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Feasibility Study of 10GBase-T on Cat-5e/-6 Cabling

P. J. Sallaway
Vativ Technologies, Inc.
(formerly Myrica Networks, Inc.)
pj@vativ.com

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Outline

- Theoretical Analysis
  - Cat-5e capacity calculations
  - Cat-6 capacity calculations
- Practical Implementation Issues
  - DSP
  - Analog / Mixed Signal

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Assumptions for Capacity Calculations

- Perfect Echo/NEXT cancellation
- Capacity calculations under two FEXT scenarios
  - FEXT perfectly cancelled
  - FEXT used in signal detection
- +10dBm transmit power
- AWGN with one-sided p.s.d. -140 dBm/Hz
- Limit lines used for insertion loss (IL) and Alien NEXT (ANEXT)

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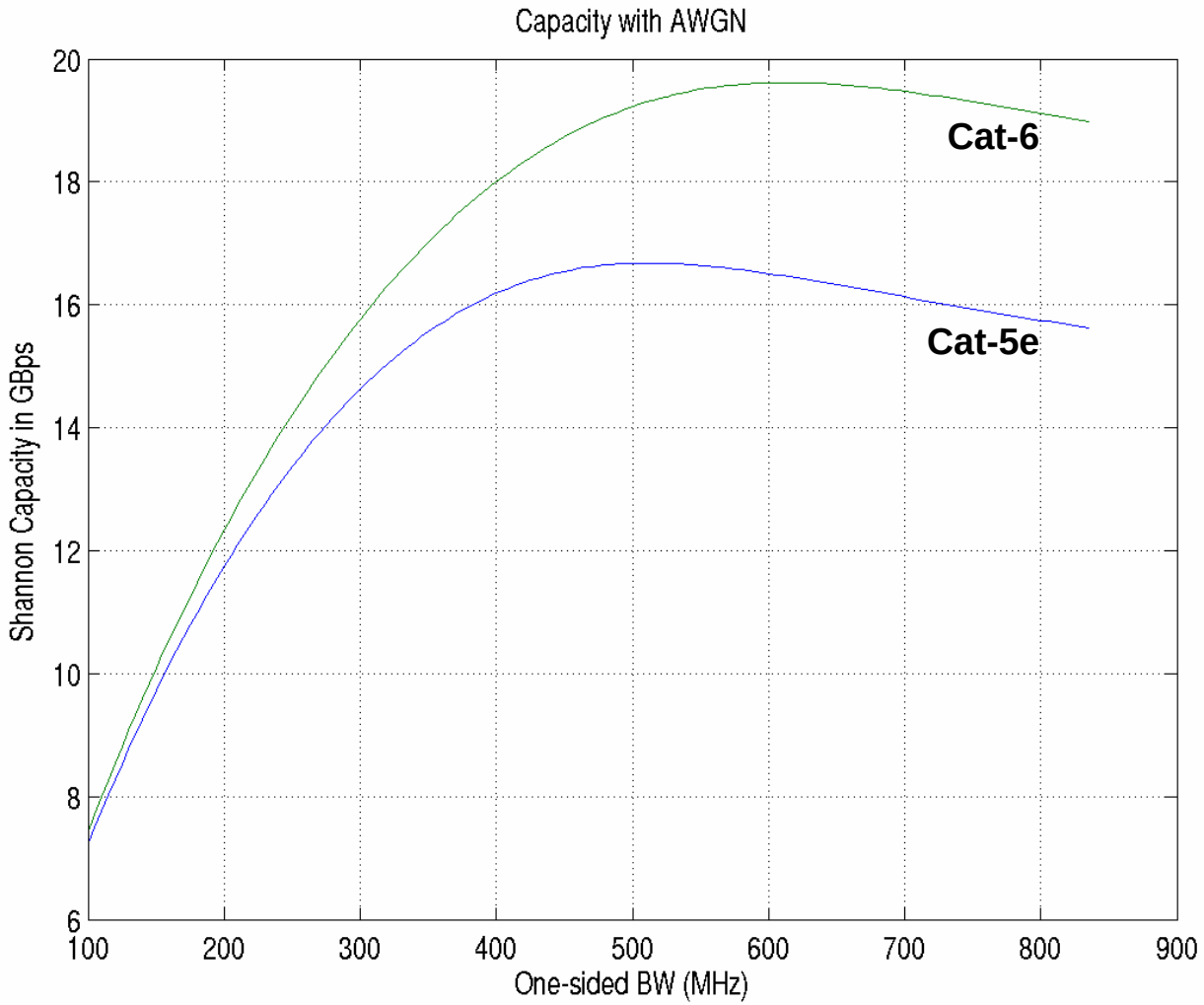
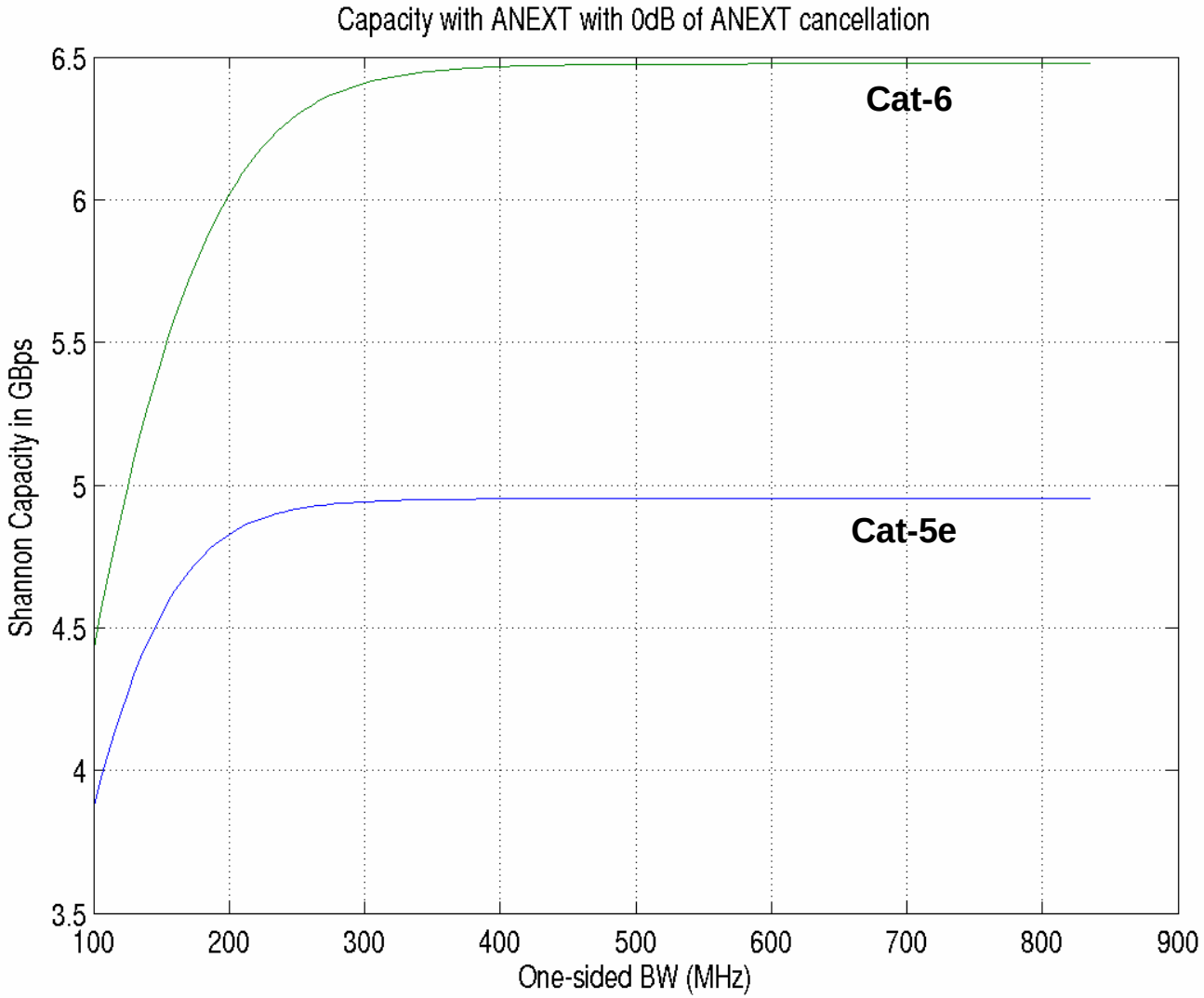
Code Used for Calculations

