Feasibility Study on High Speed Transmission over UTP Cables

IEEE Meeting July 03

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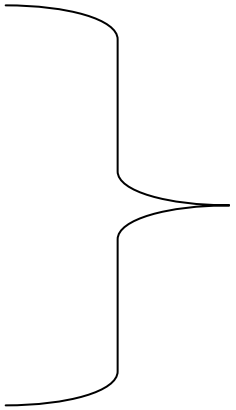
List of Supporters for This Presentation

IC Vendors:

Broadcom
Cicada
Marvell
Mysticom
Vativ



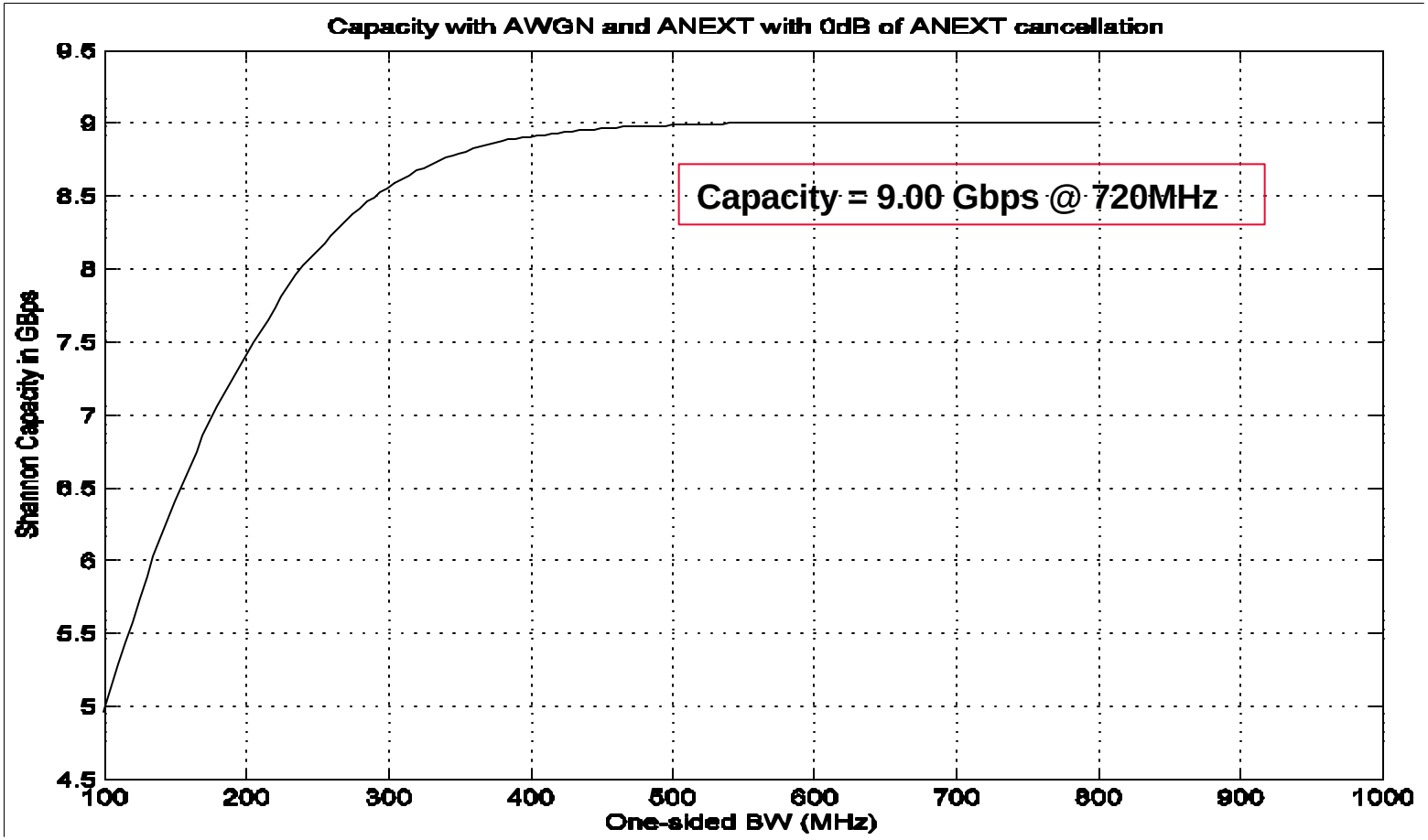
Vendors that have implemented 10/100/1000Base-T PHYs

Outline

- **Review 10Gbase-T feasibility**
- **Review alternatives for supporting existing and new media**
- **Feasibility study on alternative options**

