Downside of TH Precoding

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Outline

- TH Precoding Comes with Hidden Costs
- Rebuttal to TH Precoding Contribution
- Claimed Benefits are Questionable
- Quoted “theoretical necessity” is for a different operating regime

DSP Increases in Complexity

- Increased wordlength in cancellers
  - Largest blocks in system (80% of digital chip)
- Increase from 4 bit to 10 bit data (250% gate increase) if input to cancellers comes from THP output (recommended method)
  - Increase from 4 bit to 6 bit data (50% increase) if “effective data symbols” can be used
  - Frequency domain cancellers see at least 20% increase, not “little or no” since these would be most of the DSP chip
    - Necessitate longer signal processing latency
- Could cost up to 4 Watts, depending on implementation (ref. November ’03 tutorial)

TH Precoder Implementation

- The feedback operation of the THP combined with the nonlinearity creates a challenging worst case circuit timing problem especially when implementing with parallel structures
  - In “Precoding Proposal” timing was compared to DFSE, timing, not DFE as proposed
- In the presentation of “10GBase-T Architecture Proposal” at the March 2004 Plenary, Scott Powell acknowledges this and volunteers a contribution demonstrating feasibility
- This feasibility analysis is needed before a decision on THP can be made

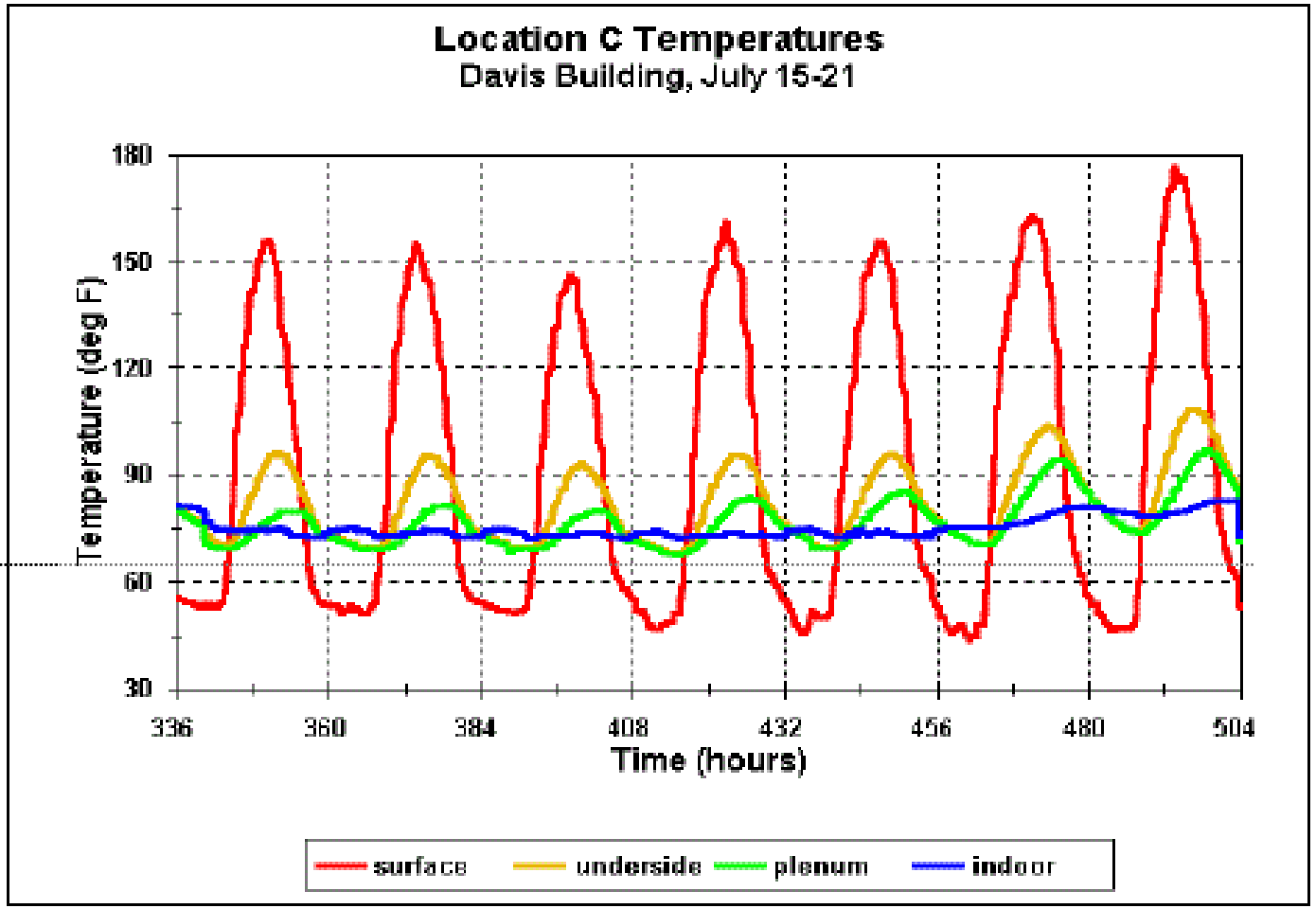
Data Mode Adaptation Problematic

- THP coefficients fixed after coefficient exchange at the start of data mode.
- Variation in the channel will result in a degradation from the mismatch. (requires more margin)
- Adaptation of the FFE enhances the degradation.
- In the presentation of “10GBase-T Architecture Proposal” at the March 2004 Plenary, Scott Powell suggests a residual receiver DFE.
  - Increased complexity
  - Analogous to the shaped DFE in the companion contribution (why then THP?)

