Deskew in 800GbE/1.6TbE for Inner FEC (CL177) updated

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Introduction

- Recap: The purpose of the Inner FEC Convolutional Interleaver is to guarantee that the 12 RS symbols that form the Inner FEC Hamming payload are from 12 different RS-FEC Codewords, i.e. 12-way RS Interleaved

- Input of the Inner FEC Convolutional Interleaver is output from CL-176 SM-PMA

- 3 delay lines are used to create 12-way RS interleaved with the RS-interleaved from CL176 SM-PMA

- Dudek_3dj_optx_01_240627 was presented at the joint optics/logic ad-hoc on 6/27/2024 and showed that skew generated between PCSL's in the 50/100G per lane PMA's and AUIs can (partially) undo the effect of the Convolutional Interleaver Delay Lines for 800G and 1.6T.

Further comments on the issue.

- The issue does not exist at 200G and 400G due to the adoption of the de-skew to 4CW markers in draft 1.0 comment resolution for the bit mux to symbol mux Clause 176 PMA's based on _shrikhande_3dj_01a_2406.pdf_.

- At 800G and 1.6T the issue only occurs when there is a clause 176 m:n PMA prior to the convolutional interleaver where m>n.   i.e. The issue does not exist if the incoming 200G lanes to the convolutional interleaver have stayed as 200G lanes from the PMA below the PCS.

- The location of the clause 176 m:n PMA is not necessarily immediately above the clause 177 FECi.   i.e. It may not be co-located with the FECi.   E.g. the PCS could have a 100G AUI C2C connection to a retimer followed by a 200G AUI C2M connection to a module. The FECi would be in the module and the 176 m:n PMA would be in the retimer.

Potential paths forward.

- Option 1.   Do nothing.   Accept the marginal performance degradation. This however would result in different PMD performance depending on the incoming skew and the worst case would have to be adopted for the PMD budgeting. This is therefore not recommended.

- Option 2.   Provide de-skew at the input to the convolutional interleaver.

- Option 3.   Provide de-skew for 800G and 1.6T   m:n PMA's where m>n.

Option 2. Provide Deskew at the input to the Inner FEC Convolutional Interleaver.

- Add full-deskew to align RS-FEC CW between PCSLs, either within PMA lanes or across PMA lanes so that the output of the Convolutional Interleaver is always 12-way RS Interleaved

  - Full deskew memory needed should be more than 16ns (SP1) but less than 25ns (SP2) for both 800GE and 1.6TbE
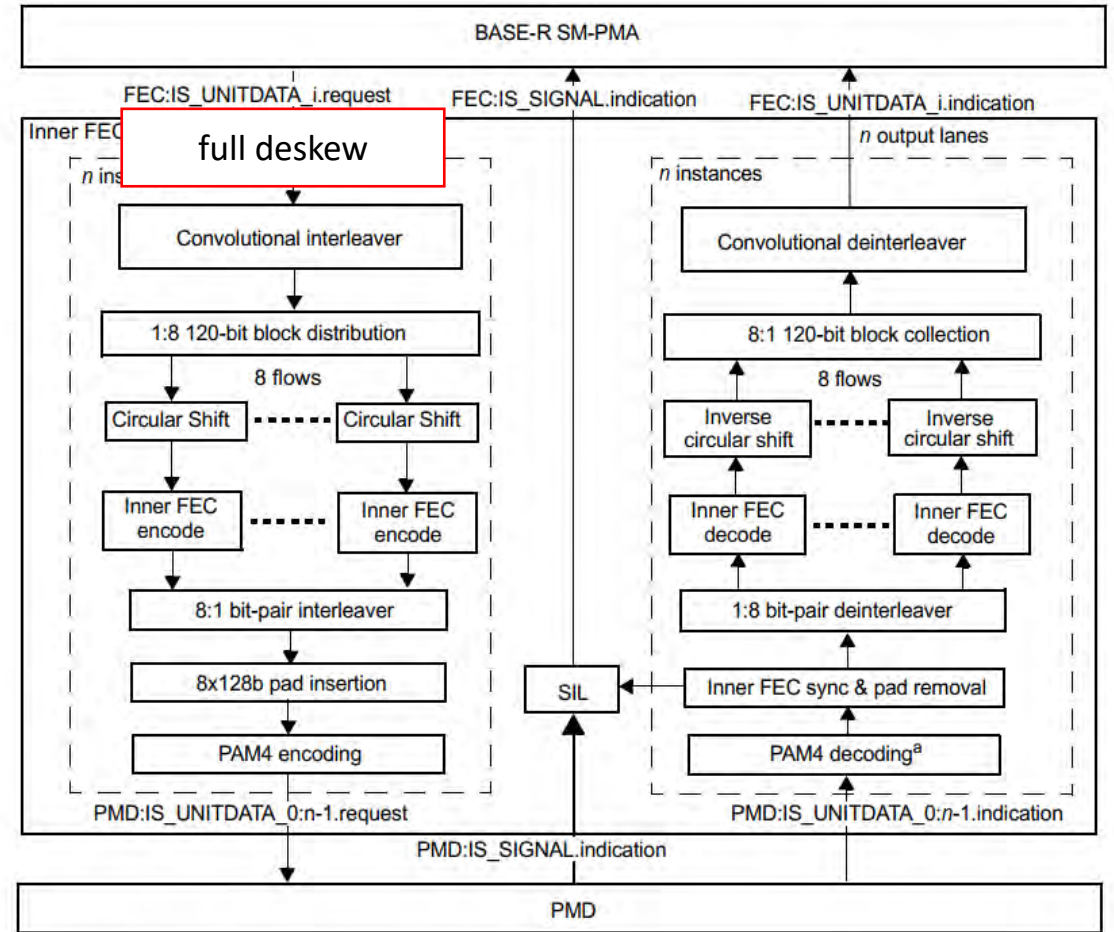
Figure 177–2—Functional block diagram