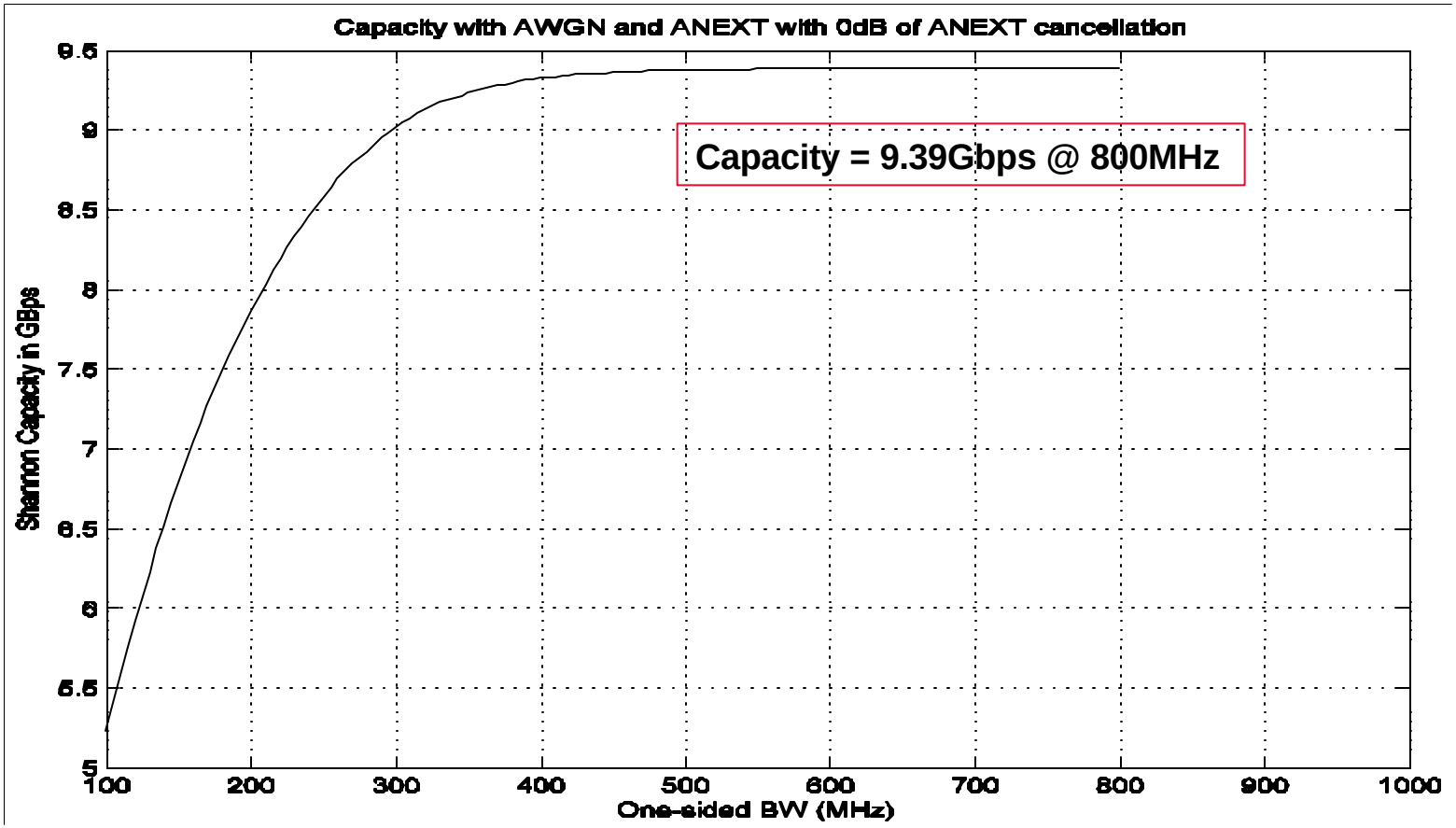
Review Cat5e Channel Capacity

- **Based on <u>unscaled measured data</u> from 100m - 2 connector channel**
  - Not representative of worst case channel
  - Refer to 10GBase-T channel criteria presentation on May 2003 at IEEEE interim meeting



Review CAT6 Channel Capacity

- **Based on <u>unscaled measured data</u> from 100m - 4 connector channel**
  - Not representative of worst case channel
  - Refer to 10GBase-T channel criteria presentation on May 2003



10GBase-T over 100m UTP Cables

- **There is less than 10Gbps capacity on a nominal 100m Cat5e and Cat6 channels**
- **Capacity calculations with measured data indicate that 10 Gigabit data transmission over 100m Cat 5e or Cat 6 UTP cable plant as specified in ISO 11801 is not feasible**
- **Alien Cross Talk is a fundamental limit.**
  - There has been no contribution that shows Alien Cross Talk can be canceled
- **Elimination of cable bundling practices will be required for UTP cables to mitigate Alien Cross Talk**
- **Unrestricted installation can only be accomplished with a new higher quality cable**

What Are the Options ?

