Feasibility Study for 10G Over 100m Cat 7 and <100m UTP

PAM-10 Solution

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Topics for 10Gbps Feasibility

1) ADC requirements for 100m Cat 7 cable

2) Maximum cable reach on Cat 5e/6

3) Power estimation

Assumptions for ADC and Reach Analysis

- **PAM-10 architecture (baseline)**
  - Ideal analog hybrid echo canceller
  - Digital echo, NEXT, and FEXT cancellation (no round-off noise)
  - Digital equalization with DFSE (no round-off noise)
  - Ideal transmit and receive amplifiers (no noise or distortion)

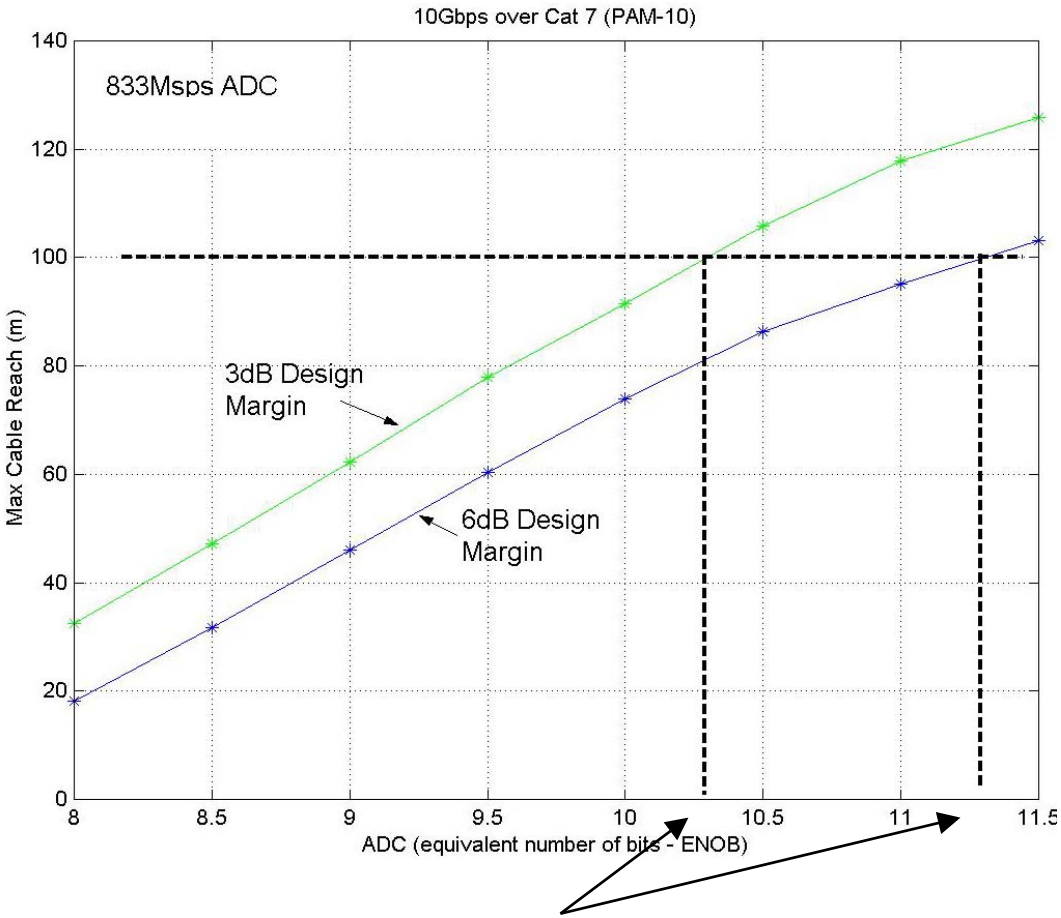
- **Measured channel model**
  - Scaled to ISO/IEC 11801 limit lines within the specified bandwidth
  - Measured ANEXT data was not scaled - it already touches the proposed limit line
    - See May 2003 10GBASE-T presentation Sallaway_1_0503.pdf page 10

- **Minimum MSE solution with actual noise and cable characteristics***
  - Best theoretical performance achievable for a given channel, given filter lengths and ADC/jitter specifications
  - Previously shown to closely match end-to-end time domain simulations