Option 3. Provide Deskew for 800G and 1.6T m:n PMA's where m>n.

- Extend the "CW boundaries deskew" proposed in *"shrikhande_3dj_01a_2406.pdf"* to support full deskew for 800GE 8:4 SM-PMA and 1.6TbE 16:8 SM-PMA

  - This requires less memory than 4CW boundaries deskew for 200GE/400GE and a multi-rate device can share this memory.

Pros and Cons of Option 2 and 3.

- Option 2 requires additional memory in all Convolutional Interleavers .

- Option 3 does not require additional memory in the convolutional interleaver or Clause 176 PMAs that are capable of 200G or 400G.   It does require additional memory in 800G 32:4 PMA and 1.6T 16:8 PMA's that don't.

- How likely is it that 800G PMA's in the future will not be capable of 200G and 400G and still want 100G inputs?

Backup (slides from Dudek_3dj_optx_01_240627)

Skew output of SM-PMA (CL176): 200GE/400GE

- 200GE/400GE: per "*shrikhande_3dj_01a_2406.pdf*", skew output of the SM-PMA lane(s) is deterministic :

  - All even PCSLs are aligned

  - All odd PCSLs are 1370/690 bits delayed compared to even PCSLs

  - The Skew introduced by different delays in 200G per lane C2C or C2M links between the SM-PMA and the FECi input does not change the skew within the 200G lanes

- As a result, the Inner FEC Convolutional Interleaver which operates on a 200G lane basis can guarantee 12-way RS Interleaved

