Use of Advance Packaging to Reduce Optical Module PCB Losses

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Overview

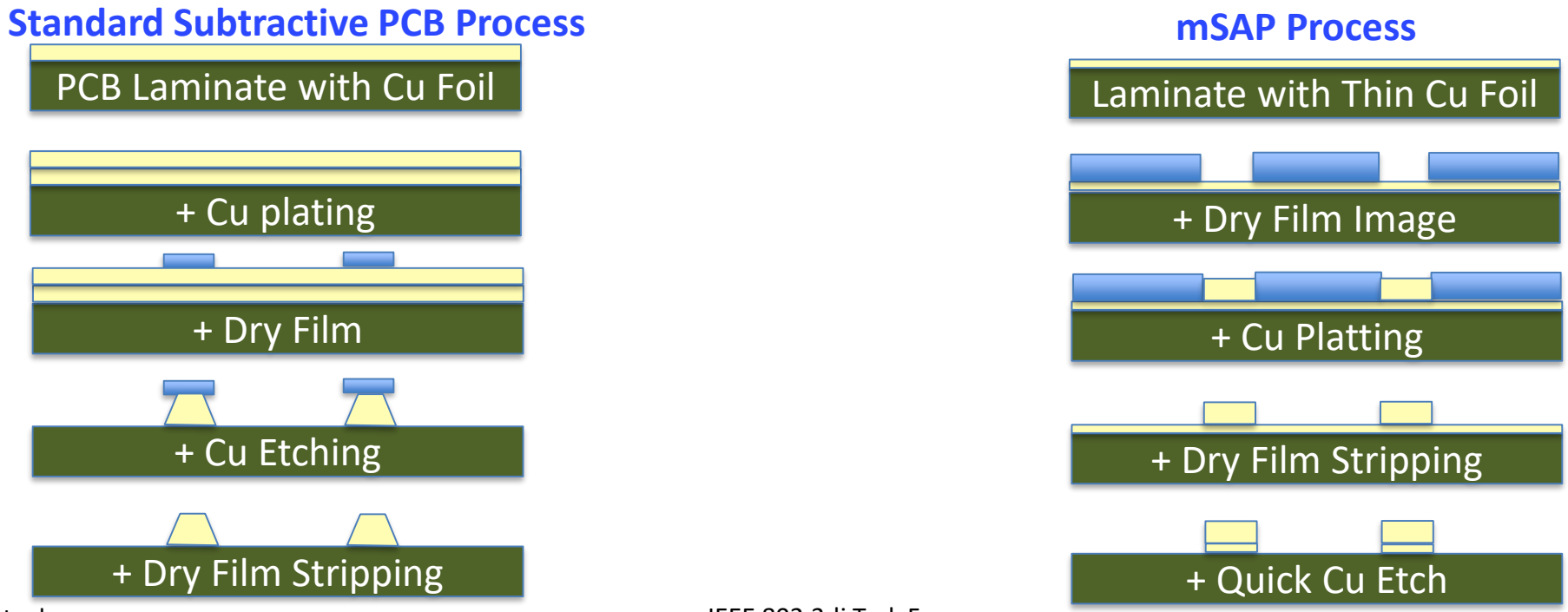
- **Advance packaging**
  - mSAP
- **Module DC blocks**
- **Simulation of module plug board losses**
- **Module plug board construction options**
- **Summary.**

Advance Packaging for Optical Modules

- **The primary reason optical modules are using advance 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 guarantee signal integrity and low power
  - Several 53 GBd optical DSP offering have integrated TIA
    - Due to noise sensitivity the PD must be bumped or wire bounded on the same substrate/PCB
    - Eliminating TIA saves power and cost
- **Advance optical modules are using mSAP (modified Semi Additive Package) to save cost and power**
  - mSAP was developed in the last 7-10 years in support of smart phones and watches.

