# Welcome

# 10 Gbps Ethernet on 4X Twinax Cabling
# Call For Interest

IEEE 802
Kauai, Hawaii
November 9-12, 2002

***10GBASE-CX4***

# Contributors

Organization and Planning

- **Dan Dove – *hp* ProCurve Networks**

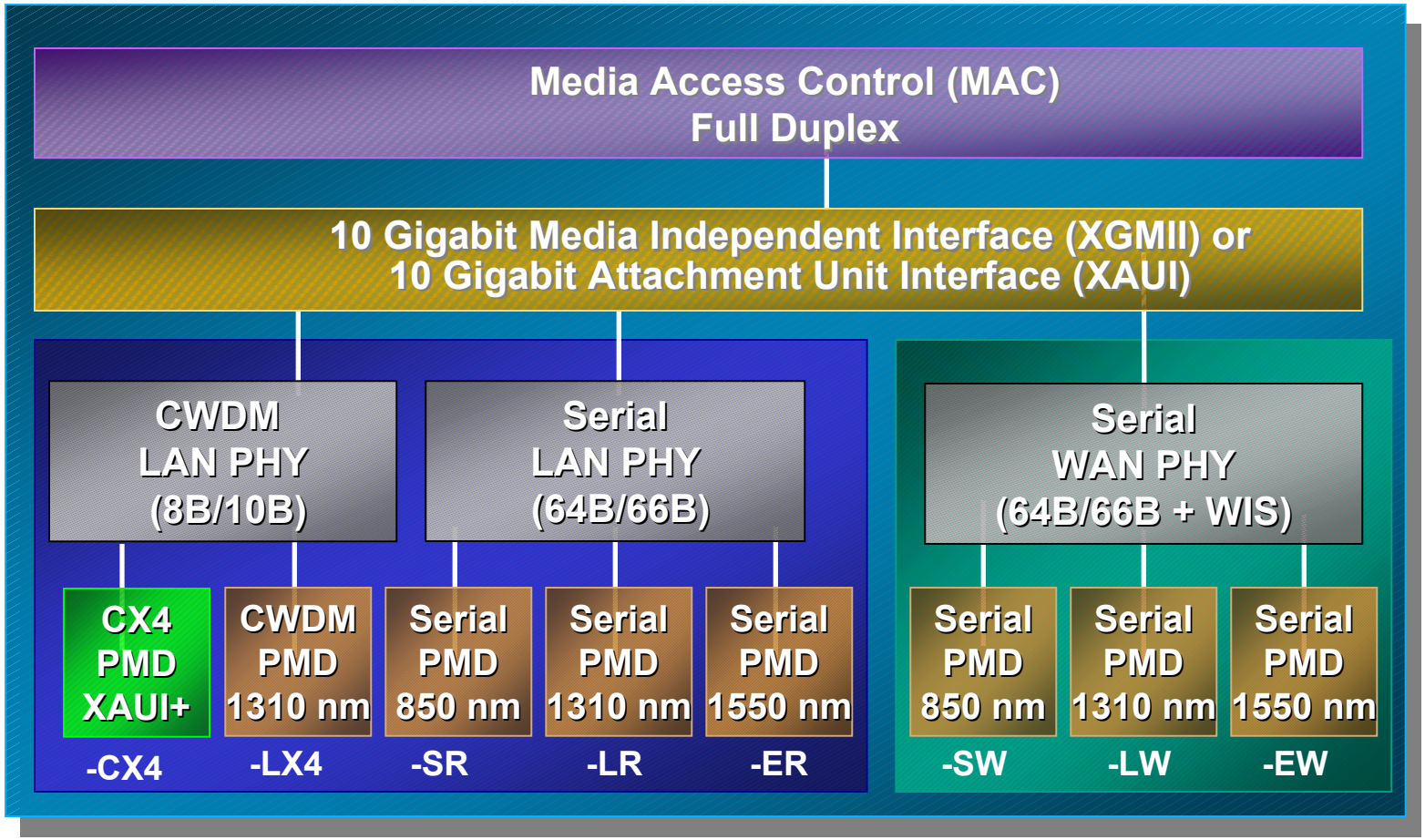
Market Requirements and Potential

- **Bruce Tolley – Cisco**
- **David Law – 3Com**

Technical Feasibility

- **Kamal Dalmia – Marvell Semiconductor, Inc.**
- **Nariman Yousefi – Broadcom**
- **Gary Oleynick - FCI**
- **Craig Theorin – W.L. Gore & Associates, Inc.**
- **Bob Thornton – Fujitsu**
- **Chris DiMinico – CDT Corporation**

# 10 GbE Layer Diagram



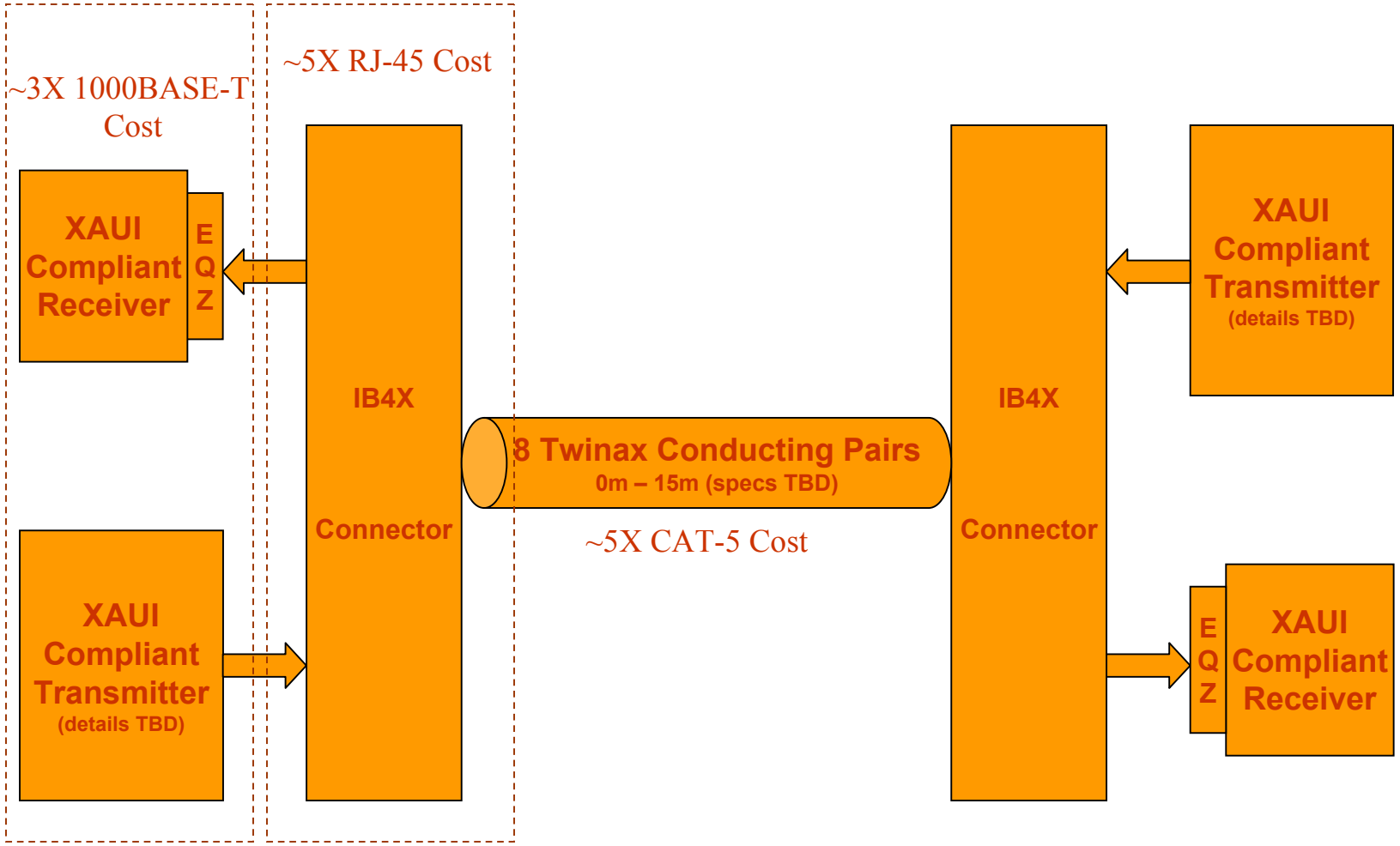

CWDM= coarse WDM

PMD= physical media dependent sublayer or transceiver

WIS= WAN interface sublayer

PHY = physical layer

# Basic Concept




IB4X refers to the InfiniBand 4X copper physical layer specified by the InfiniBand Trade Association

# Basic Concept

## Transmitter

- XAUI Compatible transmitter
- Specified amount of Pre-distortion
- More specific template required, balance spec needed
- Based upon 10m channel characteristics

## Receiver with Equalization "EQZ"

- XAUI Compatible receiver
- Unspecified amount of equalization
- Based upon 15m – 24awg channel characteristics
- BER constrains performance

## IB4X Connector (*)

- Reference the IB specification for mechanicals
- Develop pin-mapping of XAUI to IB4X proposal
- Integrate connector performance into total channel spec

## 8 Pair Twinax Cable

- Develop minimum and maximum channel specs for
    - Insertion Loss
    - Return Loss
    - Delay Skew, Balance, etc…

# Proposed Pin Mapping

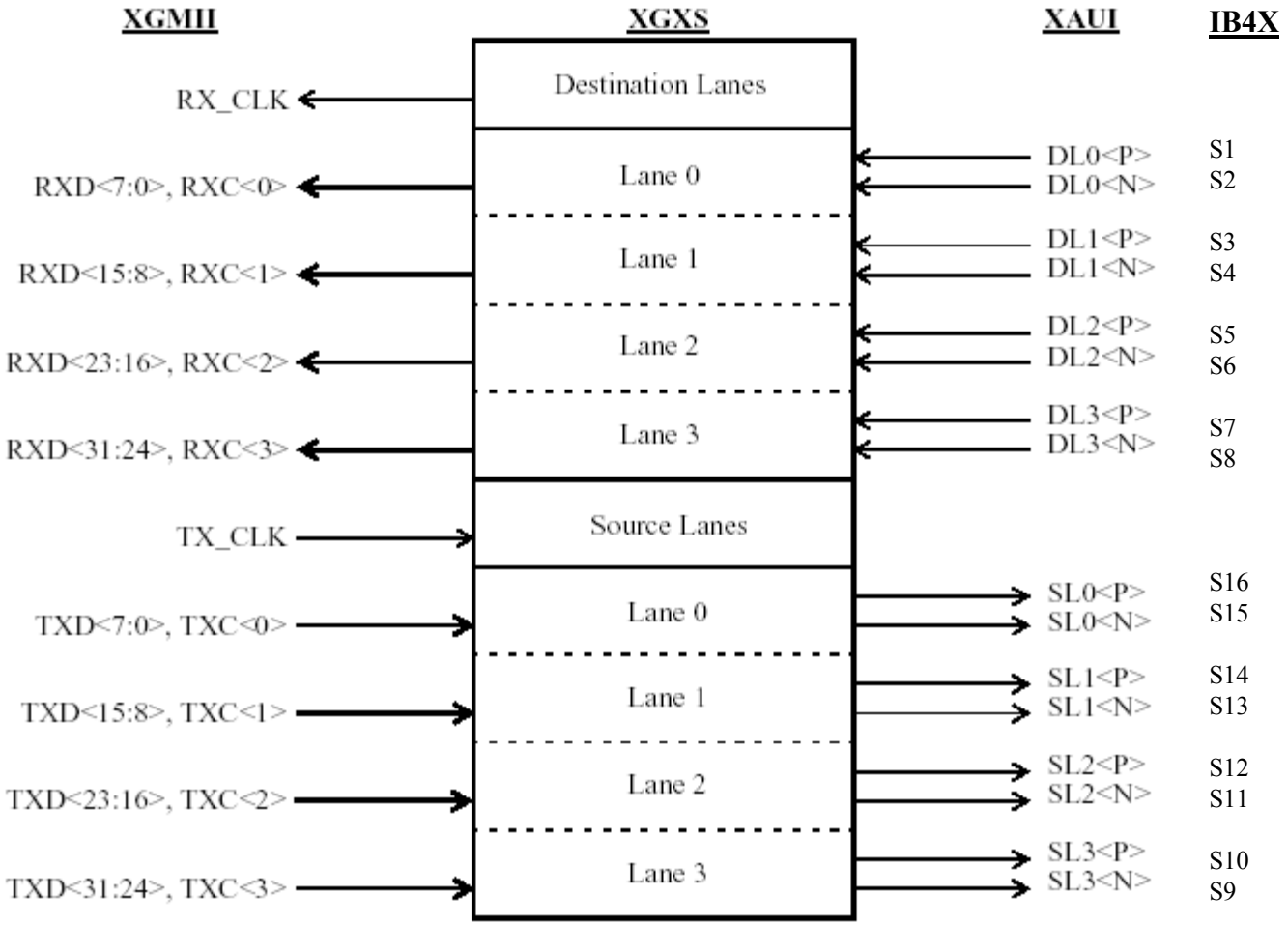
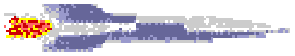



**Figure 47–2—XGXS inputs and outputs**

# The Fuse is Lit… Let's get going!!



# Market Potential

Bruce Tolley: Cisco Systems

# 10 GbE First Principles

- It's too expensive*
- It's too expensive
- It's too expensive
- We need LX4 to support installed MM fiber
- It does not support installed Cat 5 copper
- It is too expensive

* Total cost: transceiver plus system plus media

# Facts: Today

Ways to lower cost

- –Lower cost of transceiver
- –Increase density of ports on line card
- –Lower cost of system
- –Leverage investments already made (e.g. XAUI)
- –Leverage existing specifications for cable and connectors (IB4X) (IB,10GFC,SATA2,SAS)

- Gigabit to the Desktop switches demand low-cost interconnection for stacking and aggregation

# 10 GbE Applications

- Large majority of 10 GbE ports will be enterprise for deployment in-building, constrained by installed base and by structured cabling standards
- Significant and material portion will be data center deployment, less constrained by installed base and less constrained by structured cabling standards
  - –Includes switch to server, switch to switch in rack or same room
  - –Includes switch to DWDM in same room
- Material portion will be enterprise, building-to- building and service provider/metro ports (outside the building)

