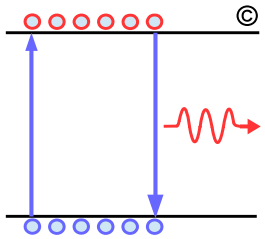


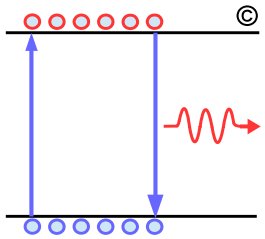
# Supporting 200G PMDs with Multiple AUIs and Concatenated FEC

**Ali Ghiasi, Ghiasi Quantum/Marvell**

**802.3df Task Force Meeting**

**Bangkok**

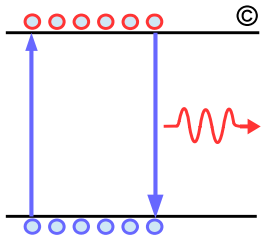
**November 14, 2022**



# Overview

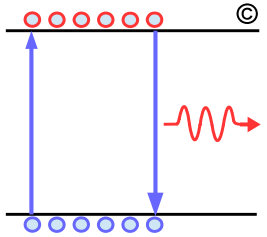
- AUI straw poll result
- PCB, package, cable losses
- Various AUI and PPI implementations
- 100G AUI budget
- 200G AUI budget
- Scaling BS FEC architecture to df/dj with SFEC
- Summary.

# Task Force Interest in Defining Multiple AUI Classes



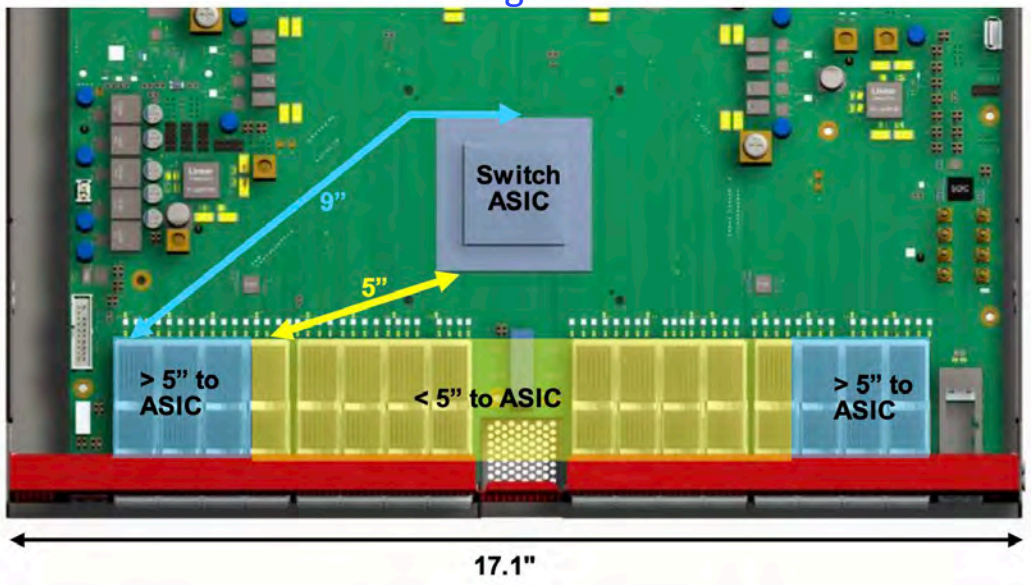
- **Straw Poll - For the front panel pluggable use case, I am interested in 200 Gbps/lane AUI C2M specifications for:**
  - A. medium loss only (e.g., up to ~22 dB IL die-die per lusted_3df_01_220927)
  - B. higher loss only (e.g., up to ~36 dB IL die-die per lusted_3df_01_220927)
  - C. both medium and higher loss
  - D. need more information
  - pick one
  - Results: A: 17, B: 11, C: 49, D: 12
- **Straw Poll - I'm interested in 200 Gbps/lane AUI C2M specifications for co-packaged or near-packaged use cases**
  - Y: 54 , N: 10 , A: 22
- **Next will explore bottom-up loss analysis of several AUI classes and if it would be feasible to operate these AUIs with end-end KP4 FEC + SFEC for the optics.**