- **Use shielded cable or create a new UTP cable with restriction on bundling**
- **Settle for shorter cable length than 100m on UTP cable plants**
- **Stay with 1000Base-T as the highest speed copper PHY on installed base**
- **Support lower data rates such as 2.5G and 5G**
  - The only option to speedup data rate on ISO 11801 specified channel is to decrease data rates lower than 10Gbps

What data rates are feasible on 100m Cat5, Cat5e and Cat6 cables

- **2.5 Gigabit per second is feasible on 100m Cat5, Cat5e and Cat6 cable plants**
- **5 Gigabit per second is feasible on 100m Cat6 cable plants**
  - Nominal ANEXT improvements is required

2.5Gbps/5Gbps Feasibility Study

- **Use PAM-10 for feasibility study**
  - Consistent with previous 10Gbps analysis in 10GBASE-T group
  - Architectures not optimized, for feasibility only

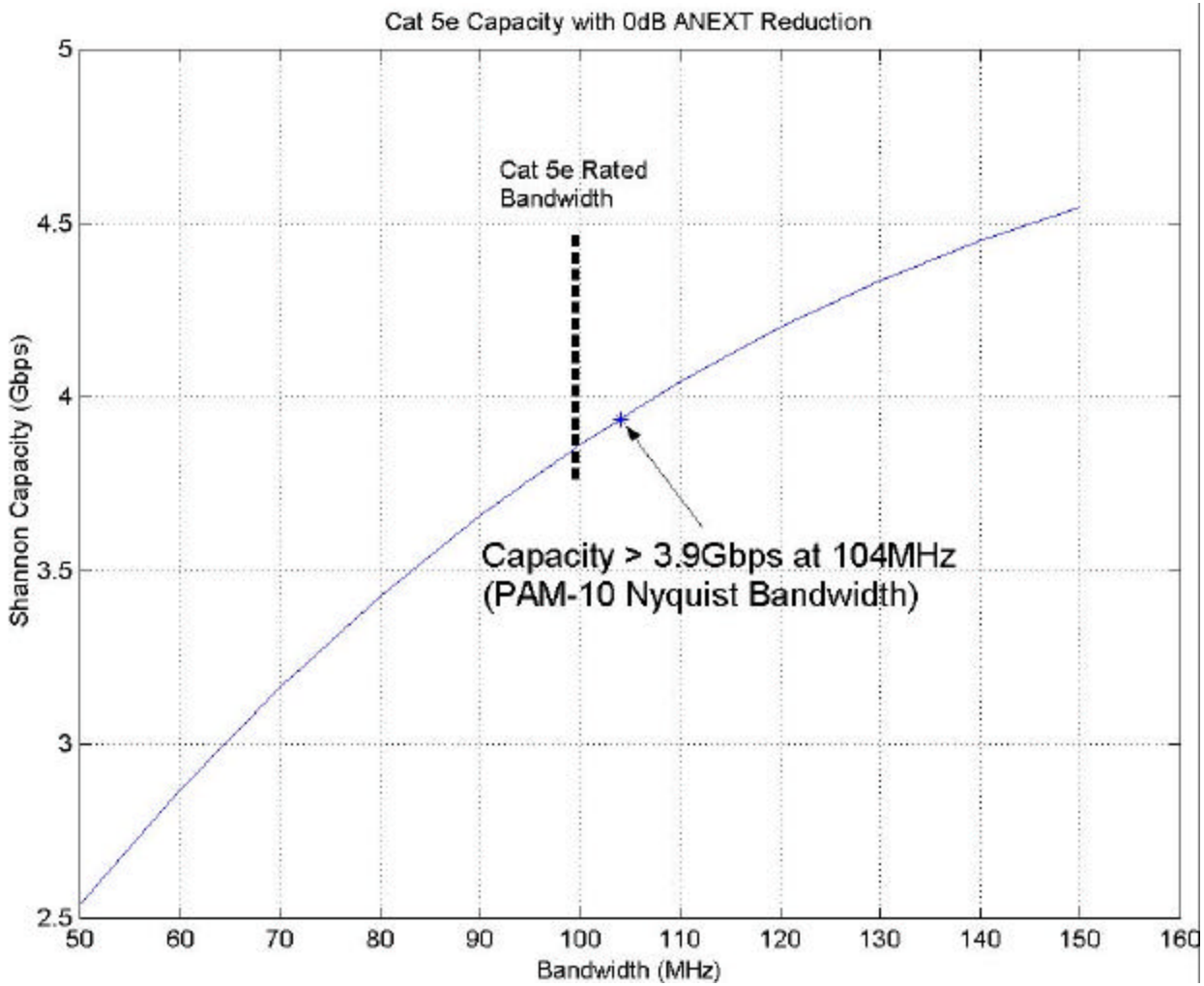
- **Show feasibility with margin on an appropriate cable using 3 different techniques:**
  - Shannon capacity*
  - Minimum MSE solution with actual noise and cable characteristics**
    - Finite length DFE, residual “colored” echo/NEXT/FEXT, ADC, jitter
  - Time domain simulation with actual noise and cable characteristics