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

10Gbps Over 100m Cat 7

- No NEXT or FEXT cancellation filters required

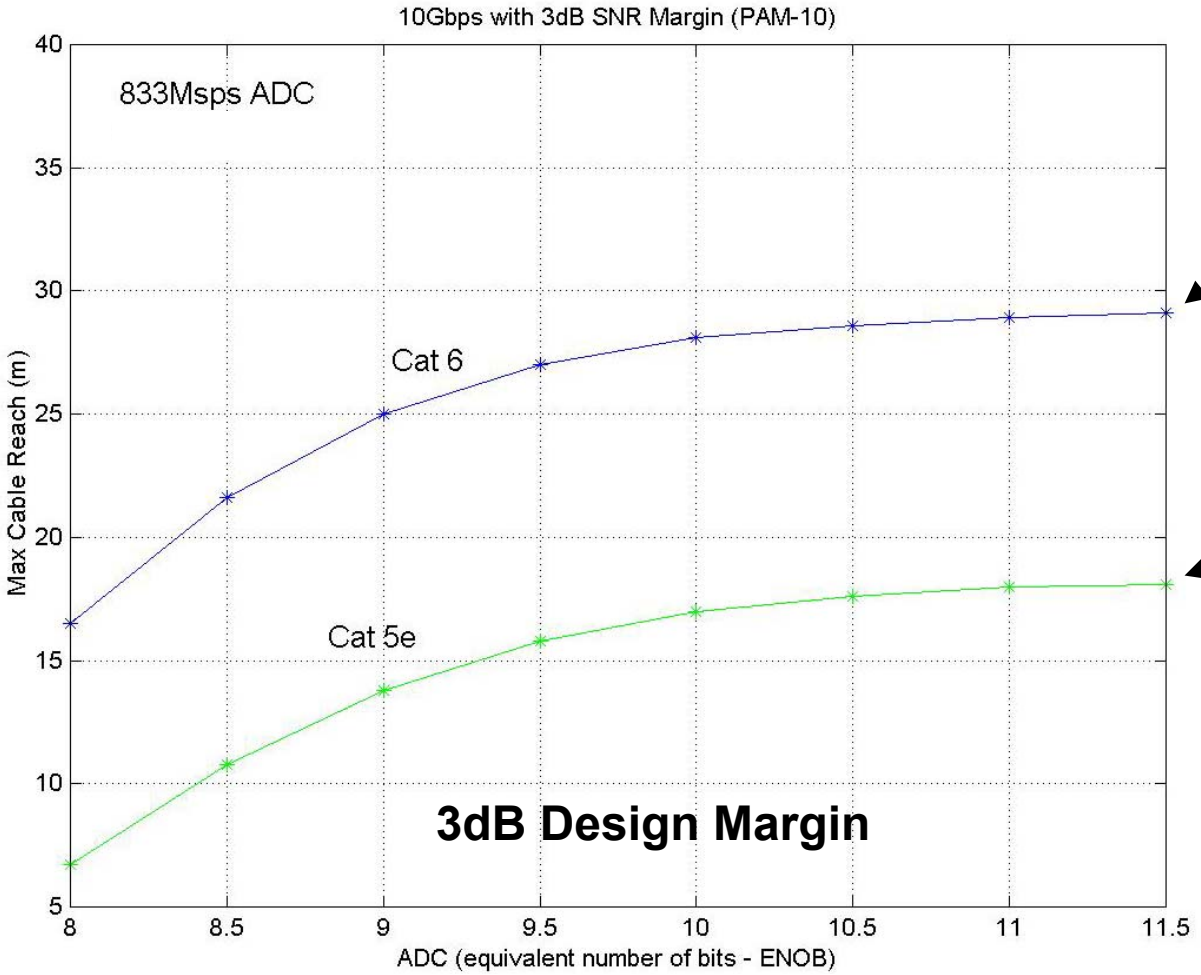


- Cable reach is limited by maximum achievable ADC ENOB at 833Msps
- Example: if ENOB=9bits is best achievable ADC at 833Msps, Cat 7 cable reach will be limited to 45-60m

- <u>ENOB of 10.5-11.5 bits required for 10Gbps over 100m Cat7</u>

10Gbps Over Reduced Length Cat 5e and Cat6 UTP

- >200 tap NEXT cancellation filters required (12x)



PAM-10

Cat 6 UTP reach < 30m

Cat 5e UTP reach < 20m

- Insertion loss and FEXT scaled with length
- No cable installation restrictions