# 1RU Switch Implementation

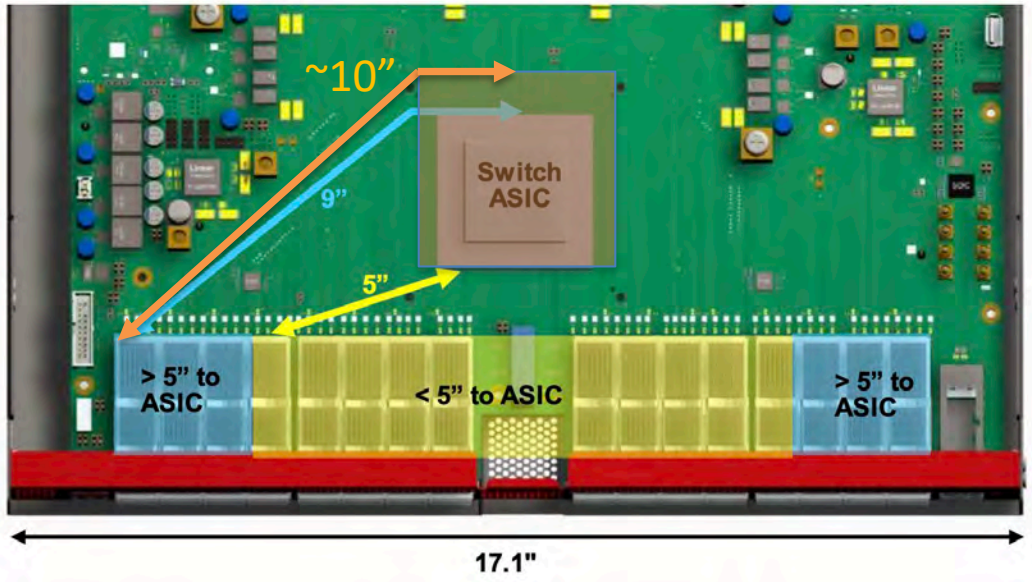


- **To support convention PCB implementation in the 802.3ck CL120G was defined based on 11.9 dB or ~9” of PCB on Megtron 7 with 1.2 dB/in per recommendation [stone_3ck_01a_0518]**
  - A 51.2T switch will have to use ~90x90 package vs stone assumed package of ~69x69
  - Considering larger package to connect balls on the N side require 10” instead of Stone assumed 9”.