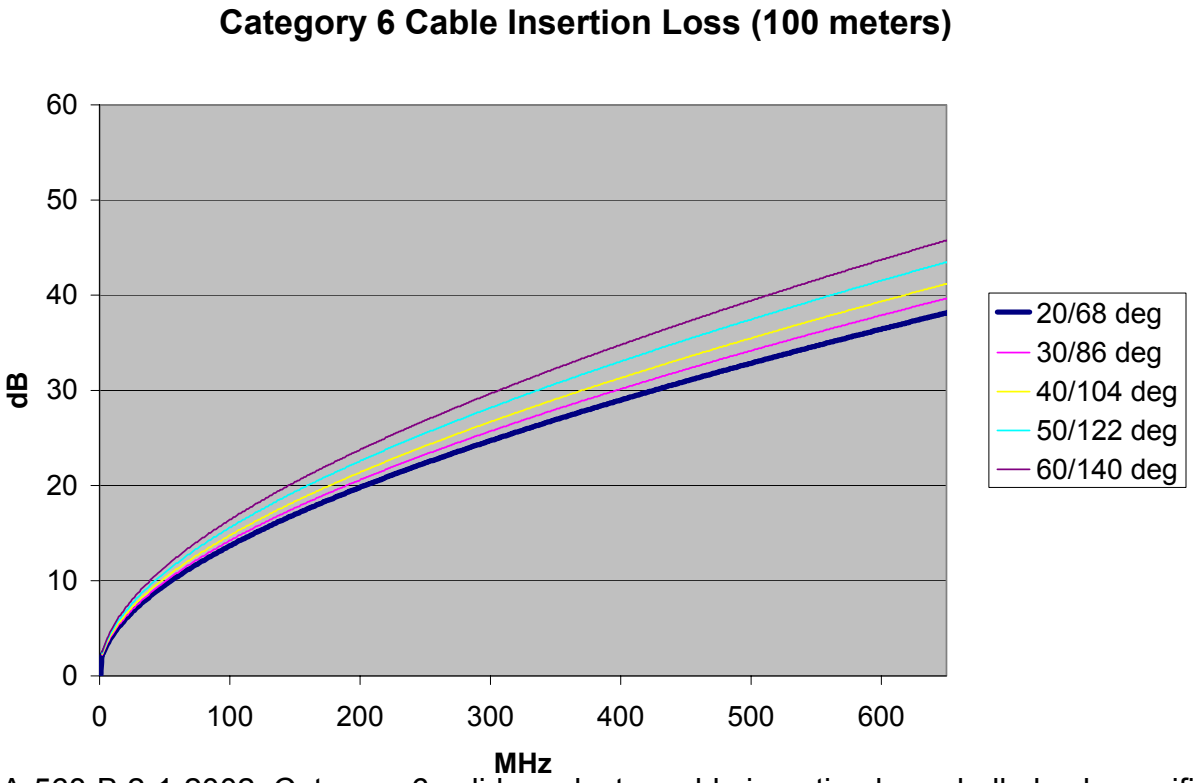
Temperature variation with time

37°C

Balmy



Cable variation with Temperature



ANSI/TIA/EIA-568-B.2-1-2002: Category 6 solid conductor cable insertion loss shall also be verified at a temperature of 40 ± 3 °C and 60 ± 3 °C and shall meet the requirements of equation (2) after adjusting for temperature. The maximum insertion loss for solid conductor UTP cables shall be adjusted