Power Estimation

- **Target rate: 10 Gbps**
- **Target media: 100m Cat 7 and 30m Cat 6**
  - 100m Cat 7 drives ADC spec and echo canceller complexity
  - 30m Cat 6 drives NEXT/FEXT canceller complexity
- **Baseline Architecture: PAM-10**
  - Cancellers and equalizer sized using MMSE analysis
- **First order power analysis based on public information and aggressive assumptions on future scaling**

10Gbps Over 100m Cat 7 and 30m Cat 6 UTP

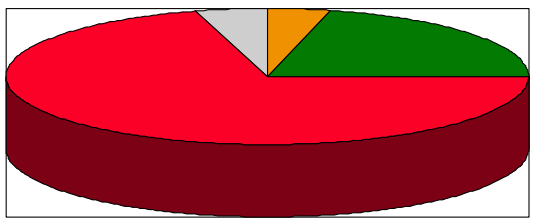
- PAM-10, Fbaud = 833.3Msps, Target slicer SNR = 32 dB

BER = 10^{-11}

Filter	# Taps
FFE+DFE	36
Echo	800
NEXT	200
FEXT	10

ADC Param.	
ENOB	10.5 bits
Bandwidth	417 MHz

30m Cat 6

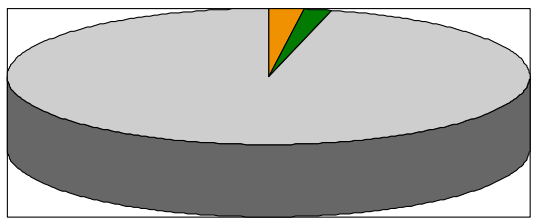


isi
echo/N,FEXT
ANEXT
Quant + jitter

Total Slicer SNR = 27.7dB

(30.5dB @ 20meters)

100m Cat 7



isi
echo/N,FEXT
ANEXT
Quant + jitter

Total Slicer SNR = 30.4dB

10G ADC Power

- **Require ENOB ≈ 10.5 bits at 833Msps**
  - For power estimation purposes, assume alternate approach may be found to provide 1 bit relief in ENOB requirement

- **Current State of the Art:**

Part	ENOB (bits)	Speed (Msps)	Power (W)	
AD12400	10.3	400	7	ENOB ≈ok but too slow
TC1200	8	1000	5.5	
TS83102	7.8	3000	4.6	Speed ok but ENOB too low
MAX108	7.5	1500	8.5	

- **Assume in 5 years that either**
  - Resolution (ENOB) can increase 4x-8x with no increase in power
  - Speed can increase 2x with no increase in power

- **ADC power is projected to be about 4W x 4 = 20W (4 ADC's)**
  - Assume an "as-yet to be discovered" design trick can reduce this 50%

$Padc_{2008} \approx 8W$ **May be closer to 16W+**

IEEE 802.3 Interim Sept 2003 10GBASE-T

10G DSP Power

- **Assume echo/NEXT cancellers account for roughly ½ of DSP power in 1G phy**
  - Assume DSP of today's gig phy requires approx 0.25W (≈0.125W for echo/NEXT)
  - (833/125) = 6.7x more taps running 6.7x faster => 5.6W for echo/NEXT (0.13μm)
- **Assume complexity of other 1G operators (DFE etc) double for 10G**
  - Power of "other" 1G operators ≈0.125W
  - 2x more circuitry running 6.7x faster = 1.7W (0.13μm)
- **Assume FEXT canceller is roughly ¼ echo/NEXT cancellers**
  - Approx 1.5W (0.13μm)
- **Assume 0.13um → 90nm → 65nm results in 4x power reduction**
  - 0.25(5.6+1.7+1.5) = total DSP power in 5 years

$Pdsp_{2008} \approx 2.2W$

Total 10G Transceiver Power = 10 – 18W in 5 years

Depends heavily on significant reduction in analog circuit power

Conclusions (PAM10)

- **Cable reach limitations may not warrant support for 10G over Cat 5e/6**

	Cat 6 UTP	Cat 5e UTP
Max reach	30m	20m

- **Feasibility over 100m Cat 7 critically dependent on feasibility of 833Msps ADC***

	100m Cat 7
ADC ENOB	>10.5* bits @ 833Msps

* Or feasibility of alternate implementation to reduce ENOB

- **Power dissipation may limit applications**

10-18W** per port in 5 years

* "Cat 7-only" reduces power approx 1W/port