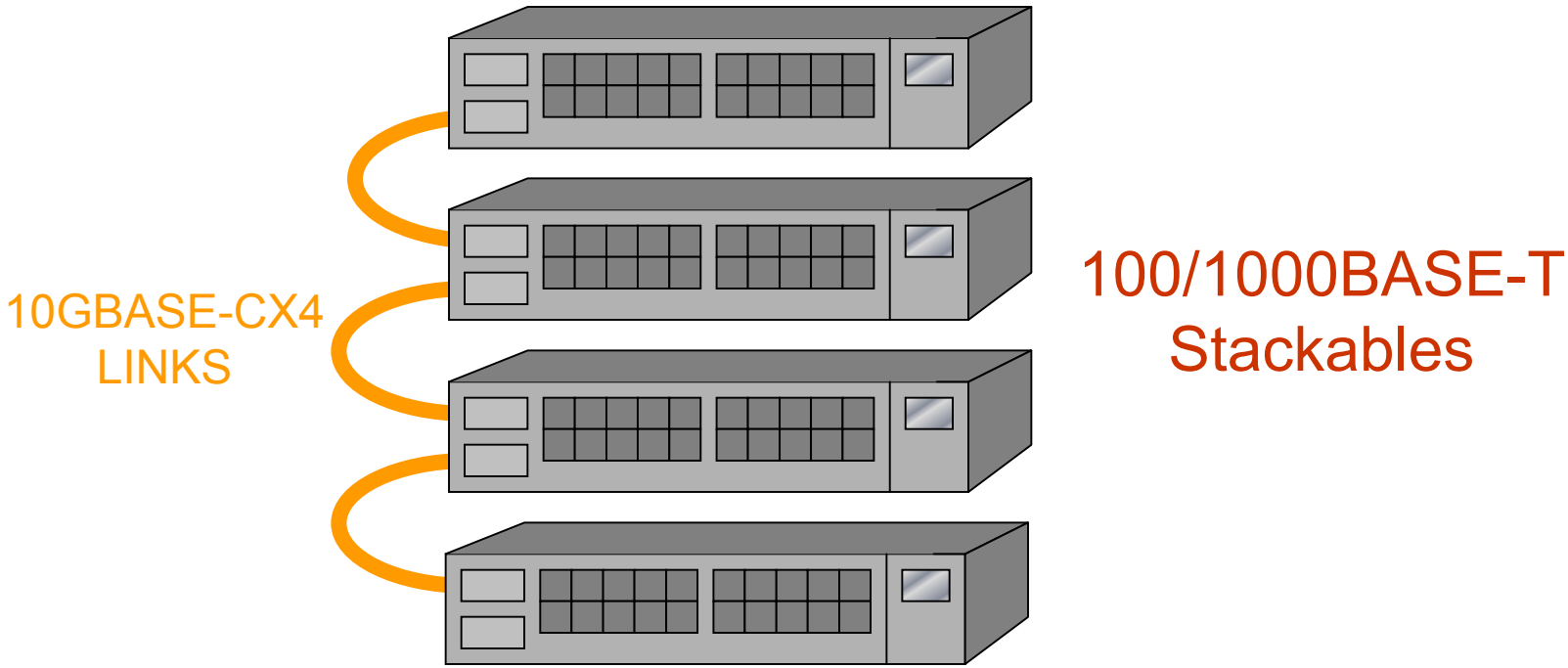
**In other words: Majority of the market is enterprise/data center**

# 10GBASE-CX4 Applications

| Application | 10GBASE-fiber | 10GBASE-CX |
|---|---|---|
| **In-building horizontal copper** | **No** | **No** |
| **In building vertical** | **Yes LR on SM** | **No** |
| **Data center/Server farms** | **Yes: -SR high end if cheap enough** | **Yes** |
| **External backplane for stackables** | **Not likely** | **Yes** |
| **Between buildings, metro** | **Yes** | **No** |

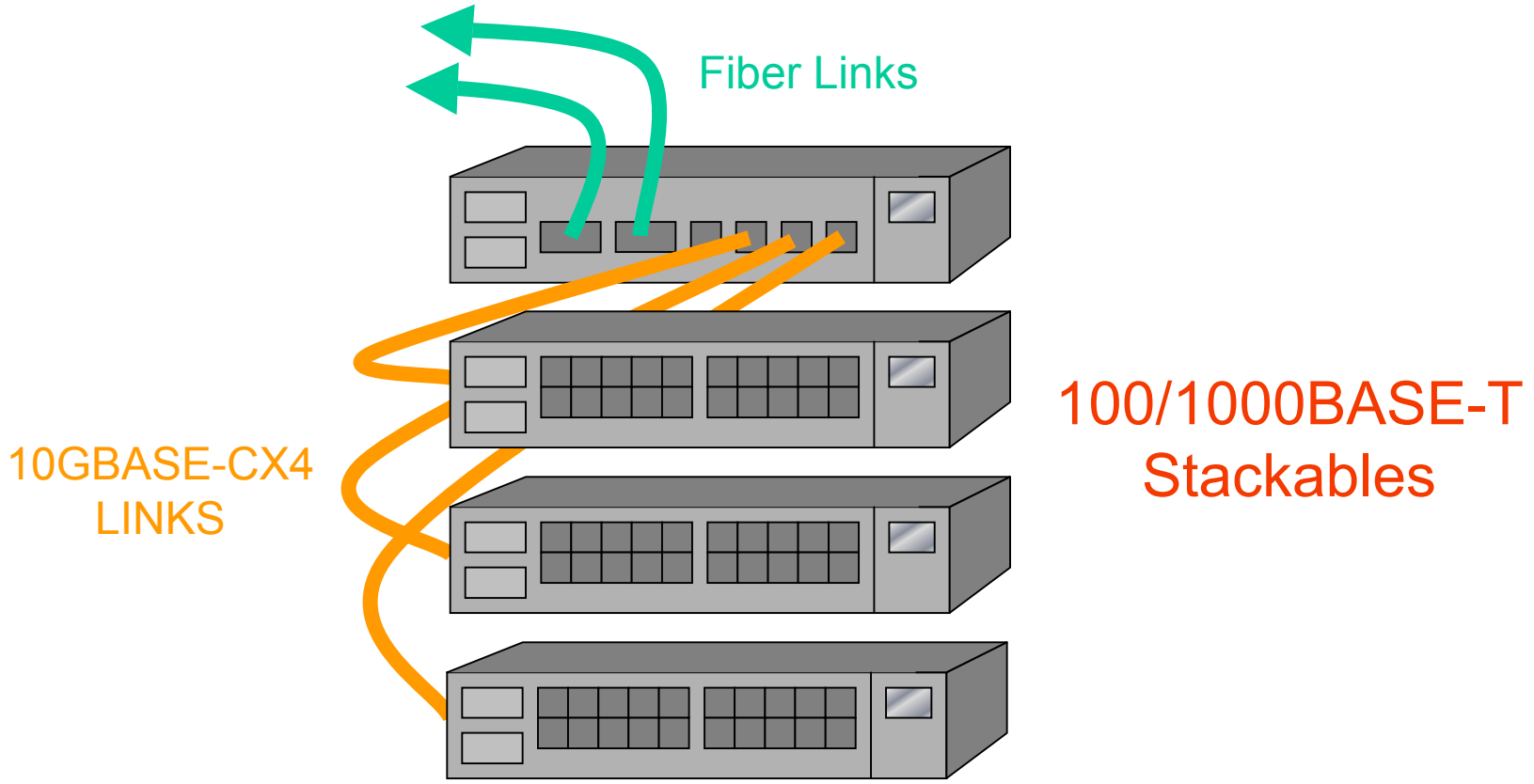
# 10GBASE-CX4 Applications

## External backplane for stackables



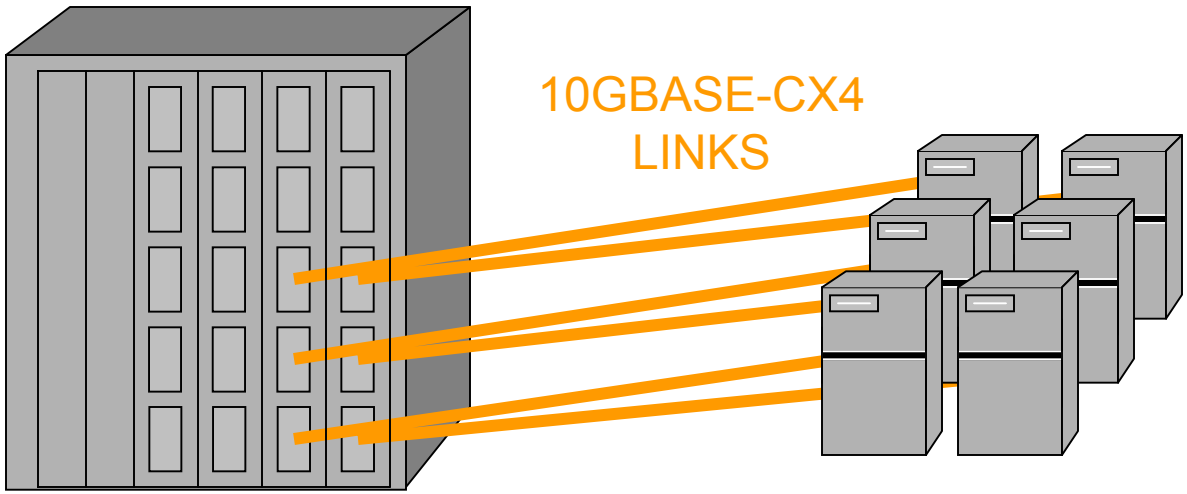
# 10GBASE-CX4 Applications

## Aggregator for stackables

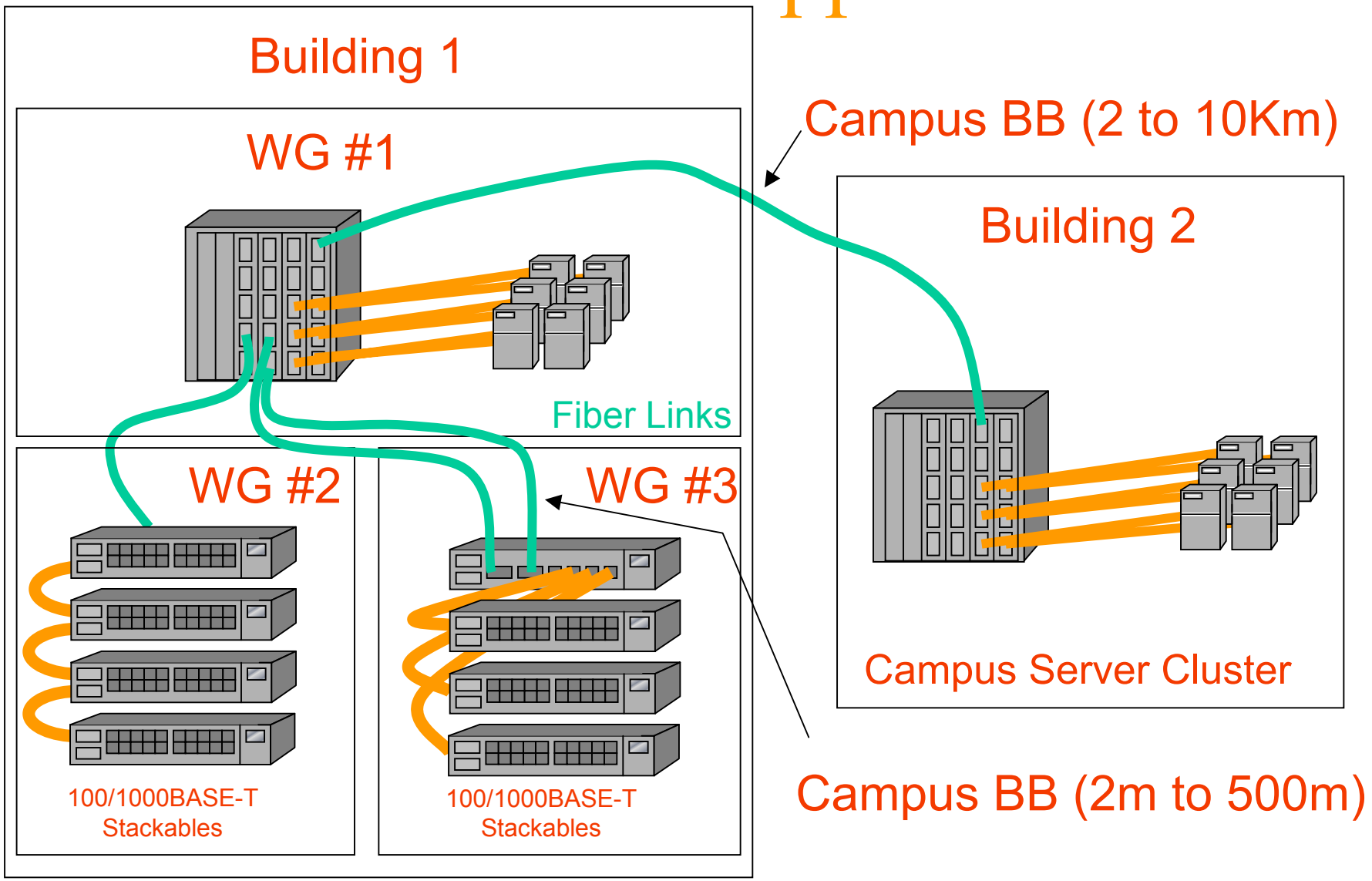


# 10GBASE-CX4 Applications

## Data Center / Server Farms



# 10GBASE-CX4 Applications



# 10GBASE-T vs 10GBASE-CX4

CX4

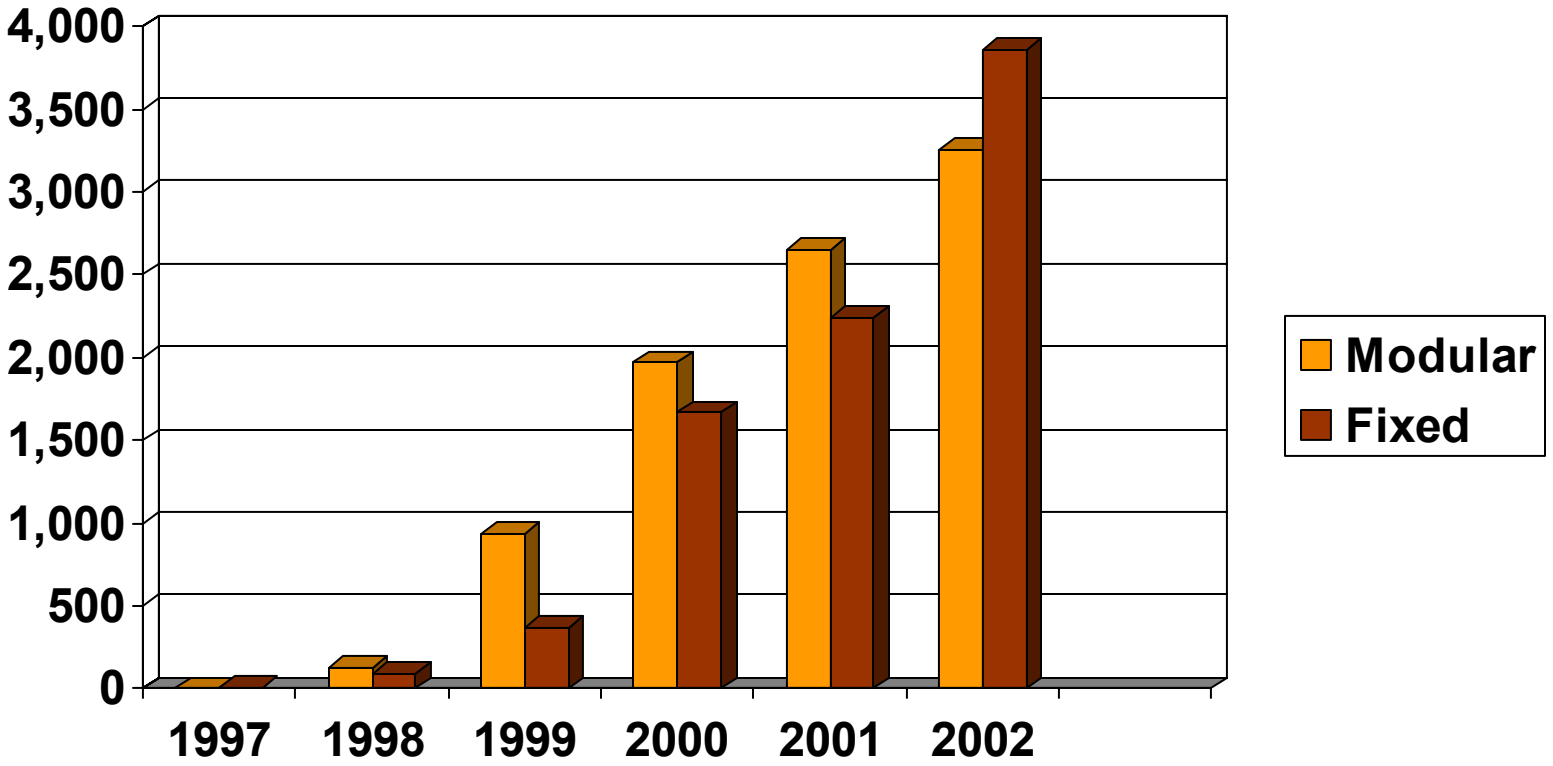
- Differentiated in time: NOW
- Differentiated in application:
  - CX4 will not be used in structured cabling,
  - will not be used by “late majority” technology adopters