*** Capacity code submitted to 10GBASE-T reflector 2/25/03**

**** Standard analysis: See, for example pp521-524 in “Digital Communication” by Edward Lee and David Messerschmitt**

2.5Gbps Over 100m Cat 5e: *Shannon Capacity*

- **Measured channel scaled to worst case limit line**



2.5Gbps Over Worst Case 100m Cat 5e: MMSE Analysis

- **PAM-10, Fbaud = 208.3Msps, Target slicer SNR = 31.7 dB**

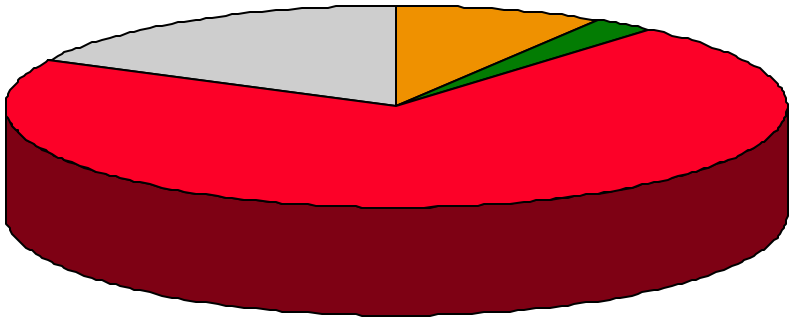
BER = $4x10^{-11}$

Example only, NOT OPTIMIZED

Filter	# Taps
FFE+DFE	80
Echo	200
NEXT	64
FEXT	10

ADC Param.	
ENOB	9 bits
