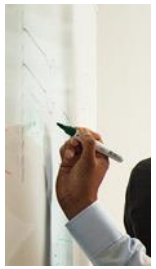
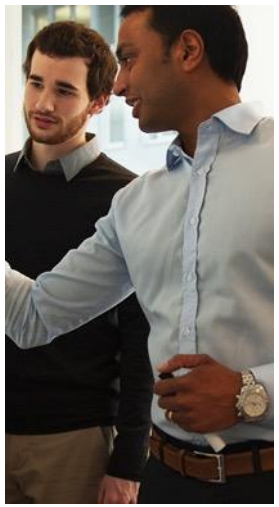




Channel Simulations for 100G Direct Attach Cable (Copper) Analysis

Nathan Tracy

March 7, 2018

Supporters

Mark Nowell, Cisco

Howard Heck, Intel

Tom Palkert, Molex

Scott Sommers, Molex

Phil Sun, Credo

Jeff Twombly, Credo

Joel Goergen, Cisco

Jane Lim, Cisco

Jeff Maki, Juniper

Pirooz Tooyserkani, Cisco

Upen Reddy, Cisco

Frank Chang, Inphi

Chris DiMinico, PHY-SI

Greg McSorley, Amphenol

Dave Ofelt, Juniper

Objective: Provide Channel Analysis to Support DAC Reach

- Why are Direct Attach Copper cables (DAC) used?
- How are they used today and into the future?
- Analysis of a 100Gbps PAM4 DAC based channel
- Summary

Why Are Direct Attach Copper Cables Used?

Based on current use cases and applications in enterprise and cloud data center applications, direct attach copper cables provide significant “value” in meeting high volume, low cost, high performance requirements.

Chart shows quantity of links per “section” of a data center with at least 16 sections in a cloud data center.

Copper cable quantity is shown to be approx. 4.5 times the number of optical links

Interconnection Volume

- Four sections per colo & multiple colos (≥ 4) per data center
- Volumes below are per section (except DCR to Metro)

A End	Z End	Volume	Reach (max)	Medium	Cost Sensitivity	Market Space
Server ǂ	TOR	10k – 100k	3 m	Copper	Extreme	LAN
TOR	LEAF	1k – 10k	20 m	Fiber (AOC)	High	
LEAF	SPINE	1k – 10k	400 m	SMF	High	
SPINE	DCR	100 – 1000	1,000 m	SMF	Medium	Campus
DCR	Metro	100 – 300	10 - 80 km	SMF	Low	WAN

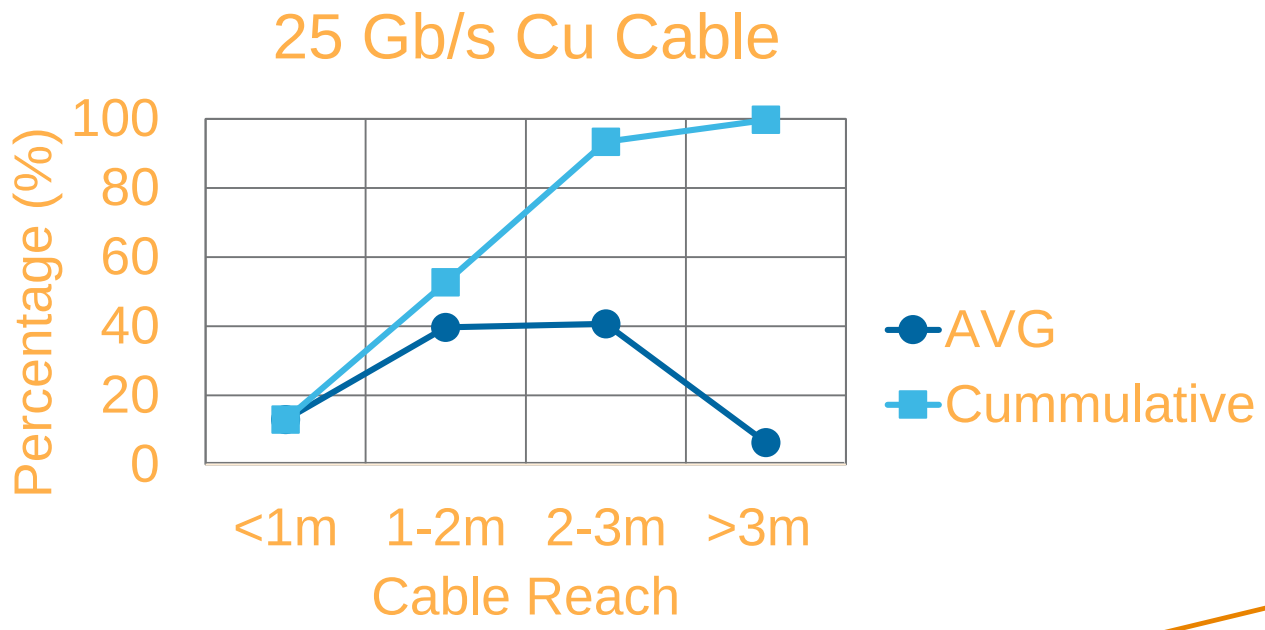
ǂ Server-TOR links may be served by breakout cables