BASE-T

- Technical Challenges more substantial
- Cable characterization more complex

# The Role of Stackables

GbE Switches, Port Shipments (000s)




Dell'Oro Group August 2002

# Conclusions

We need 10GBASE-CX4

- To lower the cost of 10 GbE solutions
- To enable Gigabit to the Desktop
- To grow the 10 GbE market
- To support the sweet spot
  - –Switch to switch links in data center
  - –Switch to server: high end server farms
  - –External stackable backplanes
- We need to execute this STD quickly

We should form a study group

# Technical Feasibility

Kamal Dalmia: Marvell Semiconductor

# 10GBase-CX4 Technical Feasibility

- Proposed Architecture Diagram
- Feasibility Testing Results
  - 2 Silicon Vendors
  - 2 Connector/Assembly vendors
  - 10 and 15 meter cables
  - Simulation results
- XAUI compliance channel Vs IB4X Cables
- Discussion of cables/connectors
- Summary

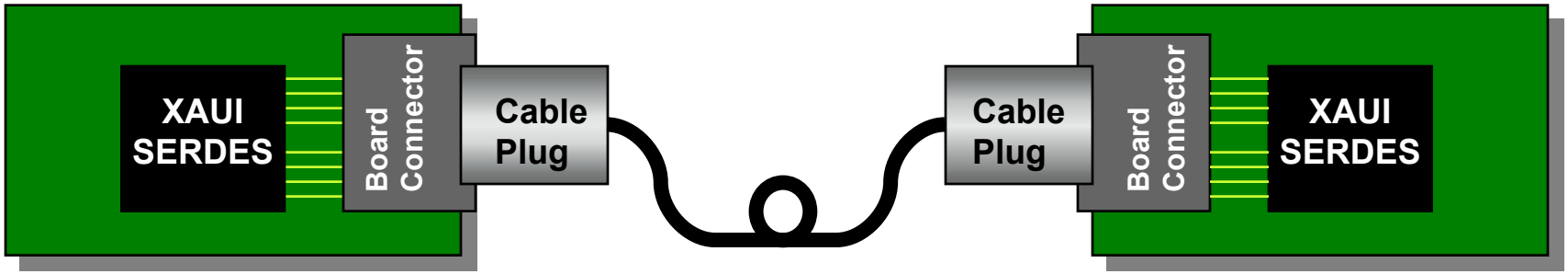
# Cable and Silicon Vendor Matrix

- Silicon Vendor 1, Cable Assembly Vendor 1 (10 meters)
- Silicon Vendor 1, Cable Assembly Vendor 2 (15 meters)

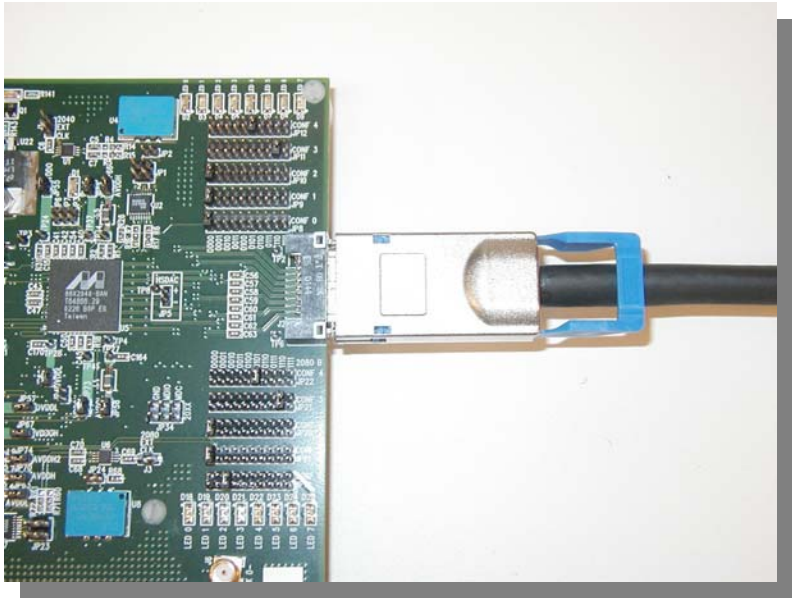
- Silicon Vendor 2, Cable Assembly Vendor 1 (15 meters)
- Silicon Vendor 2, Cable Assembly Vendor 2 (10 meters)

# Feasibility Test Setup

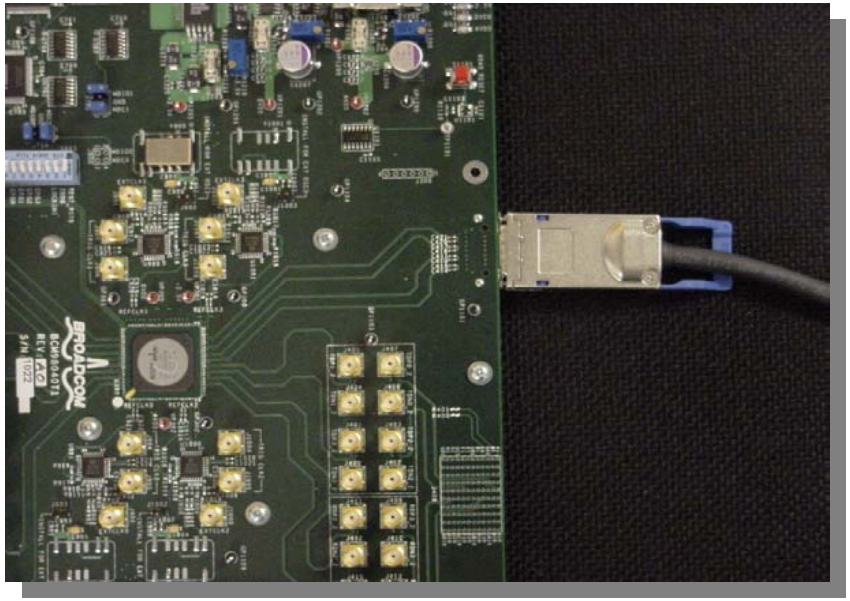
- XAUI signaling
- Data rate: 4x3.125 Gbps (Full Duplex)
- Standard IB4X  Copper Cable (8 Pairs)
- 24 Gauge copper wires
- IEEE 802.3ae CJPAT data patterns
- Full MDNEXT configuration
- Asynchronous testing
- BER better than $10^{-15}$ (Tests run for 100 hours)



# Copper Cable Setups



Silicon Vendor 1



Silicon Vendor 2

# XAUI Specifications & De-emphasis (For Reference only)

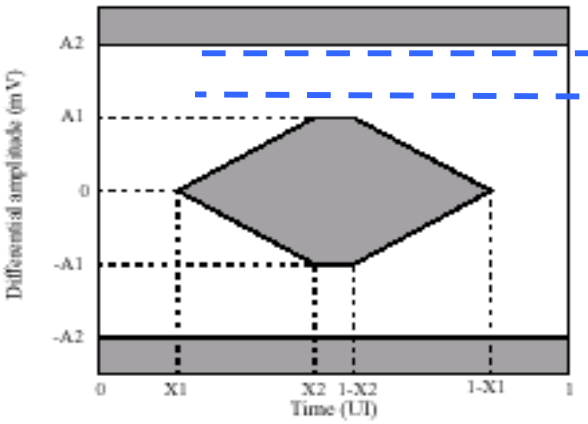



Figure 47–4—Driver template

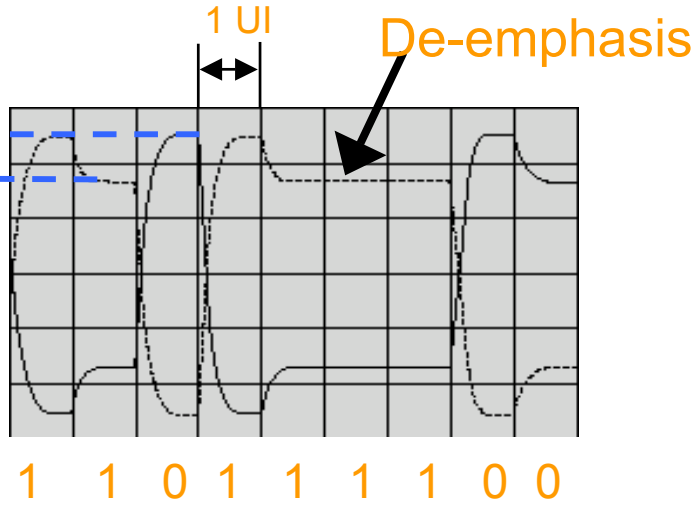



Table 47–2—Driver template intervals

| Symbol | Near-end value | Far-end value | Units |
|---|---|---|---|
| X1 | 0.175 | 0.275 | UI |
| X2 | 0.390 | 0.400 | UI |
| A1 | 400 | 100 | mV |
| A2 | 800 | 800 | mV |

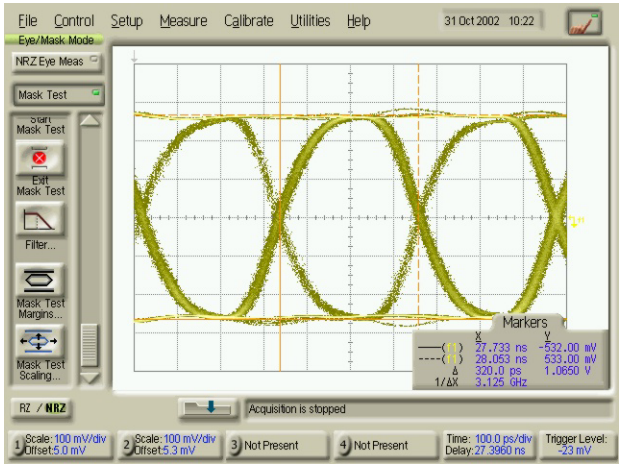
Differential ‘peak-to-peak’ amplitudes are 2x

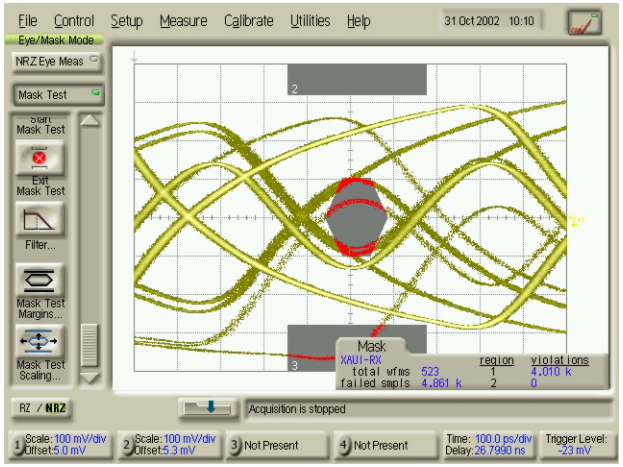
# Test Results Silicon Vendor 1/Cable Vendor 1

**TX amplitude = 1000 mV  Cable Length = 10m**

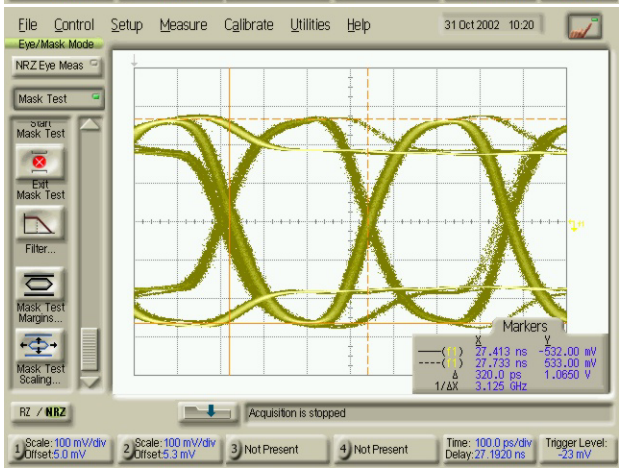
**Transmit eyes**  **Receive eyes**

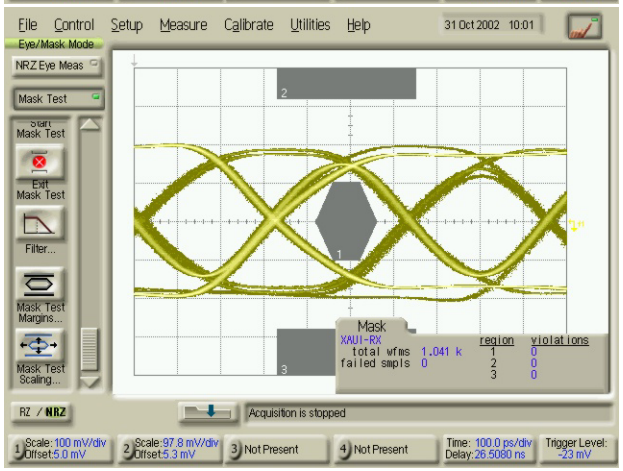
**No De-emphasis**




**With De-emphasis**



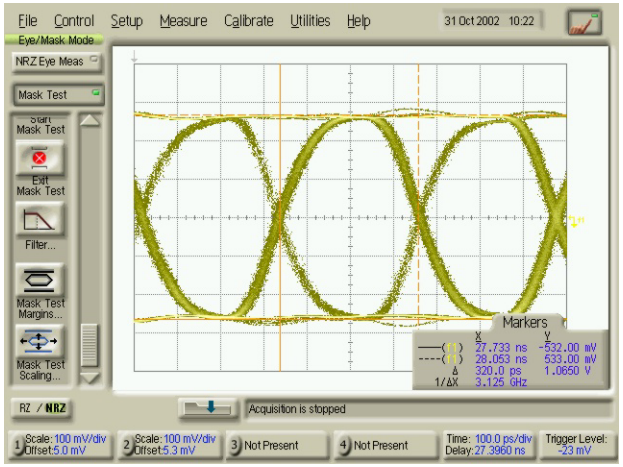



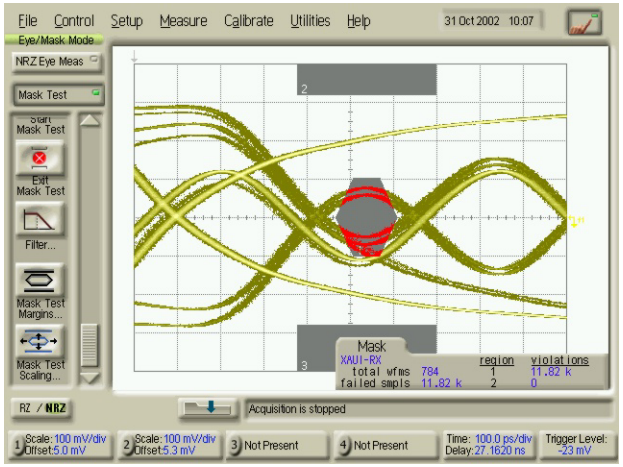
# Test Results: Silicon Vendor 1/Cable Vendor 2

