Copper Cable Technology for High Performance Computing

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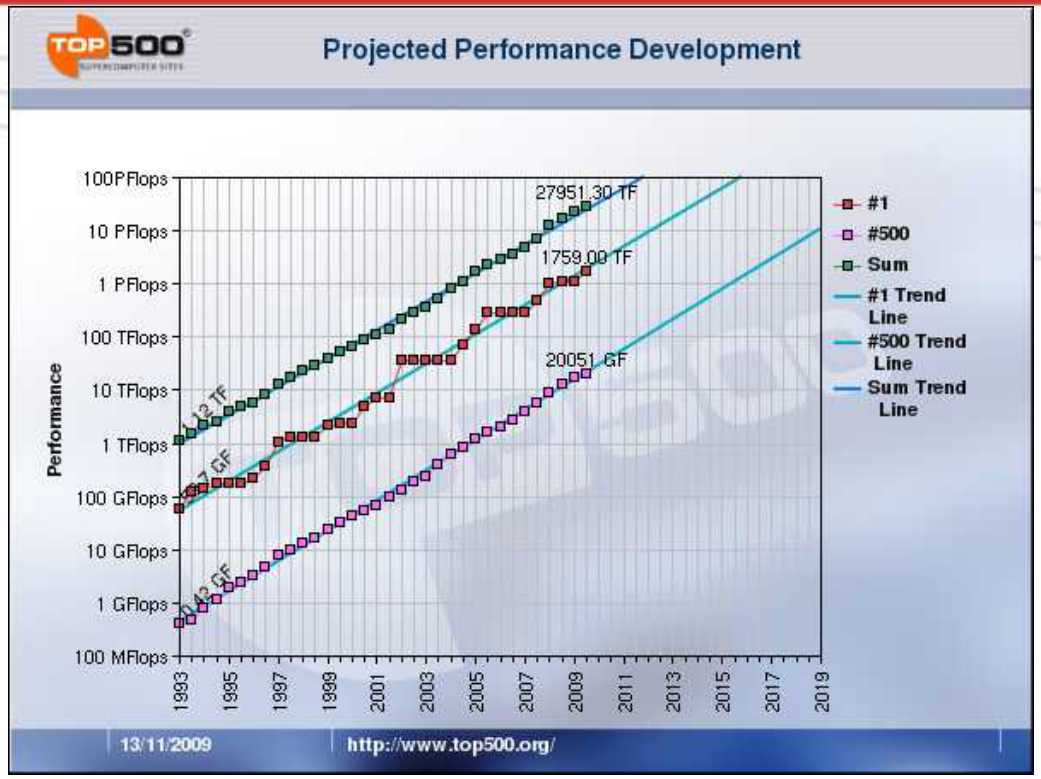
Market Trends

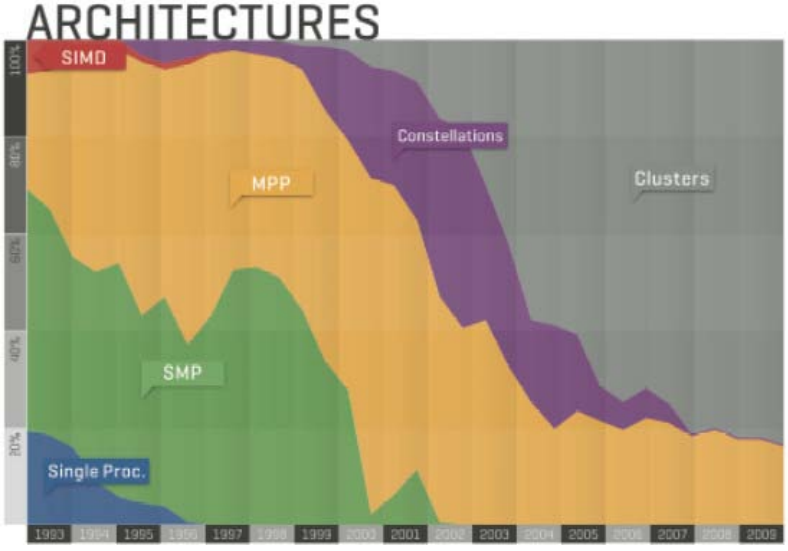
- Industry Direction & Roadmaps
- Copper Cables advantages over Optical – **Eco-Green Friendly**
  - Low/No Power Consumption
  - Cooling
  - Reliability (no Electrical-Optical-Electrical conversion, less heat)
  - Lower Latency (no conversion)
  - Capital Cost
- Industry push for lower impedance on boards/systems, impact on cabling (85 ohms being pushed by Intel)
- Faster Data Rates (25 Gbps coming in 2 years)
- Higher cable bandwidth - 18.75 GHz for 25 Gbps
- Advanced SERDES technologies (market pushing for lower SCD21 values, etc. . .)
- Longer encoded bit streams (64B66B)
  - Creates challenges for equalization

