



Higher Speed Copper Operation

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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+ copper AdHoc has extended the concept of direct attach copper at 10Gb/s to > 10 m reach.**
 - SFP+ assumes LRM (14,5) equalizer
 - WDP penalty of using 2 or 3 tap DFE is only 0.25 dBo.
 - WDP is based on LRM TWDP code with channel set to [0100].
- **HSSG can leverage the work of SFP+ direct attach copper.**
 - XTALK model must be extended and studied for 4x and 10x links.

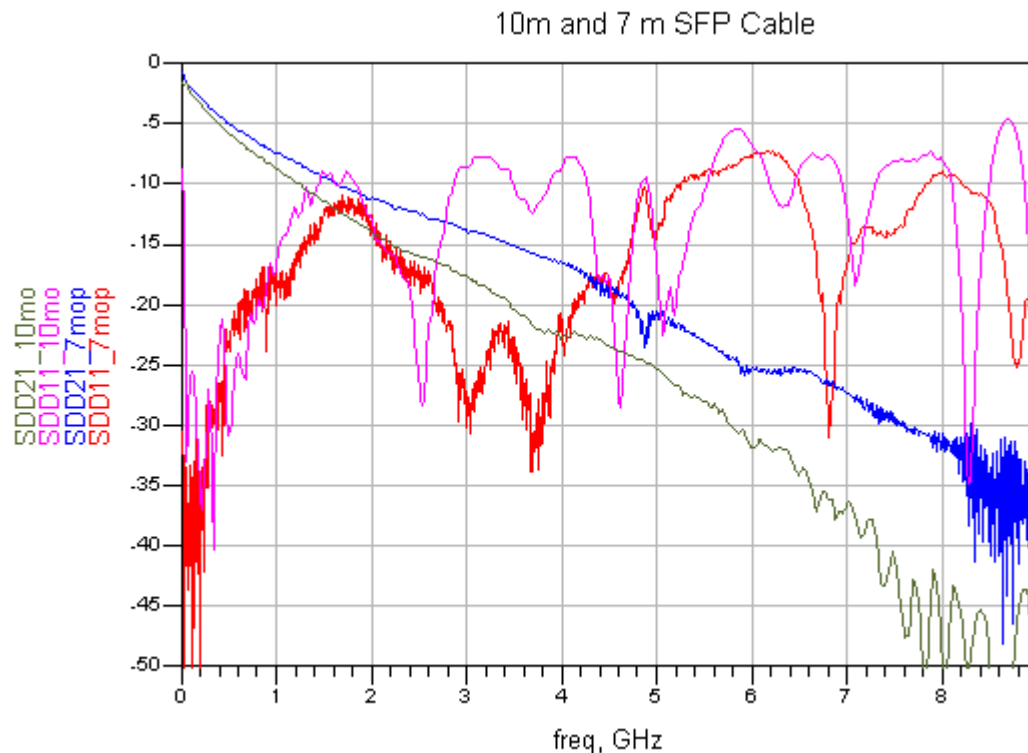
SFP+ Direct Attach Cable

- Using host EDC SFP+ cable can operate to >10 m on passive cables.
 - Longer reach with active driver.
 - 4x implementation already exist
 - 10x connector concept exist