at elevated Temperatures using a factor of 0.4 % increase per °C from 20 °C to 40 °C and 0.6% increase per °C for temperatures from 40 °C to 60 °C. The maximum insertion loss for solid conductor ScTP cables shall be adjusted at elevated temperatures using a factor of 0.2% increase per °C from 20 °C to 60 °C.

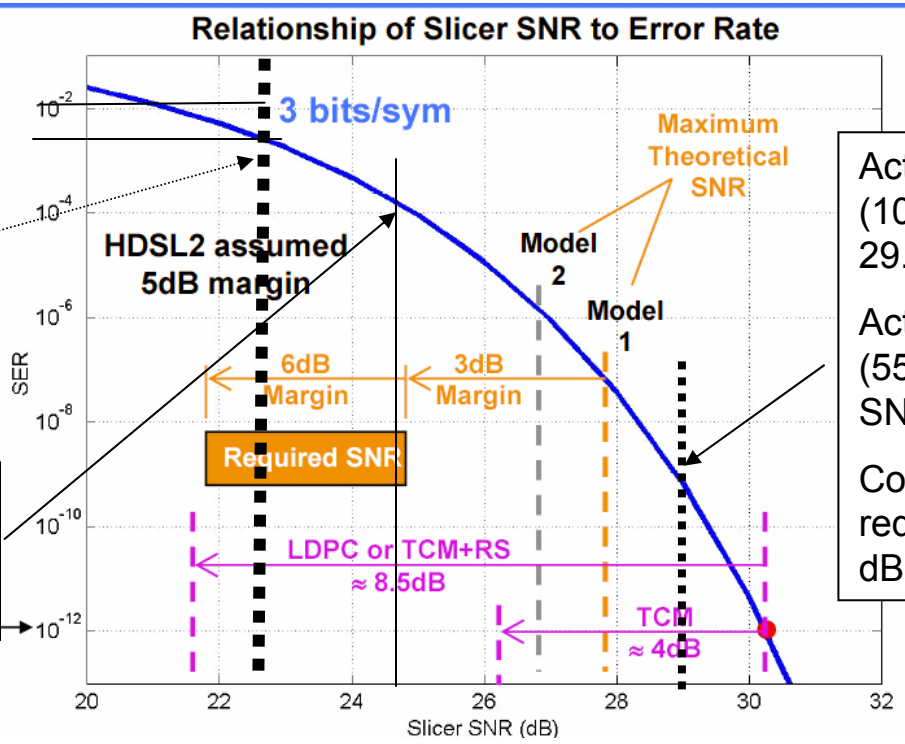
Rebuttal: Required Coding Gain and Low Operating SER Exaggerated

