Benefit of Pre-Coder for Optical Links

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Overview

- Evolution of optical link training proposal
- Beneficial parameters to adjust on optical link
- Background on Ethernet link training
- Why pre-coder control is need for 200G optics
- Proposed optics pre-coder control
- Reuse clause 162 DME pages
- Reuse clause 136 state diagram
- Summary.

Evolution of Optics Link Training Proposal

- **Initial optics link training proposal in Sept-23 interim added Auto-neg like feature into link training exchange**
  - "Extending Link Configuration and Training to Optics" ghiasi_3dj_01a_2309
  - Combining AN and LT reduces the process steps but scheme wouldn't be scalable and deviates from CL73 (AN) and CL136/162(LT)
- **During Nov-23 plenary meeting optics LT improved by separating AN from LT**
  - "Thoughts on optical automatic link configuration" brown_3dj_01_2311 defines AN by leveraging and extending CL73 to optics
  - "Benefits of Transmitter Adaptation for Optical Links" ghiasi_3dj_01_2311 defines LT by leveraging CL136/162 by creating an additive set of presets (pre-emphasis, CD preset, and compression) to optimize the link
    - Deviation from CL136/162 without getting the full benefit of link training
- **This proposal Jan-2024 align the optics pre-coder control with CL136/162 and leveraging 15+ years of knowhow**
  - Proposal is to define only pre-coder on/off capability per method of CL136/162.

Beneficial Parameters to Tune on Optical Links

- **Pre-coder on/off based on receiver feedback – topic of this proposal**

- **Other beneficial parameters to set or adjust on optical link**
  - Preset
  - Adjusting transmit FFE (pre-emphasis)
  - OMA control
  - MZM compression
  - EA modulators asymmetrical compression
  - CD penalty on links > 2km on outer wavelengths L0 and L3.

Background on AN and Link Training

- **For proposed optics AN, see [Brown_3dj_01_2311]**
- **Optics pre-coder control leverages 802.3 CL 136/162 LT**
  - CL136/162 Control/status fields are transmitted with DME (Differential Manchester Encoding) at 1/8 the Baudrate followed by PRBS13Q as PAM4 training pattern
    - FECo DME control/status operates at 1/8 of 106.25 GBd (13.28 GBd) with training pattern at full rate
    - FECi DME control/status operates at 1/8 of 113.4375 GBd (14.18 GBd) with training pattern at full rate.