**TX amplitude = 1000 mV Cable Length = 15m**

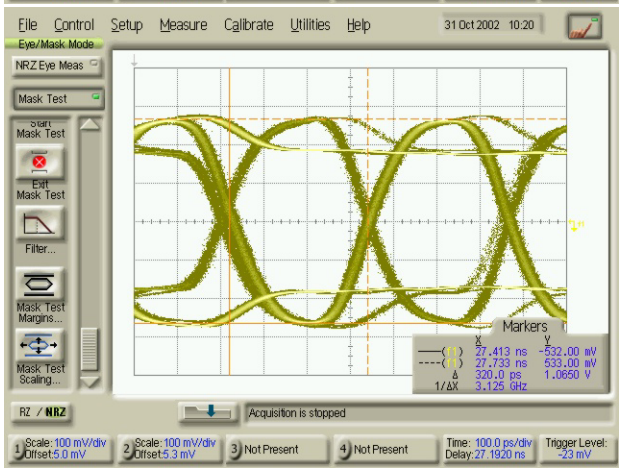
**Transmit eyes** **Receive eyes**

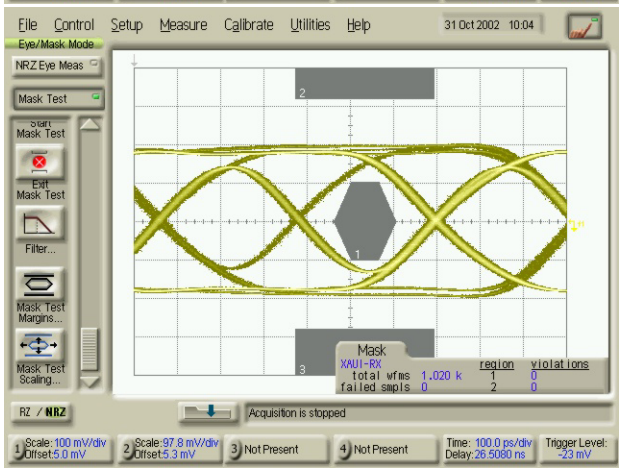
**No De-emphasis**




**With De-emphasis**



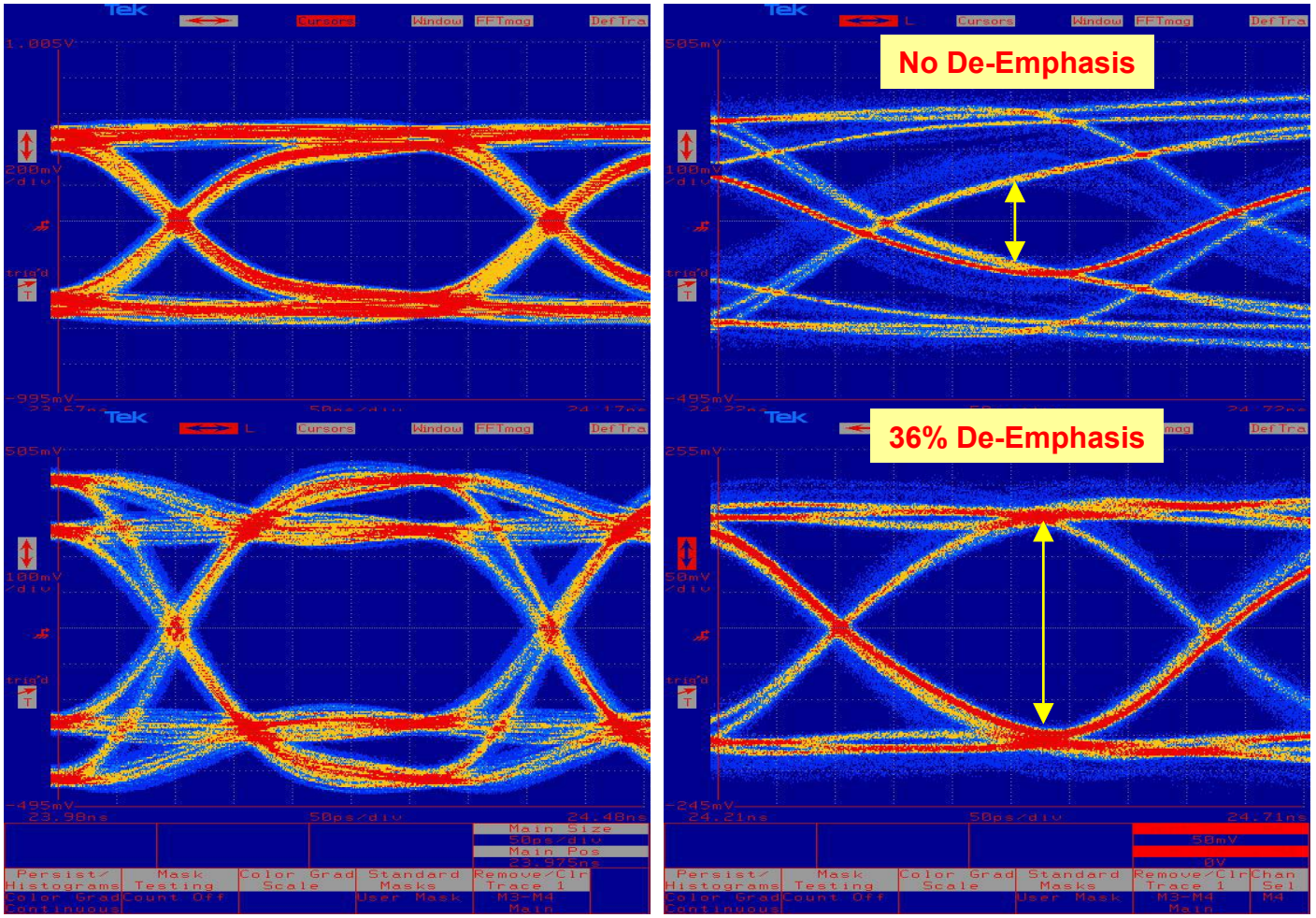



# Test Results: Silicon Vendor 2 - Cable Vendor 1

**Transmit** **Receive**

1Vpp

1Vpp




**10 meters 24awg 150mVpp**

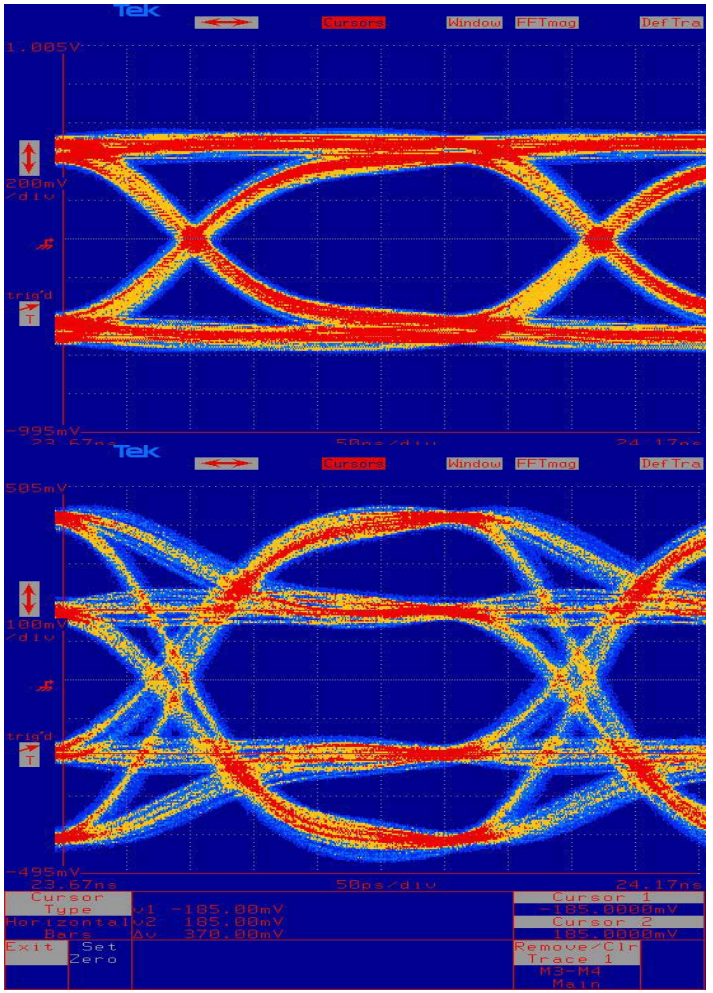
**10 meters 24awg 290mVpp**

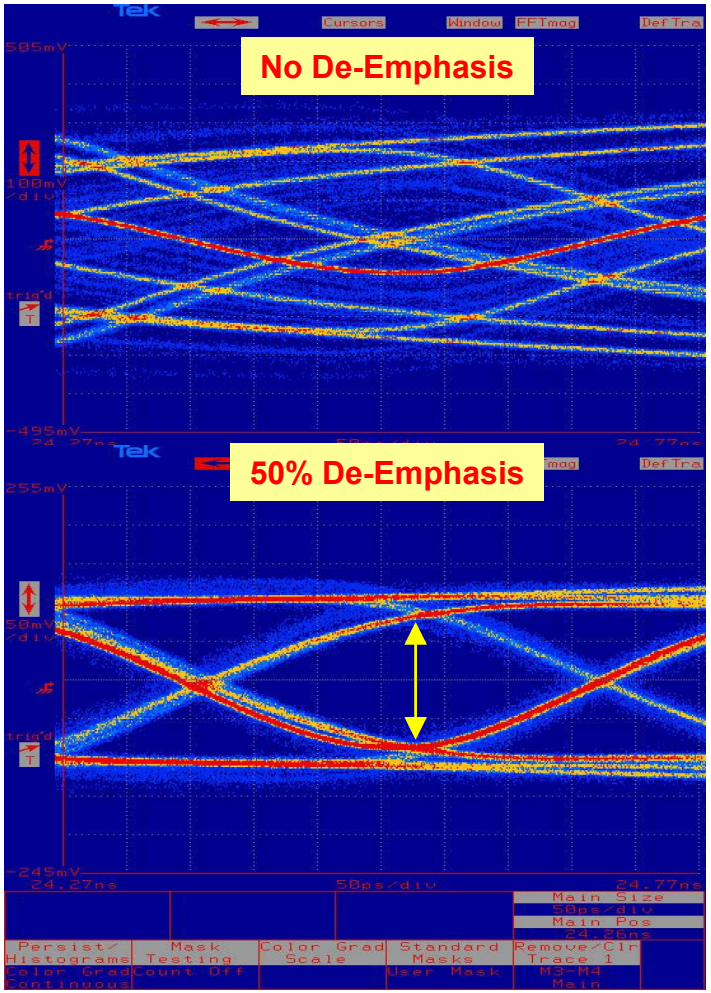
# Test Results: Silicon Vendor 2 - Cable Vendor 2

**Transmit** **Receive**

1Vpp

1Vpp






15 meters
24awg
No Eye
Opening

15 meters
24awg
100mVpp

# Summary of Electrical Results

- All tests performed with BER better than $10^{-15}$
- Minor modifications are required to XAUI specifications for 15 meters
- Potential changes to XAUI specs
  - Increased TX amplitude
  - Improved RX sensitivity
  - RX Equalizer
  - Combinations of above techniques

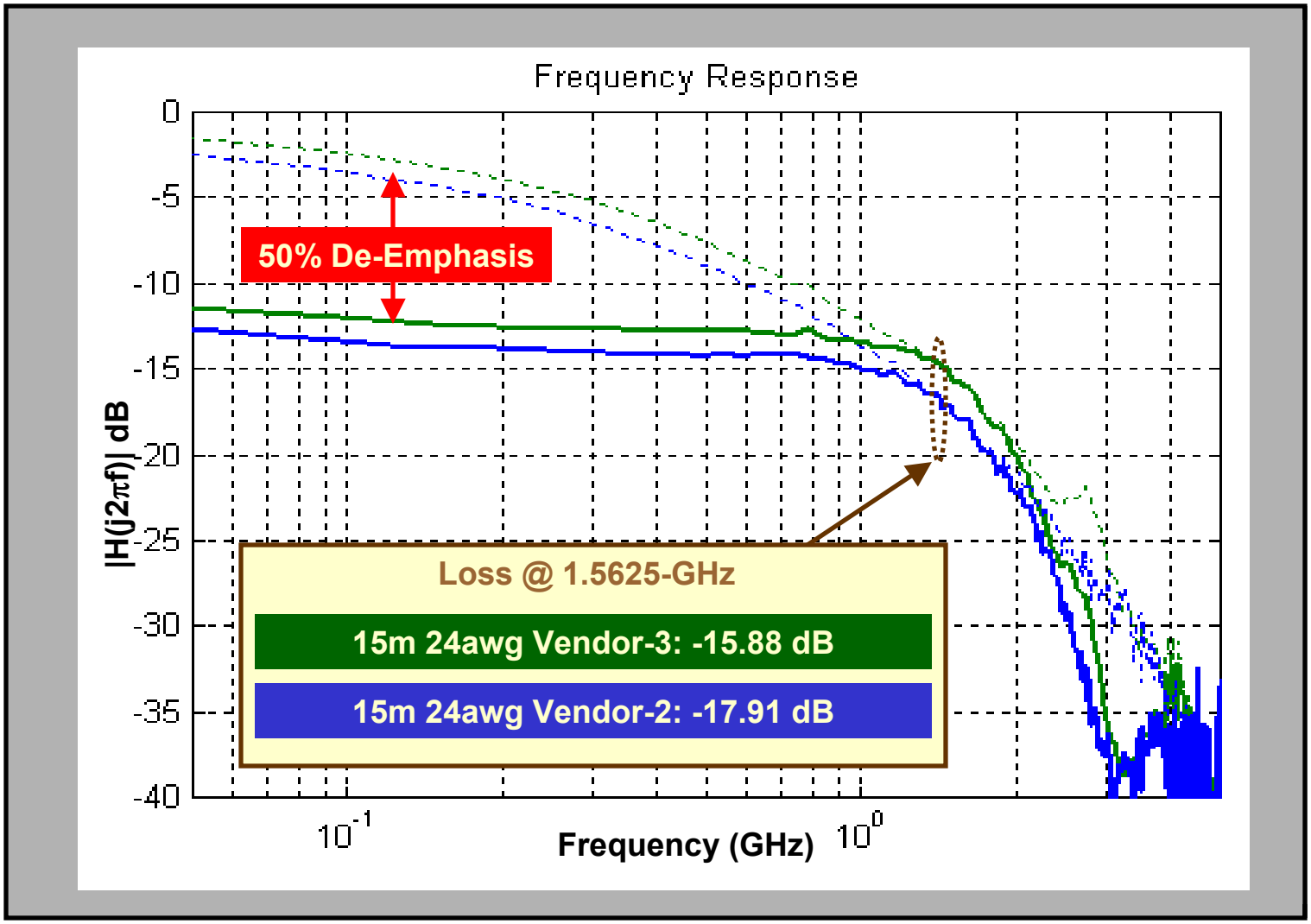
# Driver, Channel & System Models

Nariman Yousefi: Broadcom

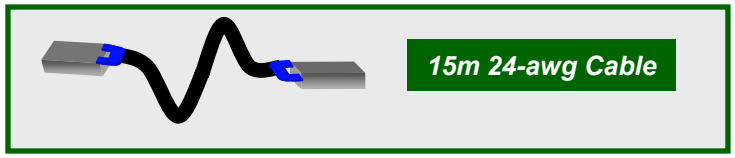
# Outline

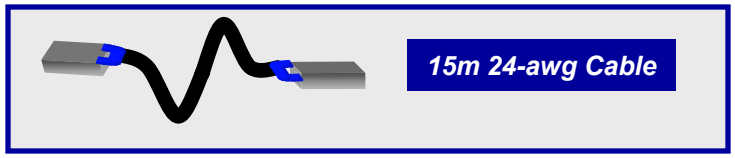
- Signal Integrity
  - Channel analysis. Frequency response and time domain response
- Eye pattern measurement and simulation results at transmitter and receiver for 10m and 15m cable
- System Analysis
  - BER prediction
  - BER results for 15m