Stone Hypothetical 25.6T Switch
Package ~69x69

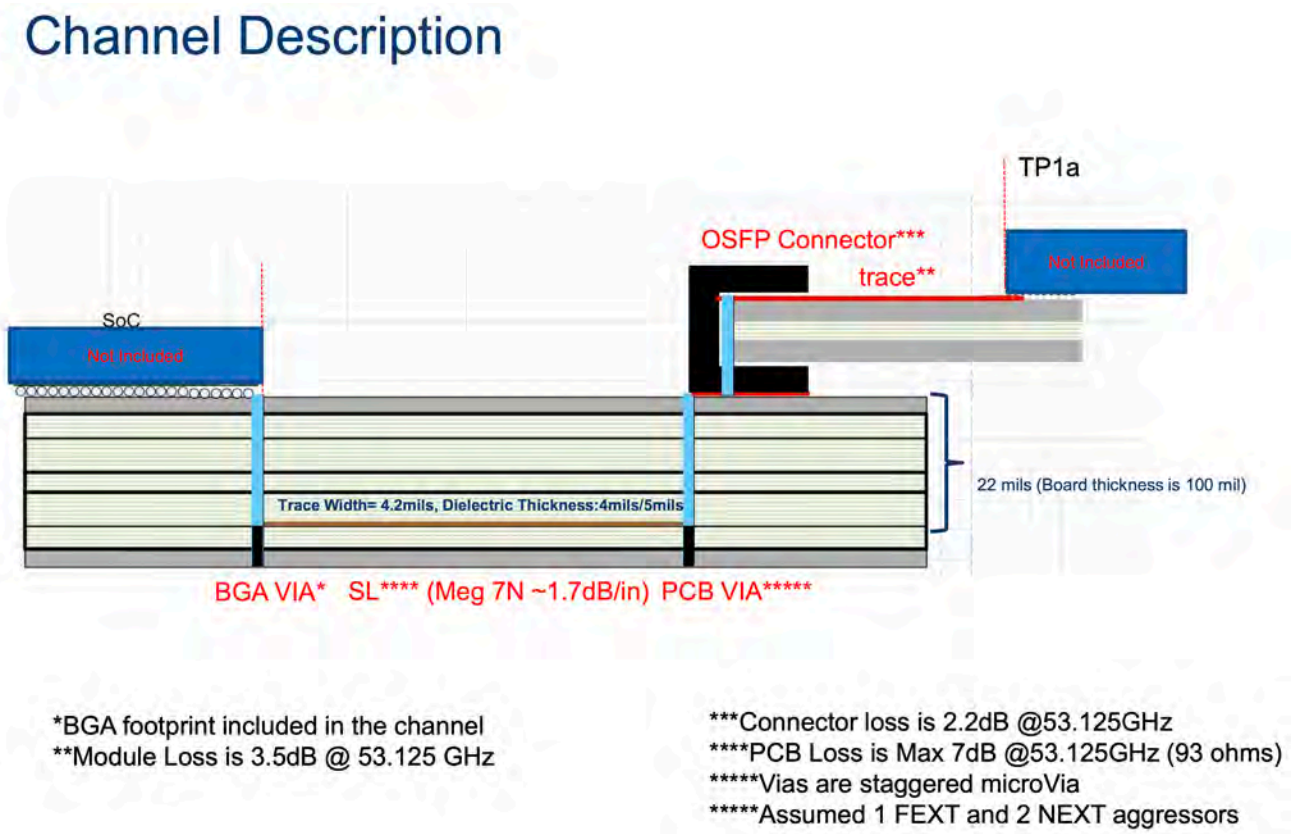



Hypothetical 51.2T Switch
Package ~90x90

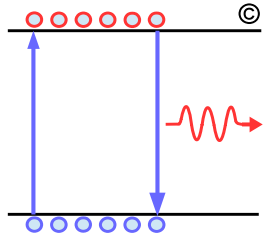


# NIC Channel Implementation

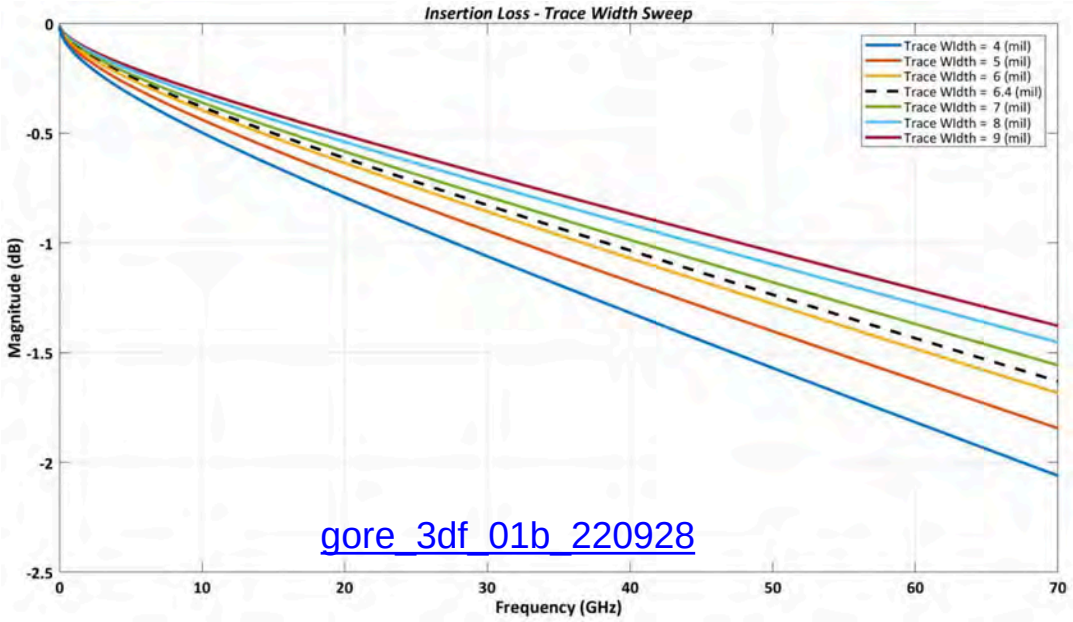
- **akinwale_3df_01_20220502 (see figure) does not mention the length of NIC channel but is estimated to be ~5" @1.7 dB/in at 53 GHz**
  - Considering NICs are cost sensitive, and the loss is < AUI Type-II with cabled host the loss assumed is 1.8 dB/in with 15 dB from TP0-TP1a instead of assumed 13 dB by Akinwale
  - Results generally failed 3 dB by over 1 dB for pre-FEC BER 1E-5
  - At pre-FEC BER of 1E-4, 2 out of 8 channels failed 3 dB COM even NIC card my benefit operating at pre-FEC BER higher than 1E-5!



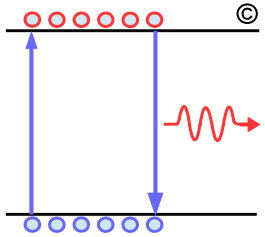
# PCB Loss at 53 GHz



- **Loss of advance next generation PCBs**
  - gore_3df_01b_220928 measured result for 6 mils stripline on next Gen advance PCB material at 20 ºC is 1.33 dB/in and the estimated loss at 70 ºC expected to be ~1.6 dB/in
  - ghiasi_3df_01_220927 simulated 6 mils stripline on Rogers 3003G2 at 70 ºC 1.67 dB
  - akinwale_3df_01_20220502 NIC loss for 4.6 mils wide trace is 1.7 dB/in or ~1.6 dB/in at room temperature based on Gore results, 1.8 dB/in will be assumed as worst-case loss for NIC