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 construction ~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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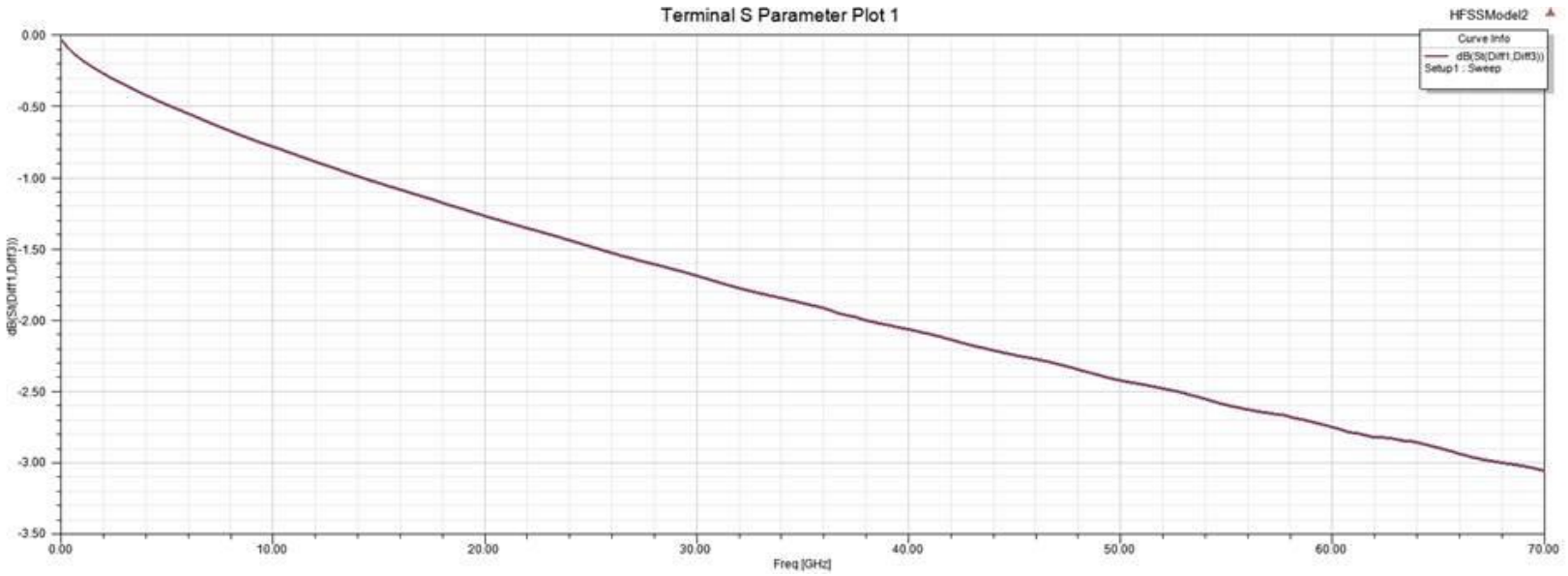
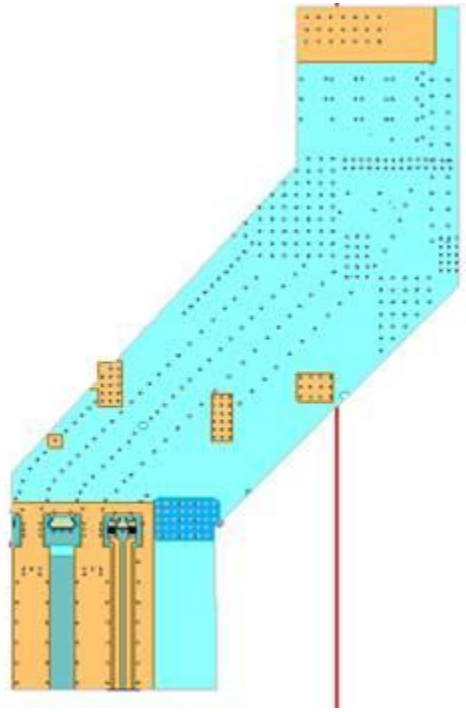
200G Module Plug Implementation

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





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 **3.6 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
22.5 mm	0.15	3.4	0.5	3.9

