construction only that can can provide some relief**
  - Considering the powerful C2M equalizer adopted not clear if there will be sufficient benefit not to support conventional module with 1st level package
  - Supporting a 1st level package expect to be sufficient to also support various SiPho implementation with EIC.