Jitter	10ps rms
Bandwidth	104 MHz

Breakdown of Slicer Noise

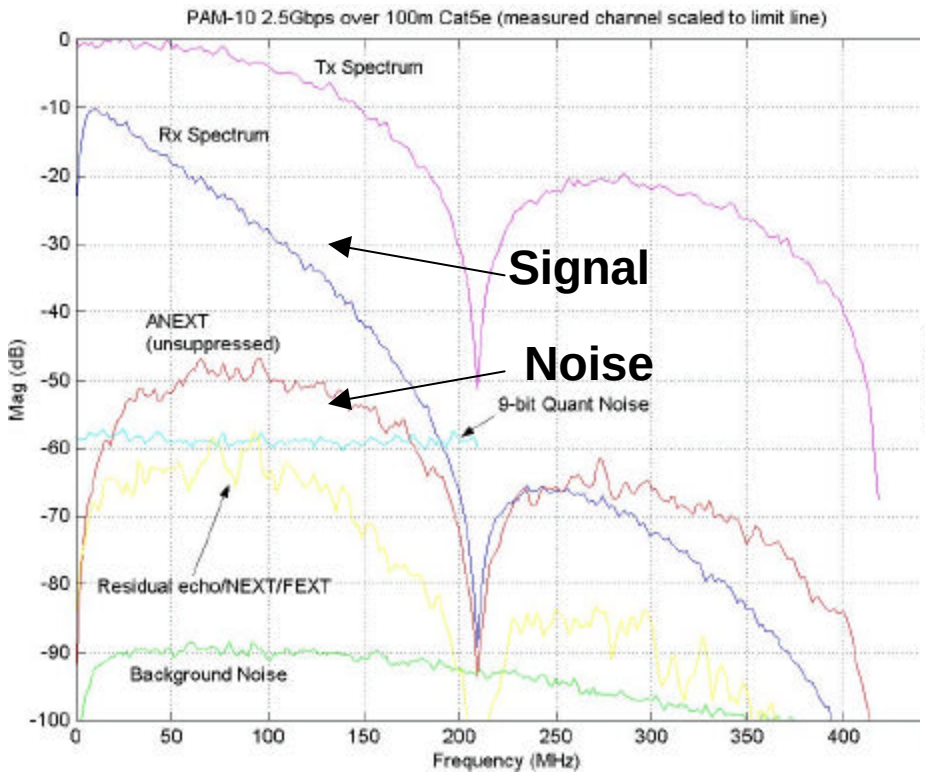


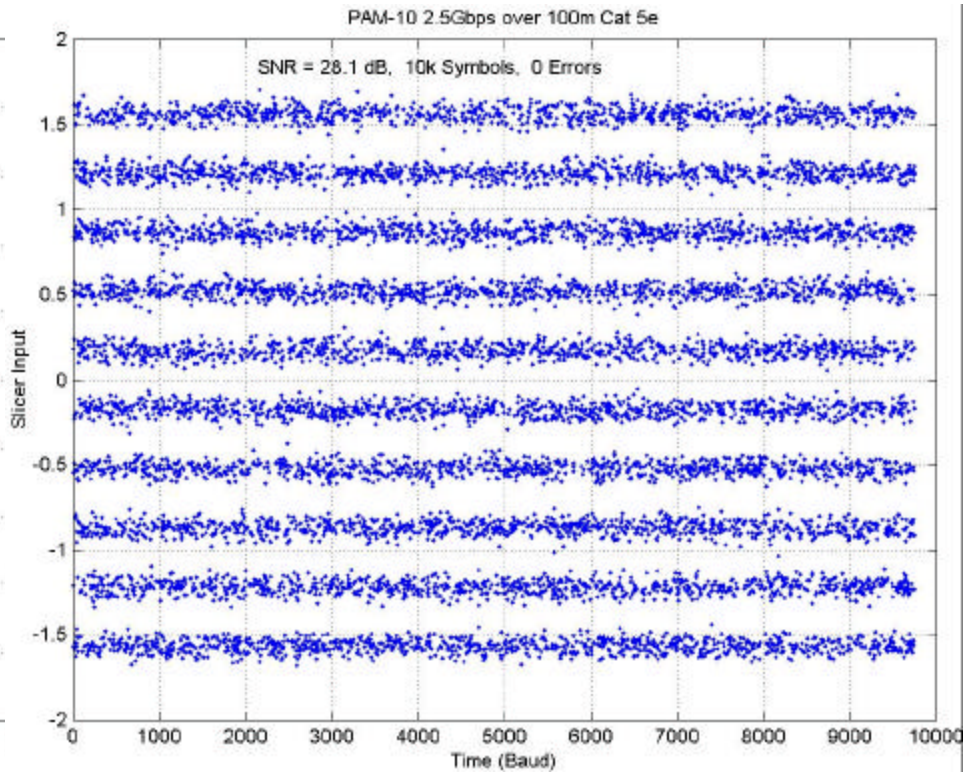
Approx 2dB margin with TCM coding gain

Total Slicer SNR = 27.7dB

2.5Gbps Over 100m Worst Case Cat 5e: Time Domain Simulation

Measured Channel Scaled to Limit Line



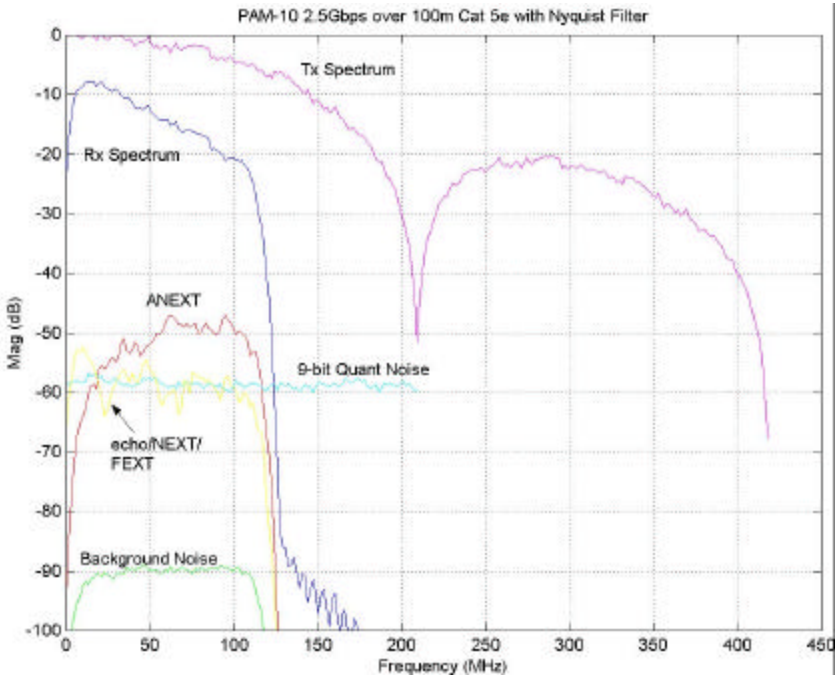


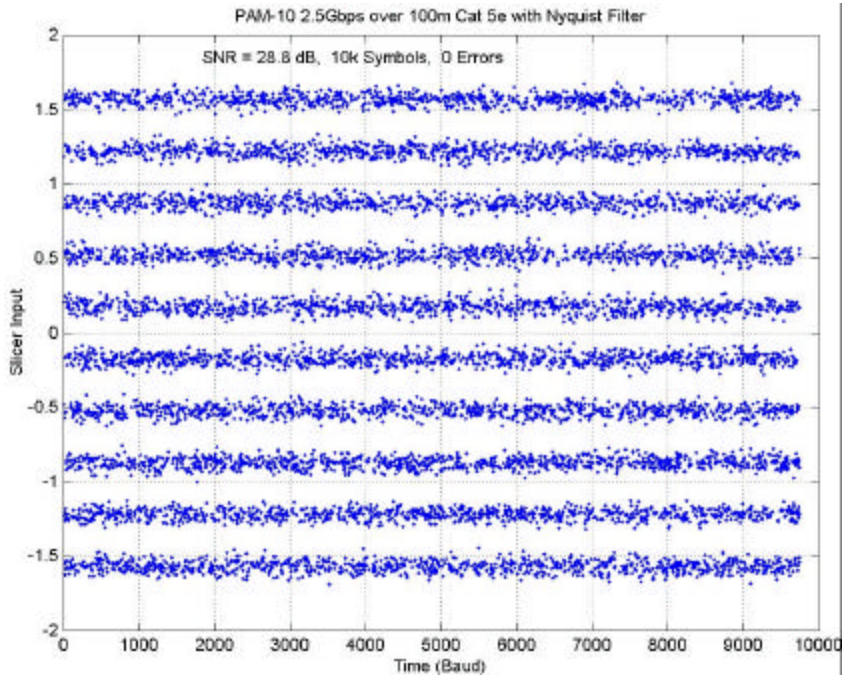
- **Includes Tx and Rx filters**
- **DFE adapted with LMS algorithm**

- **Uncoded, Equalized SNR = 28.1 dB**
- **TCM can theoretically achieve up to 6dB coding gain**

