



Higher Speed Copper Operation

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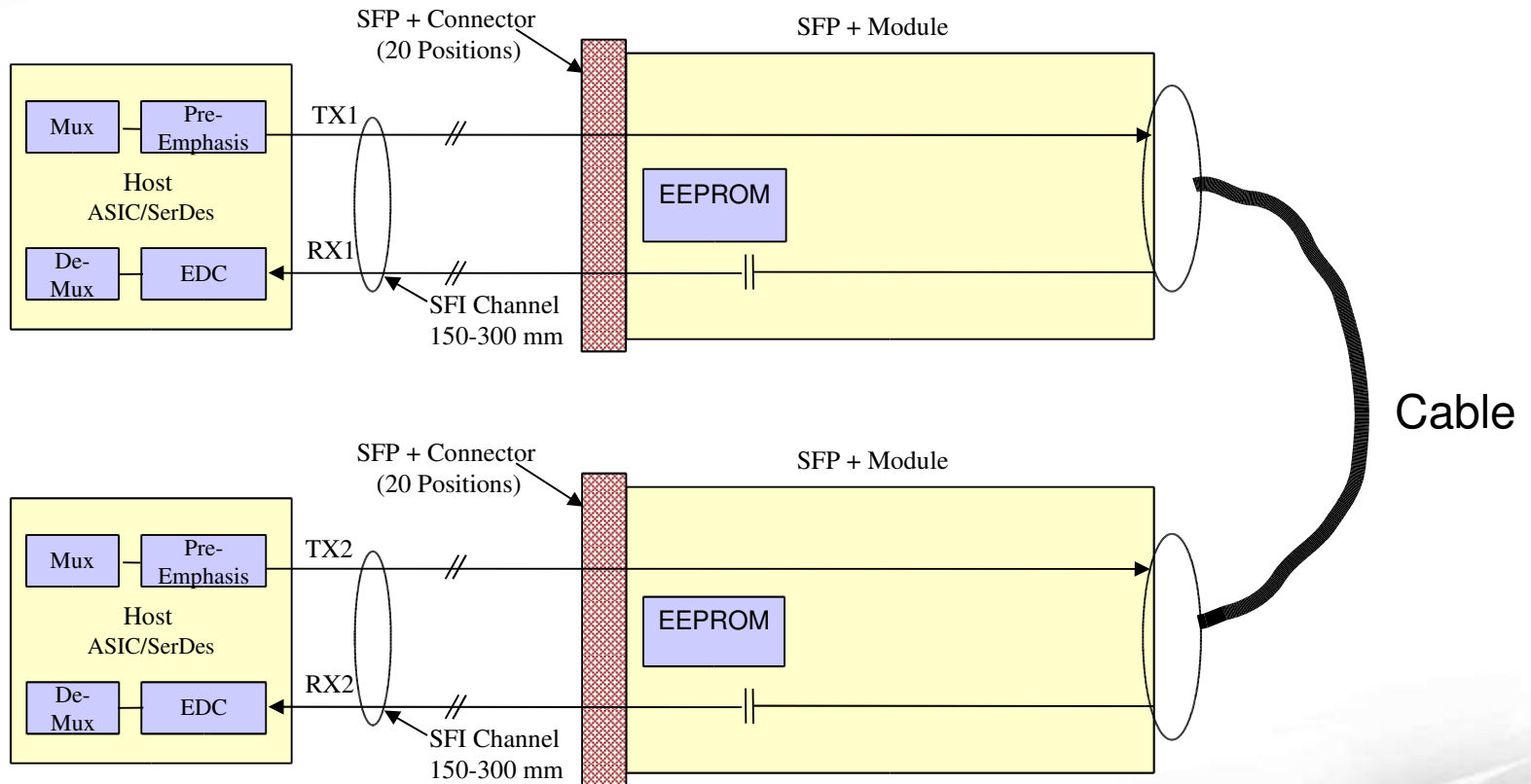
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Overview

- **SFP direct attach was first deployed in 4Gig FC for stacking application**
 - Lower cost and fully compatible with optical port.
- **SFP+ group has added appendix for direct attach copper at 10Gb/s to > 10 m reach.**
 - SFP+ assumes LRM (14,5) equalizer.
- **With addition of transmit pre-emphasis a simpler equalizer would support 10 m of copper**
 - 6 T/2-spaced FFE + 2 or 3 T spaced DFE could be sufficient for HSSG purpose.
- **HSSG can leverage the work of SFP+ direct attach copper.**
 - XTALK model must be extended and studied for 4x and 10x links.

