

Extending Optical ILT for 200G MMF PMDs

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Overview

- ☐ End user's feedback
- ☐ Benefit of enabling ILT Presets for optics
- ☐ Respond from 802.3dj on OLT
- ☐ Optical link up is outdated
- ☐ Key benefit of ILT
- ☐ Excessive overshoot is problematic
- ☐ Enabling ILT Presets
 - Other possible ILT capabilities
- ☐ PMD and MDI requirement to support ILT
- ☐ Summary
- ☐ Backup Material on RTS propagation.

End Users Feedback on OLT

❑ Traditional DC/Enterprise

- With 11 IMDD PMDs with 5 based on FECo and 6 based on FECi OAN can facilitate deployment and configuration
- Dual mode module can be configured based on remote module capability
- OAN enables zero-touch in fronthaul networks [parkholm 3dj 02 2311](#)

❑ Hyperscale feedback

- Reliable link up in timely manner with OLT and RTS
 - Based on past experience reliable optical link may take much longer than 802.3ck AN+LT link up timers (Make it clear)
 - Expecting reliable optical link up at 200G will be more challenging
- OMA control with LT is most interesting (limited benefits with VCSELs)
 - Mitigate overload
 - Mitigate compression
 - Energy efficiency

❑ OIF EEI (Energy Efficient Interfaces) project has interest in collaborating and potentially leveraging OLT

- See liaison received from OIF [OIF liaison IEEE EEI Project 21Jan24 Redacted](#).

Respond to Questions from 802.3dj Jan/March-2024

❑ What are the key benefit of OLT

- Provide coordinated segment by segment reliable link bring up with RTS
- Pre-coder control
- Reliable link up starting with known NRZ pattern then transitioning to PAM4 for training

❑ Link training should be end-end

- OLT build on the [ran 3dj elec 01 240229](#) multi-segments training for AUI, CR, KR links
- A key element of Ran proposal for reliable-predictable link up is sending RTS (Ready to Send) across multiple link segments
- OLT will be compatible with Ran proposal and will pass the RTS across the optical link for more robust-predictable end-end link bring up and training

❑ Compatibility of OLT with TDECQ

- The current OLT proposal defines only pre-coder control and passing the RTS, so doesn't affect TDECQ test methodology
- DJ or future IEEE task force may enable additional OLT features that may require some adjustment to TDECQ test methodology but that is not part of this baseline proposal.

Why Optical Link Up Challenging

- ❑ **Today's optical SerDes must calibrate and adapt to blind data without even knowing if there is good data**
- ❑ **Link training facilitates multi-segment coordinated bring up resulting in more reliable and timelier link up than just relying on blind link up**
- ❑ **Before any link up and timing recovery**
 - 1st the SAR(Successive Approximation Register) ADCs must be calibrated
 - Offset calibration between all 16/32/64 sub-SAR ADCs
 - Gain calibration between all 16/32/64 sub-SAR ADCs
 - Timing skew calibration between all 16/32/64 sub-SAR ADCs
 - AGC adjust input signal to fully utilize ADC resolution
 - CDR loop, Mueller-Muller or other type of clock recovery
 - DSP equalizer and adaptation
- ❑ **Today's optical DSP SerDes operating with blind start up may require several reset by the module uC while waiting and in hope of getting better SNR**
 - OLT will improve ADC calibration, improve timing recovery, and adaptation!

Optical Link Up Process Outdated

❑ Current IMDD link up goes back to early days of FC

- Early optics were unretimed without any equalization on AUIs/PPI or optics with PCS relying on SD (Signal Detect)

❑ What is making the current optical link up cumbersome and complex

- CMIS initializes module and data paths
- CMIS configures AUI SI parameters, then module enables its optical TX
- SD and CDR locks are used as indicator of good optical signal
- As the module CDR/DSP is calibrating its ADC, recovering, equalizing, and propagating data to host there is no guarantee good data is being transmitted to the optical receiver
- Downstream electrical link may simultaneously be trying to adapt/equalize to “not guaranteed good data” and may end up adapting to invalid data
- Optical links are multi-segments and complex, and inherently unpredictable to host-module and PMD-PMD interactions
- By relying on SD/CDR lock to unsquelch module out may result sending invalid data to the host that require host keep resetting the module Egress DSP and hoping for the best!