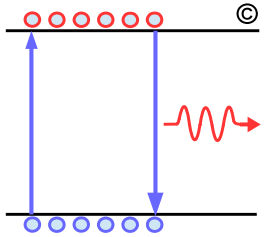



# Package Loss



- **What should be our assumption regarding 200G high radix package loss?**
  - mli_3df_01a_220316 proposes to use skip ABF layers to allow using wider traces to lower loss/mm to ~0.14 dB/mm @53 GHz (loss include transition via/BGA)
  - benartsi_3df_01b_2207 uses best ABF conventional 27-45-27 μm construction and reports trace loss of 0.31 dB/mm @53 GHz (loss include transition via/BGA)
    - Benartsi 0.31 dB/mm is too pessimistic and expected to be ~0.22 dB/mm after accounting for improved surface roughness
  - ghiasi_3df_01_220927 states that with availability of thicker ABF film one may construct wider 38-52 μm traces without needing to use skip layer but traces wider than 40 μm are not suitable for high radix switches due to congestion
    - Next Gen ABF loss for geometry similar to Benartsi 27x15 μm at 90 ºC expected loss is 0.225 dB/mm
    - Next Gen ABF loss for 38x15 um at 90 ºC expected loss is 0.189 dB/mm
    - If one uses next Gen ABF with tall geometry 38x30 um at 90 ºC expected loss is 0.155 dB/mm but this design has its own challenges
  - Considering these data, the recommended loss for 200G package is 0.18 dB/mm
    - The 0.18 dB/mm loss is very aggressive and does require next Gen ABF film and construction!