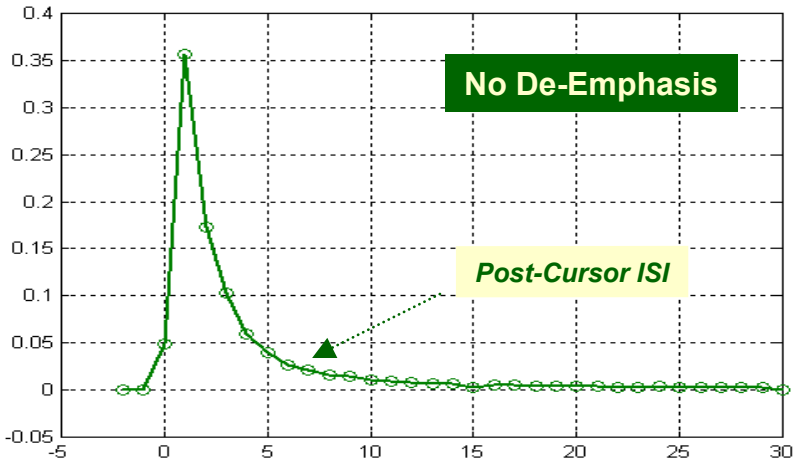
# Frequency Response: 50% De-Emphasis

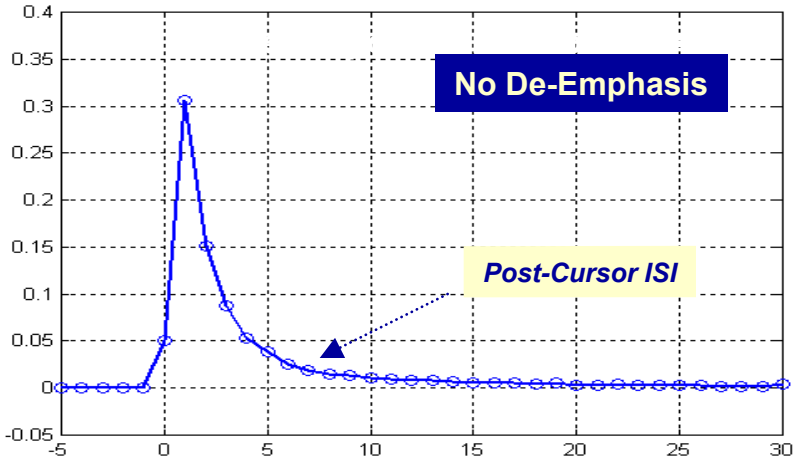


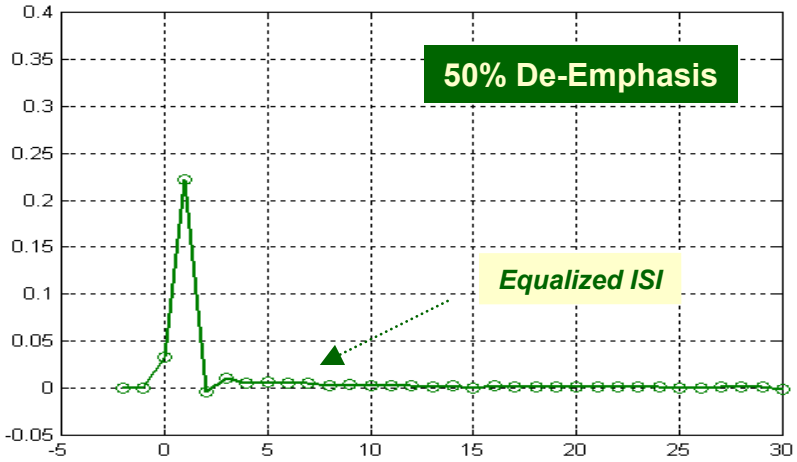
# 15-m IB4X: 3.125-Gb/s Pulse Response

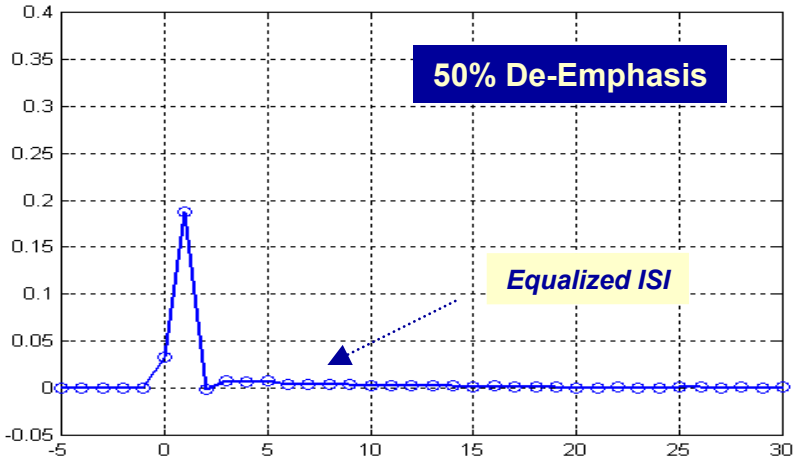


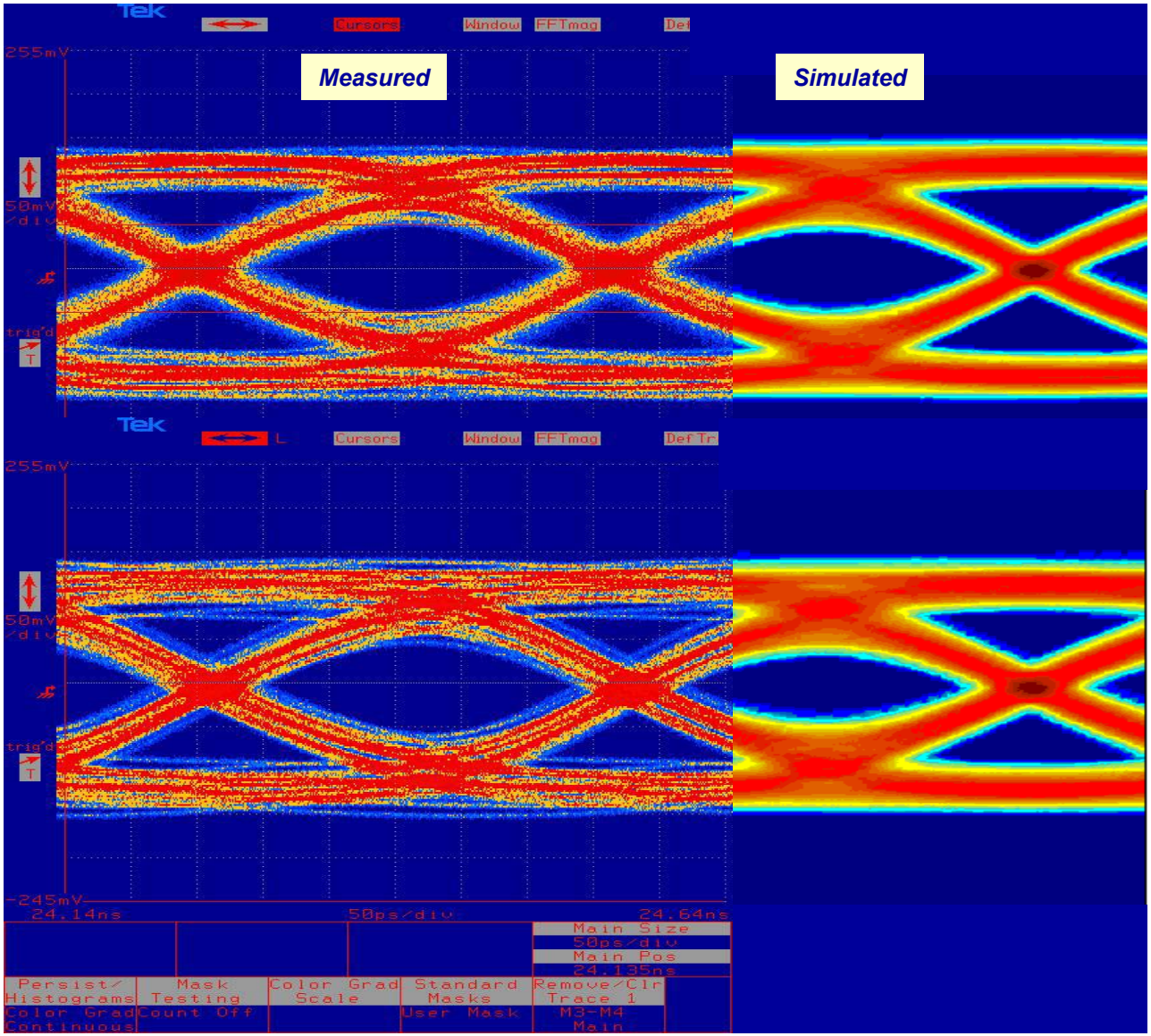



# Comparison of Measurements & Simulations



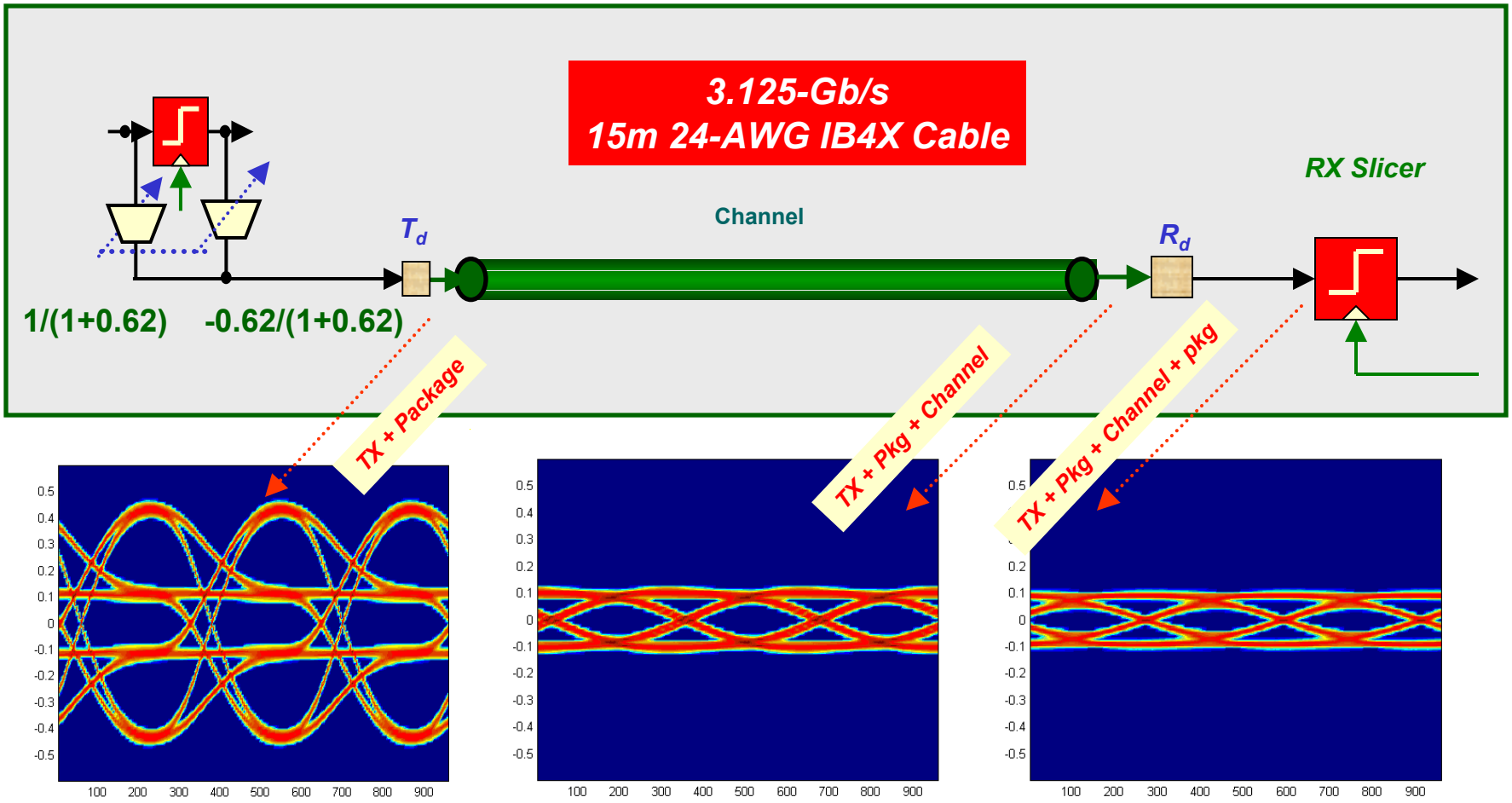

**50% Pre-Emphasis**

*15m 24-awg Cable*

**50% Pre-Emphasis**

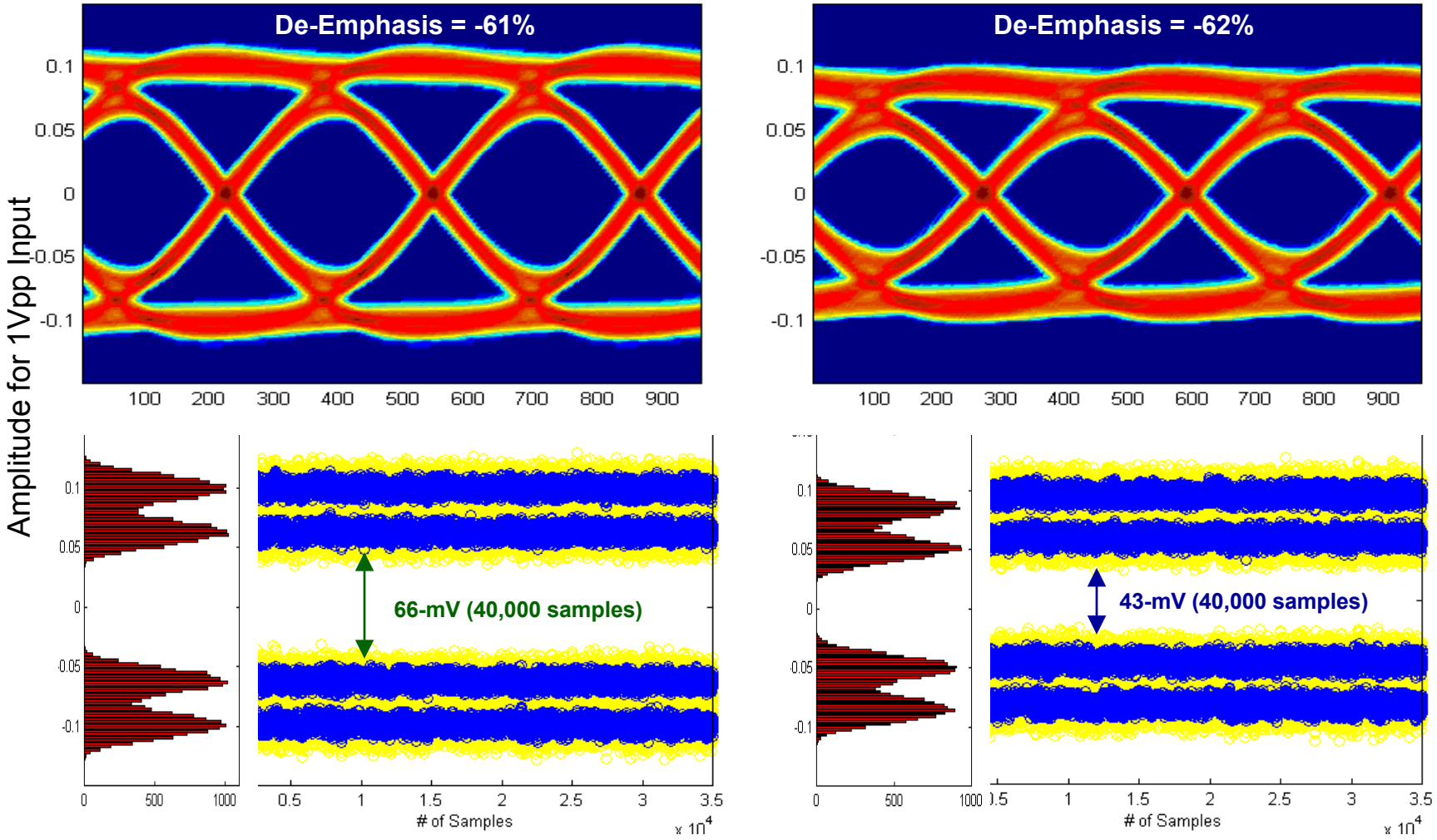