Block Diagram of Direct Attach Copper

- Plugs in to standard SFP+ linear socket



SFP+ Direct Attach Cable

- Using host EDC SFP cable can operate to >10 m on passive direct attach SFP's.
 - QSFP cable already exist



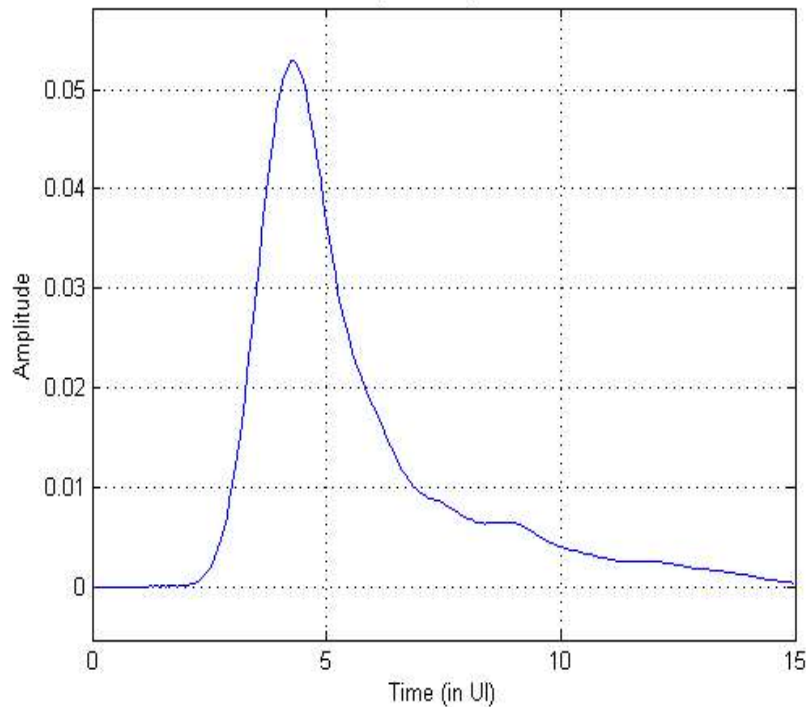
Additional Parameters Required for Copper Cable Specifications

- **Transmitter**
 - Output VMA
 - TWDP
- **Receiver tests**
 - Stress test based on the impulse responses provided here
- **Cable**
 - Must meet the same return loss as the optical modules
 - Maximum WDP distortion <5.5 dBo (11.0 dBe)
 - VMA to crosstalk ratio.

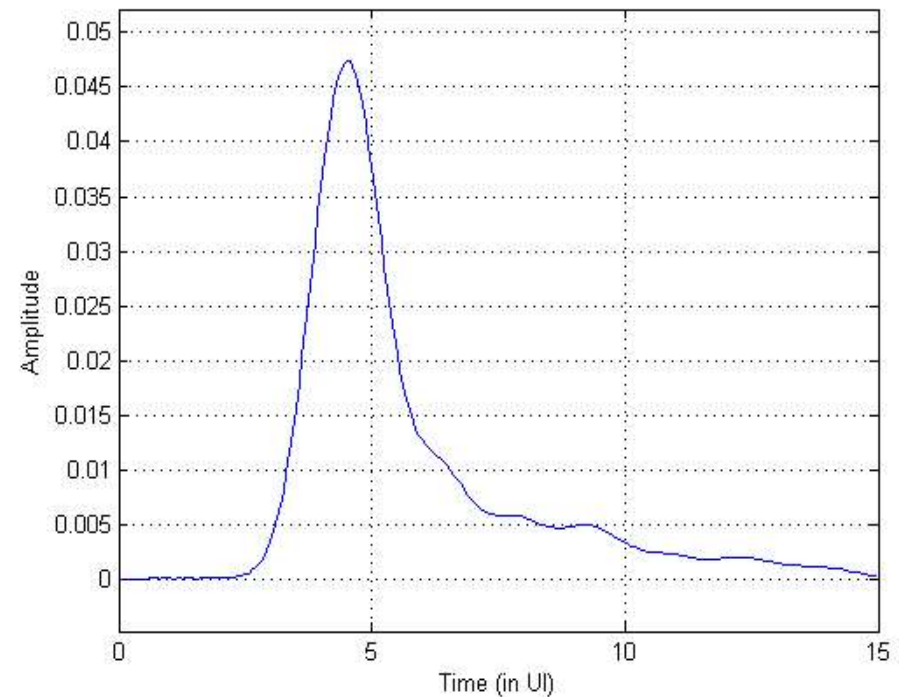
SFP+ Cable Impulse Response

- Impulse Response of three generic low cost 10 m 24AWG direct attach cable
- Measured with MCB