Improving Optical Link Up Process with ILT

- ❑ OLT start up DME facility with known NRZ PRBS then switching to PAM4 improve optical receiver/DSP calibration and adaptation
- ❑ OLT passing RTS, [ran 3dj elec 01 240229](#), will improve reliable link up on both AUIs segments and optical link
 - Optical SD/CDR lock are not always a reliable indicator of signal goodness and may falsely send RTS onto local AUI segment
 - ILT starts with known NRZ PRBS then switching to PAM4 offers improved optical SerDes receiver start up
 - But real benefit of ILT is RTS (ready to send) propagation from AUI segments across optical link
- ❑ **Reliable and predictive optical link up is required for 200G optics considering 100G optics pain points**
 - OLT(ILT) with RTS will improve 200G optics to have more reliable and consistent link up in a timely manner!

Why pre-coder on/off necessary for Optical PMDs

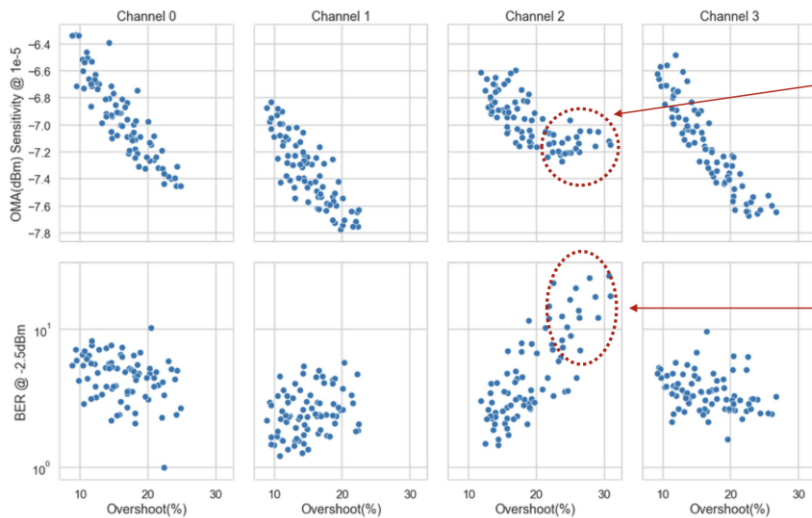
- ❑ **Largely due to severe BW limitation from TIA-VGA-ADC cascaded bandwidths requiring the DFE/MLSE to work very hard**
 - TDECQ is measured with BW=Baudrate (53.125 GHz FECo/56.72 GHz FECi) and pre-emphasis adjusted on that basis
 - Initial 200G optics front end TIA-VGA-ADC BW expect to have an aggregate BW ~34 GHz but over time aggregate BW expected to increase ~50 GHz
 - On top these BW there will be $\sim\pm 15\%$ 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**
 - Pre-coder may be required on any link from SR to LR4
 - 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.

Excessive Overshoot/Undershoot can Result in FEC Tail

❑ Currently TDECQ doesn't incorporate PAR (Peak to Average) penalty

- Without PAR penalty overshoot can drive the TDECQ lower while link BER degrades
- TDECQ not having PAR penalty the overshoot should be reduced <12% as receiver with DFE don't require such large overshoot!