2.5Gbps Over 100m Cat 5e: Excess Bandwidth

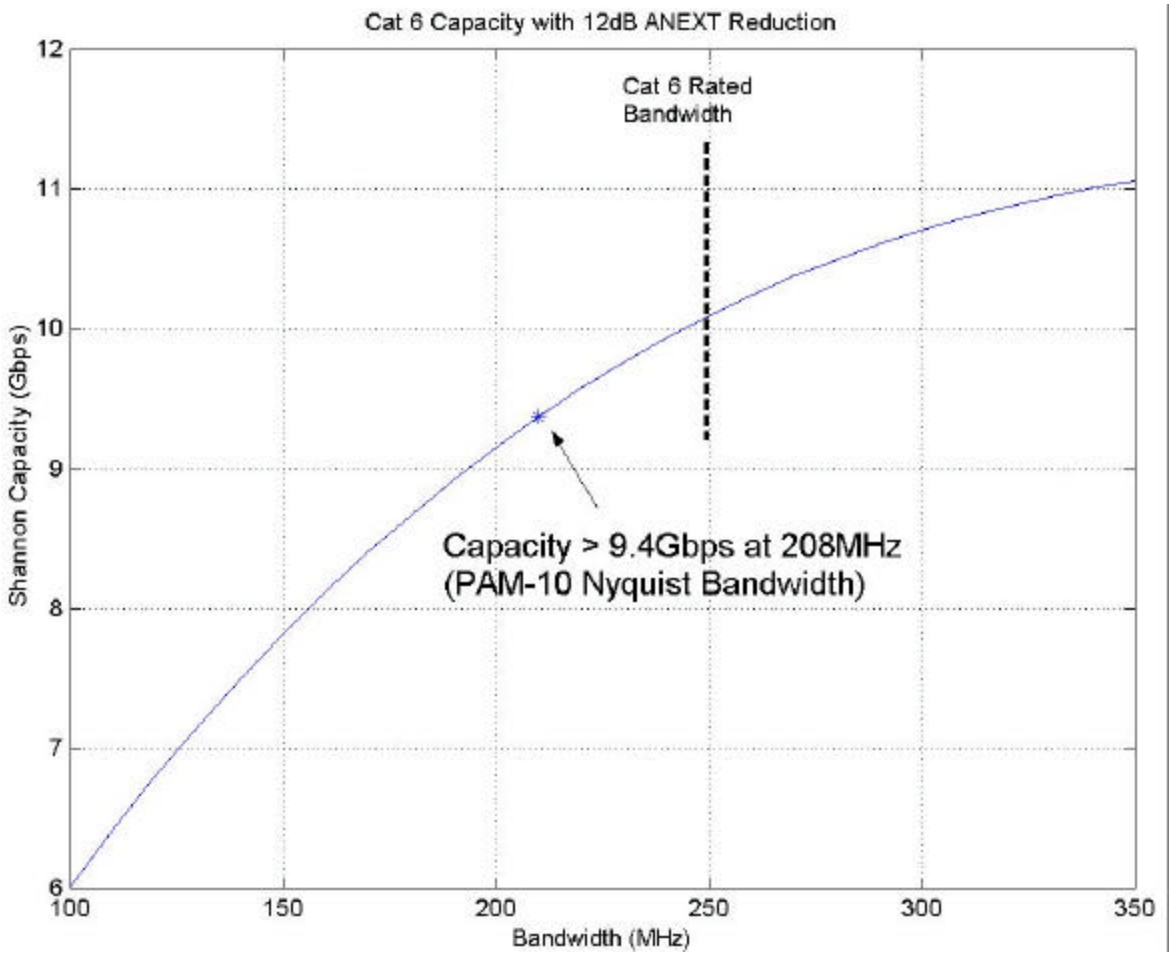
- **"Brick wall" filter at Fbaud/2 = 104MHz does not degrade performance**
  - Insertion loss characteristics beyond 100MHz should not impact performance





5Gbps Over 100m Cat 6*: *Shannon Capacity*

- **Measured channel scaled to worst case limit line**
  - ANEXT reduced 12dB



5Gbps Over 100m Cat 6*: MMSE Analysis (Channel Scaled to Limit Line)