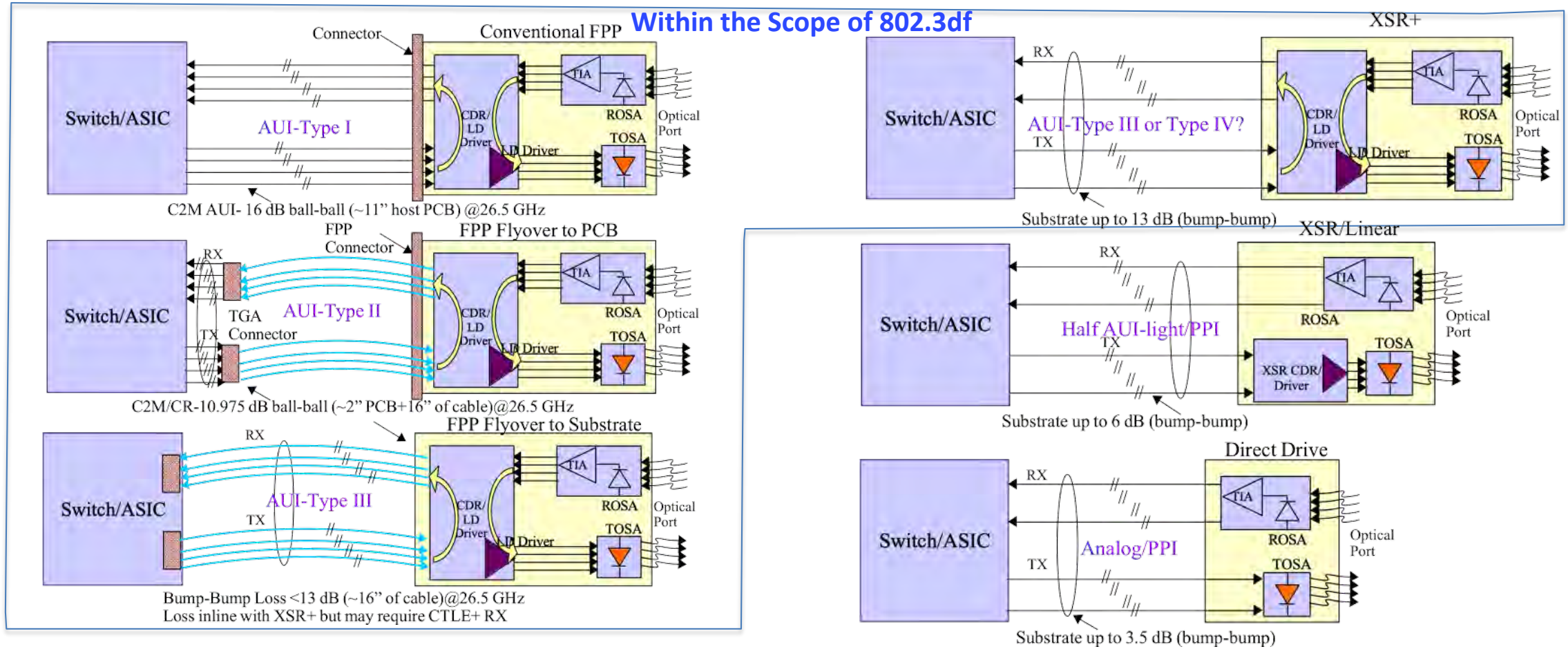
# Other Key Loss Components of the Channel