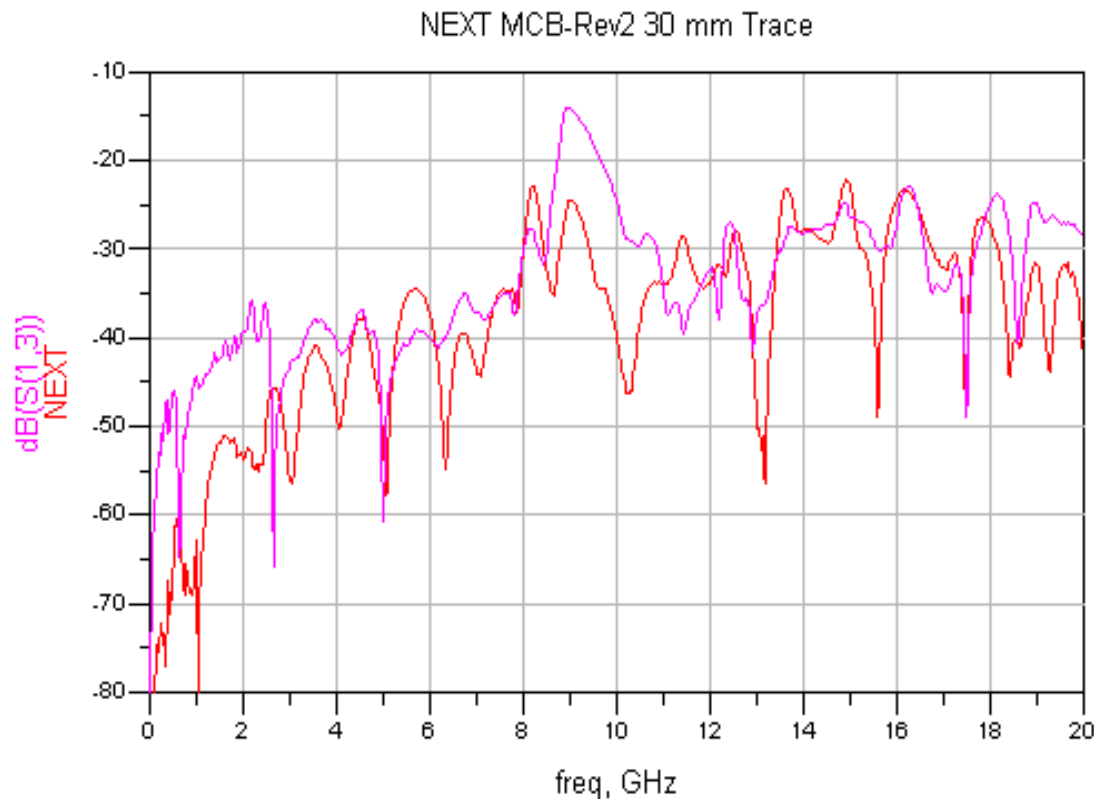
Typical Response of Direct Attach SFP Cable

- SDD21 and SDD11 are shown for 10 m and 7 m 24 gage cable measured with older FR4-13 test board
 - Newer Rogers based MCB expected to have about 1 dB lower loss



Well Design SFP+ Connector NEXT

- Multi-aggressor would increase the NEXT



VMA Loss for Cables

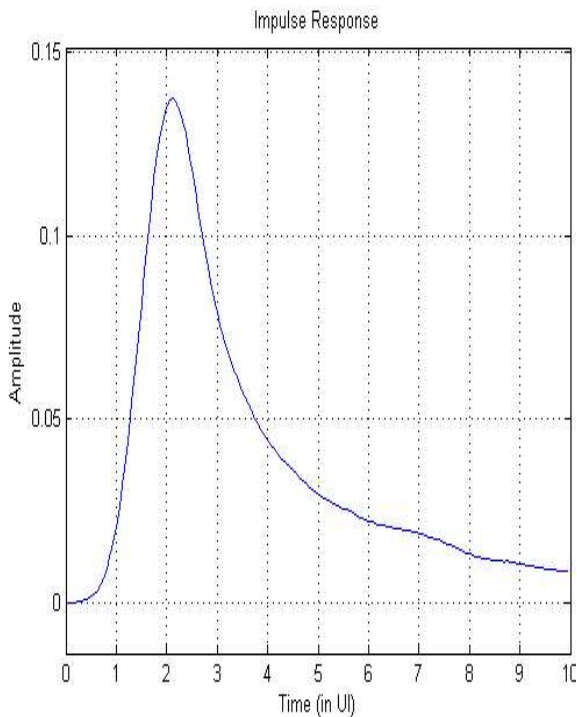
- Output at B'' calibrated with HCB at 10.3 Gb/s
- Worst case VMA loss is < 4.5 dB