Original KR CL72 LT Frame

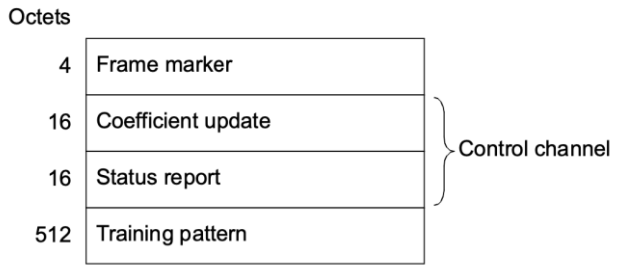


Figure 72–2—Training frame structure

Expanded CL136 LT Frame Supporting PAM4

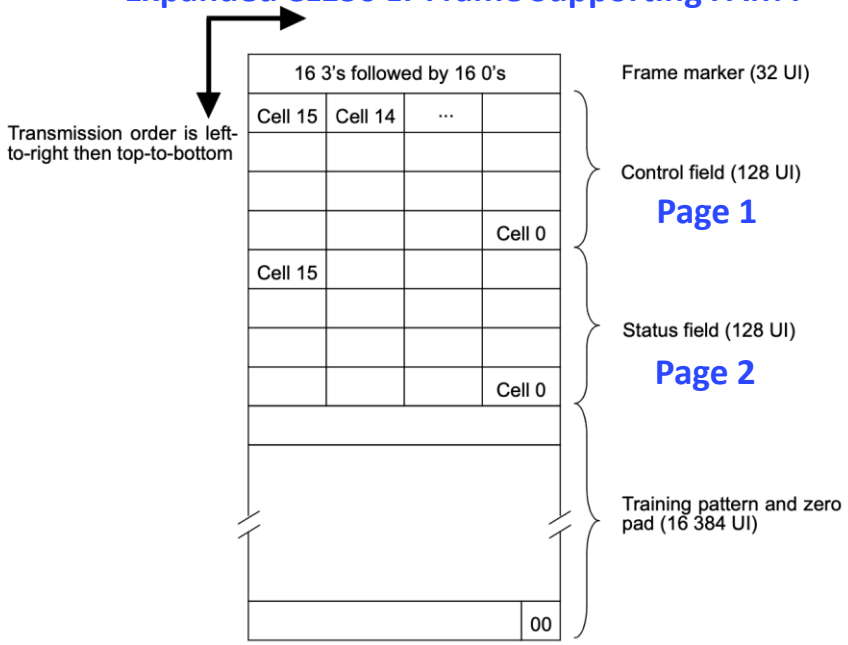
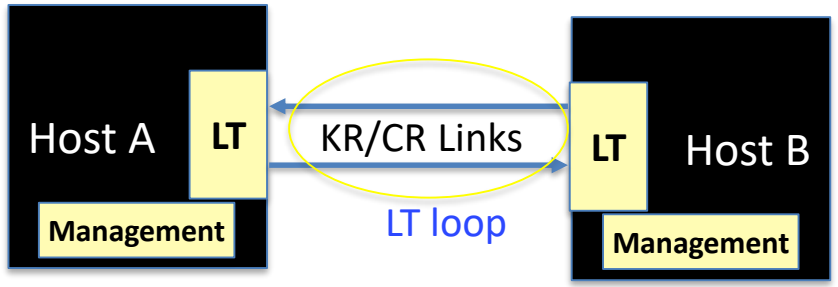


Figure 136–3—Training frame structure



Leveraging CL136 Link Training for Optics Pre-Coder Control

- **Training frame structure based on 136.8.11.1**
- **Training pattern and training PRBS pattern based on 136.8.11.1.3**
- **Control field structure and status field structure generally follows 162.8.11 with the difference captured in this contribution**
  - If 802.3dj modifies KR/CR PMD control then will follow those changes when possible.