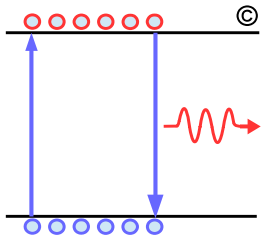
- **Cabled host loss is ~0.35 dB/in @ 53 GHz**
  - kocsis_b400g_01a_210826
- **Host via loss  is ~1.25 dB @53 GHz**
  - rabinovich_3df_elec_01b_220921
- **OSFP connector loss is ~1.6 dB @53 GHz**
  - rabinovich_3df_elec_01b_220921
- **Socket loss is ~0.2 dB @53 GHz.**

# AUI and PPI Interfaces

- **XSR/Direct drive generally require optics engine to be bumped and the interface is an engineered analog drive – not an AUI interface**
  - With in the scope of 802.3df we have potentially up to 4 AUI classes and as few as 2 classes!



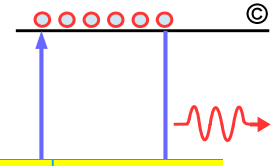
# 100G C2M/XSR+ Ecosystem



- **Following interfaces have been defined based on 100 Gb/s PAM4 in the OIF and IEEE:**
  - OIF 112G-VSR/802.3ck CL120G addressing C2M with 16 dB loss
  - 802.3ck CL162 defines CR/C2M with 10.975 dB host loss to support 2 m of passive Cu cable
  - OIF 112G-XSR+ defines NPO/CPC (co-packaged Cu) on HDI board with bump-bump loss of 13 dB.

| 53 GBd (26.55 GHz) AUIs | VSR/C2M | CR/C2M | XSR+ |
|---|---|---|---|
| TP0-TP1a Loss (dB)* | **16** | **10.975** | ~7 |
| PCB/Substrate Loss (dB) | 11.9 | 6.875 | ~7* |
| Bump-TP1a Loss (dB) | 20 | 14.975 | ~11** |
| Bump-Bump Loss (dB) | ~22 | ~16.975** | **13** |
| Loss Adv PCB(C2M) or HDI(NPO) dB/in | ~1.1 | ~1.1 | ~1.8 |
| PCB/HDI Length Supported (in) | ~10.8 | ~6.25 | ~3.8 |
| *Assume 1st level package loss 4 dB. ** PMA package loss assumed 2 dB. | | | |

# Potential 200G AUIs Ecosystem



- **Starting point for 200G AUIs/C2Ms:**
  - AUI Type I supporting 10” conventional PCB
    - TP0-TP1a loss increased from 16 dB@100G to 23.5 dB
    - Bump-bump loss ~34 dB
  - AUI Type II cabled host
    - TP0-TP1a loss 14 dB
    - Bump-bump loss ~24.5 dB
  - AUI conventional NIC supporting 5” PCB
    - TP0-TP1a loss 15 dB
    - Bump-bump loss ~19.5 dB
  - AUI Type III cabled substrate (CPC)
    - TP0-TP1a loss ~13 dB
    - Bump-bump loss ~22 dB
  - AUI Type V NPO
    - Bump-TP1a loss ~13 dB
    - Bump-bump loss ~20 dB.