Cable *	VMA (mV)	Loss (dB)
MCB + HCB	704	0
10 m Cable + MCB	529	-2.48
10 m Cable + 16'' Host	490	-3.15
15 m Cable + MCB	460	-3.7
15 m Cable + 16'' Host	419	-4.51

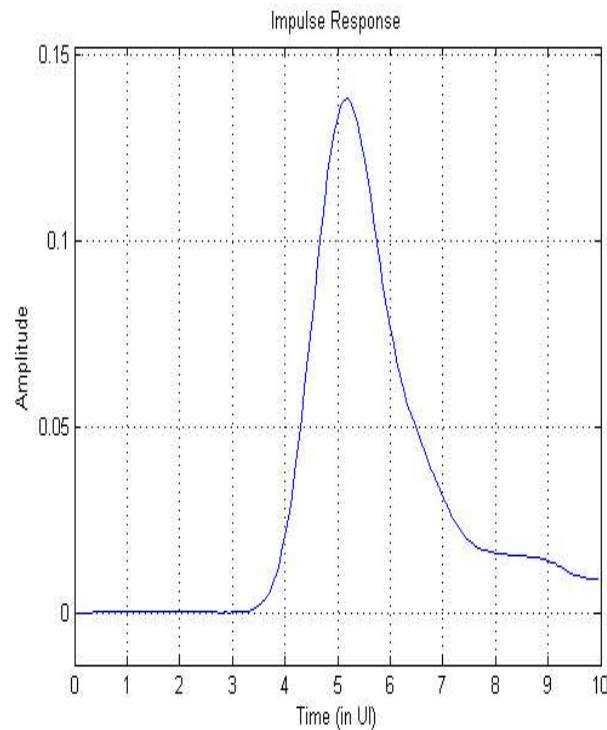
SFP+ Cable Impulse Response

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

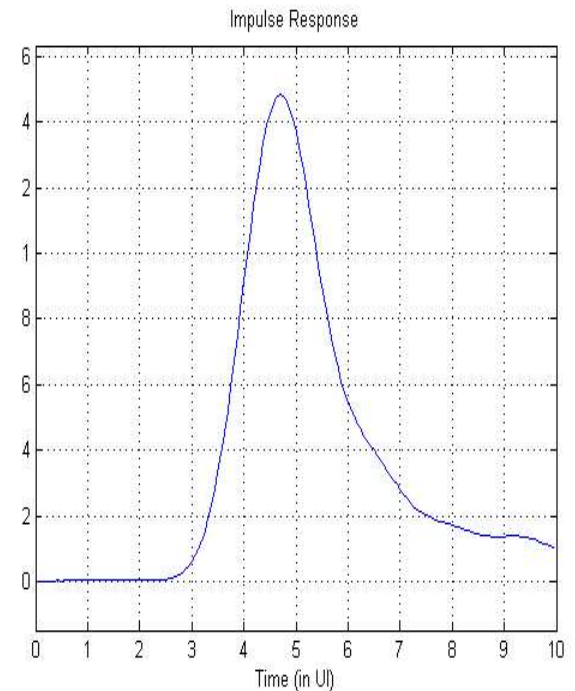
10m 24 AWG
Sup 1



10m 24 AWG
Sup 2



10m 24 AWG
Sup 3



1 UI=97 ps

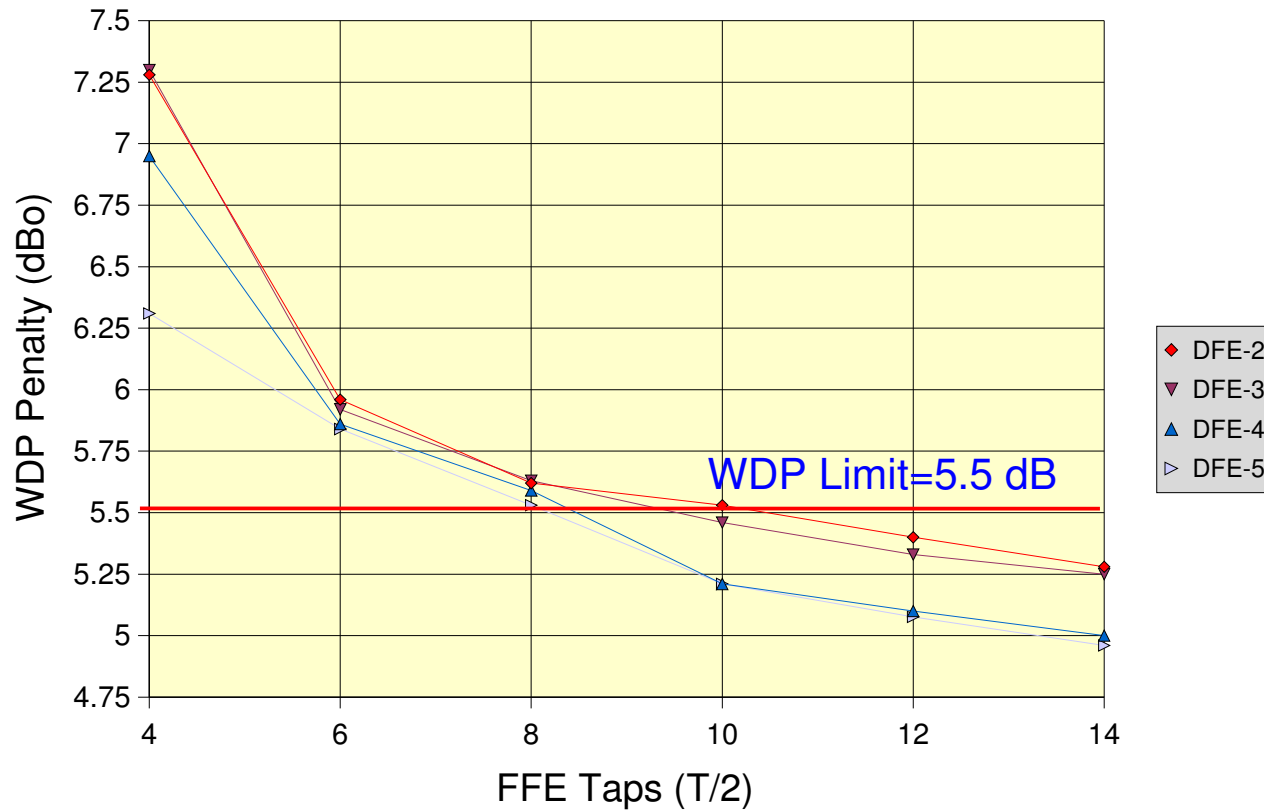
SFP+ Copper WDP Results

- Measured with WDP (14,5) EQ with no pre-emphasis
 - Measured with Module Compliance Test Board on both end
- WDP limit = 5.5 dBo (11 dBe)
- Typical LRM EDC can exceed 10 m operation

Cable *	WDP (dBo) Sup 1	WDP (dBo) Sup 2	WDP (dBo) Sup 3
3 m 26 gage	3.19		
5 m 26 gage	3.9		
10 m 24 gage	5.37	4.97	4.67
15 m 24 gage	6.79		6.1

WDP Penalty for Several Implementations

- Results shown are for 10 m cable from supplier 2.