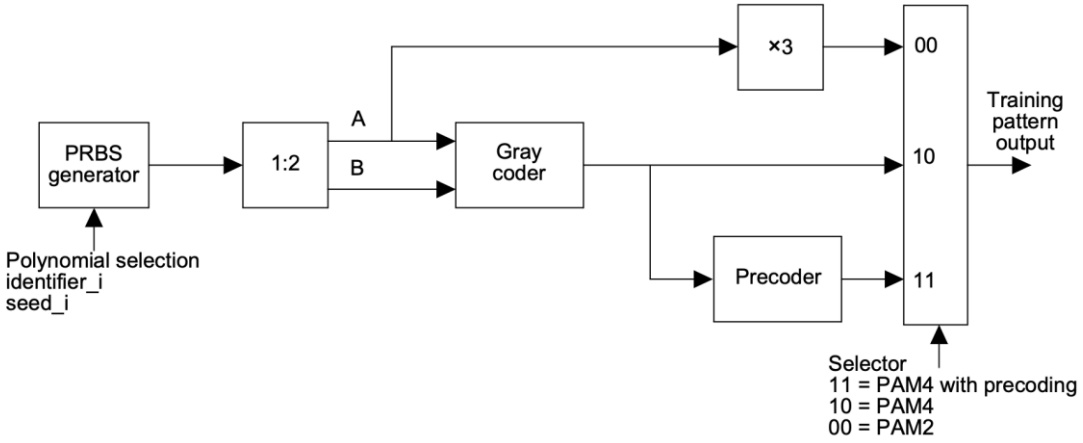


Figure 136–4—Training pattern generator

Table 136–8—Training patterns

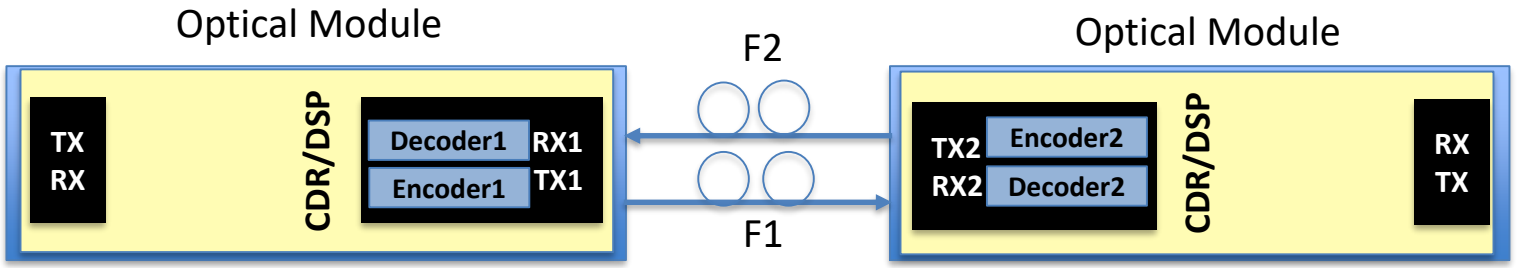
p	Polynomial_*p*, *G*(*x*)	Default seed bits[a]	Initial output, PAM2	Initial output, PAM4	Initial output, PAM4 with precoding
0	$1+x+x^2+x^{12}+x^{13}$	0000010101011	0030330330000	10313202201111[b]	1301200200101
1	$1+x^2+x^3+x^7+x^{13}$	0011101000001	3030303030333	3030213021333	3122012201212
2	$1+x^2+x^4+x^8+x^{13}$	1001000101100	0303333033030	1212332133031	1102120121301
3	$1+x^2+x^5+x^9+x^{13}$	0100010000010	3330300030330	2231210121221	2032013201110

Pre-coder Control for Optical PMDs

- **Pre-coder on/off is necessary for all DJ optical PMDs**
  - Largely due to severe BW limitation from TIA-VGA-ADC cascaded bandwidths requiring the DFE/MLSE to work very hard
  - TDECQ is measured with BW=Baudrate (53.125 GHz FECo/56.72 GHz FECi) and pre-emphasis adjusted on that basis
  - Initial 200G optics front end TIA-VGA-ADC BW expect to have an aggregate BW ~34 GHz but over time aggregate BW expected to increase ~50 GHz
    - On top these BW there will be ~±15% BW variation due to components variations (early on some low BW TIA-DSP may fail sensitivity due to low aggregate BW)
- **Some receiver may have unacceptable burst errors without a pre-coder enabled**
  - Enabling pre-coder on every optical link requires optical PMDs to have better pre-FEC BER
  - Controlling pre-coder on/off with the method of CL136/162 LT is the best proven method.

Proposed Optical Pre-Coder on/off

- **Leverage CL136/162 to enable pre-coder on/off based on receiver requests**
  - After completion of AN the DME frame (request/status) and PRBS13Q are transmitted on F1 and F2
    - RX1 or RX2 receiver may need pre-coder to be enabled on the transmitter
    - RX1 request to enable the pre-coder are transmitted on F1 to RX2 then encoder2 gets enabled, then RX1 enables its' own decoder
    - RX2 request to enable the pre-coder are transmitted on F2 to RX1 then encoder1 gets enabled, then RX2 enables its' own decoder
  - F1/F2 for illustration shown with one optical lane but link training can be supported across any 1 to N lanes PMDs as long as Tx/Rx pairing are preserved.