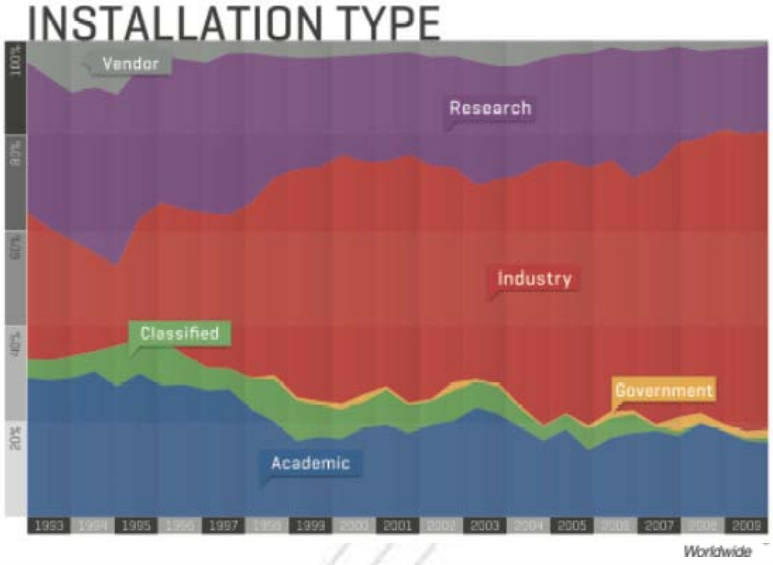
HPC ADVISORY COUNCIL
NETWORK OF EXPERTISE

TOP500 NOVEMBER 2009

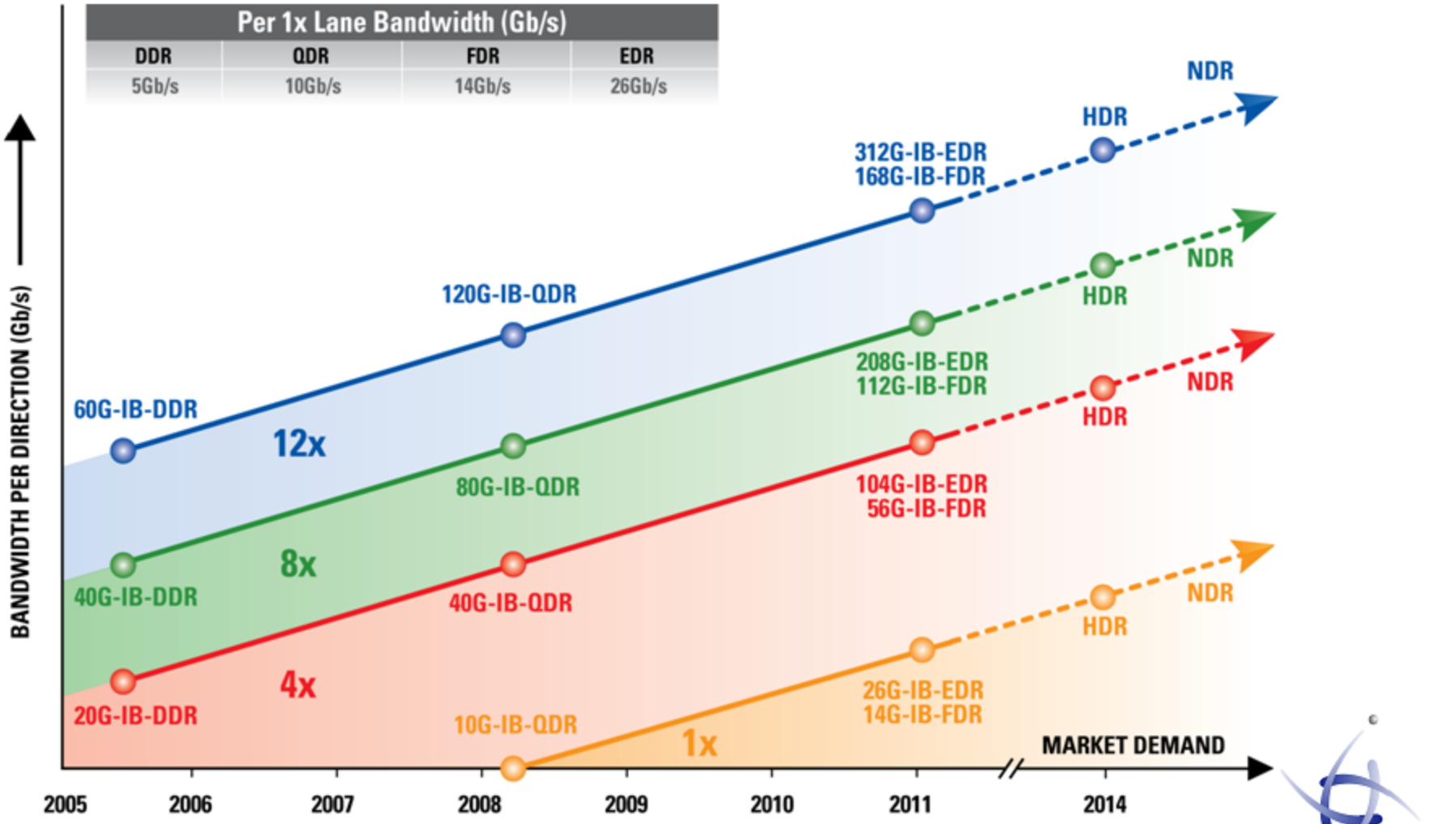
Key HPC Trends







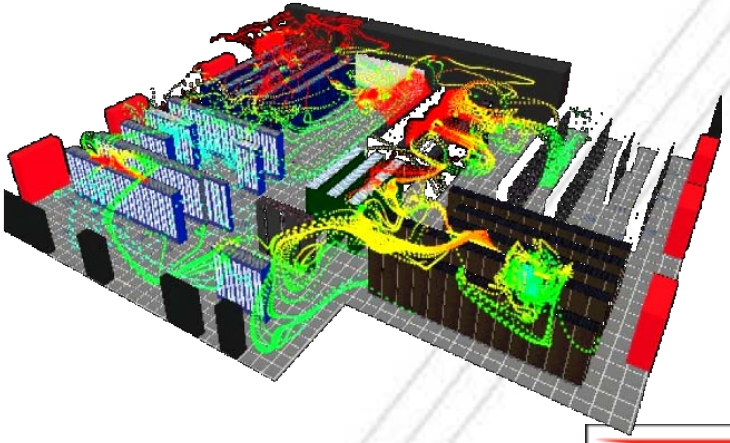
InfiniBand Roadmap



INFINIBAND TRADE ASSOCIATION

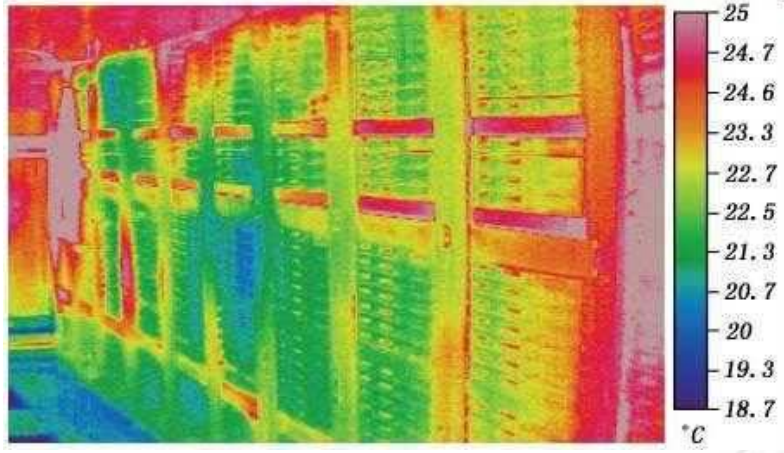
Key Interconnect Requirements

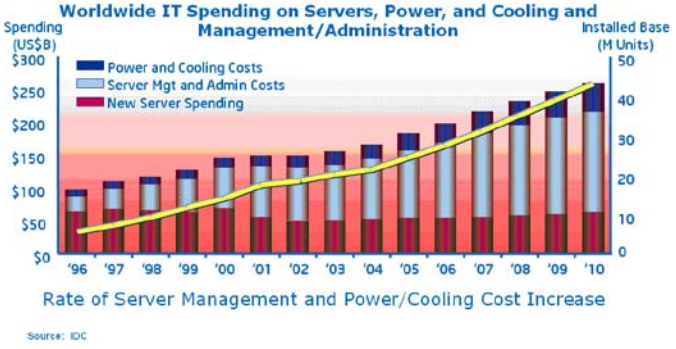
- Bandwidth must scale 10X every 3.5yrs
- Low Latency
- Scalability
- Reduced Cost
- Reduced Power

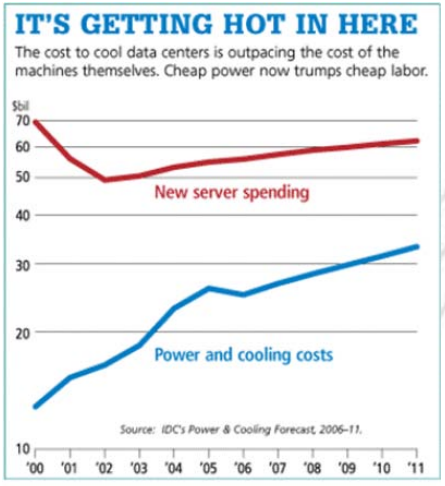


Premises Important to High Performance Computing

- Power Consumption of Tremendous Importance
- Cooling is Paramount
- Need for Reliability & Quality in Elevated Temp Environments
- Both CapEx and OpEx costs are critical