Cable VMA to Crosstalk Ratio (VCR)

- Passive direct attach cables at longer reach become limited by the NEXT.
- VCR ratio defined here is for single aggressor as is the case for SFP+ cables.

$$VCR = 20 \times \log_{10} \left[\frac{(VMA \times 10^{(-L/20)})}{(2 \times NEXT \times (1 + C))} \right]$$

$$C = \left[(0.3 \times 10^{(-L/20)}) \right]$$

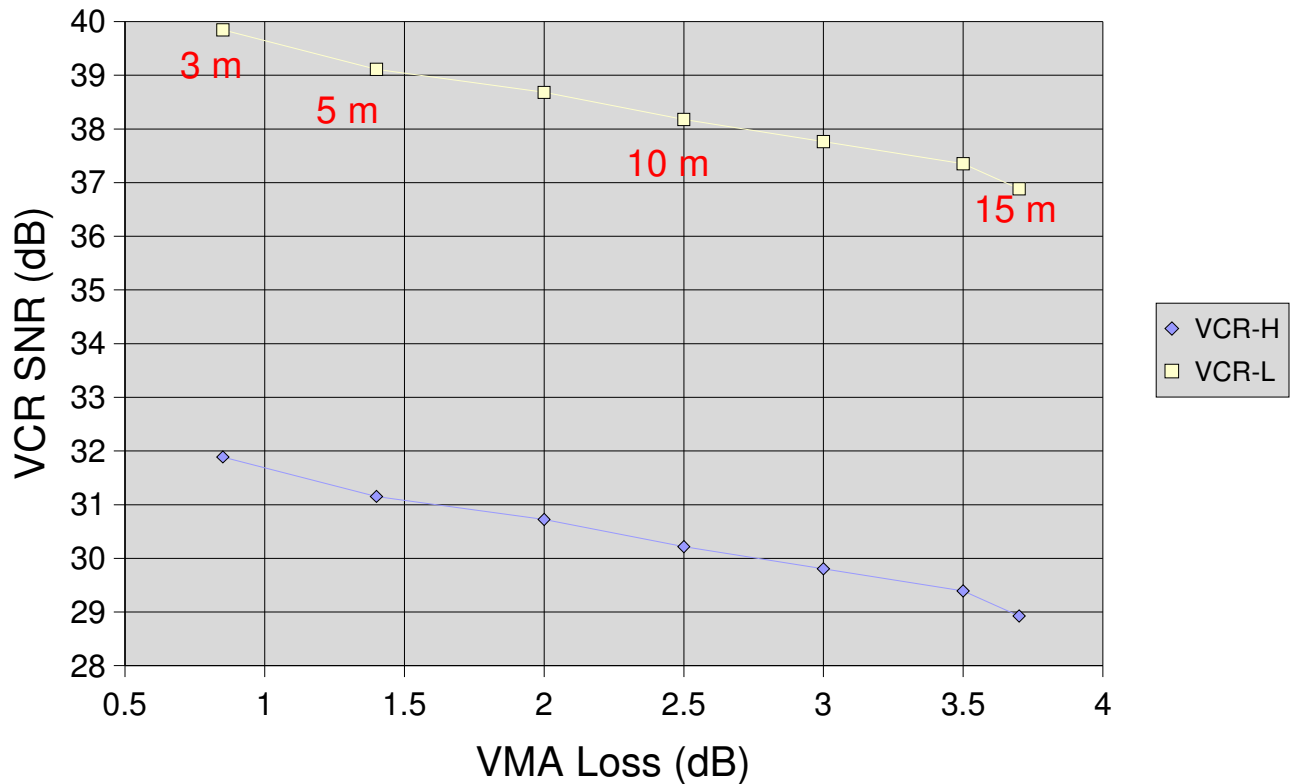
C is a constant accounting for chip finite return loss and cable loss dependent
L is the cable attenuation at 1/2 the baudrate
NEXT is the near end crosstalk in RMS