*15m 24-awg Cable*

# 2-Tap De-Emphasis: Effect of TX & RX Packages




- Typical Eye Diagrams for 2-Tap Pre-Emphasis with BGA package

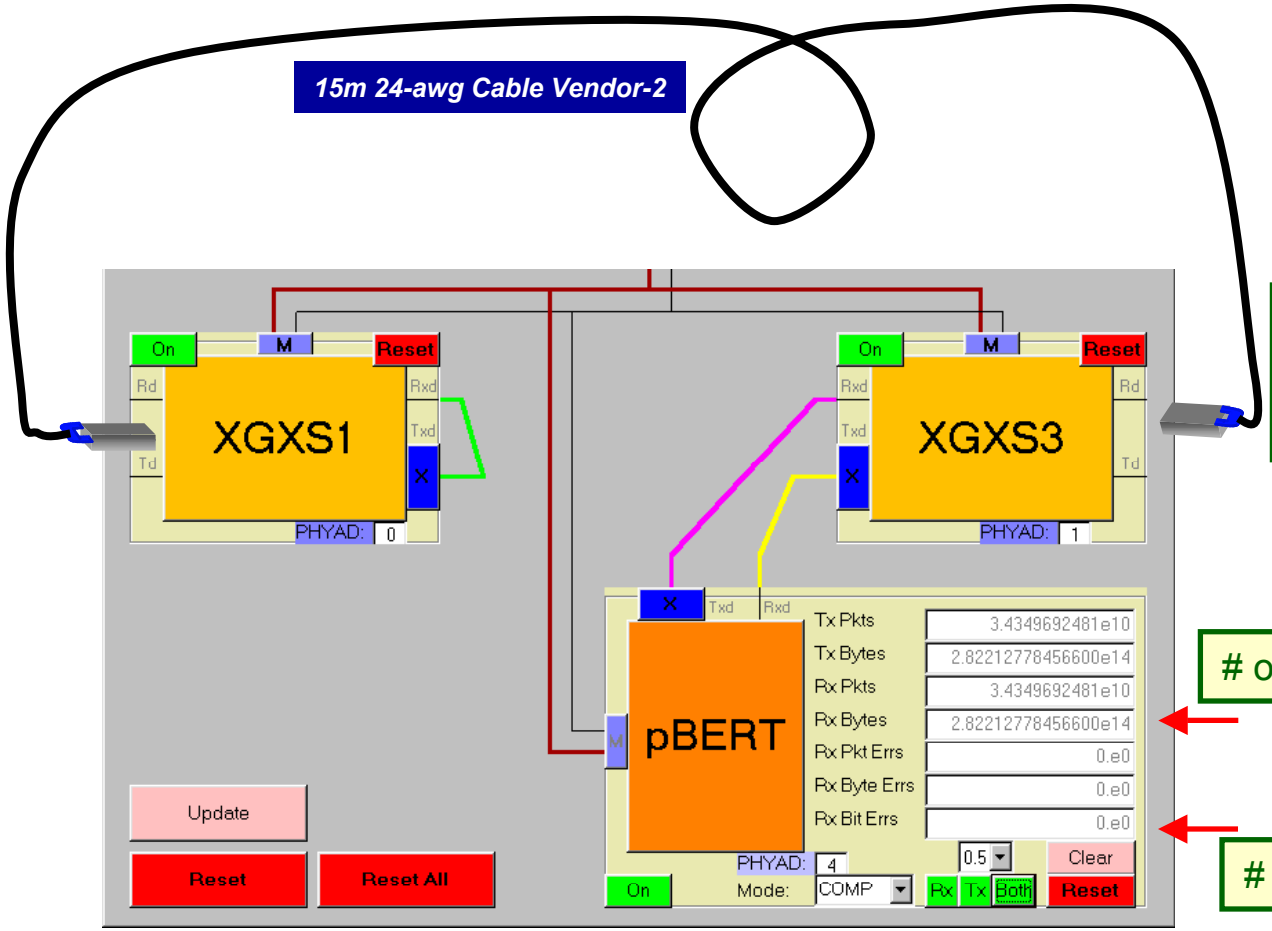
# 15-m IB4X: 3.125-Gb/s Eye Diagrams




*15m 24-awg Vendor 3 Cable*

*15m 24-awg Vendor 2 Cable*

# BERT Results: 15m IB4X Cable

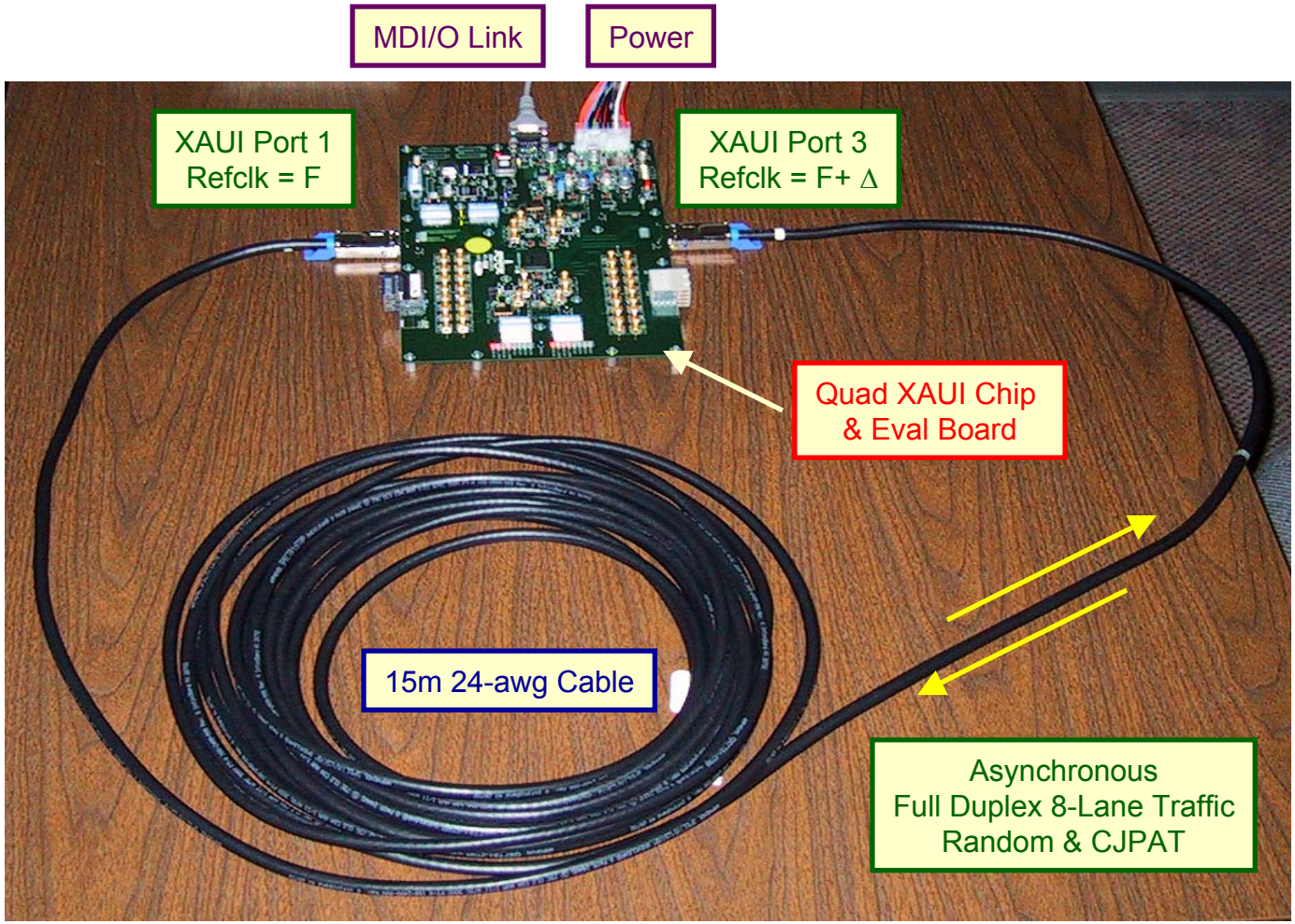



- Asynchronous
- Full Duplex 8-Lane Traffic
- Random Data

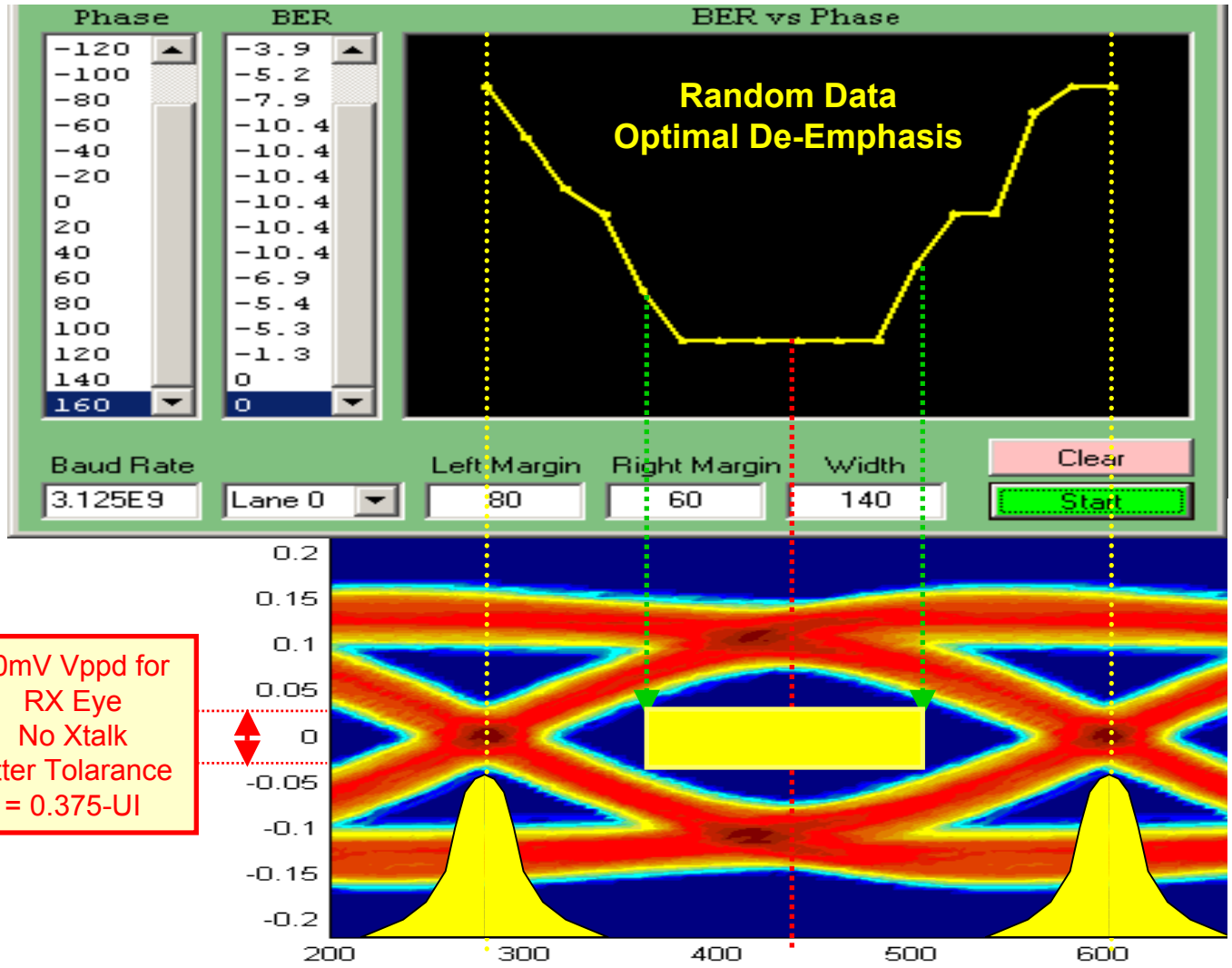
# of Bits Received = $2.8 \times 10^{15}$