Defining AN and LT Both in 802.3dj Task Force

- **Considering AN likely will be defined in 802.3dj the logic will exit to also define a bare minimum LT capability**
  - It would be best to also define bare minimum LT capability in DJ so we don't end up with fragmented implementations
- **The DR PMDs may need as much help as LR4 PMDs in case of pre-coder control**
  - Considering TIA-VGA-ADC front end bandwidth limitation the receiver would need to work very hard
  - Leveraging CL136/162 LT method to control the pre-coder will mitigate problematic burst on some combination of links
- **Defining pre-coder on/off capability in the DJ allow future expansion as needed.**

Leverage CL 136/162 Control/Status Field Structure for Pre-Coder

- **Use Table 162-9 and 162-10 with number of fields changed to reserved and only using pre-coder feature**
  - Recommending to increase the number of DME pages from 2 to 4 (with all fields in page 3 and 4 reserved).

Table 162–9—Control field structure

Bit(s)	Name	Description
15:14	Reserved	Transmit as 0, ignore on receipt
13:11	Initial condition request Reserved	13 12 11 1 1 1 = Reserved 1 0 1 = Reserved 0 1 1 = Preset 5 0 0 1 = Preset 4 1 1 0 = Preset 3 1 0 0 = Preset 2 0 1 0 = Preset 1 0 0 0 = Individual coefficient control
10	Reserved	Transmit as 0, ignore on receipt
9:8	Modulation and precoding request	9 8 1 1 = PAM4 with precoding 1 0 = PAM4 0 1 = Reserved 0 0 = PAM2
7:5	Reserved	Transmit as 0, ignore on receipt
4:2	Coefficient select Reserved	4 3 2 1 0 0 = Reserved 1 0 1 = $c(-3)$ 1 1 0 = $c(-2)$ 1 1 1 = $c(-1)$ 0 0 0 = $c(0)$ 0 0 1 = $c(1)$ 0 1 x = Reserved
1:0	Coefficient request Reserved	1 0 1 1 = No equalization 1 0 = Decrement 0 1 = Increment 0 0 = Hold

Table 162–10—Status field structure

Bit(s)	Name	Description
15	Receiver ready	1 =Training is complete and the receiver is ready for data 0 =Request for training to continue
14:12	Reserved	Transmit as 0, ignore on receipt
11:10	Modulation and precoding status	11 10 1 1 = PAM4 with precoding 1 0 = PAM4 0 1 = Reserved 0 0 = PAM2
9	Receiver frame lock	1 = Frame boundaries identified 0 = Frame boundaries not identified
8	Initial condition status Reserved	1 = Updated 0 = Not updated
7	Parity	Even parity bit
6	Reserved	Transmit as 0, ignore on receipt
5:3	Coefficient select echo Reserved	5 4 3 1 0 1 = $c(-3)$ 1 1 0 = $c(-2)$ 1 1 1 = $c(-1)$ 0 0 0 = $c(0)$ 0 0 1 = $c(1)$
2:0	Coefficient status Reserved	2 1 0 1 1 1 = Reserved 1 1 0 = Coefficient at limit and equalization limit 1 0 1 = Reserved 1 0 0 = Equalization limit 0 1 1 = Coefficient not supported 0 1 0 = Coefficient at limit 0 0 1 = Updated 0 0 0 = Not updated

Leverage CL 136/162 State Diagram

- **The basic electrical link training state diagram can be used to just control the pre-coder without any preset or tap control, see DJ proposed electrical link training ran_3dj_elec_01a_240104 .**