- **Model used is 2.5 dB worse than agreed model**
- **Operating point for SER on "powerful code" is 1.7 dB pessimistic than Rao's code**

Rao's code: 20 dB PAM-8 SNR -> 22.6 dB for 3bps, shaped PAM-10, true operating point is almost an order of magnitude better

Teranetics proposal operating point

= 24 dB



Actual "Model 1" (100m Cat7 IL) = 29.1 dB

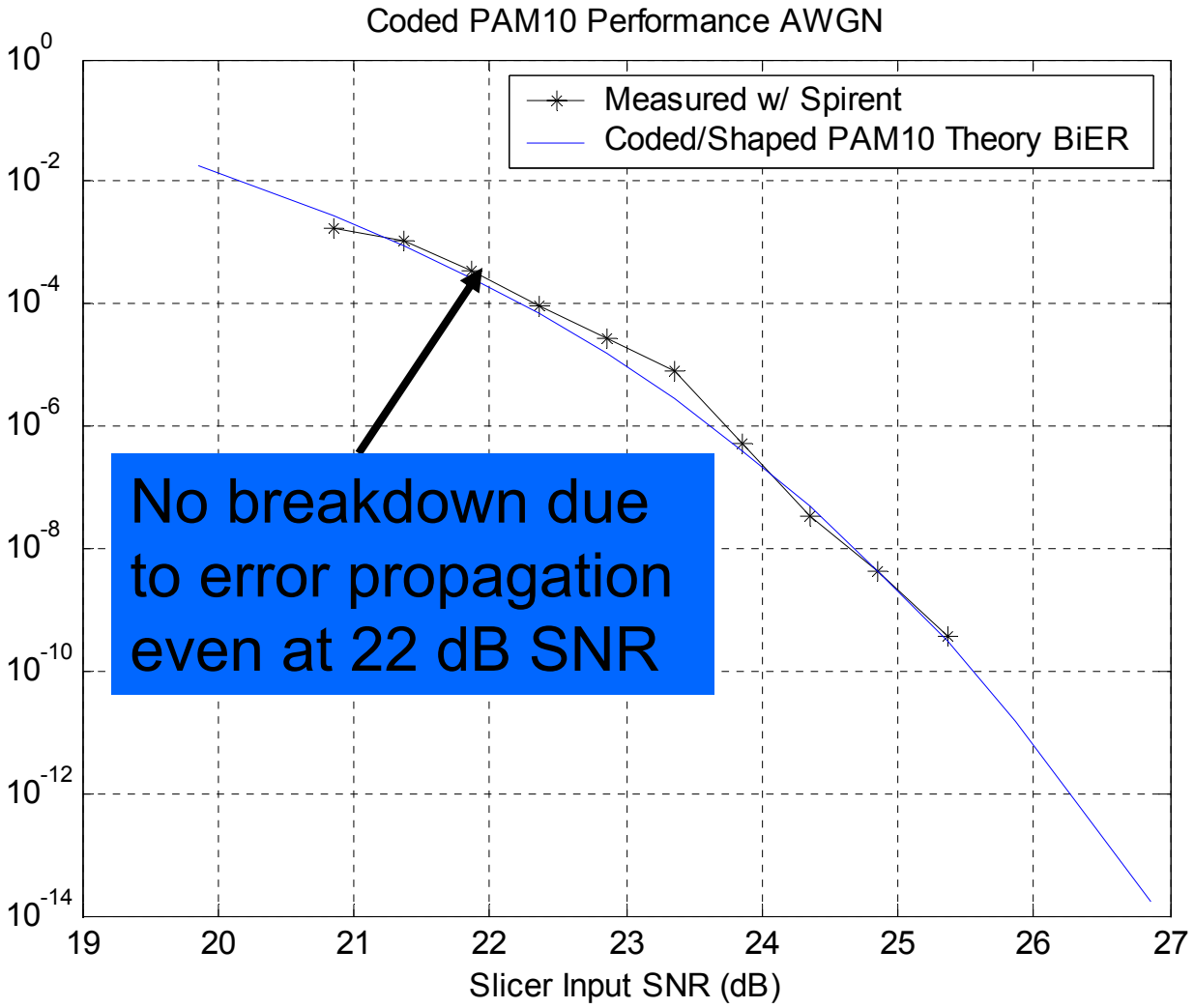
Actual "Model 2" (55m) = 28.9 dB SNR

Coding gain required is 2.5-3 dB less

DFE Error Propagation References are Old and not Relevant

- Main references are from Voice band modem work, or high error rate DSL systems
  - M.V. Eyuboglu, 1988 – Voice band modem work
    - Target BER ~ 1e-4 to 1e-6
    - Operating SER ~ 1e-1
  - VERY high uncoded error rate
  - No DSP to mitigate or shape coefficient size
- 10GBASE-T, 2004
  - Target BER ~ 1e-12
  - Operating SER < 1e-3
- Prob. Error Prop ~ (Prob Sym Error^{N}), N=1/(largest coef size/error threshold)
  - Limiting larger coefs < .2 keeps Prob. Error Prop < 1e-15