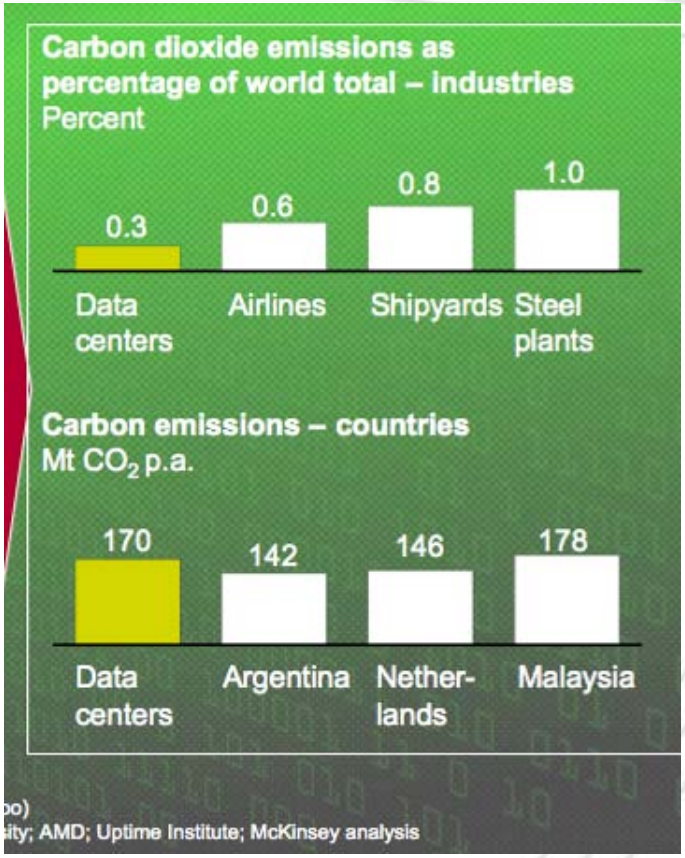




Industry needs Low Cost, Low Energy, Low Risk, Dependable and Effective Interconnects

GREEN Computing and the Need to Reduce Power

- **Data Centers are responsible for CO_2 emissions that are half that of the Airline Industry!**



Financial Times , Gartner Report

Market demands lower power interconnects

Eco-Friendly Data Centers

- Wynyard facility North East England largest & most environmentally friendly data center in Europe
- Traditional data centers use several thousand megawatt hours per year. **If centers classed as separate industry => sixth-largest user of electricity.**
- **By 2011, the average UK data center is expected to spend around $15.33M a year on cooling IT systems, equipment and plant rooms.**
- HP is committed to environmental sustainability. The company recently announced that it will **reduce the combined energy consumption of operations and products by 25 percent below 2005 levels, by 2010.**

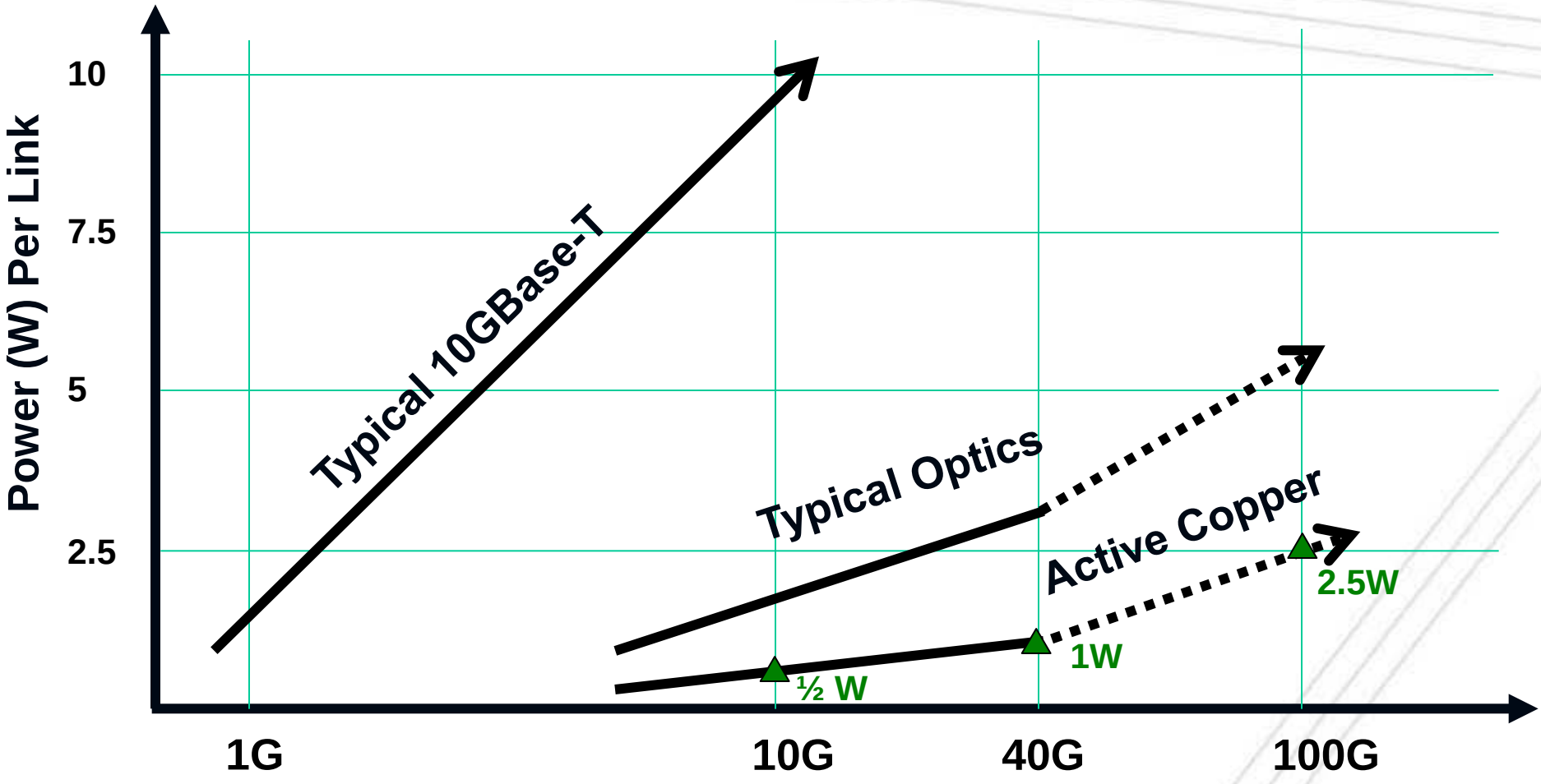
ECO:nomics
CREATING ENVIRONMENTAL CAPITAL

Wynyard Data Center - PUE of 1.16

Citi LEED-certified data center in Frankfurt, Germay (Live Wall)

GORE
Creative Technologies Worldwide

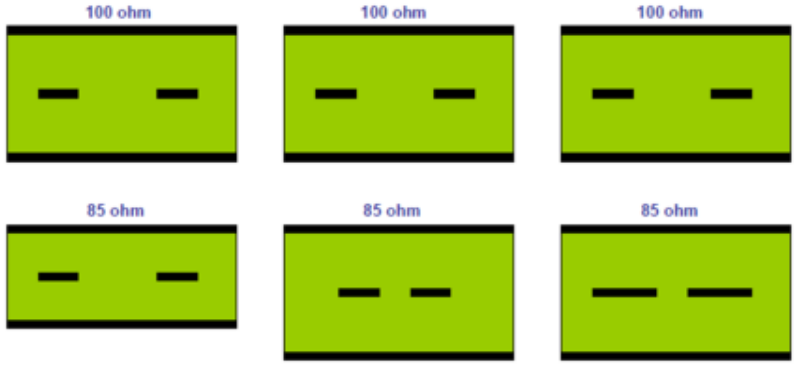
10/40/100G Interconnect Power Required Per Link