- Own MATLAB code was generated for independent verification
- Code to be published on the 10GBT reflector for all to see
- Very similar results to those currently on the reflector [X. Chen (Marvell) & Z. Roth (Mysticom)]
- Main differences
  - More accurate numerical integration was used
  - Capacity determined as a function of bandwidth

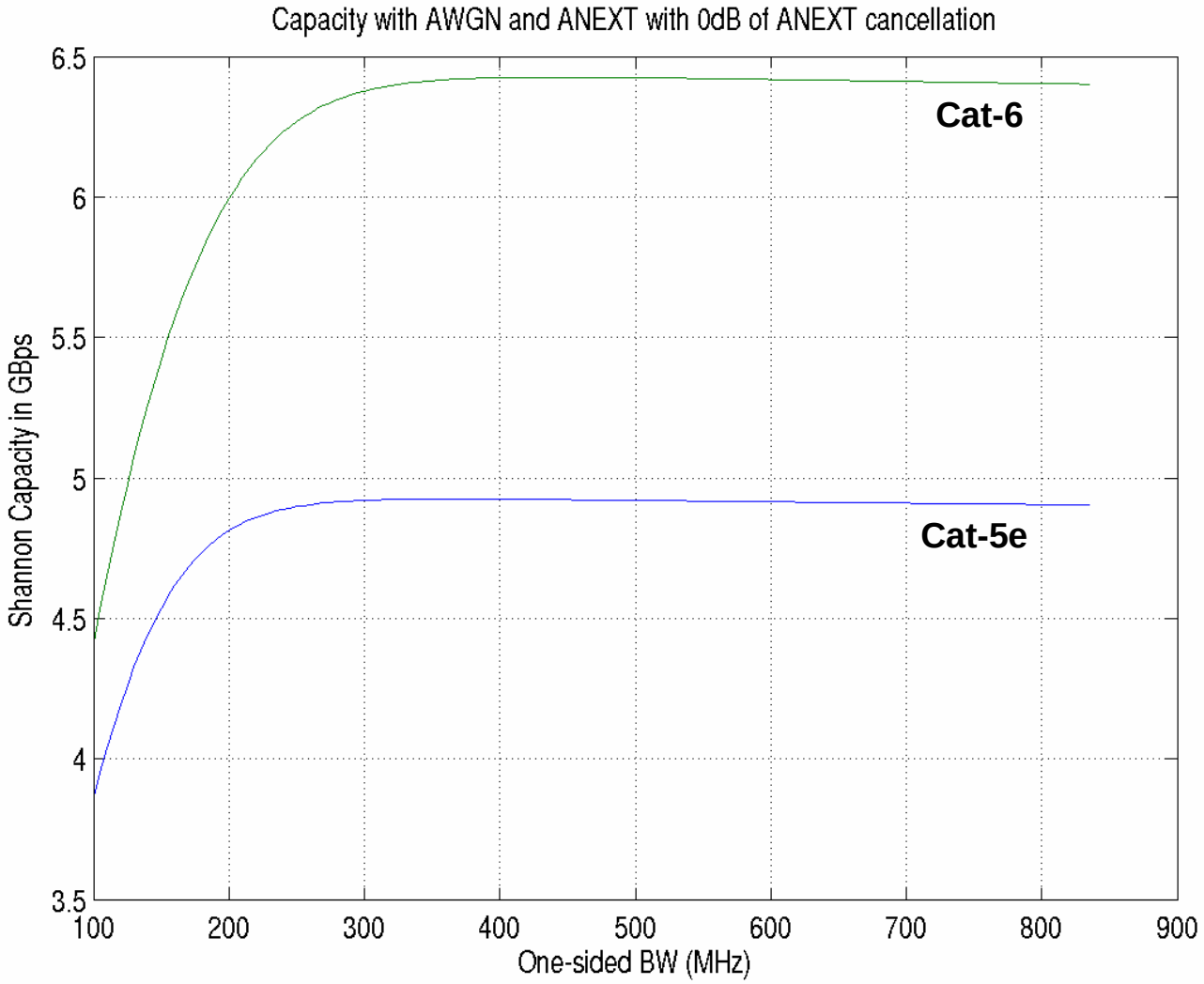
Insertion Loss, AWGN



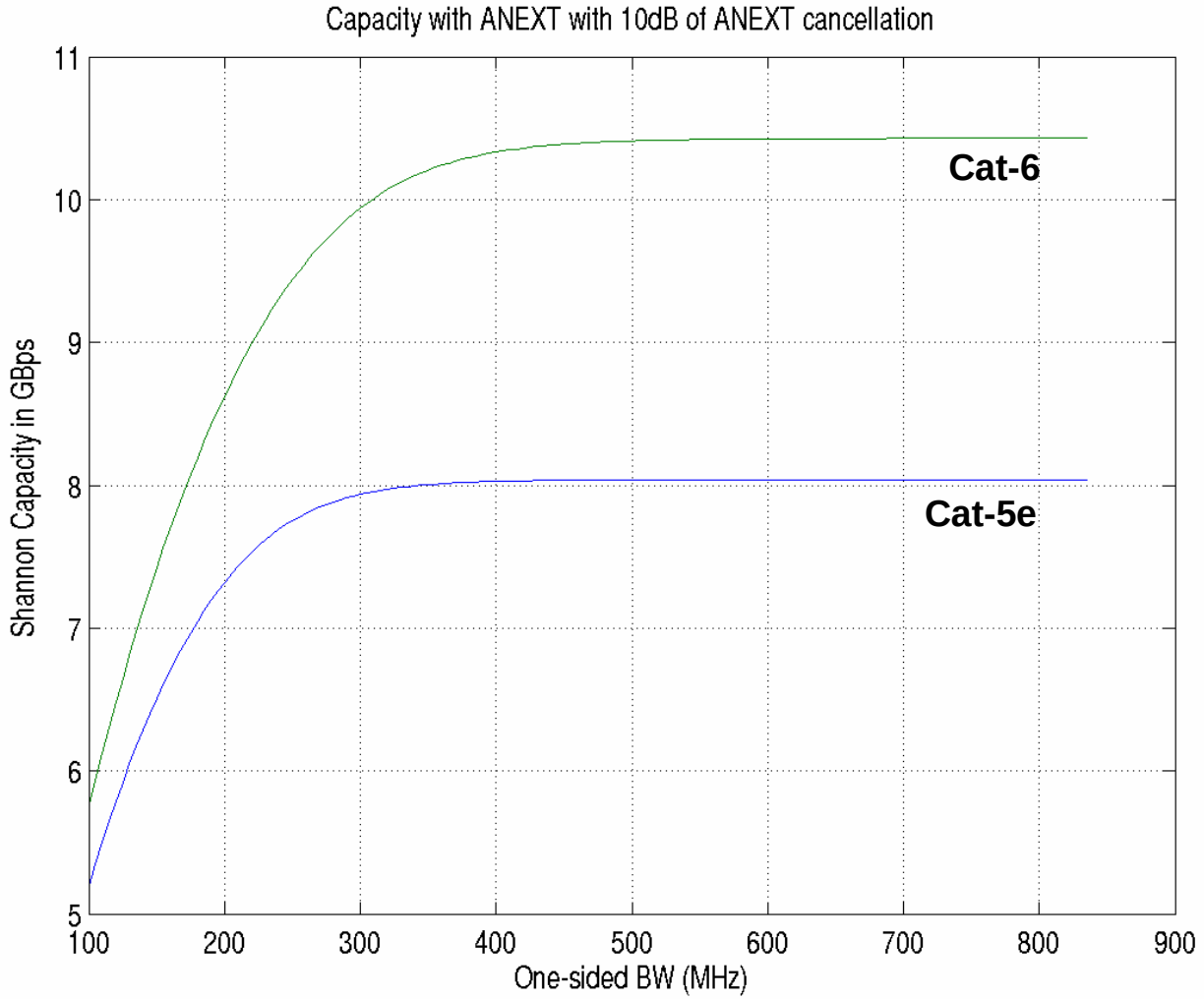
Insertion Loss, ANEXT



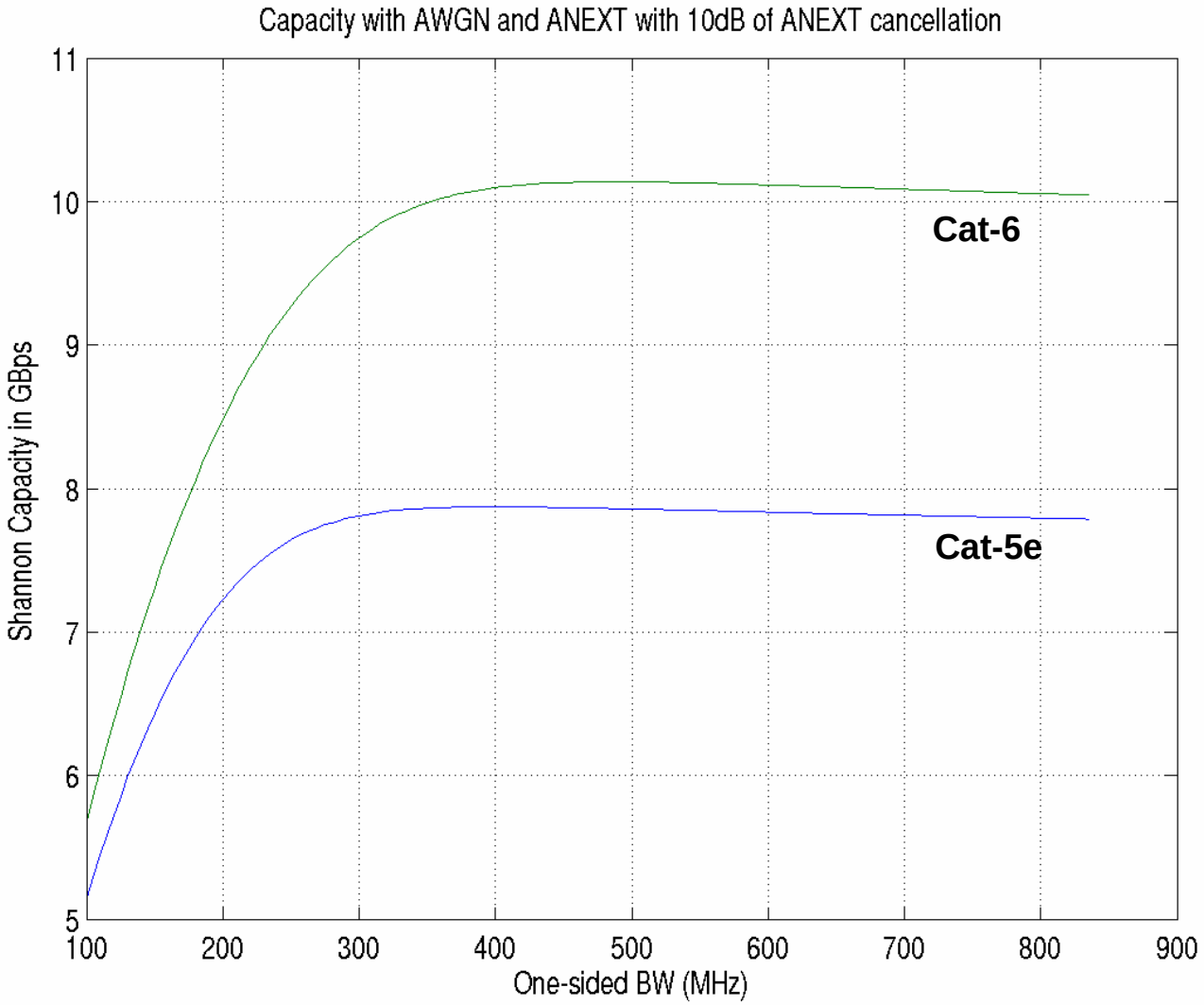
Insertion Loss, AWGN, ANEXT



Insertion Loss, (ANEXT-10dB)



Insertion Loss, AWGN, (ANEXT-10dB)



Summary of Capacity Calculations (@ optimal BW)

	Cat-5e		Cat-6	
	BW (MHz)	Capacity (Gbps)	BW (MHz)	Capacity (Gbps)
IL+ANEXT	835	4.953	835	6.476
IL+AWGN +ANEXT	365	4.925	445	6.426
IL+ANEXT-10dB	835	8.040	835	10.429