Overshoot vs Rx performance



❑ Overshoot tends to improve sensitivity. It saturates for values larger than 22%

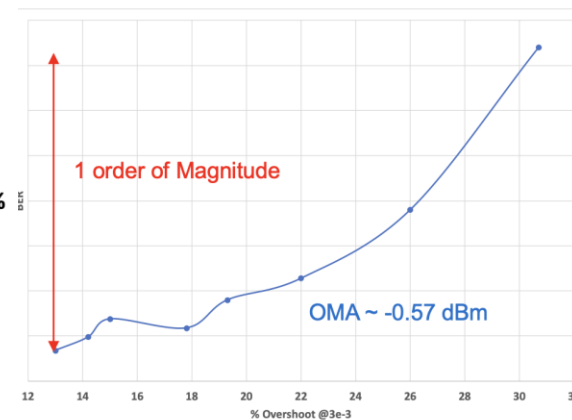
❑ Overshoot values larger than 22% increase error floor significantly

IEEE P802.3cu 2020 Mar 05

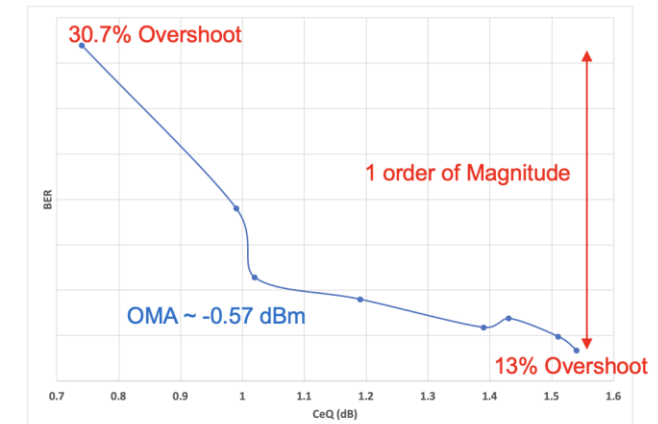
[rodes 3cu adhoc 030520 v2](#)

Overshoot vs Ceq Protecting Receiver for Excess Overshoot

- Transmitter overshoot is a direct quantitative parameter protecting the receiver for excess pre-emphasis/overshoot



IEEE 802.3db Taskforce



[ghiasi 802.3db 01 092321](#)

Current Clause 178B ILT

□ Current copper E1 and optics O1 ILT capabilities

Table 178B-2—Control field structure for E1 interfaces

Bit(s)	Name	Description
15:14	Reserved	Transmit as 0, ignore on receipt
13:11	Initial condition request	13 12 11 1 1 1 = Reserved 1 0 1 = Preset 6 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	Continue training	1 = Continue training 0 = Switch to data when training is completed
9:8	Modulation and precoding request	9 8 1 1 = PAM4 with precoding 1 0 = PAM4 without precoding 0 1 = Reserved 0 0 = PAM2
7	Reserved	Transmit as 0, ignore on receipt
6:5	Training pattern request	6 5 1 1 = free-running PRBS31 1 0 = Reserved 0 1 = free-running PRBS13 0 0 = synchronous PRBS13
4:2	Coefficient select	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	1 0 1 1 = No equalization 1 0 = Decrement 0 1 = Increment 0 0 = Hold

Table 178B-3—Control field structure for O1 interfaces

Bit(s)	Name	Description
15:11	Reserved	Transmit as 0, ignore on receipt
10	Continue training	1 = Continue training 0 = Switch to data when training is completed
9:8	Modulation and precoding request	9 8 1 1 = PAM4 with precoding 1 0 = PAM4 without precoding 0 1 = Reserved 0 0 = PAM2
7	Reserved	Transmit as 0, ignore on receipt
6:5	Training pattern request	6 5 1 1 = free-running PRBS31 1 0 = Reserved 0 1 = free-running PRBS13 0 0 = synchronous PRBS13
4:0	Reserved	Transmit as 0, ignore on receipt

Enabling Presets for Optical O1 PMDs

- ❑ ILT already supports Presets and enabling optional Presets for O1 PMDs is straight forward as shown below but we may want to call it O2.