Passive Copper = Zero Watts

85 Ohms Driven by Intel QPI to on the PCB Design … Impacts Cable

- Driven by Intel QPI (Quick Path Interconnect) processor connection
- Emerging design approach gaining momentum - moving from 100 to 85 Ohm system impedance
- Designers incorporating thinner backplanes and linecards, increasing density using same board thickness
- **These design changes impact connector impedance designs (thus impact impedance matching cable)**
- **Lower impedance cable has higher loss – in this case, roughly 23% higher**



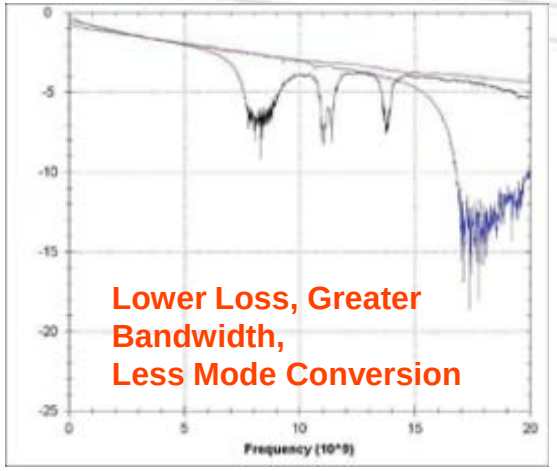
Board Design Impact

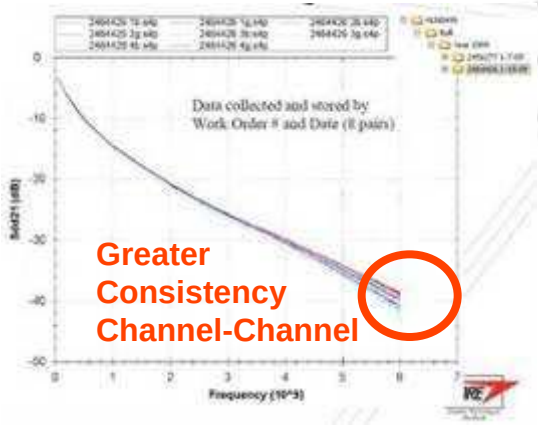
- Maintain the trace width and reduce the board thickness
- Keep the board build-up and the trace width unchanged, but move the traces within a differential pair closer together
- Keep the board build-up & routing density, increase the trace width

* **FCI, DesignCon 2007**

Technical Advancements to Extend Useful Length of Copper

- Extended Cable Bandwidth for Harmonic Coverage and Lower Attenuation at the Fundamental
- Improvements in Connector Performance (Materials and Design)
- Better Receptacle Performance on the System Interface (Weak Link)
- Less Common Mode Conversion
- Low Crosstalk and Controlled Impedance through the Entire Link





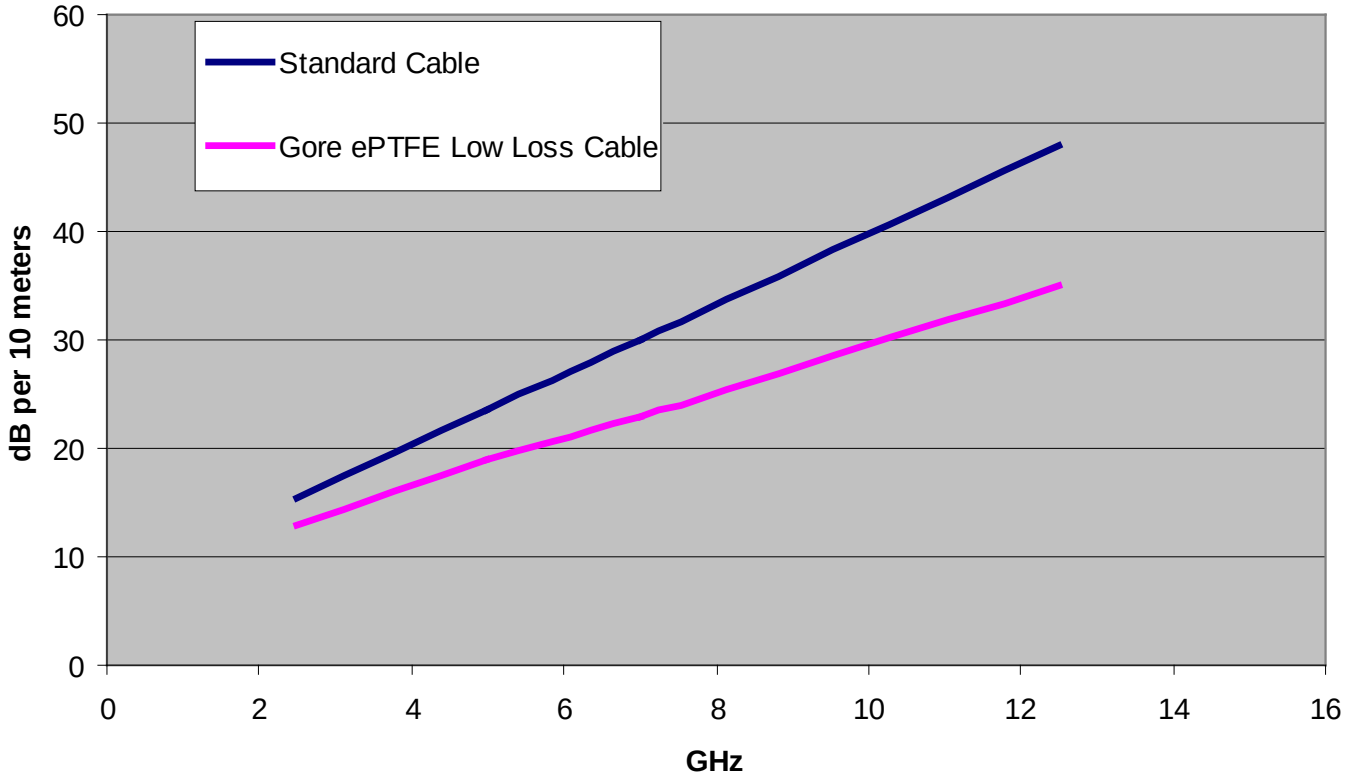
You're only as good as your worst pair …

Creative Technologies Worldwide

At 14 & 25 Gbps, Digital Signals Are Being Supported by Frequencies well into the Microwave Band!!

- **At 14 Gbps, the relevant bandwidth is 10.5 GHz and for 25 Gbps, the relevant bandwidth is 18.75 GHz**
  - These bandwidths are essentially the 150% of the “fundamental” frequency for the data-rate in question. .
  - This guideline is substantiated by optimizing de-emphasis for a channel and then applying a cut-off filter to progressively limit bandwidth until there are observed changes in the resulting eye-pattern from a PRBS input signal. . .
- **At 10 GHz, dielectric losses begin to predominate over conductor (resistive) losses**
  - Resistive losses are a function of the *square-root of frequency*
    - $R_l = 1/(2 \pi r) * (2 \pi f \mu / 2 \rho)^{1/2}$
    - *Where: r = conductor radius, f = frequency, μ = permeability and ρ = wire resistance*
  - Dielectric losses, in contrast, are a *direct function of frequency.*

Dielectric losses begin to Predominate over Conductor (Resistive) Losses at Higher Bit Rates