Skew output of SM-PMA (CL176): 800GE

- 800GBASE-R 8:32 PMA can have 16ns skew, which is ~

  0.625 x 4CW

- 20b deskew in 800GE SM-PMA is not enough to align

  RSFEC CW between PCSLs
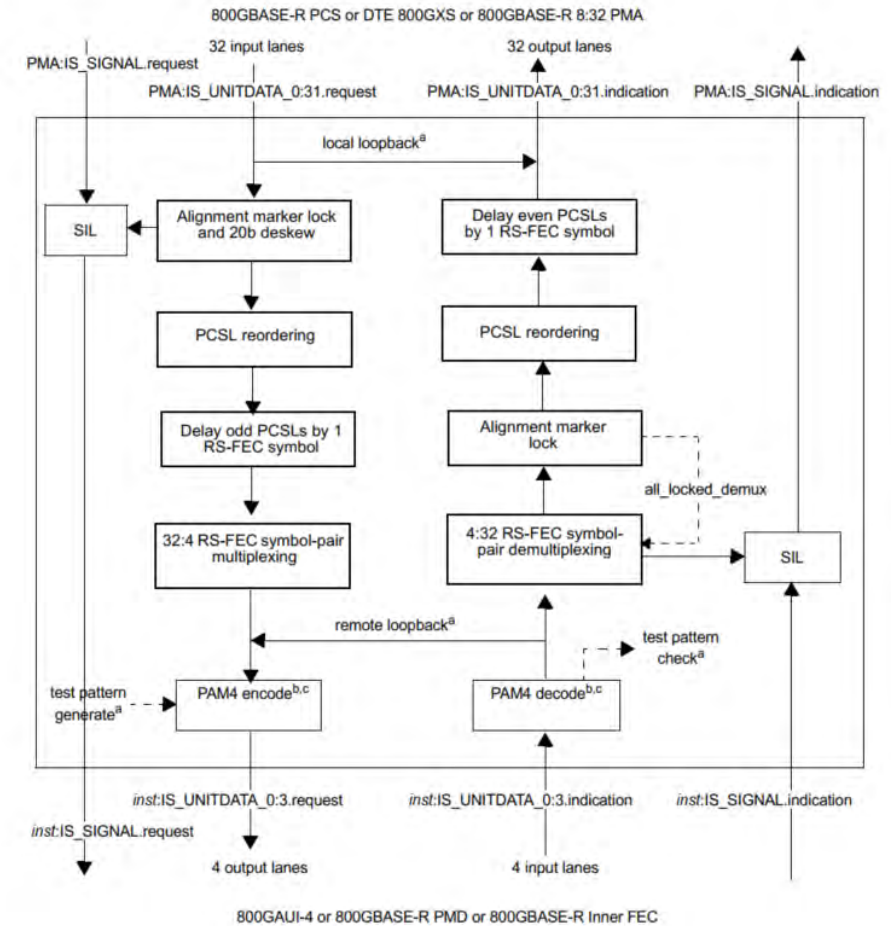
Skew impact to Inner FEC Convolutional Interleaver Illustration (1.6TbE)

Zero skew scenario

All PCLSs 0,1 are from 4-RS CW set (ABCD)

One 200G Convolutional Interleaver instance

D	C	B	A	D	C	B	A	D	C	B	A

PCSL0 (2)   **PCSL1**   **PCSL0 (1)**

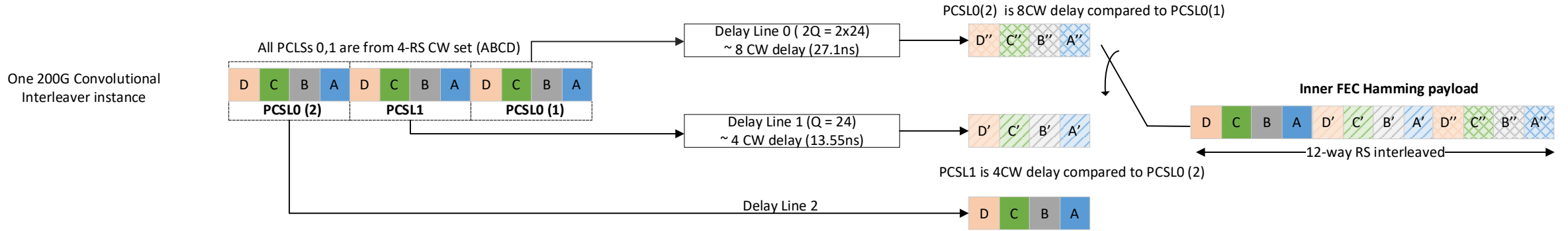Delay Line 0 (2Q = 2x24)
~ 8 CW delay (27.1ns)

PCSL0(2) is 8CW delay compared to PCSL0(1)

D'' C'' B'' A''

Delay Line 1 (Q = 24)
~ 4 CW delay (13.55ns)

D' C' B' A'

PCSL1 is 4CW delay compared to PCSL0 (2)

Delay Line 2

D C B A

Inner FEC Hamming payload

D	C	B	A	D'	C'	B'	A'	D''	C''	B''	A''