# of Bits Errors = 0

# BERT Bench Setup



# BER vs. CLK Skew: 15m Vendor 2 Cable




Measured BER vs. RX CLK Offset

60mV Vppd for RX Eye No Xtalk Jitter Tolarance = 0.375-UI

Eye Diagram at RX for Random Pattern No Xtalk

# Cable & Connector Specifics
Chris Di Minico: CDT

# 10GBASE-CX4 Cable Assembly Characteristics

## IB4X Cable Assembly

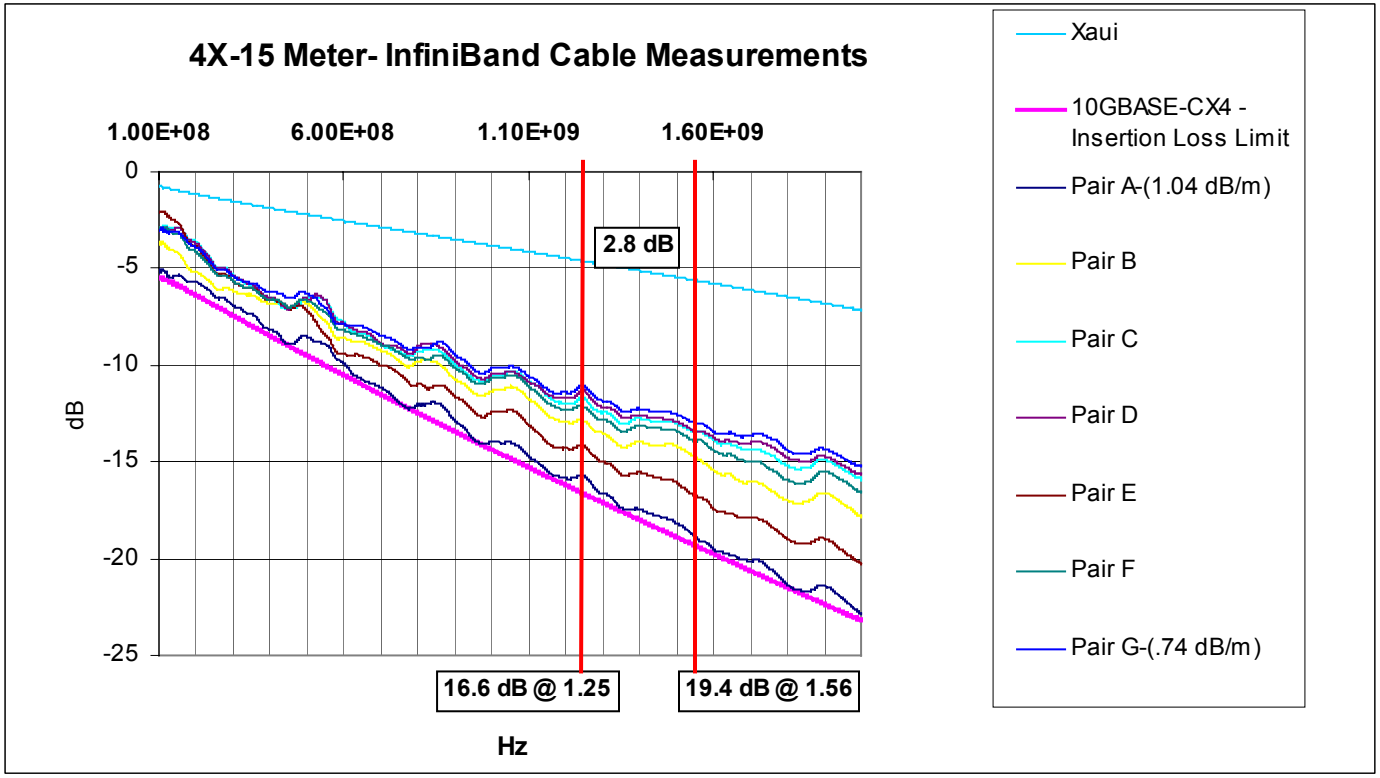
## IB4X Electrical Requirements (1.25 GHz)

| Description | Value | | Unit |
|---|---|---|---|
| Differential Impedance Nominal value | 95 | 155 | ohm |
| Differential Impedance deviation from Nominal value | 5 | | ohm |
| Insertion Loss | 10 | | dB up to 1.25 GHz |
| Pair to pair skew | | | ps |
| Jitter | 0.25 | | UI |

## 10GBASE-CX4 Additional Electrical Requirements (1.56 GHz)

| Description | Value @ 1.56 GHz | Unit |
|---|---|---|
| Insertion Loss | TBD | dB |
| Return Loss | TBD | dB |
| MDNEXT | TBD | dB |

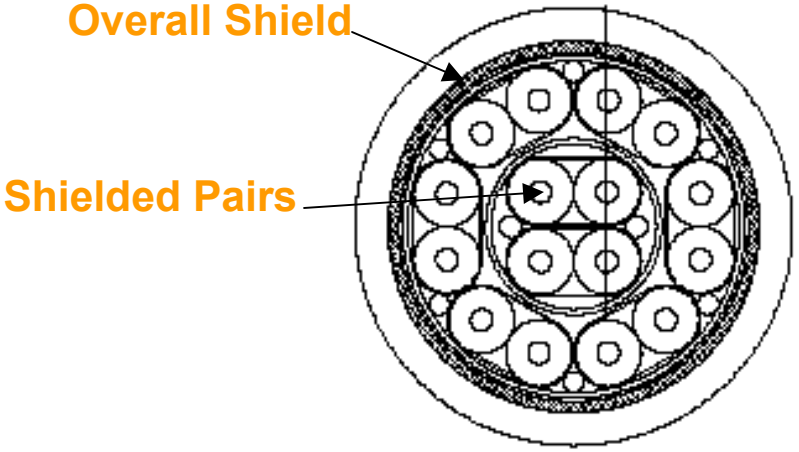
# 10GBASE-CX4 Compliance Channel




**10GBASE-CX4- Compliance Channel Insertion loss:**

The insertion loss of each pair of the CX4 cable assembly shall be less than: **Insertion_Loss(*f*) < TBD (dB)** at all frequencies from TBD MHz to TBD GHz. This includes the attenuation of the differential cabling pairs, and the connector (i.e., the assembly).

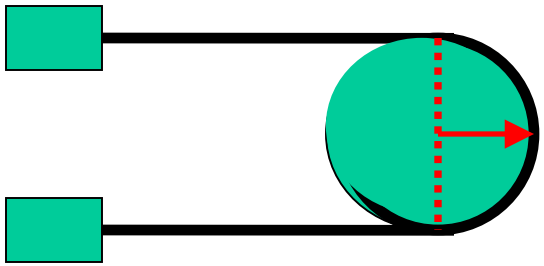
# 10GBASE-CX4 Assembly Characteristics- Cable




**Eight Differential Pairs 24 AWG ( Form Factor IB4X)**

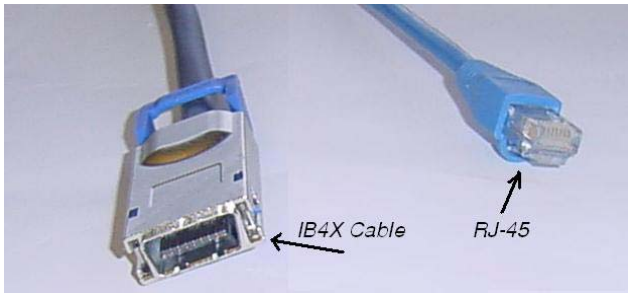
**shielded pairs with overall shield**

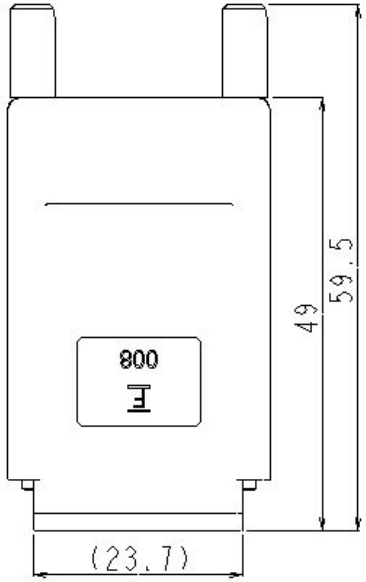
**24 AWG-Nominal OD - ~(.380” - .420”)**
**US Dime --- ~.71”**

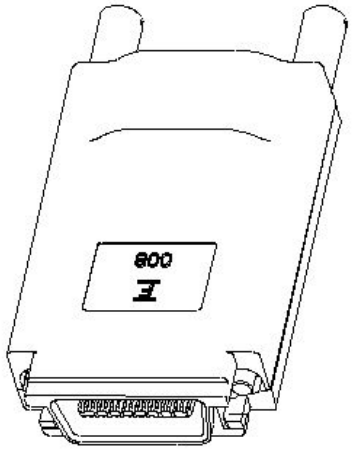


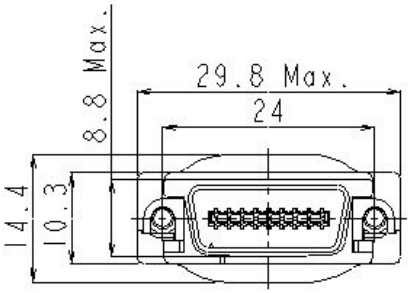
**Cable Bend Radius - 24 AWG - 2 inches**

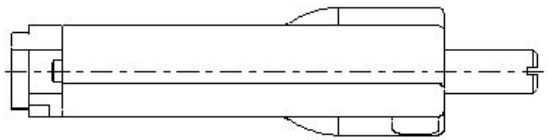
# 10GBASE-CX4 Cable Assembly - Connector