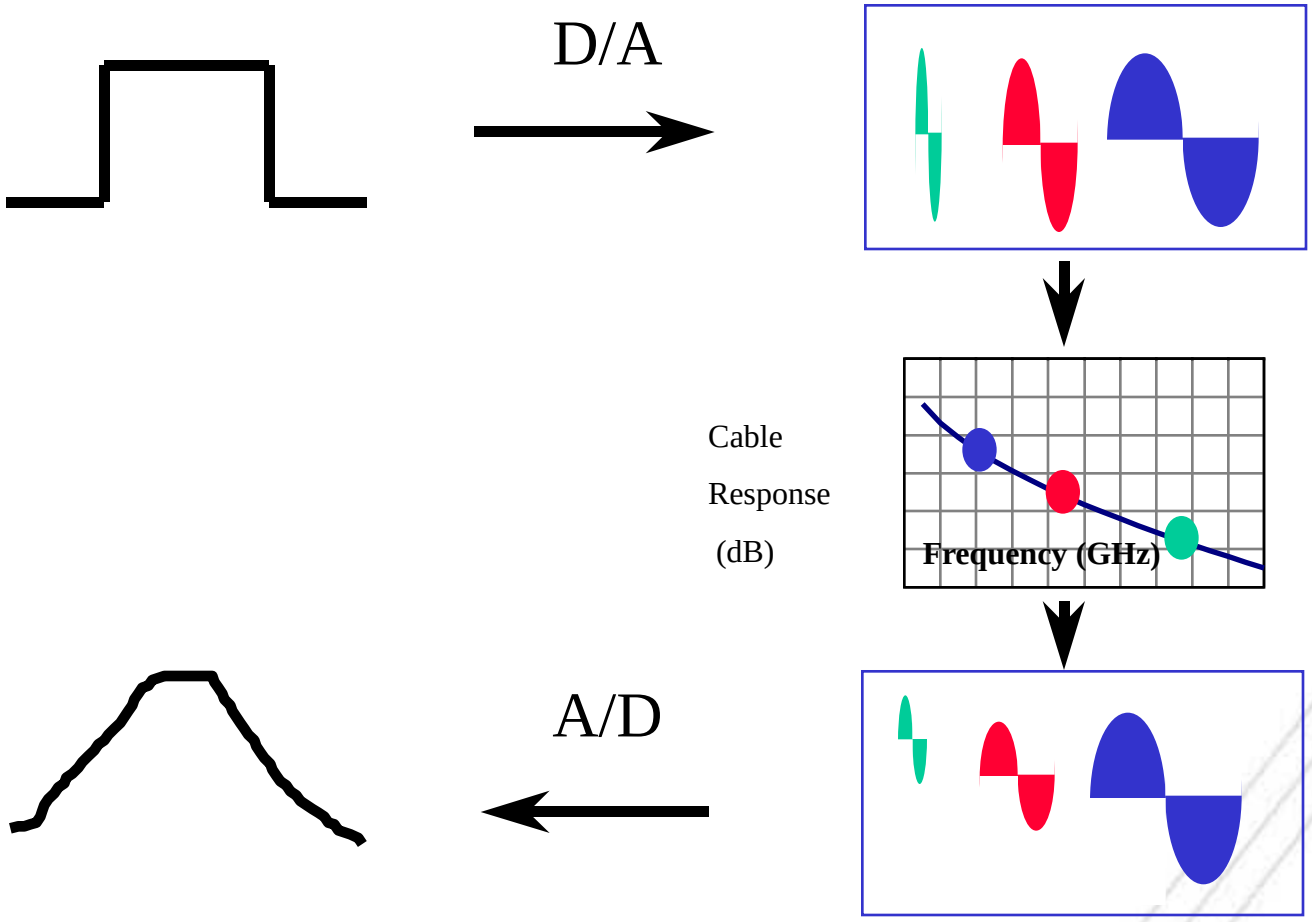
GHz	2.5	5	7	12.5
% Higher	19%	24%	30%	37%

* AWG26 Conductor Gauge Size

25 Gbps Receptacles Need Reduced:

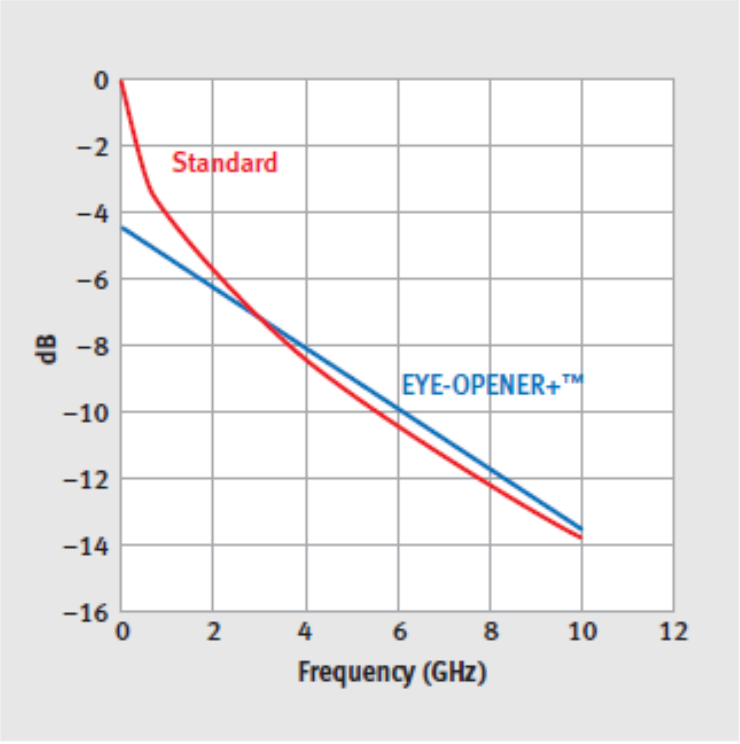
- Number and Amplitude of Impedance Discontinuities
- Cross-Talk
- Common Mode Conversion
- *** It has been Gore's experience that there's much scrutiny on the plug connectors, but virtually none on the header/receptacles. The mated-pair performance is degraded considerably by the receptacle-half of the connection.*

Unequal Analog Attenuation Causes Digital Signal Degradation



Advantages of Eye-Opener+ ™ Conductor

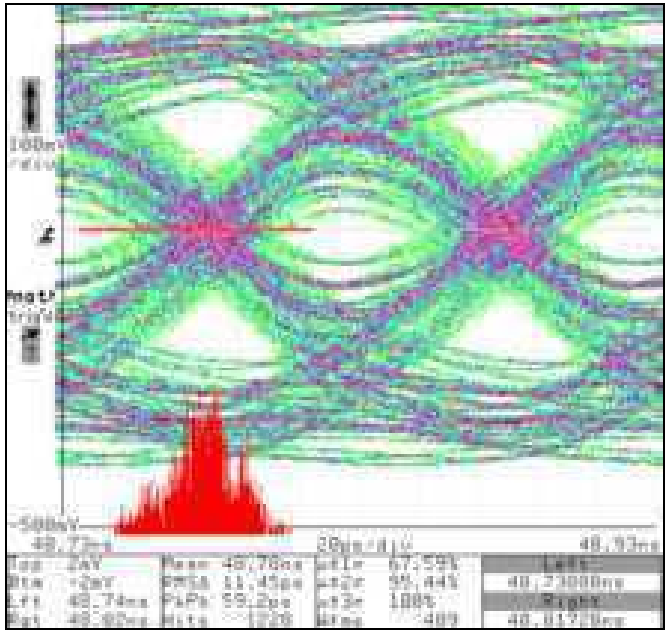
- Designed to Better Equalize Loss across Frequency
  - Provides Digital Pulse Benefits
  - More consistent Rise Time
  - Less “rounding” of pulse edges
- Self-Equalizing
  - Per Unit-Length Equalization
    - . .any assembly built from EOP cable automatically has the right amount of equalization
- Reduces Jitter over 20%