IL+AWGN +ANEXT-10dB	400	7.782	485	10.137

Summary of Capacity Calculations (@ 416MHz BW)

	Cat-5e		Cat-6	
	BW (MHz)	Capacity (Gbps)	BW (MHz)	Capacity (Gbps)
IL+ANEXT	416	4.952	416	6.468
IL+AWGN +ANEXT	416	4.924	416	6.426
IL+ANEXT-10dB	416	8.031	416	10.355
IL+AWGN +ANEXT-10dB	416	7.872	416	10.113

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Capacity Assuming Ideal FEXT Utilization (@ optimal BW)

	Cat-5e		Cat-6	
	MUD (Gbps)	Signal Only	MUD (Gbps)	Signal Only
IL+ANEXT	5.017	4.953	6.511	6.476
IL+AWGN +ANEXT	4.987	4.925	6.460	6.426
IL+ANEXT-10dB	8.205	8.040	10.520	10.429
IL+AWGN +ANEXT-10dB	8.029	7.872	10.222	10.137

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Capacity Assuming Ideal FEXT Utilization (@ 416MHz BW)

	Cat-5e		Cat-6	
	MUD (Gbps)	Capacity (Gbps)	MUD (Gbps)	Capacity (Gbps)
IL+ANEXT	5.015	4.952	6.502	6.468