Table 178B-3 Control field O1 supporting optional Presets

Bit(s)	Name	Description
15:14	Reserved	Transmit as 0, ignore on receipt
13:11	Initial condition request (new item to support Preset)	13 12 11 1 1 1 = Reserved 1 0 1 = Preset 6 1 1 0 = Preset 5 1 0 0 = Preset 4 0 1 1 = Preset 3 0 1 0 = Preset 2 0 0 1 = Preset 1 0 0 0 = Reserved
10	Continue training	1 = Continue training 0 = Switch to data when training is completed
9:8	Modulation and precoding request	9 8 1 1 = PAM4 with precoding 1 0 = PAM4 without precoding 0 1 = Reserved 0 0 = PAM2
7	Preset Supported (needed only if support of Preset is Optional)	0 = Preset not supported 1 = Preset supported
6:5	Training pattern request	6 5 1 1 = free-running PRBS31 1 0 = Reserved 0 1 = free-running PRBS13 0 0 = synchronous PRBS13
4:0	Reserved	Transmit as 0, ignore on receipt

Table 178B-5 Status field O1 supporting Presets

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	ILT	Transmit as 1
13:12	Training pattern status	13 12 1 1 = free-running PRBS31 1 0 = Reserved 0 1 = free-running PRBS13 0 0 = synchronous PRBS13
11:10	Modulation and precoding status	9 8 1 1 = PAM4 with precoding 1 0 = PAM4 without precoding 0 1 = Reserved 0 0 = PAM2
9	Receiver frame lock	1 = Frame boundaries identified 0 = Frame boundaries not identified
8	Initial condition status (new item to support Preset)	1 = Updated 0 = Not updated
7	Parity	Even parity bit
6:0	Reserved	Transmit as 0, ignore on receipt

How to Configure the Presets

❑ Number of Presets

- CR/KR have enabled 6 Presets with 2 reserve
- MMF project if needed can enable all 8 possible Presets

❑ How one may configure the Presets

- Following Preset configuration allow for overshoot adjustment, OMA, and inner/outer eyes if required or Preset table can be simplified to fewer settings

- Preset 1 – Default optimized for mid-reach with ~12% overshoot
- Preset 2 – Optimized for short reach with ~6% overshoot
- Preset 3 – Optimized for long reach with 22% overshoot
- Preset 4 – Lower OMA by 1 dB
- Preset 5 – Increase upper eye by 1%
- Preset 6 – Increase lower eye by 1%
- Preset 7 – Decrease upper eye by 1%
- Preset 8 – Decrease lower eye by 1%

OMA adjustment and outer eye adjustment are applied to Preset 1, 2, or 3.

Requesting Preset 1, 2, 3 will reset these settings.

If Preset 4 is requested twice the OMA will be lowered by 2 dB.

Optical OLT PMD Requirements

- ❑ **Transmit and receive must be grouped in duplex pairs PMDs to support optical loop back and breakout applications**
 - Current definition of optical PMDs
 - TX TX TX TX - RX RX RX RX
 - Was defined for convenience of routing any TX to RX lanes
 - We would need to define the optical PMDs as following
 - TX1 TX2 TX3 TX4 - RX4 RX3 RX2 RX1
 - Support breakout and optical loopback
- ❑ **In IEEE we have not grouped the TX/RX into duplex pairs but actual products are based on duplex pair grouping**
 - QSFP-DD MSA and OSFP MSA specify TX/RX lane # on the MDI
 - CMIS associate PMA lanes to optical PMD lanes – otherwise you wouldn't know which transmitter was turned on
- ❑ **Structure cable plants compliant to ANSI/TIA-568.3-E 2022 preserve duplex pairs and lane grouping.**

Both CMIS and Optical Modules Enforce Tx/Rx Pairs

CMIS data-path pairs electrical Tx/Rx lanes to optical Tx/Rx lanes

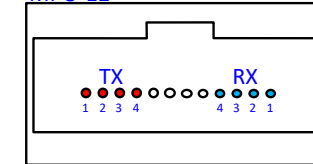
- Table and figure below from [QSFP-DD MSA Rev. 7.0](#) illustrates the concept.