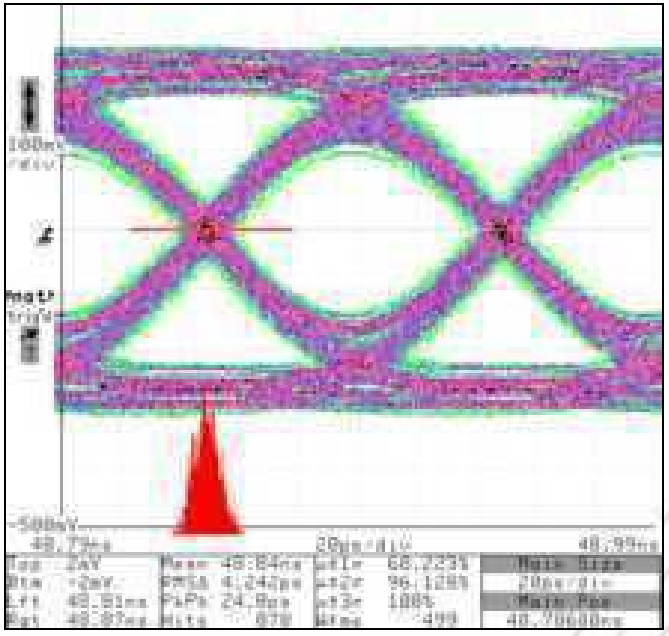


EYE-OPENER+™ Conductor Performance: Minimizes Jitter

Standard Cable ***EYE-OPENER+™***

10Gbps



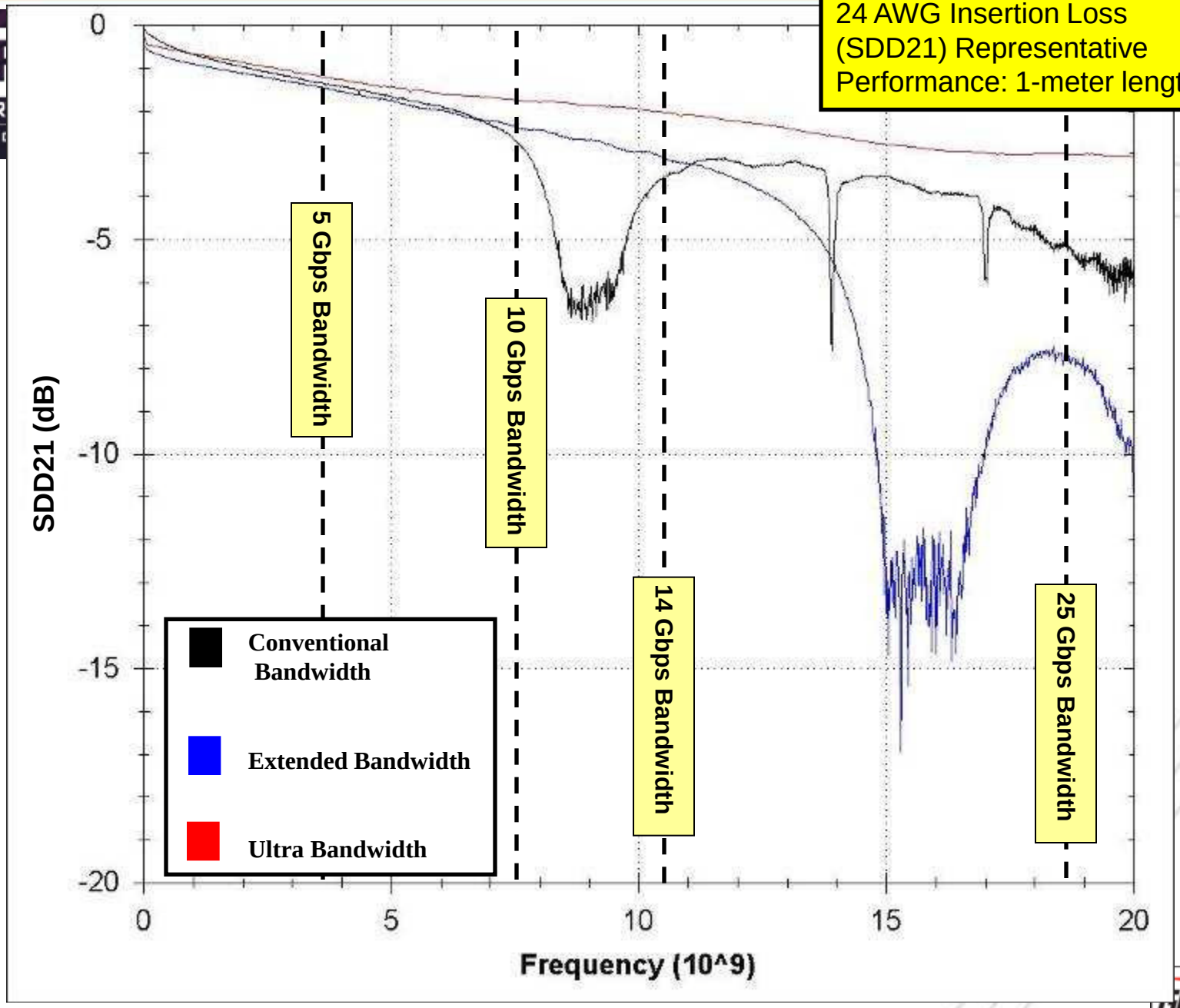


EYE-OPENER+™ Technology
5 meters, 26 AWG, Twinax
No Signal Conditioning

Differential-Pair Bandwidth:

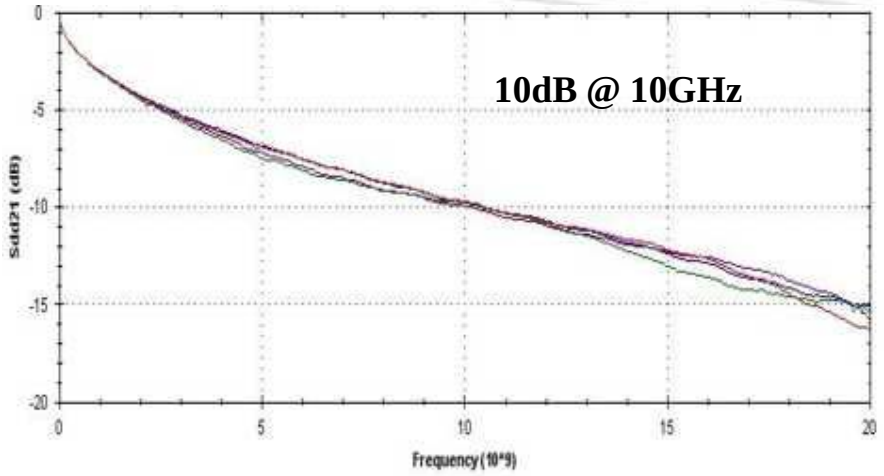
- Gore has differential pair designs that can provide monotonic (continuous slope) insertion loss performance through 20 GHz and beyond. . .