IL+AWGN +ANEXT	4.987	4.924	6.459	6.426
IL+ANEXT-10dB	8.189	8.031	10.431	10.355
IL+AWGN +ANEXT-10dB	8.028	7.872	10.189	10.113

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Summary of Capacity Calculations

- Not enough capacity on Cat-5e nor Cat-6 to achieve 10Gbps
  - Choice of a modulation (e.g. PAM/QAM) & coding (Trellis) will only offer less throughput than Shannon Capacity
  - Transceiver implementation considerations will further reduce the achievable throughput
- Alien NEXT models from Cabling Group not expected to fundamentally alter the main result
  - Will confirm once accepted models are available

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Practical DSP Considerations of the Proposed PAM scheme

- Complexity comparison to Gigabit Ethernet
  - ≈7x clock speed
  - >7x number of taps
  - Higher precision data path
  - Additional pipelining in the data path

    ▶ Digital Complexity >> 50x GigE
- DDFSE needs to be implemented to combine DFE with error correction
  - Can critical path meet timing?
- MIMO does not reduce the computational requirements

Practical Considerations of the Analog/Mixed-signal Issues

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- ADC precision & linearity
- Clock jitter effects on ADC, cancellers, & equalization
- Transmit driver linearity
- Analog data path SNR requirements
- Transmit & receive filter requirements

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Conclusions

- Shannon Capacity calculations indicate that CAT-5e and CAT-6 cables cannot realistically support 10 Gbps over 100m
- Proposed PAM-10 scheme has serious practical limitations
- We should look at a new medium – perhaps Cat-7 or others