Electrical data input/output	Optical port mapping (see Figure 15)					
	Duplex LC, CS, SN, or MDC	MPO-12, Dual (CS, SN, MDC, Duplex LC, or MPO-12)	MPO-12, Quad (SN or MDC)	MPO-12 (two row), MPO-16, or Dual MPO-12	MPO-12, SN, MDC (BiDi)	
	1 TX fiber 1 RX fiber ¹	2 TX fibers 2 RX fibers ¹	4 TX fibers 4 RX fibers ¹	8 TX fibers 8 RX fibers ^{1,3}	8 Tx (Rx) fibers _{2,3}	
Tx1	TX-1	TX-1	TX-1	TX-1	TR1	
Tx2			TX-2	TX-2	TX-2	RT1
Tx3				TX-3	TX-3	TR2
Tx4			TX-2	TX-4	TX-4	RT2
Tx5		TX-2		TX-5	TX-5	TR3
Tx6				TX-6	TX-6	RT3
Tx7				TX-7	TX-7	TR4
Tx8				TX-8	TX-8	RT4
Rx1	RX-1	RX-1	RX-1	RX-1	RT1	
Rx2			RX-2	RX-2	RX-2	TR1
Rx3				RX-3	RX-3	RT2
Rx4			RX-2	RX-4	RX-4	TR2
Rx5		RX-2		RX-5	RX-5	RT3
Rx6				RX-6	RX-6	TR3
Rx7				RX-7	RX-7	RT4
Rx8				RX-8	RX-8	TR4

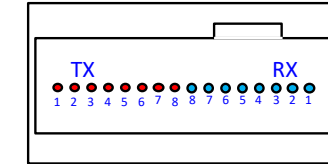
Notes:

1. TX-n or RX-n where n is the optical port number as defined Figure 15.
2. TRn or RTn where n is the optical port number as defined Figure 15.
3. Some QSFP-DD/QSFP-DD800/QSFP-DD1600 modules may require fewer CS, SN, or MDC connectors. In such cases, Port #1 is always the left-most port. Successive ports then follow sequentially from left-to-right as shown in Figure 15.

MPO-12



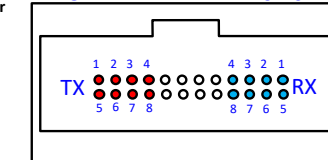
MPO-16



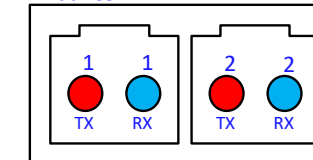
Note: The MPO 12, 2 row optical MDI is used for breakout applications and is not intended for structured cabling applications.

MPO-12

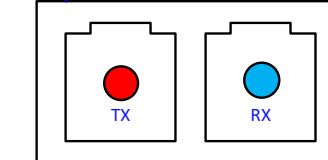
Two Row



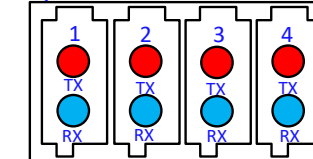
Dual CS



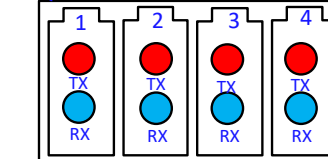
Duplex LC



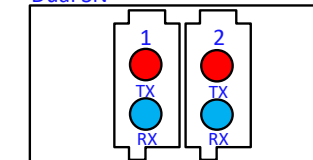
Quad SN



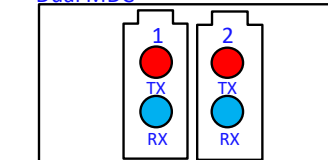
Quad MDC



Dual SN



Dual MDC



Other Potential OLT Capabilities

- ❑ **OLT baseline with 4 pages will have sufficient space that future projects may choose to control various type of optical parameters to improve optical link performance and/or reach – not part of current proposed baseline**
 - Preset
 - Adjusting transmit FFE taps autonomously (pre-emphasis)
 - OMA control
 - MZM compression
 - EA modulators asymmetrical compression
 - CD penalty on links > 2km on outer wavelengths L0 and L3
- ❑ **Some of the above controls may impact baseline TDECQ which not always produce the best BER, as long as adjustment are not disruptive receiver MMSE will converge to the best link BER.**