- Gore has three (3) “grades” of differential pair cable products:
  - **“Conventional Bandwidth”**
    - This product typically provides monotonic insertion loss through 6 GHz
      - Several years of high-volume production
  - **“Extended Bandwidth”**
    - This product typically provides monotonic insertion loss through 10+ GHz
      - In high-volume production now. . .
  - **“Ultra-Bandwidth”**
    - This product typically provides monotonic insertion loss through 20+ GHz
      - Currently, in development. . . Sample availability TBD

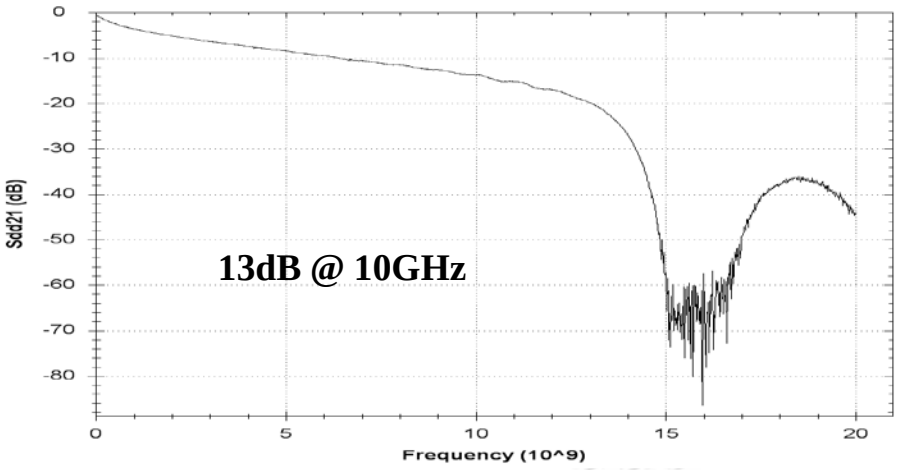

24 AWG Insertion Loss (SDD21) Representative Performance: 1-meter length
SDD21 (dB)
0
-5
-10
-15
-20
0
5
10
15
20
Frequency (10^9)
5 Gbps Bandwidth
10 Gbps Bandwidth
14 Gbps Bandwidth
25 Gbps Bandwidth
Conventional Bandwidth
Extended Bandwidth
Ultra Bandwidth