Image from Brad Booth, “booth_400_01_1113.pdf” IEEE 802.3 400Gb/s Ethernet Study Group

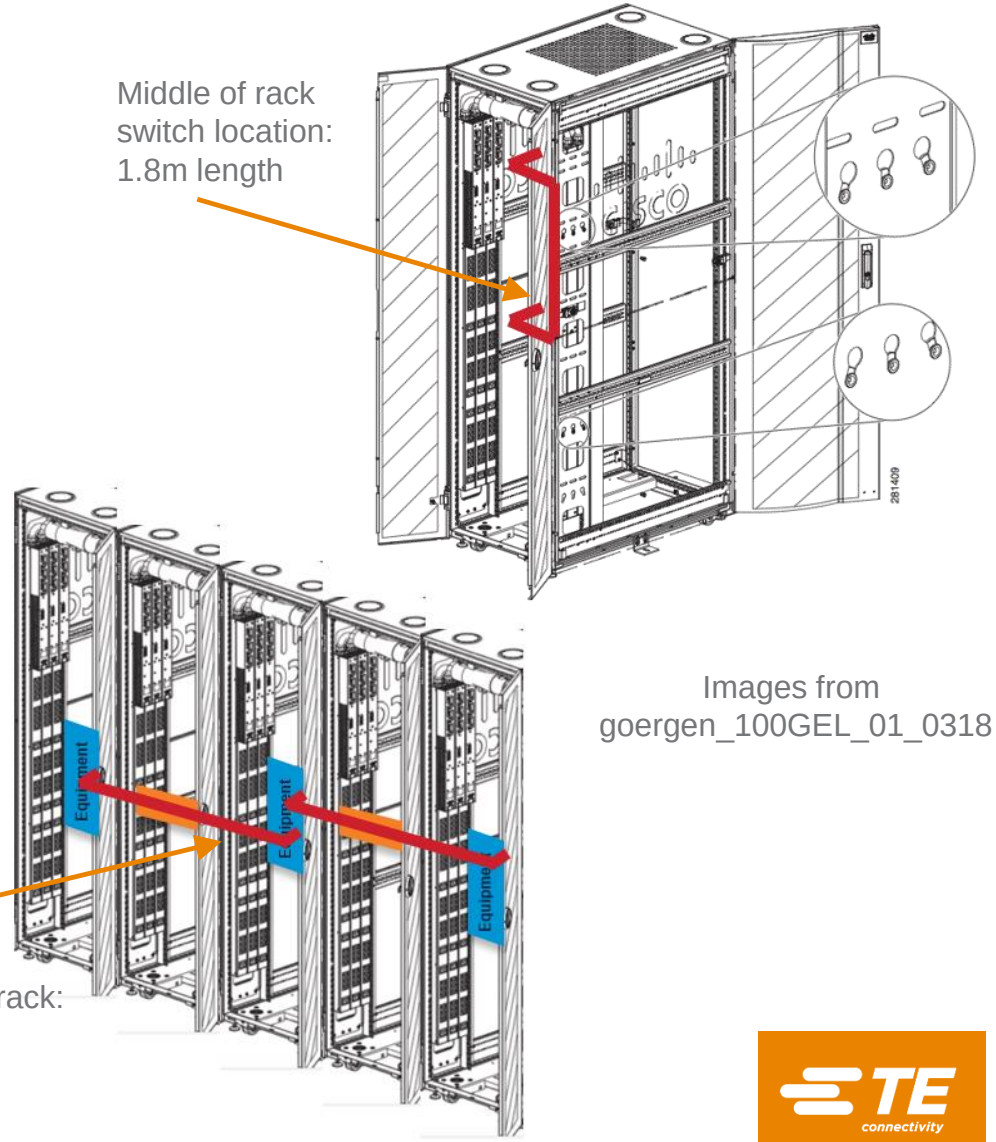
Cable Reach

Distribution of cable assembly market demand at 25 Gbps per channel by cable length for TE, Amphenol and Molex combined:

- Greater than 50% of demand is under 2 meters

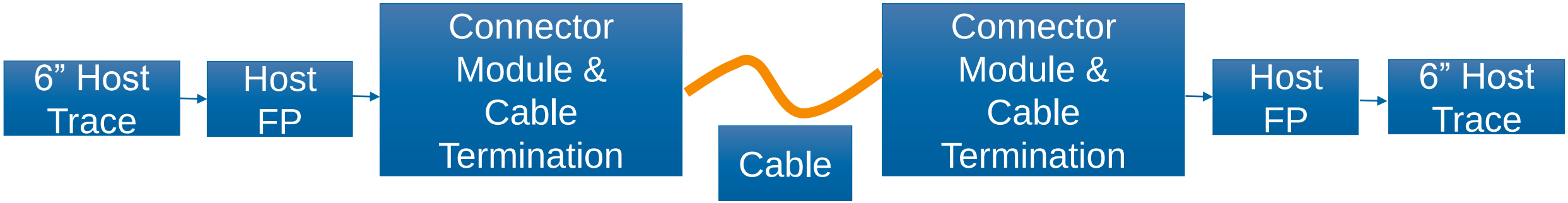


Data center architectures can be configured for <2m length to enable usage of low cost copper cables



Channel Details

Based on low technical risk assumptions



Host Trace
5-7-5 Trace (1.3dB/in)
Meg7 HVLP

Based on TE’s measured and contributed results

Host Footprint
151 mil Thick, 16 Layers
Signal routed on L15
8mil stub on signal vias

Performance is based on today’s capabilities

Connector
OSFP SMT, two worst case aggressors

Performance is based on today’s connector

Cable
2m 26AWG

Performance is assumed to be similar to TE’s 50GBaud cable being tested today

Connector
OSFP SMT, two worst case aggressors

Performance is based on today’s connector

Host Footprint
151 mil Thick, 16 Layers
Signal routed on L15
8mil stub on signal vias