←————————— 12-way RS interleaved —————————→

12.8ns skew scenario

PCSL1 is 4CW delay compared to PCSL0

One 200G Convolutional Interleaver instance

D	C	B	A	D'	C'	B'	A'	D	C	B	A

PCSL0 (2)   **PCSL1**   **PCSL0 (1)**

Delay Line 0 (2Q = 2x24)
~ 8 CW delay (27.1ns)

PCSL0(2) is 8CW delay compared to PCSL0(1)

D'' C'' B'' A''

Delay Line 1 (Q = 24)
~ 4 CW delay (13.55ns)

D'' C'' B'' A''

PCSL1 is **8CW** delay compared to PCSL0 (2)

Delay Line 2

D C B A

Inner FEC Hamming payload

D	C	B	A	D''	C''	B''	A''	D''	C''	B''	A''

←————————— **8-way** RS interleaved —————————→

Skew output of SM-PMA (CL176): 1.6TbE

- 1.6TAUI-16 can have 16ns skew (SP1), which is ~ 1.25 x 4CW (*per Table 174–5—Summary of Skew constraints*)

- 40b deskew in 1.6TbE SM-PMA is not enough to align RSFEC CW between PCSLs

Skew impact to Inner FEC Convolutional Interleaver Illustration (800GE)
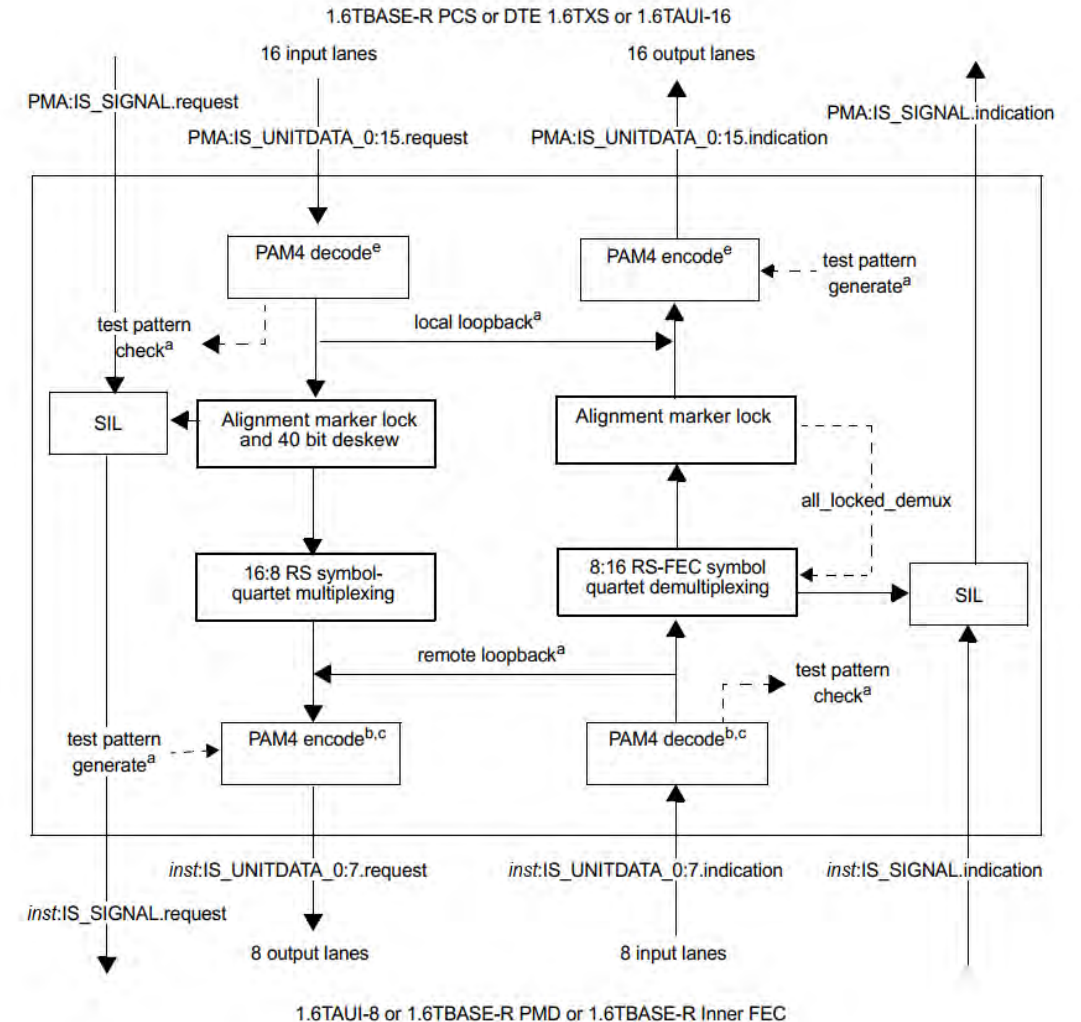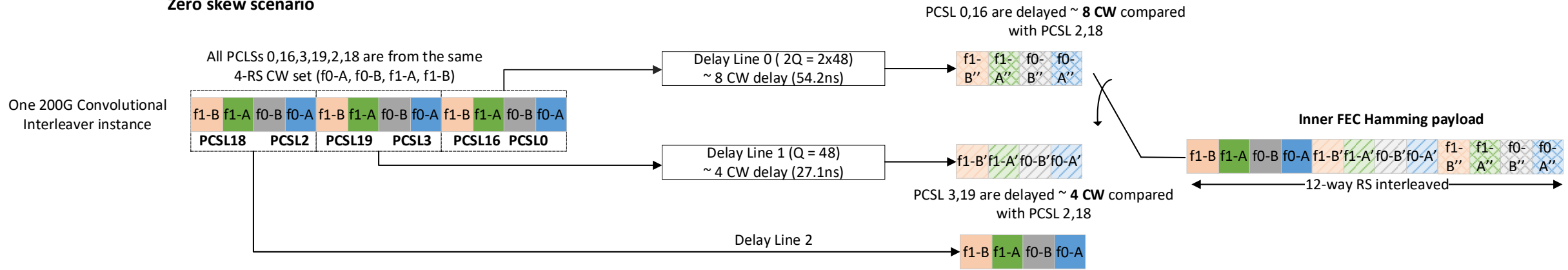