  - Confirmed by lab and simulation results over variety of cables

Laboratory Results



Claimed Benefits are Questionable

- Coded Modulation and Equalization NOT decoupled
- No analog savings in Echo/NEXT limited systems
- Error propagation not mitigated when decision-directed FEXT mitigation is required

Decoupling Coding & Equalization?

- Couples code to equalization through constellation choice
- Eliminates Shaping Gain from coding strategies (up to 1.5 dB loss)
- TH precoding loss relative to coding depends on constellation
  - Can be tricky

Precoding Loss = 0.43 dB

Analog Requirements

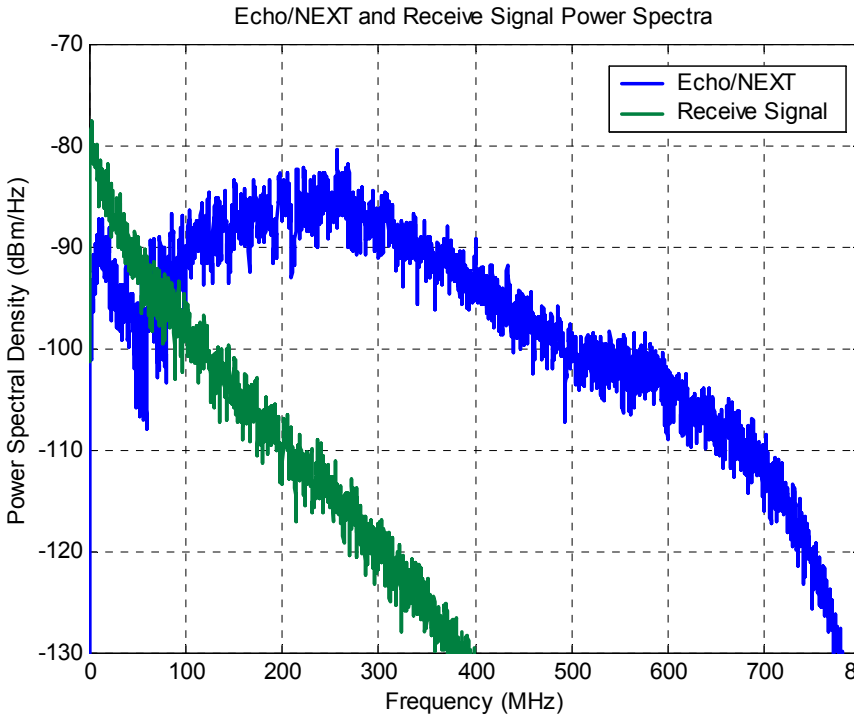
- Transmitter and receiver linearity requirements:
  - Driven by Echo & NEXT Cancellation (~50-60 dB)
    - Complexity is independent of equalization strategy
  - Confirmed by Precoding presentation
- No analog complexity savings with TH Precoding
- No change to the transmit spectrum required for DFE shaping (see separate presentation)