Performance is based on today’s capabilities

Host Trace
5-7-5 Trace (1.3dB/in)
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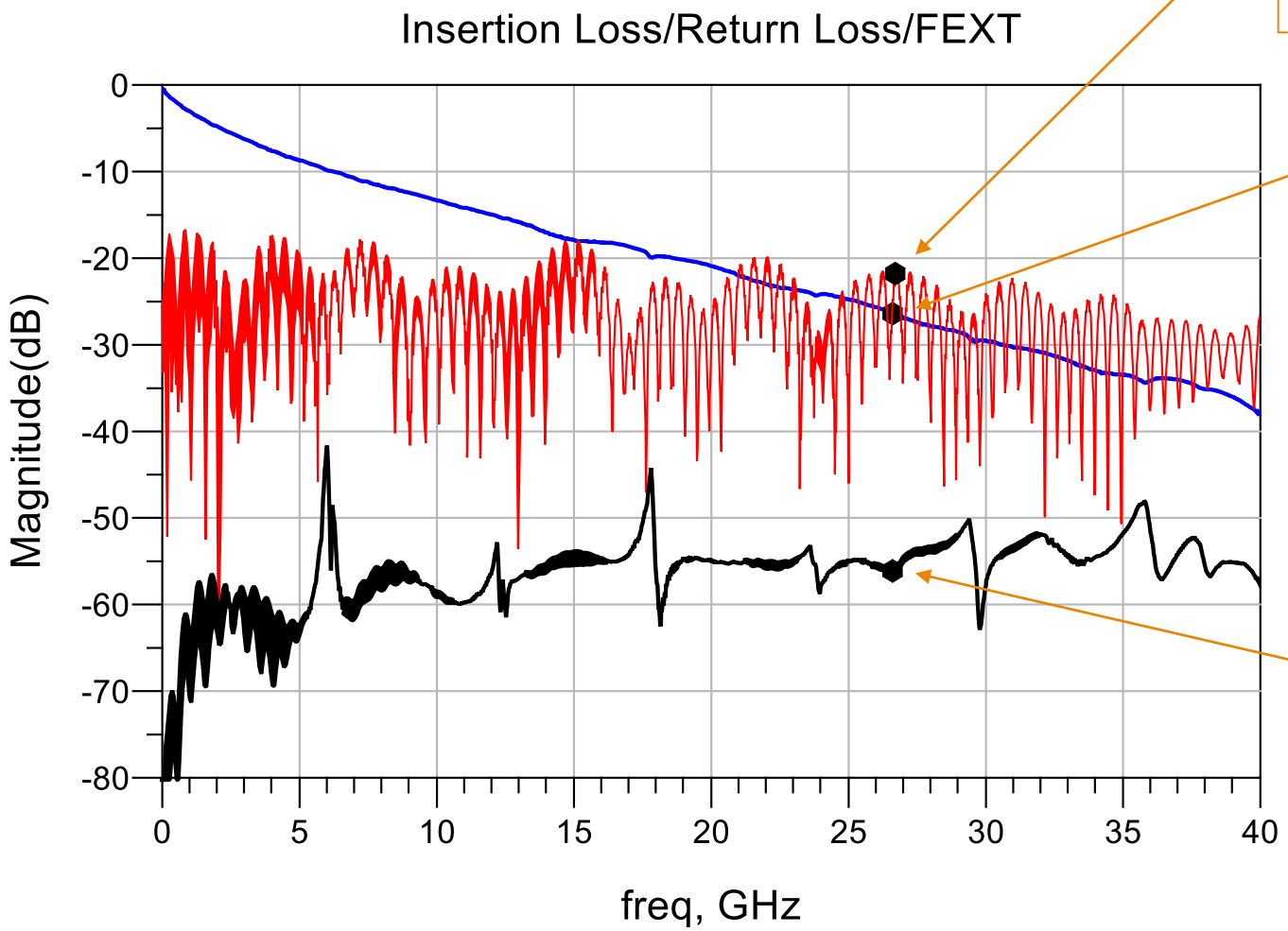
Based on TE’s measured and contributed results

Channel Results



Return Loss: 21.800dB

Insertion Loss: 26.402dB

FEXT Cross Talk: 56.126dB

Summary

- “Ball to ball” 100 Gbps PAM4 serial channel link analysis primarily based on existing and low risk channel elements
    - Host PCB is based on Meg7N measurements that TE has shared with the IEEE at Geneva Jan’18 meeting
    - Connector footprint and vias are based on today’s conventionally used structures
    - Connector is based on TE’s OSFP connector with minor enhancements for a backwards compatible future version. OSFP is used because we have measured data at 100G to provide a baseline, but it is fully expected other form factors will be extended to work as well.
    - Cable termination is based on enhancements of today’s termination process
    - Bulk cable is based on TE’s current 56 GBaud twinax cable
- All channel elements are anticipated to improve over the next two years, providing further improvement.
- Internal cable assemblies such as TE’s OTB cable solution provide further improvement/reach
- Data shows that 25 Gbps per channel applications at 2m and less represent over 50% of cable demand
- Based on TE’s analysis, I recommend adopting a 2m direct attach cable objective with a 30dB loss budget for the eventual 100G electrical project