Zero skew scenario

PCSL 0,16 are delayed ~ **8 CW** compared with PCSL 2,18

All PCLSs 0,16,3,19,2,18 are from the same 4-RS CW set (f0-A, f0-B, f1-A, f1-B)

One 200G Convolutional Interleaver instance

f1-B f1-A f0-B f0-A f1-B f1-A f0-B f0-A f1-B f1-A f0-B f0-A
PCSL18 PCSL2 PCSL19 PCSL3 PCSL16 PCSL0

Delay Line 0 (2Q = 2x48) ~ 8 CW delay (54.2ns)

f1-B'' f1-A'' f0-B'' f0-A''

Inner FEC Hamming payload

Delay Line 1 (Q = 48) ~ 4 CW delay (27.1ns)

f1-B' f1-A' f0-B' f0-A'

PCSL 3,19 are delayed ~ **4 CW** compared with PCSL 2,18

Delay Line 2

f1-B f1-A f0-B f0-A

f1-B f1-A f0-B f0-A f1-B' f1-A' f0-B' f0-A' f1-B'' f1-A'' f0-B'' f0-A''

12-way RS interleaved

16ns skew scenario
(overlapped duration, when PCSL3,19 are delayed ~4 CW compare with PCSL 2,18)

PCSL 0,16 are delayed ~ **8 CW** compared with PCSL 2,18

One 200G Convolutional Interleaver instance

f1-B f1-A f0-B f0-A f1-B' f1-A' f0-B' f0-A' f1-B f1-A f0-B f0-A
PCSL18 PCSL2 PCSL19 PCSL3 PCSL16 PCSL0

Delay Line 0 (2Q = 2x48) ~ 8 CW delay (54.2ns)

f1-B'' f1-A'' f0-B'' f0-A''

Inner FEC Hamming payload

Delay Line 1 (Q = 48) ~ 4 CW delay (27.1ns)

f1-B'' f1-A'' f0-B'' f0-A''

PCSL 3,19 are delayed ~ **8 CW** compared with PCSL 2,18

Delay Line 2

f1-B f1-A f0-B f0-A

f1-B f1-A f0-B f0-A f1-B'' f1-A'' f0-B'' f0-A'' f1-B'' f1-A'' f0-B'' f0-A''

8-way RS interleaved