AWG24 Conductor, 5 meters

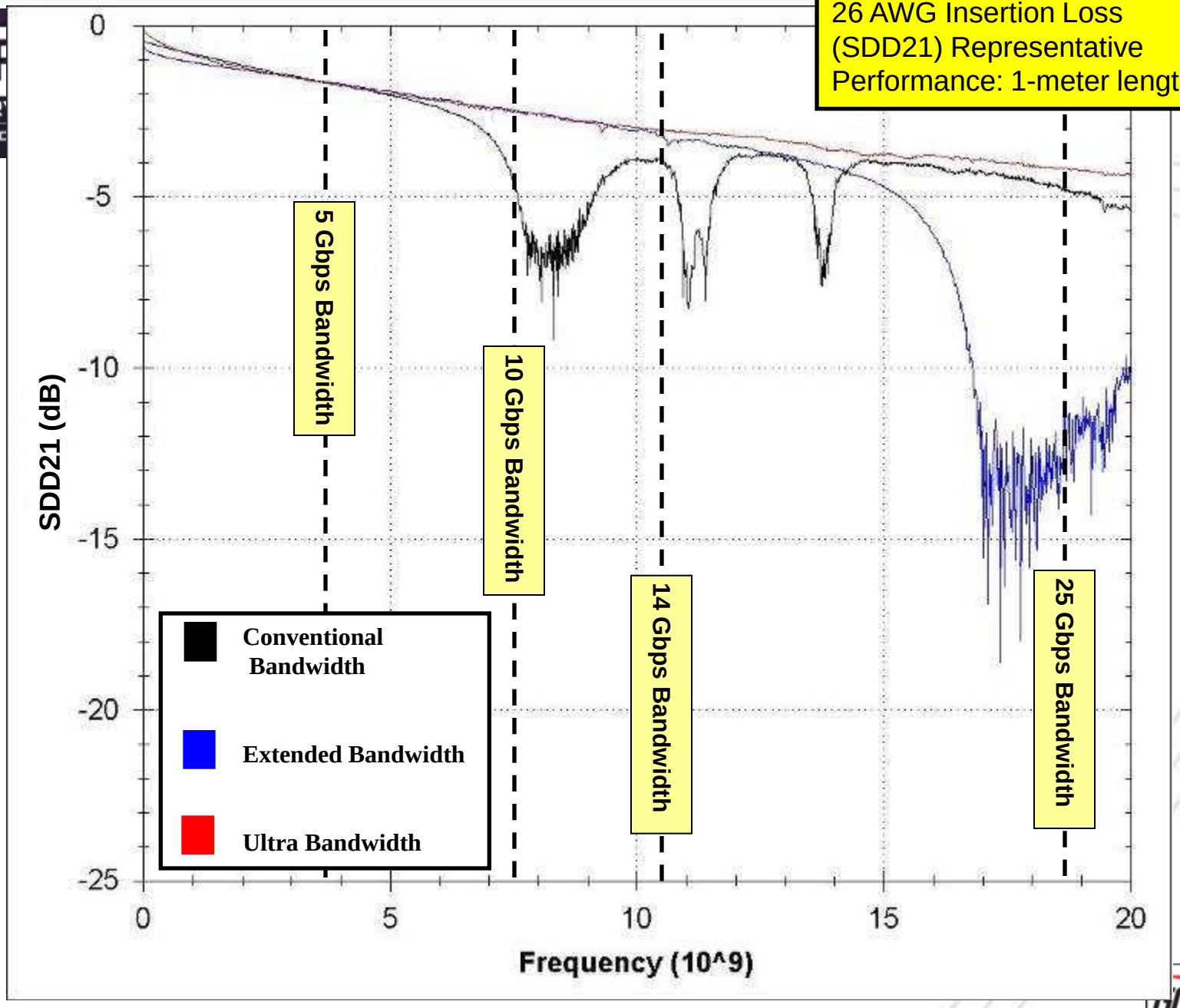
Ultra Bandwidth Cable: 10 dB @ 10 GHz



Extended Bandwidth Cable: 13dB @ 10 GHz

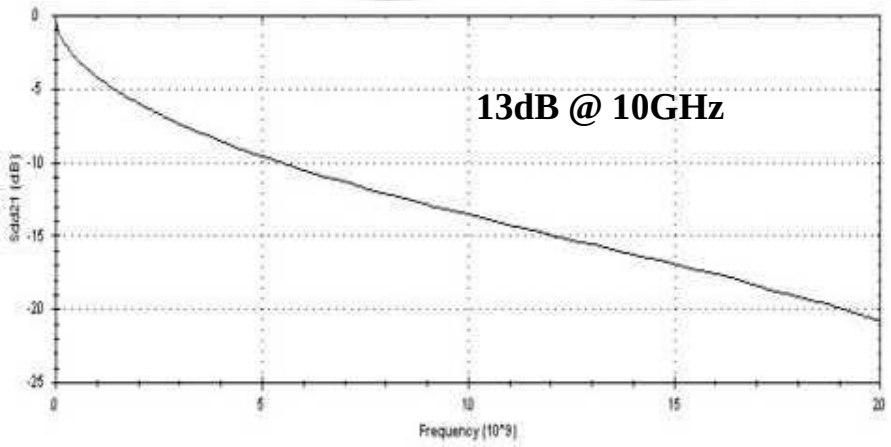


Much More Bandwidth and 30% Less Attenuation

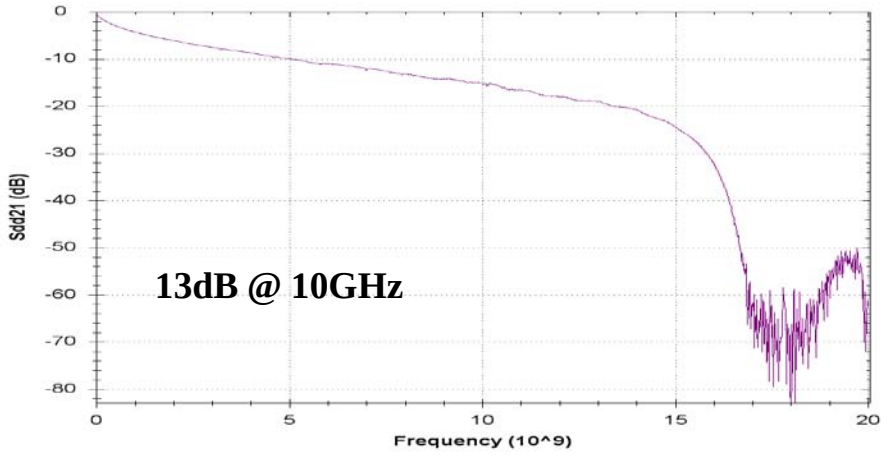

26 AWG Insertion Loss (SDD21) Representative Performance: 1-meter length
SDD21 (dB)
0
-5
-10
-15
-20
-25
0
5
10
15
20
Frequency (10^9)
5 Gbps Bandwidth
10 Gbps Bandwidth
14 Gbps Bandwidth
25 Gbps Bandwidth
Conventional Bandwidth
Extended Bandwidth
Ultra Bandwidth

AWG26 Conductor, 5 meters

Ultra Bandwidth Cable: 13 dB @ 10 GHz



Extended Bandwidth Cable: 15dB @ 10 GHz

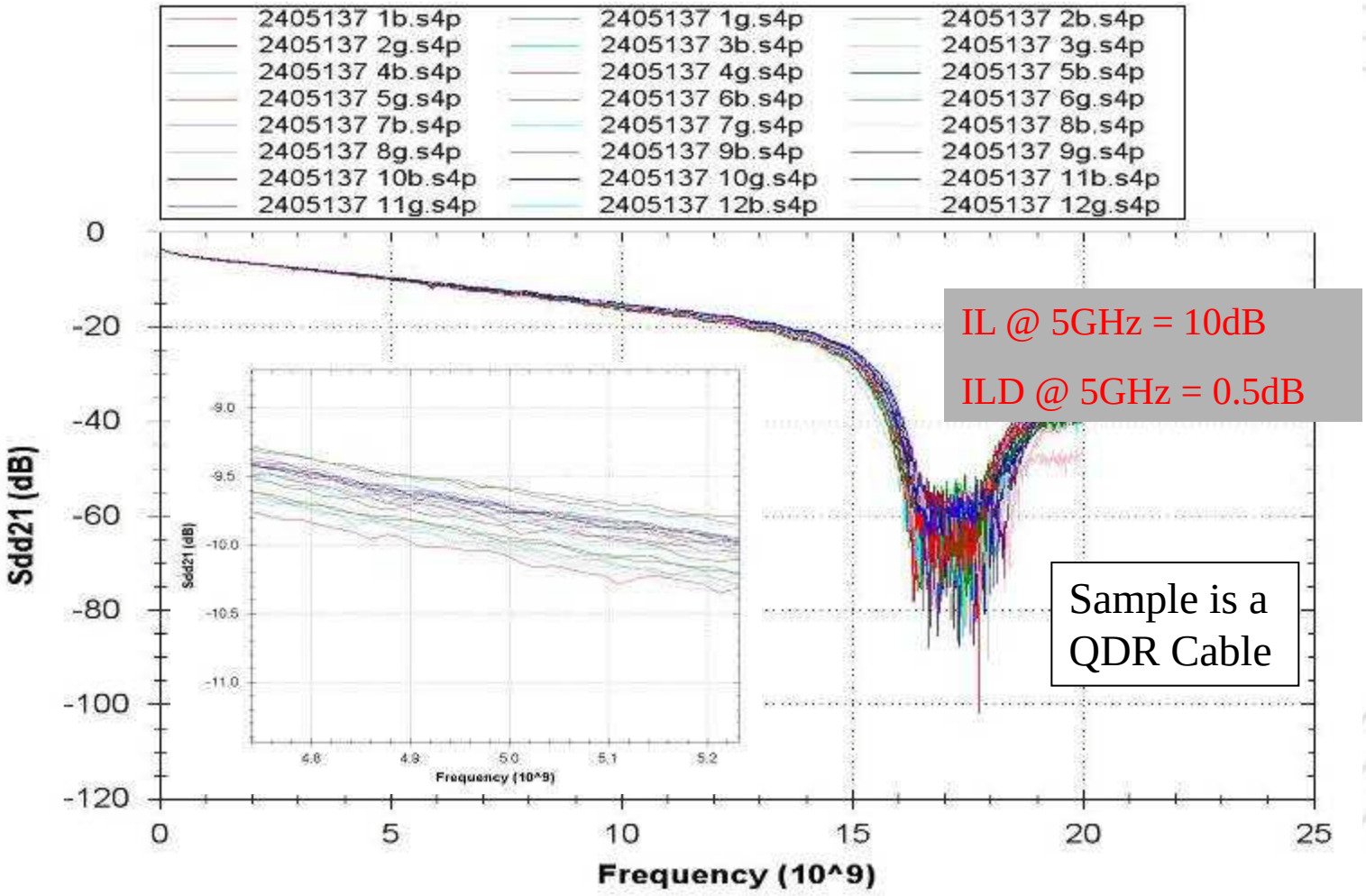


Much More Bandwidth and 25% Less Attenuation

Comparison of Cables

- Extended Bandwidth Cable
  - Bandwidth-limited to approx. 13 GHz
  - AWG26, 5 meters, 15 dB @ 10 GHz
  - **AWG24, 5 meters, 13 dB @ 10 GHz**
- Ultra Bandwidth Cable
  - Bandwidth exceeds 20 GHz, Assume +25 Gbps usage
  - **AWG26, 5 meters, 13 dB @ 10 GHz, 16 dB @ 12.5 GHz**
  - AWG24, 5 meters, 10 dB @ 10 GHz, 12 dB @ 12.5 GHz
- AWG26 Ultra Bandwidth cable has the loss of AWG24 Extended Bandwidth Cable!
- Ultra Bandwidth Cable nearly ***doubles*** the bandwidth of the Extended Bandwidth Cable!
  - This is critical for 25 Gbps InfiniBand . . .

Pair-Pair Insertion Loss Deviation



You're only as good as your worst pair …

100G Interconnect at 25G x4

- 25.78125 Gbps
  - Next Generation Ethernet
  - InfiniBand EDR
- Signal integrity challenges limit standard passive copper to < 2m
- Lower Loss Dielectrics (such as Expanded PTFE) will extend passive copper cables to 5 meters at 25 Gbps

Closing Comments

- Copper cable interconnects will continue to be the most practical, lowest cost & power and still the most reliable interconnect
- Next generation, 100 Gigabit (25 Gigabit per channel) will require lower loss dielectrics and frequency equalization to achieve 5 meters
- “Active” silicon technologies will roughly double use length of copper assemblies

About Gore

Founded in 1958, Gore is known as much for its unique culture as its unique products. Gore offers unique capabilities through a remarkably versatile polymer PTFE. Gore utilizes PTFE into numerous products for electronic signal transmission; fabric laminates (GORE-TEX®); medical implants; as well as membrane, filtration, sealant, and fiber technologies for diverse industries. Gore is one of only thirteen companies included in every selection of Fortune Magazine's "100 Best Companies to Work For" since the list began in 1984. For 2010, Gore ranked 13th.

For more information about Gore, visit the Company's web site at: www.gore.com/highspeed