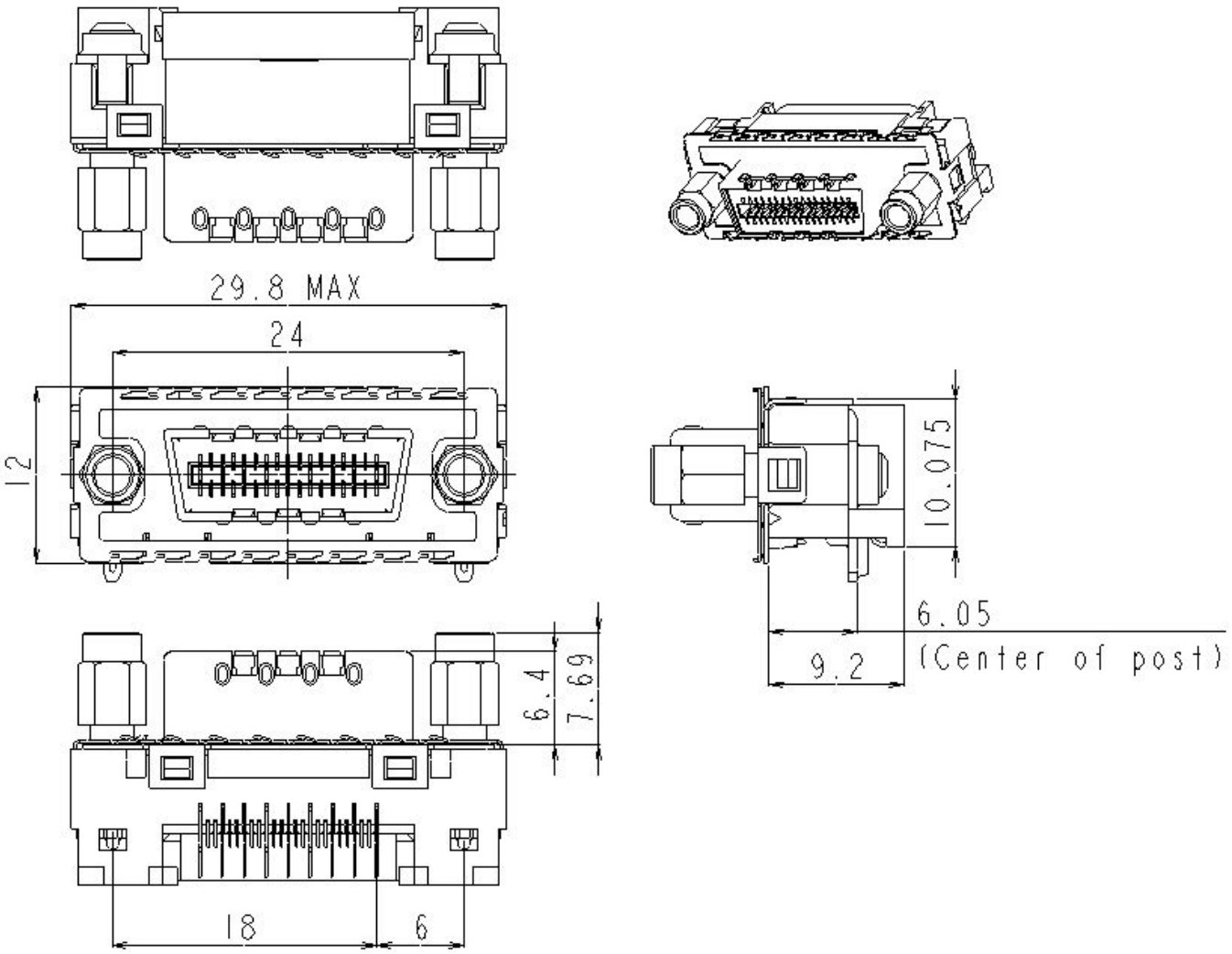



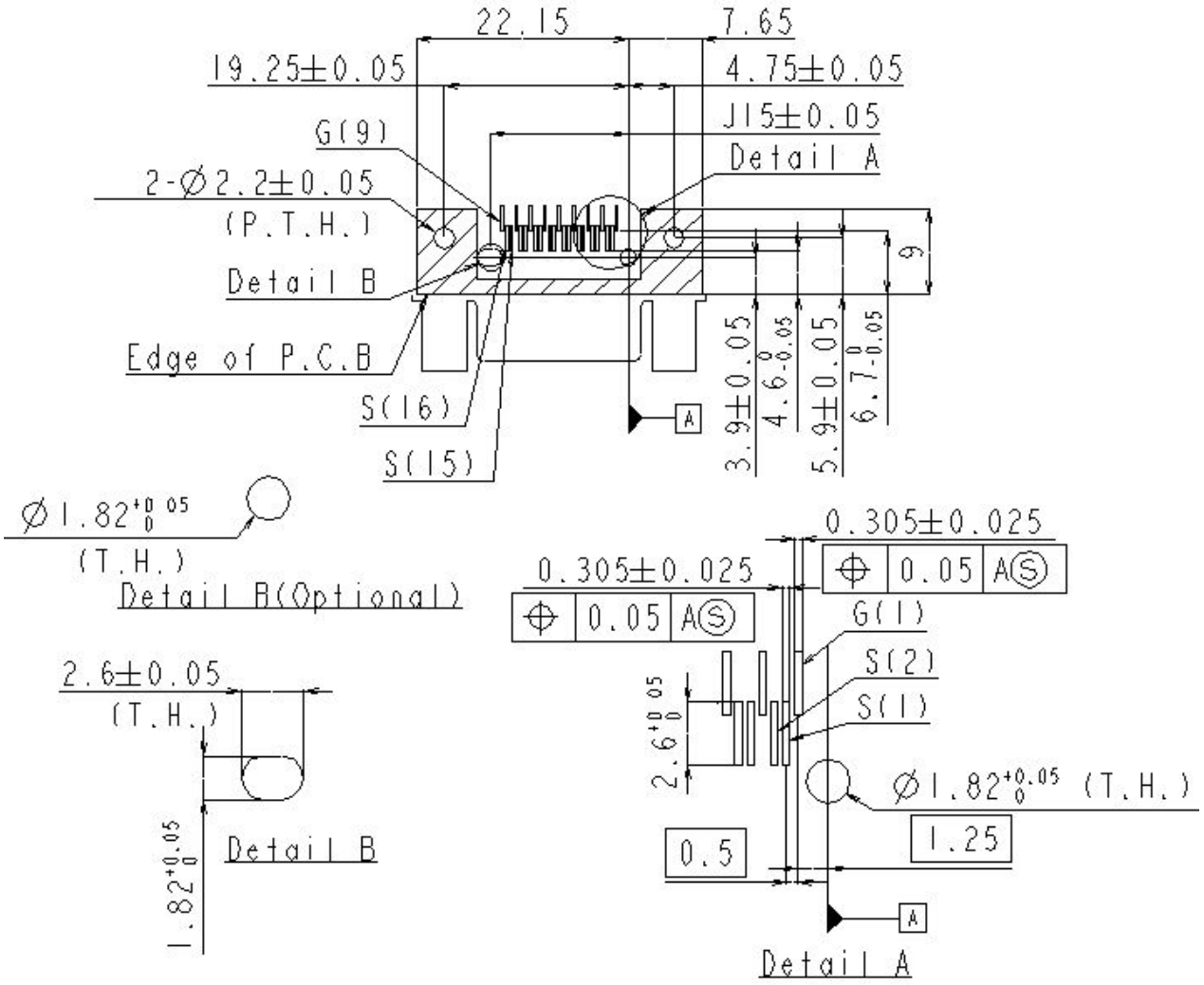



# Outline of Socket Connector



# Recommended P.C.B. Pattern for Socket



# Wrap - Up

Dan Dove: HP ProCurve Networks

# 10GBase-CX4 Proposal Summary

- Technical feasibility of 10 Gigabit Ethernet to 15 meters of copper cable has been demonstrated
- Cable/connector to be based on IB4X specification
  (with addition of thumbscrew per SFF8470)
  Adopted by T10, T13, T11, IBTA
- Electrical signaling to be derived from IEEE 802.3ae XAUI specification
- Several silicon, cable and connectors vendors participated in feasibility and testing
- Results are based on actual silicon and cable assemblies

# Broad Market Potential

**Broad set( s) of applications**
**Multiple vendors, multiple users**
**Balanced cost, LAN Vs. attached stations**

**• As customers move to 1000BASE-T attached desktops, the demand for a very low-cost 10Gbps link to interconnect switches gains demand. 10GBASE-CX4 meets that demand.**
**• A 10 Gb/s 802.3 copper PMD solution extends Ethernet capabilities providing higher bandwidth for multimedia, distributed processing, imaging, medical, CAD/CAM, and pre-press applications by lowering the cost of high performance 10Gbps network links for:**
**– LAN Backbone and Server and Gateway Connectivity**
**– Switch aggregation**
**– Storage Area Network (SAN)**
**• xxx participants attended the 10 Gigabit Copper call-for-interest, representing at least yyy companies, indicate that they plan to participate in the standardization of 10 Gb/s 802.3.**
**• This level of commitment indicates that a standard will be supported by a large group of vendors. This in turn will ensure that there will be a wide variety of equipment supporting a multitude of applications.**
**• 10GBASE-CX4 helps bring a cost sensitive solution to this performance space.**

# Broad Market Potential

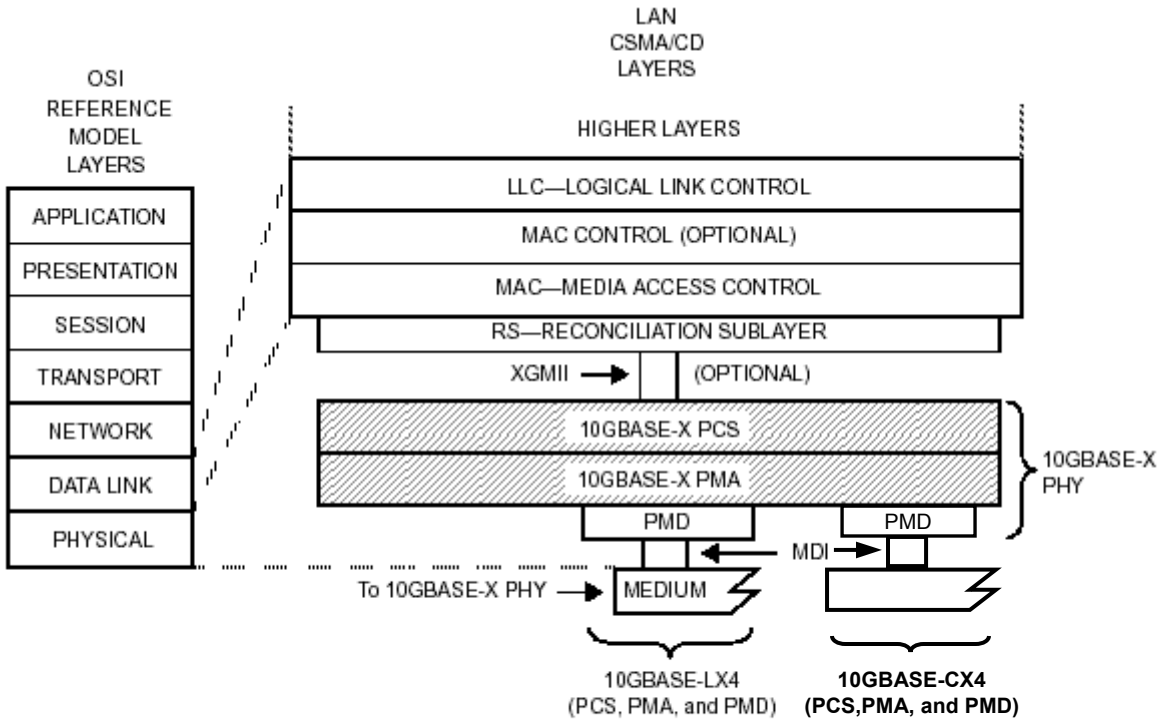
3COM
Accelerant
Alvesta
Vendor 3
Analogix Semiconductor
Broadcom
CDT Corporation
Centillium
Cicada
Cisco
FCI
Foundry
Fujitsu Components America, LTD
HP
Intel
Marvell
Maxim
Meritec
Micrel - Kendin
Molex
Mysticom
National Semiconductor
Silicon Labs
Texas Instruments
Tyco
Velio
Vitesse
WL Gore
Xilinx
LAN Technologies UK

# Compatibility with IEEE Std 802.3

**Conformance with CSMA/ CD MAC, PLS**
**Conformance with 802.2**
**Conformance with 802 FR**

- **The proposed standard will conform to the full-duplex operating mode of the 802.3 MAC, appropriately adapted for 10 Gb/ s operation.**
- **As was the case in previous 802.3 standards, a new physical layer will be defined for 10 Gb/s operation.**
- **The proposed standard will conform to the 802.3 MAC Client Interface, which supports 802.2 LLC.**
- **The proposed standard will conform to the 802.1 Architecture, Management and Interworking.**
- **The proposed standard will conform with the 802 Functional Requirements Document (with the possible exception of Hamming distance).**
- **The proposed standard will define a set of systems management objects which are compatible with OSI and SNMP system management standards.**

# Compatibility with IEEE Std 802.3




MDI=MEDIUM DEPENDENT INTERFACE
PCS=PHYSICAL CODING SUBLAYER
PHY=PHYSICAL LAYER DEVICE

PMA=PHYSICAL MEDIUM ATTACHMENT
PMD=PHYSICAL MEDIUM DEPENDENT
XGMII=10GIGABIT MEDIA INDEPENDENT INTERFACE

# Distinct Identity

**Substantially different from other 802.3 specs/ solutions**
**Unique solution for problem (not two alternatives/ problem)**
**Easy for document reader to select relevant spec**

- **The current 802.3 10Gb/s specification includes only fiber-optic media types for interconnection of devices. There are no copper media types and thus the minimum cost for a 10Gb/s connection is bounded on the low end by a substantially higher cost than copper can provide.**
- **The proposed solution, 1000BASE-CX4 takes advantage of the XAUI interface which is already specified by the IEEE and may be integrated into CMOS silicon devices. This enables a solution which is completely integrated and thus eliminates substantial cost elements of the overall system.**
- **The specification will be done in a format consistent with the IEEE document requirements thus making it easy for implementers to understand and design to.**
- **The proposed specification will use copper media similar to other high speed networking technologies (FibreChannel, IB4X) but does so with the IEEE 802.3 MAC as the over-riding layer which will result in higher compatibility and lower cost for Ethernet systems.**

# Technical Feasibility

**Demonstrated feasibility; simulations, reports - - working models**
**Proven technology, reasonable testing**
**Confidence in reliability**

**• Technical presentations, given to 802.3, have demonstrated the feasibility of using the copper media in useful network topologies at a rate of 10 Gb/s.**
**• The principle of extending higher speeds to copper media has been well established by previous work within 802.3. The 10 Gb/s work will build on this experience.**
**• Vendors of CMOS components and systems are building reliable products which operate at 10 Gb/s on copper media, and meet worldwide regulatory and operational requirements.**
**• Component vendors have presented research on the feasibility of physical layer signaling at a rate of 10 Gb/s on copper media using a wide variety of innovative low cost technologies.**

# Economic Feasibility

**Cost factors known, reliable data**
**Reasonable cost for performance expected**
**Total Installation costs considered**

**• Cost factors are extrapolated from the XAUI component supplier base and technology curves.**
**• A target cost increase of 3X of 1000BASE- X with a ten-fold increase in available bandwidth in the full duplex operating mode will result in an improvement in the cost- performance ratio by a factor of 3. This cost model has been validated during both the 100 and 1000 Mb/s Ethernet deployment.**
**• Installation costs for new patch cords based on established standards are well known and reasonable.**
**• Network design, installation and maintenance costs are minimized by preserving network architecture, management, and software.**

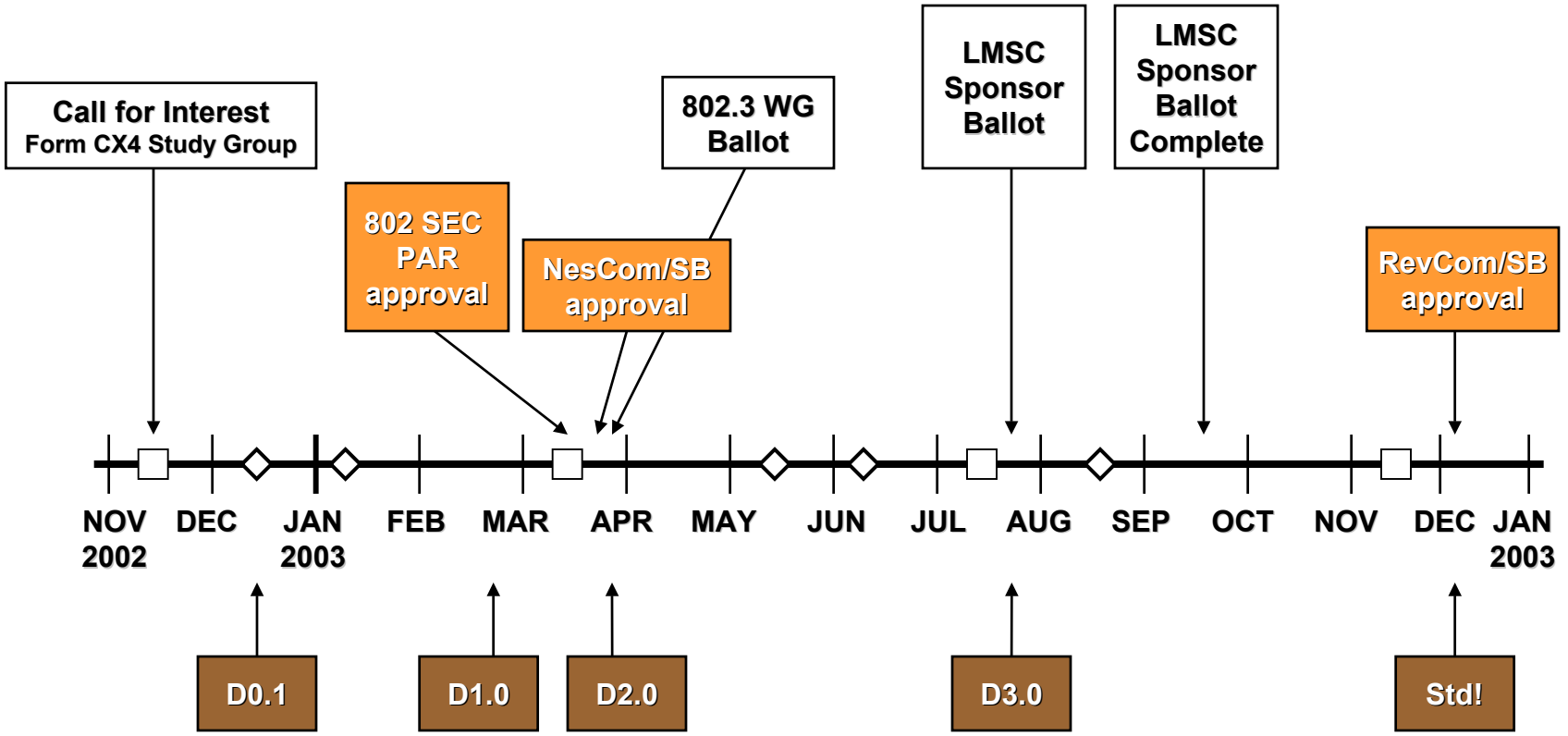
# Project Objectives

**Use existing technology wherever possible**
- XAUI
- IB4X Connectors/Cables

**Proceed quickly**
- Aggressive Schedule
- Solid number of Contributors

**Non-Objectives**
- New signaling or codes
- New connectors or cables
- Long, protracted discussions about the various ways we can solve this problem

# 10GBASE-CX4 Estimated Timeline




□ = Plenary Mtg
◇ = Interim Mtg

# Straw Poll

**Individuals support formation of a 10GBASE-CX4 Study Group**

**Y__75_____ N__0____ A__9____**

**Companies support formation of a 10GBASE-CX4 Study Group**

**Y___38____ N___0____ A__2____**

**802.3 voters support formation of a 10GBASE-CX4 Study Group**

**Y___44___ N___0___ A__1___**

**Individuals will attend and contribute to a 10GBASE-CX4 Study Group**

**Y ___34____**

**Attend NoCaL Interim in Dec? _____32**