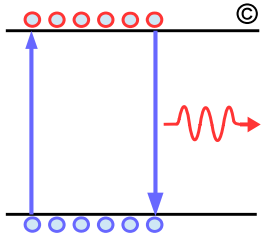
| Loss Parameters @ 53 GHz<br>A. Ghiasi - Rev 1.0<br>10/30/2022 | Loss | Length or # | AUI Type I Conventional PCB | AUI Type II Cabled Host | AUI NIC Conventional PCB | AUI Type III Cabled Substrate | XSR+ NPO |
|---|---|---|---|---|---|---|---|
| Host PCB Loss (dB/in) | 1.65 | 10 | 16.5 | NA | NA | NA | NA |
| NIC PCB Loss (dB/in) | 1.8 | 5 | NA | NA | 9 | NA | NA |
| Cabled Host PCB Loss (dB/in) | 1.65 | 2 | NA | 3.3 | NA | NA | NA |
| Cable Loss (dB/in) | 0.35 | 10 | NA | 3.5 | NA | 3.5 | NA |
| Plug Board/PIC Loss (dB/in) | 1.65 | 1.7 | 2.805 | 2.805 | 2.805 | 2.805 | 2.805 |
| AUI Connector Loss (dB) | 1.65 | 1 | 1.65 | 1.65 | 1.65 | 1.65 | NA |
| Host Via Loss (dB) | 1.25 | 2 | 2.5 | 2.5 | NA | NA | NA |
| NIC Via Loss (dB) | 0.75 | 2 | NA | NA | 1.5 | NA | NA |
| Host Package Loss (dB/mm) | 0.18 | 40 | | | | | |
| NIC Package Loss (dB/mm) | 0.225 | 16 | | | | | |
| CDR Package Loss (dB/mm) | 0.18 | 10 | | | | | |
| Host/NIC Package Loss (dB) + 1dB | 1 | NA | 8.2 | 8.2 | 4.6 | 8.2 | 8.2 |
| CDR Package Loss (dB) + 0.4 dB | 0.4 | NA | 2.2 | 2.2 | 2.2 | 2.2 | NA |
| TGA Connector Loss (dB) | 0.3 | NA | NA | 0.3 | NA | NA | NA |
| Socket Loss (dB) | 0.2 | NA | NA | NA | NA | 0.2 | 0.2 |
| NPO Substrate Loss (dB/mm) | 0.095 | 50 | | | | | |
| NPO Substrate Loss (dB) | 4.75 | NA | NA | NA | NA | 4.75 | 4.75 |
| TP0-TP1a Loss (dB) | NA | NA | 23.455 | 14.055 | 14.955 | 12.905 | 4.95 |
| Bump-TP1a (dB) | NA | NA | 31.655 | 22.255 | 19.555 | 21.105 | 13.15 |
| Bump-Bump Loss (dB) | NA | NA | 33.855 | 24.455 | 21.755 | 23.305 | 15.955 |

High Loss AUI FEC@5E-4, 1E-4?

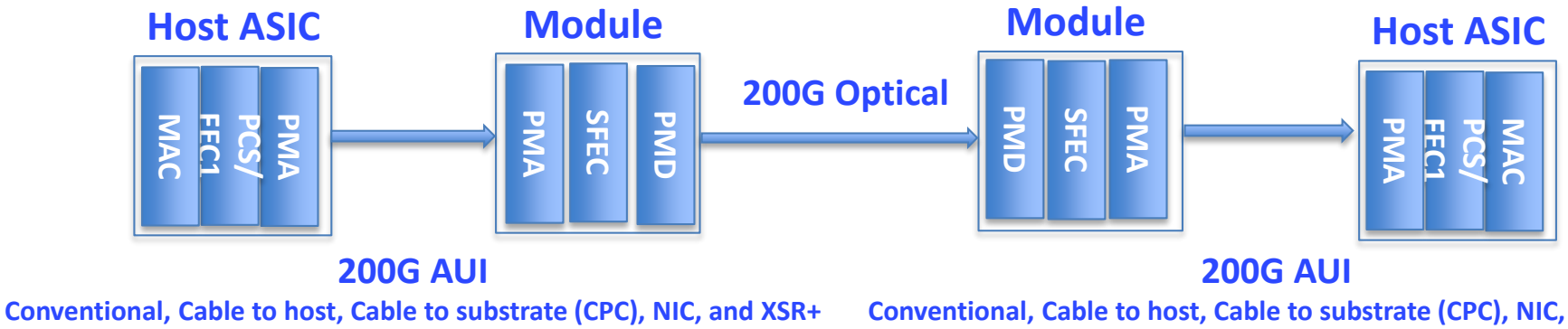
Mid-Loss AUI FEC@5E-4, 1E-4?