Summary

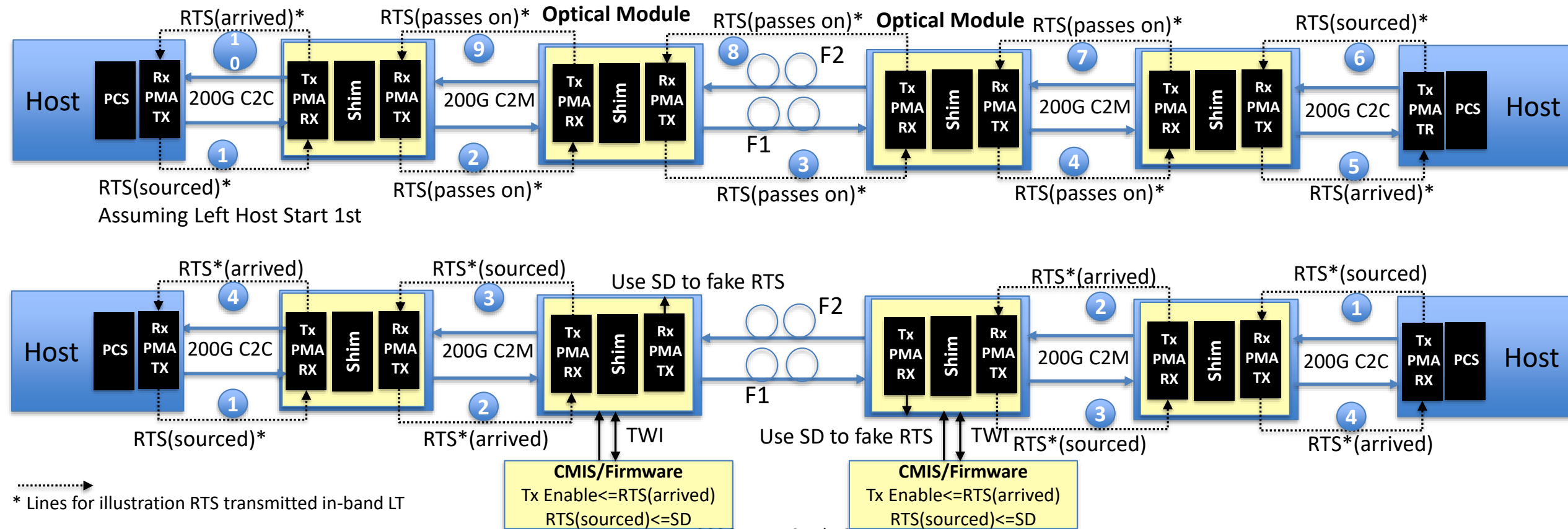
- ❑ **Current TDECQ reference receiver doesn't incorporate effects such as compression and ADC ENOB, and there is no penalty for degradation due to non-linearities**
 - TDECQ improves with increasing overshoot often drives link to lower TDECQ which may not result in optimum block BER as TDECQ doesn't currently incorporate Peak to Average Ratio penalty
- ❑ **Enabling ILT O1 PMDs Presets is straight forward and control field 7 can be used to advertise optional Presets support**
 - If Presets is mandatory, then optional advertisement field can be removed
- ❑ **Presets can be used for link optimization based on reach/overshoot, OMA, and inner/outer eye non-linear adjustment**
- ❑ **As the number of Presets increases testing TDECQ for every Preset may be prohibitive**
 - Preset 1 could be tested for TDECQ compliance
 - Preset 1-3 are also tested with Functional Receiver that block errors are met
 - Preset 4-8 requested several times can result in link flap but the DSP has all the necessary information to avoid these pitfalls.