VMA to Crosstalk Ratio (VCR) SNR

- SNR for two cases

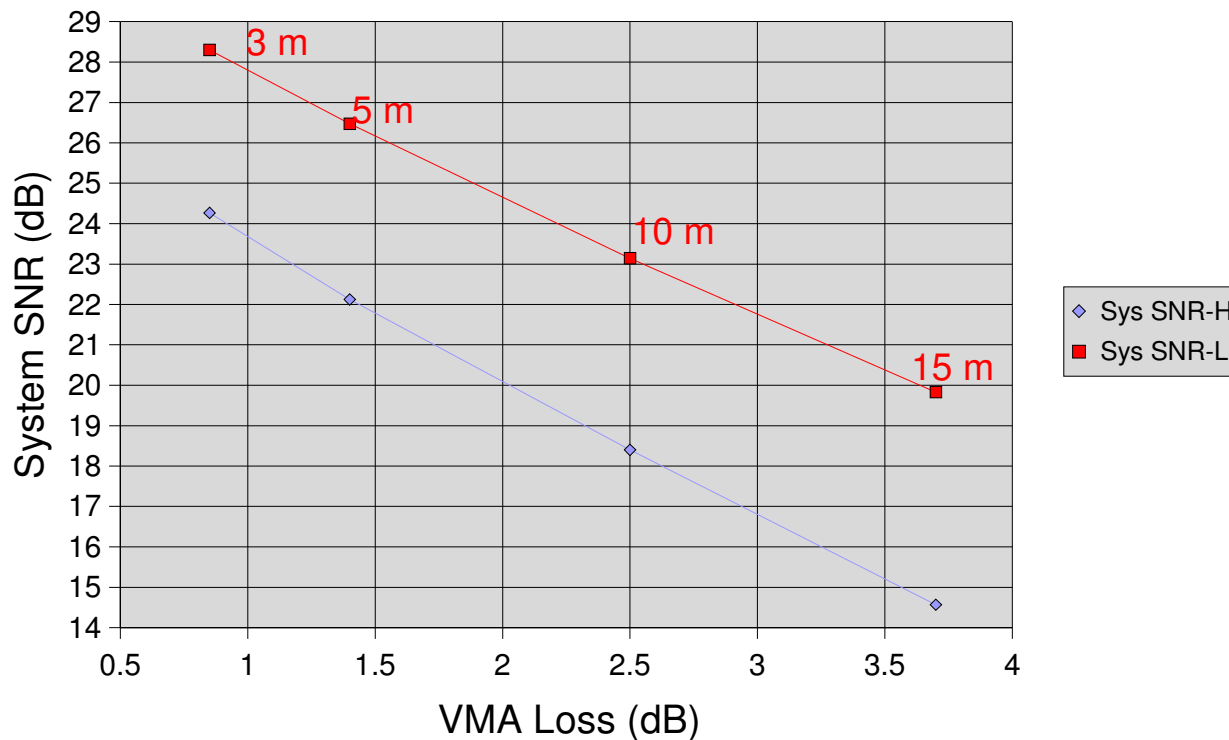
- Cable with low NEXT=1.2 mV RMS with 700 mV p-p TX (VCR-L)
- Cable with high NEXT=3 mV RMS with 700 mV p-p TX (VCR-H)

VMA to Crosstalk Ratio



System SNR for 10 m Cable from Supplier 1 and 2 with XTALK

- **System penalty for cable with high and low NEXT**
 - Assumes combined TX and RX SNR of 36 dB
 - Cable with high NEXT=3 mV RMS (Measured 17.4 dB SNR with LRM EDC chip)



Summary

- **SFP+ is in the process of defining 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 based on IEEE LRM TWDP code is an excellent metric for cable and system penalty measurements.**
- **Cable maximum reach is determined by:**
 - Transmitter SNR
 - Cable WDP
 - XTALK
 - Receiver SNR
- **Typical WDP for 10 m cable is in the range of 4.9-5.4 dBo**
- **NEXT has large variation ~3x due to cable termination.**