XSR+ FEC@1E-5

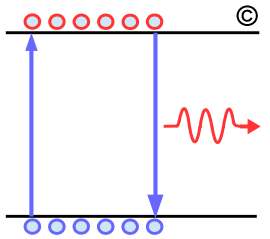
# 802.3bs FEC Architecture Can be the Template for 802.3df



- **It is unlikely that 802.3df task force will be able to follow 802.3bs by allocating only 0.1 dBo and support 4 AUI sub-links**
  - For the above to be true the AUIs must operate at pre-FEC BER of 1E-5
  - Based on current C2M package/channel model operating AUIs at 1E-5 is extremely challenging
    - Only for CPC and NPO one may assume pre-FEC BER ≤1E-5 can be archived
  - SFEC need to be evaluated in the context of potentially allocating larger portion of FEC gain 0.3-0.8 dB to the AUIs!

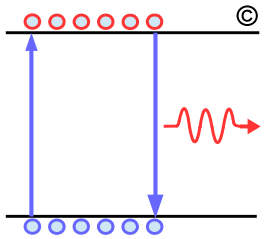


# Implication of 200G AUI on Optics SFEC



- **With more realistic Liav package model and/or 40 mm package trace on next Gen ABF film/construction the 200G large ASIC package loss will be ~ 8dB**
- **The conventional AUI Type I based on PCB the bump-bump loss is least 34 dB**
  - This implementation due to high loss expected to require 5e-5 to 1E-4 pre-FEC BER
- **Medium loss AUI Type II, III, and NIC with bump-to-bump loss of ≤25 dB**
  - AUI-II with cabled host due to cascaded reflections between cable TGA connector-BGA-die some early data indicate is as challenging as high loss 34 dB channel and will benefit from operating with 5e-5 to 1E-4 pre-FEC BER
  - AUI-III cable to substrate expect to operate at 1E-5 pre-FEC BER
  - AUI-NIC as shown in akinwale_3df_01_20220502 also benefit from operating with 5e-5 to 1E-4 pre-FEC BER
- **Near Package Optics (NPO) with 16 dB bump-bump loss**
  - Expect to operate at 1E-5 pre-FEC BER
- **Unless SFEC can support pre-FEC BER of 5E-5 to 1E-4 then high loss AUI and the most common medium loss AUIs will be forced into segmented RS FECs + RS FEC/SFEC**
  - CMIS-LT could be used to train the link then selectively turn segmented RS FEC on/off based on pre-FEC BER considering both high loss and some of the medium loss AUI may require selective FEC termination at 1E-5.

# Summary



- **200G AUI classes can categorized into the following types**
  - High loss with at least 34 dB bump-bump AUI based on conventional PCB
  - Medium loss AUI with up to 25 dB bump-bump loss addressing cabled host, CPC, and NIC
  - Near package optics NPO AUI with ~16 dB FEC
- **Early indications are that high loss AUI and medium loss cabled/NIC AUIs all will require operating at pre-FEC BER 1E-4 to 5E-5**
  - This implies one must allocate >>0.1 dBo that was allocated in 802.3bs to support 4 AUI sub-links
- **Early indication are that only CPC and NPO may operate at pre-FEC BER of 1E-5**
- **With optics and Cu/AUIs soon to be all part of the same 802.3dj task force**
  - We can't choose an SFEC that only works with 100G-AUI and the 200G-AUI end up requiring segmented RS FEC termination
  - This is the worst combination in regard to latency and power
- **Concatenated SFEC bliss_3df_01_220929 and patra_3df_01_220518 providing 2+ dB NCG are attractive for the optics but require further study if it can support pre-FEC BER of 1E-4 to 5E-5 on AUI sub-links with error burst!**