Back up

RTS Propagation

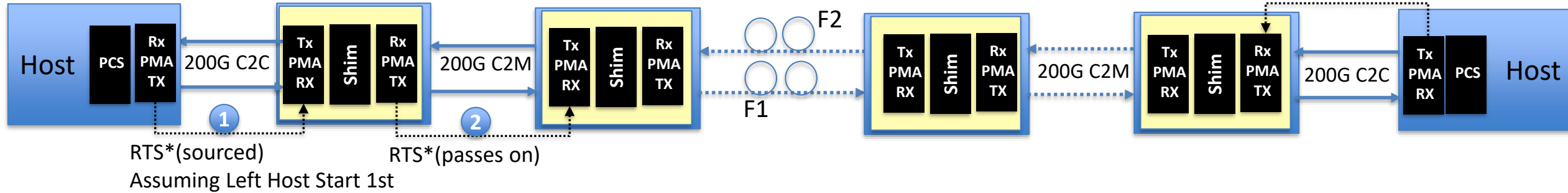
□ RTS propagated across optical link with OLT offers reliable-consistent link up in timely manner

- RTS terminated in the optical module doesn't address optical link up challenges
- Generating RTS based on not always reliable SD/CDR lock can exasperate optical link up!

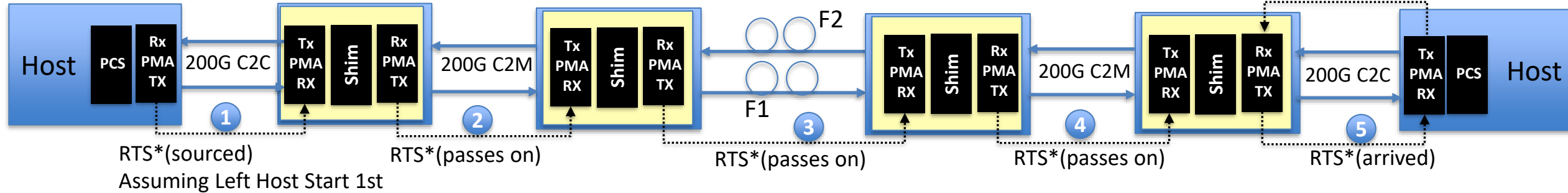


Example of RTS Propagation

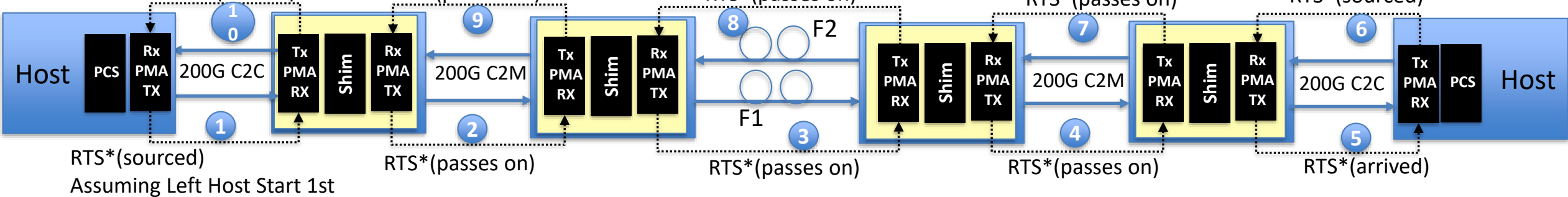
Time X1



Time X2



Time X3



Time X4 – Training/LT done PCS Starts

*Lines for illustration RTS transmitted in-band LT
RTS is forwarded only after all lanes are trained.

A. Ghiasi

Indicate segment not trained yet

Indicate segment trained

200G MMF Study Group