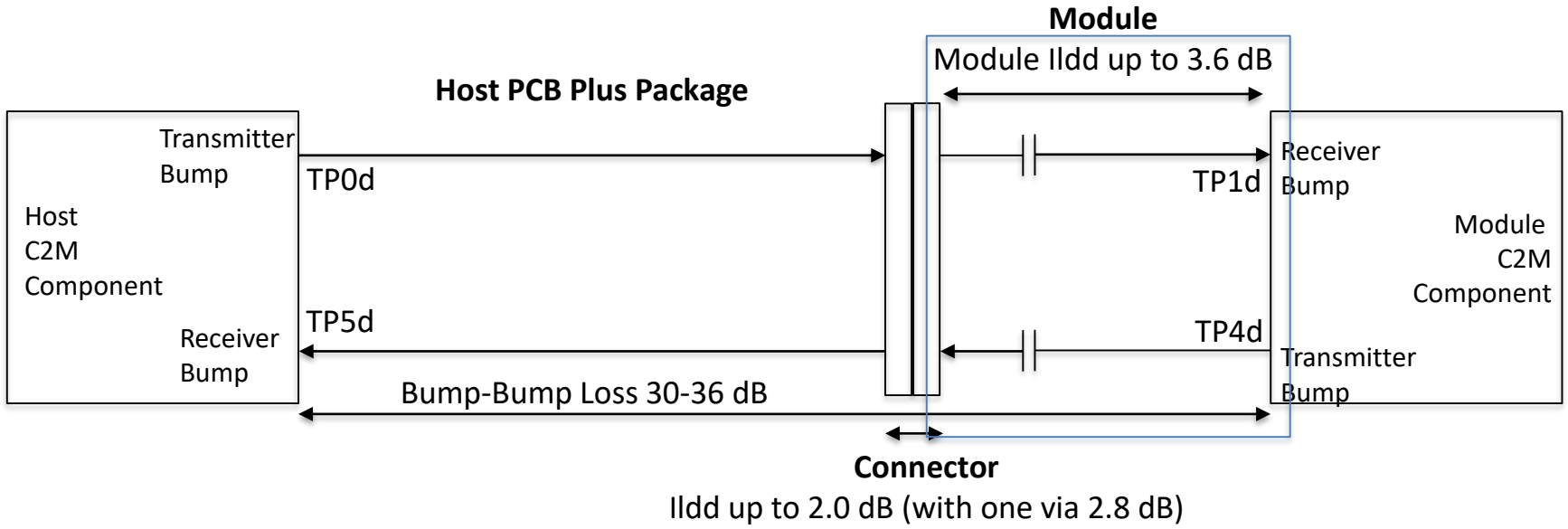
mSAP Construction

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
25.4 mm	1.5	1.5	0.5	0.195	10	1.95	3.95

Conventional Construction

AUI C2M Application Reference Model

- **Up to Sept-23 the assumed module plug+PKG losses were ~6 dB**
  - This analysis show that module plug+PKG losses can be reduced to 3.6 dB
  - For the same bump-bump loss host now may have ~2.4 dB more budget.



Summary

- **A 200G single lamda module plug board with mSAP construction has 2.6 dB loss at 56 GHz**
  - The plug board loss include DC blocks
  - To support broader mSAP implementation and conventional PCB construction the recommendation is to define loss of the plug board to the CDR/DSP bumps **≤ 3.6 dB**
- **The 3.6 dB will support both improved SI mSAP and conventional PCB construction**
- **If majority of implementations move to mSAP, should the reference equalizer support more challenging conventional PCB + PKG or should the module accommodate for its additional penalties?**
  - The bump side of mSAP plug board will be similar to HCB TP1a/TP4a
  - Measurement performed at TP1a/TP4a in case of mSAP will be at the bump but in case of conventional construction will be at the ball
  - With conventional construction TP1 stress input would need to support additional package impairments
- **Considering AUI C2M budget is rather tight, mSAP construction can provide relief in term of both loss and reflections.**