No Pre-emphasis
Impulse Response



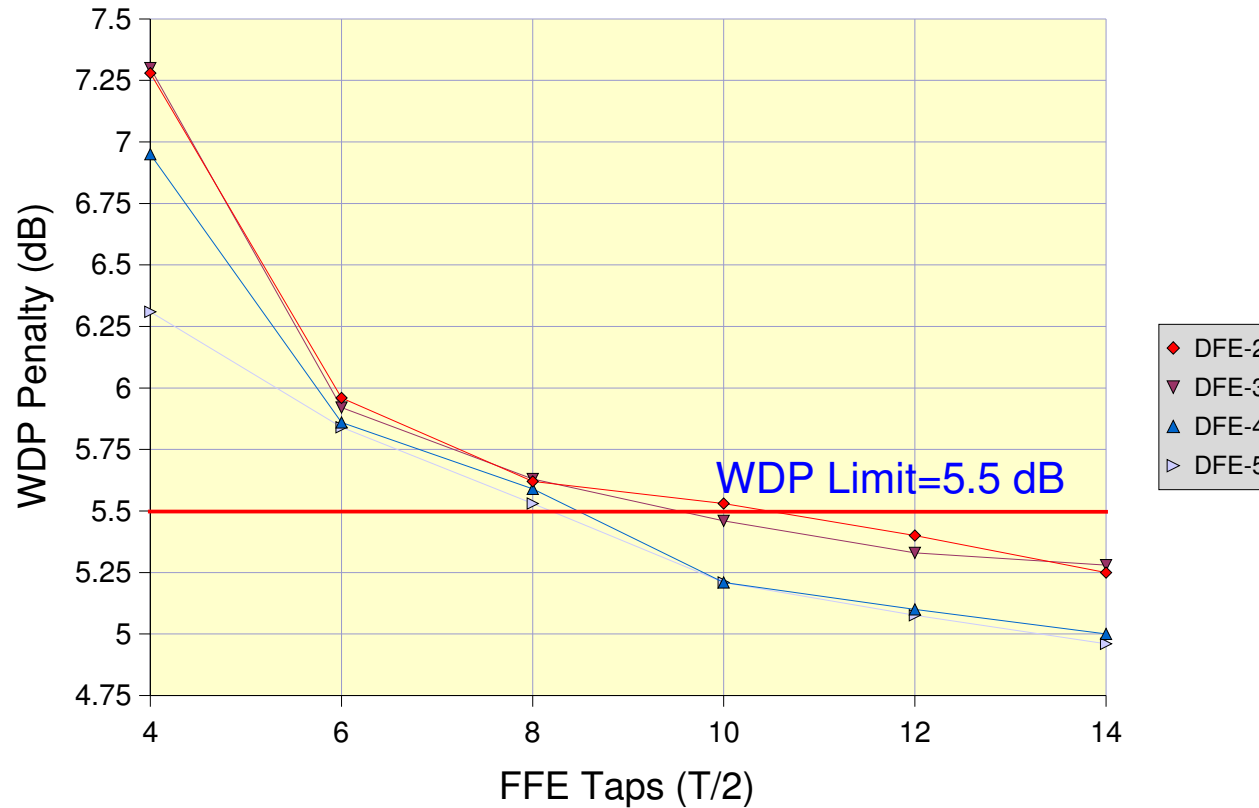
Pre-emphasis 36%
Impulse Response



1 UI=97 ps

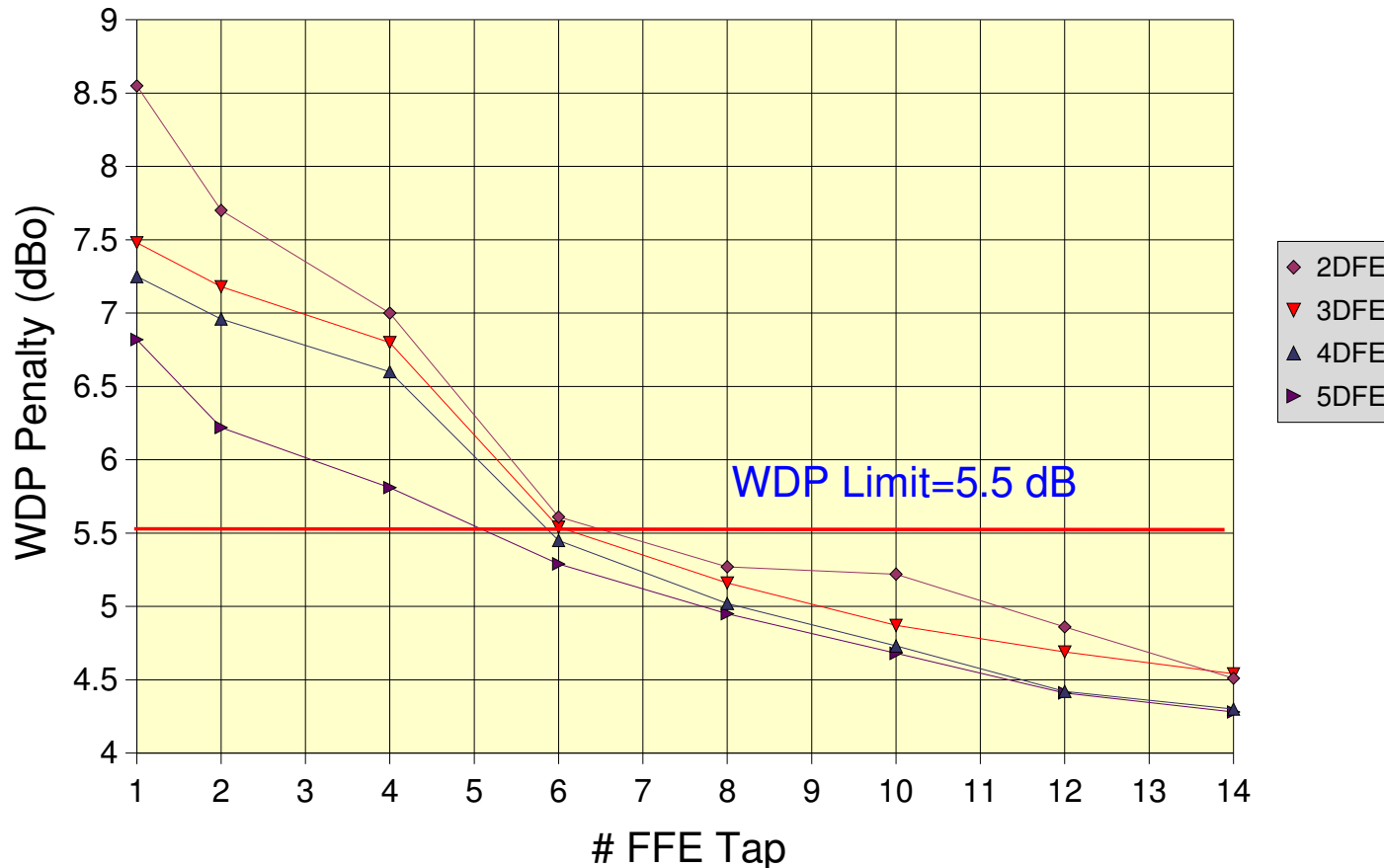
WDP Penalty for Several Implementations

- 10 m cable pre-emphasis=0
- Min EQ required =10 T/2 FFE+3 DFE



WDP Penalty for Several EDC Implementations

- 10 m cable pre-emphasis=36%
- Min Eq required 6 T/2 FFE+2 T DFE or 8 T/2 FFE+ 2 T DFE



Summary

- **SFP+ has defined short reach copper based on twin-ax cables for operation at 10.3125 Gbaud.**
 - Most of this work is applicable to the HSSG copper definition.
- **WDP results shown here were measured with low loss test board and does not include transmit PCB channel.**
- **Copper cable has strong pre-cursor therefore receive FFE would be required even with transmit pre-emphasis**
- **A single linear receiver with 6 T/2 FFE+2 or 3 T spaced DFE can support both copper up to 10 m and mitigate optical channel impairments**
 - This will result in a common SerDes architecture which will support linear optics, limiting optics, copper cable, and backplane.