PAR Enhancement and AFE

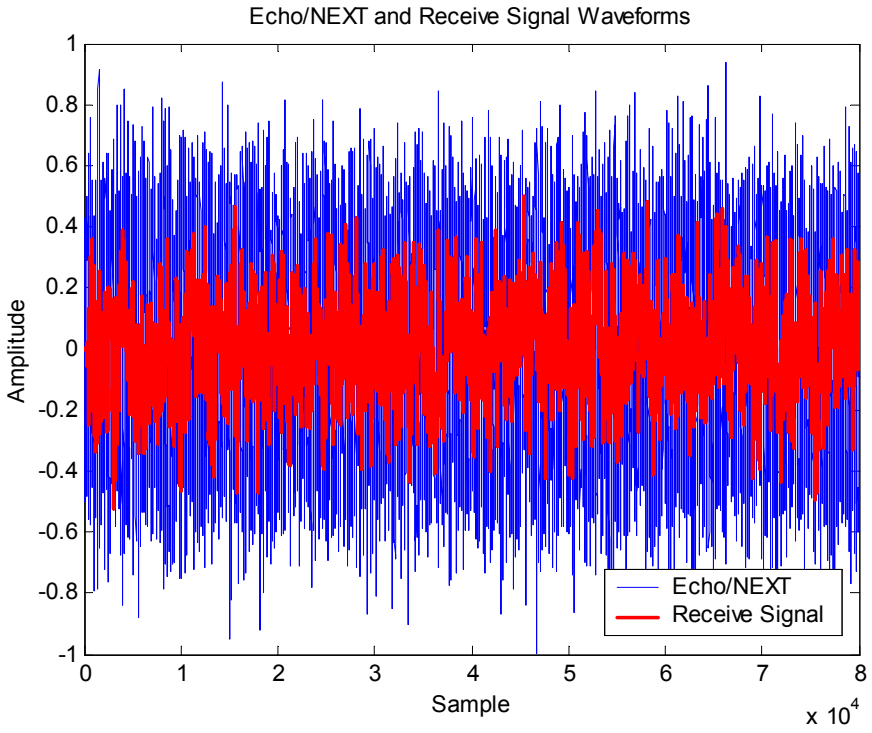
- Analog headroom drives linearity
- Precoding peak power depends highly on the constellation choice
  - "About 1 dB" (Precoding proposal)
  - Could use this for higher TX power or AFE savings (1 dB = 26% power, 12% voltage)
  - High-probability peaks cause "shaping loss" and linearity issues
    - Shaped or Gaussian constellations would be less damaging to AFE due to low probability peaks

Received Signal & Echo

- **Echo/NEXT dominates received signal on long lines**
  - **No AFE linearity savings from equalization or line code**



100 meter channel, 11 dB hybrid rejection



100 meter channel, 11 dB hybrid rejection

Does Error Propagation Really Go Away?

- Linear FEXT Cancellation limited by:
  - "Inverse SNR" relation (FEXT leakage to other channel)
    - Maximum cancellation < 1/SNR
      - For 55m Cat6, limitation is < 14 dB
      - Causes 1 to 2.5 dB margin loss on Models 1 & 2
  - In addition, Alien NEXT in adjacent pair adds to noise
- Decision-based techniques re-introduce error propagation
- Techniques compatible with TH Precoding providing sufficient gain need to be demonstrated

Conclusion

- Equalization, Noise mitigation, and Coding strategies are interdependent
- A decision should not be made independently