- **PAM-10, Fbaud = 416.7Msps, Target slicer SNR = 32.0 dB**

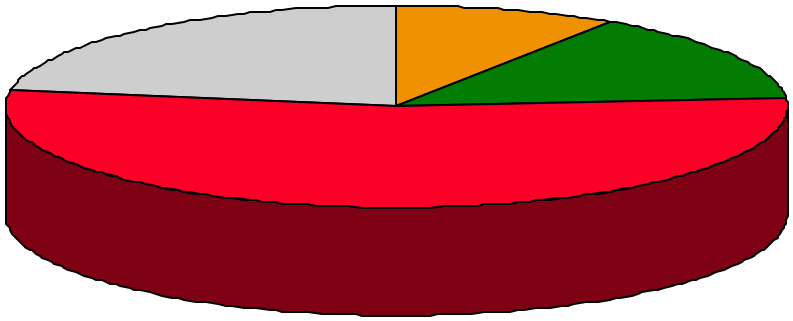
BER = 10^{-11}

Example only, NOT OPTIMIZED

Filter	# Taps
FFE+DFE	80
Echo	400
NEXT	128
FEXT	10

ADC Param.	
ENOB	10.25 bits
Jitter	7ps rms
Bandwidth	208 MHz

Breakdown of Slicer Noise



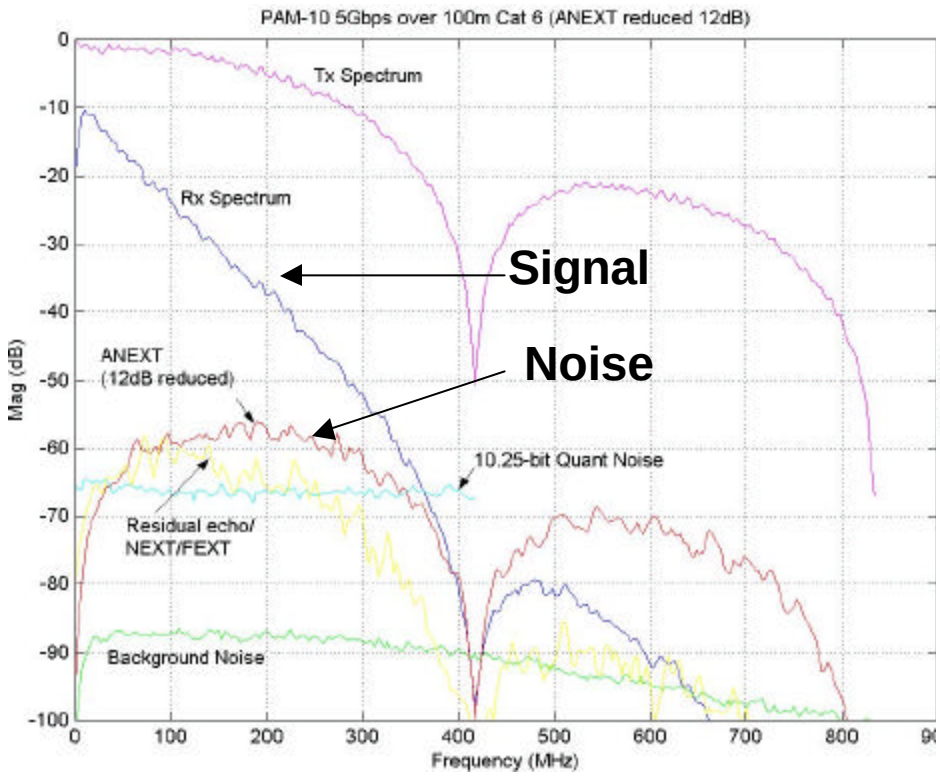
Approx 3dB margin with TCM coding gain

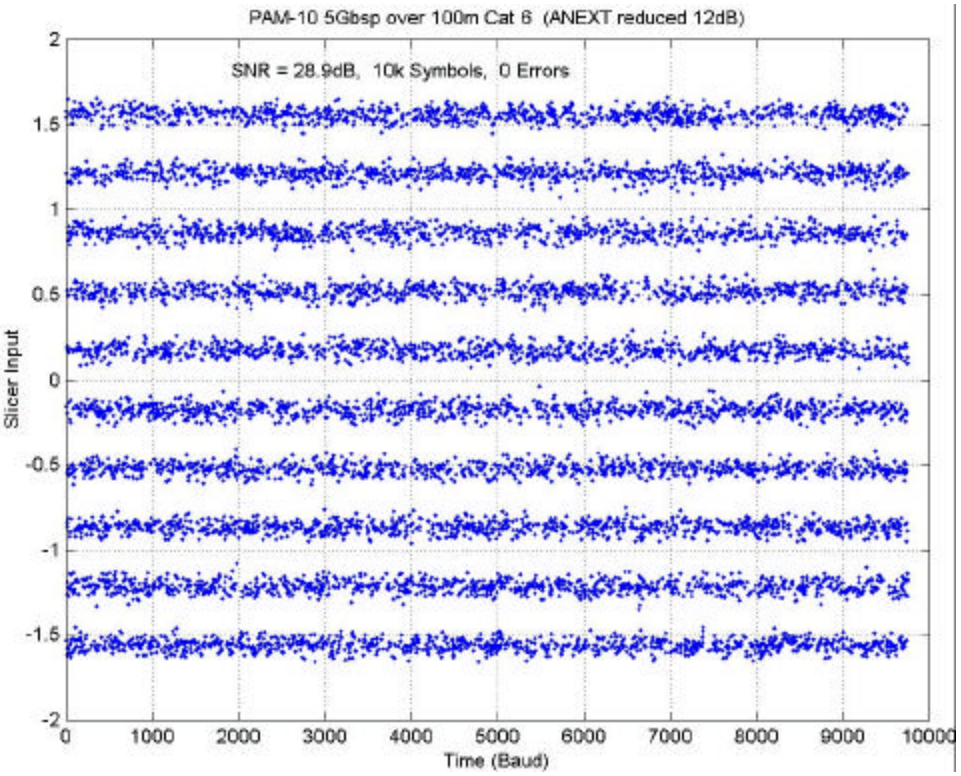
Total Slicer SNR = 28.9 dB

* Cat 6 with 12dB ANEXT reduction

5Gbps Over 100m Cat 6*: Time Domain Simulation

Measured channel scaled to limit line w/ worst case ANEXT reduced 12dB





- **Includes Tx and Rx filters**
- **DFE adapted with LMS algorithm**

- **Uncoded, Equalized SNR = 28.9 dB**
- **TCM can theoretically achieve up to 6dB coding gain**

*** Cat 6 with 12dB ANEXT reduction**

Summary

- **10Gbase-T on 100m Cat5e and Cat6 is not feasible**
- **2.5Gbps is feasible on 100m Cat5e per ISO 11801 spec**
- **5Gbps is feasible on 100m Cat6 with specified ANEXT**