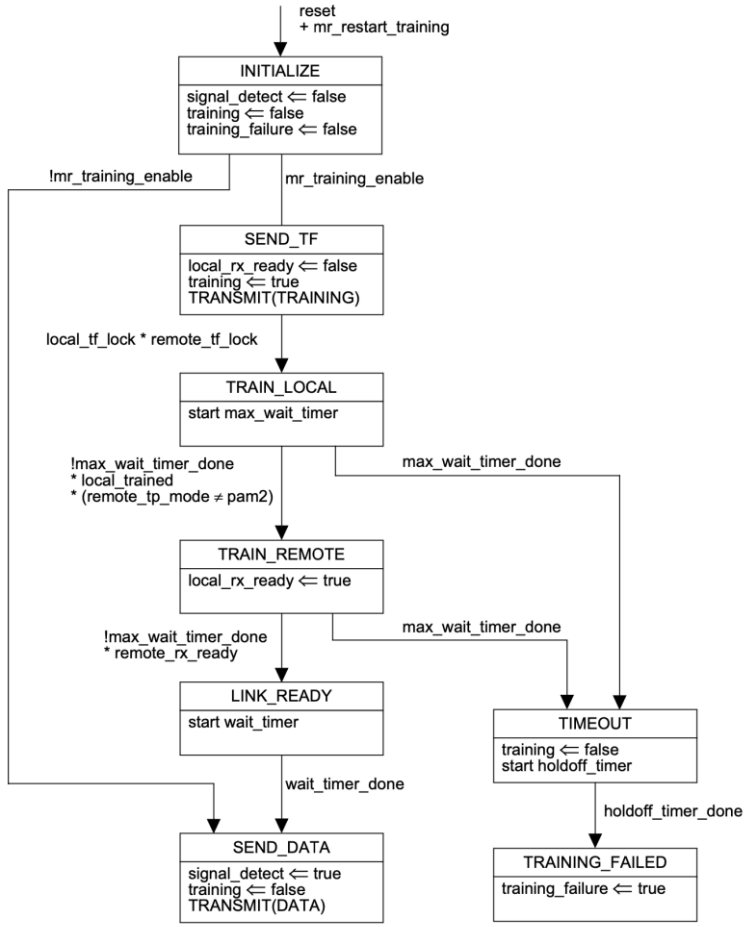


Figure 136–7—PMD control state diagram

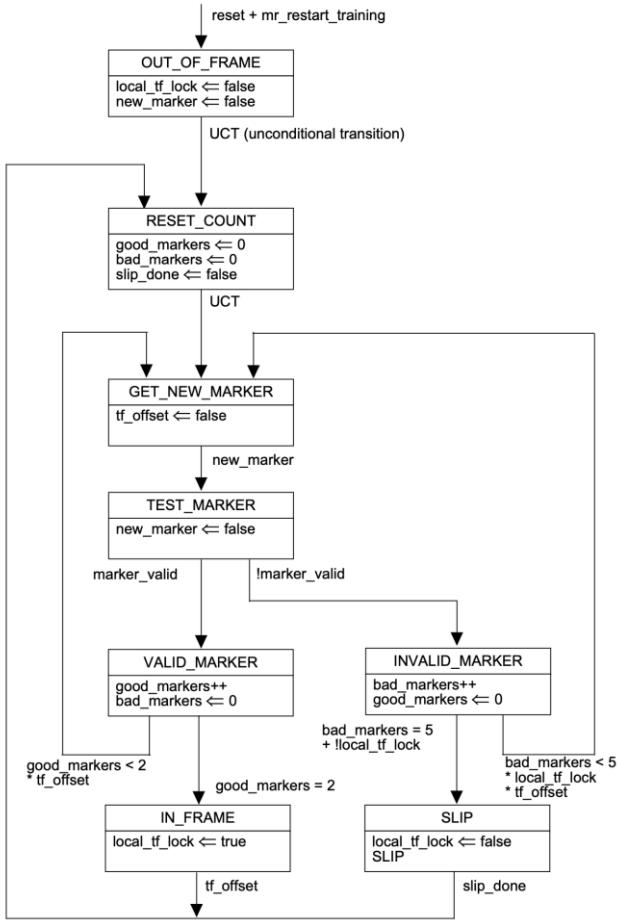


Figure 136–8—Training frame lock state diagram

Summary

- **Assuming optical automatic link configuration for optics (AN), Brown_3dj_01_2311 is adopted the DME facility will exist to perform transmitter adaption for optical links**
  - Optics pre-coder on/off will leverage as much as possible proven Clause 136/162 training and flow
- **Proposal is to define a basic LT facility to support pre-coder on/off operation**
  - The method of CL136/162 page structure offer additional capabilities that DJ task force or future 200G MMF task force may choose to enable as needed.