Coding for 10GBASE-T:
RS and TCM

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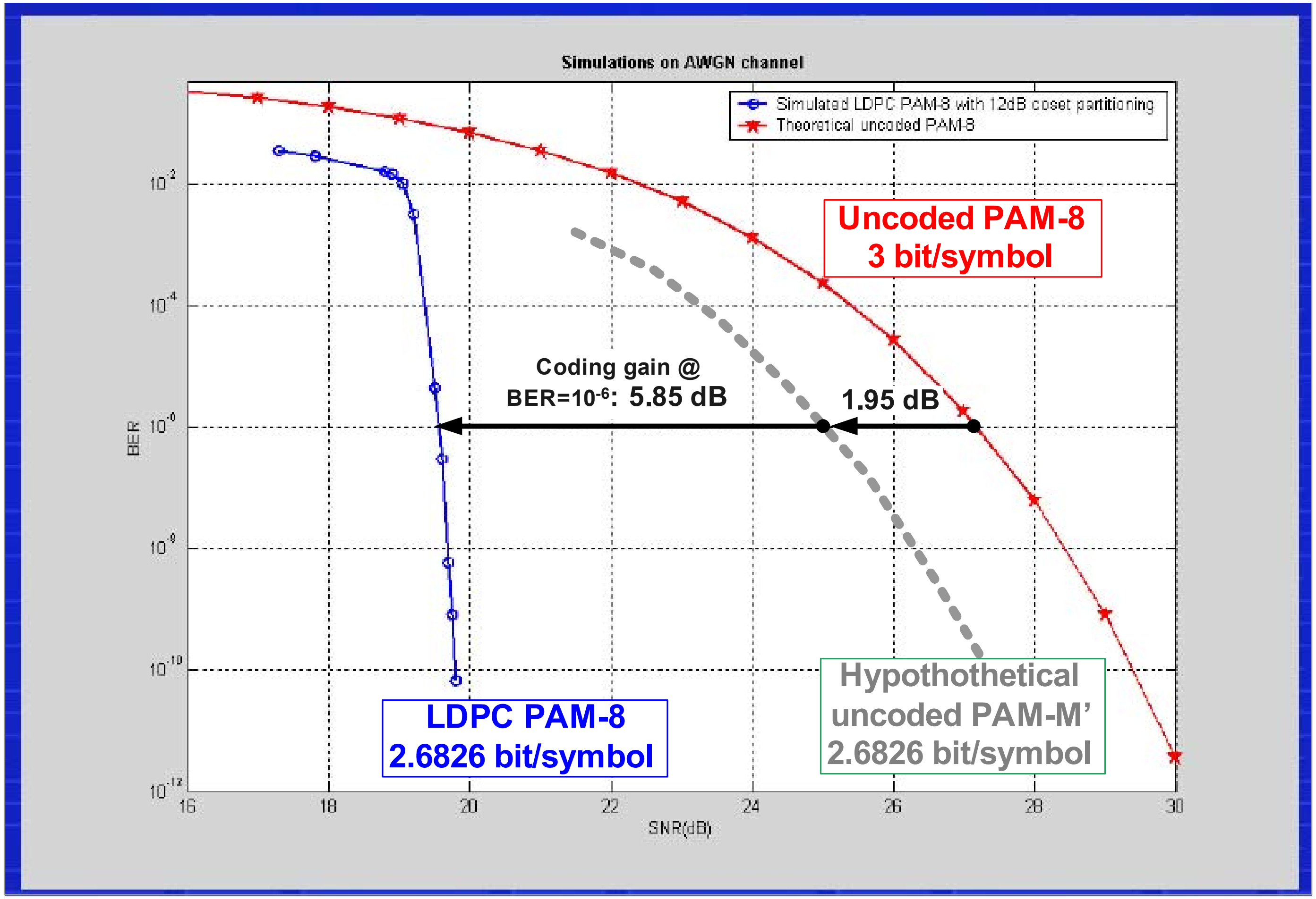
Gottfried Ungerboeck

Agenda and Objective

- Current proposals for 10GBASE-T
  - ❖ LDPC PAM-8
  - ❖ RS + TCM PAM-8
- Further details on RS + TCM
- Understand performance differences
- Discuss latency
- Conclusions

LDPC PAM-8

Slide adapted from “The 4-D PAM8 Proposal for 10GBASE-T” by Sailesh Rao et al., IEEE 802 Plenary, Albuquerque, Nov 10-13, 2003; 10GBASE-T Working Group)



$$R = \frac{2747}{1024} = 2.6826 \text{ bit/PAM symbol} \Rightarrow M' = 2^R = 6.4201 \Rightarrow \frac{E_{PAM-8}}{E_{PAM-M'}} = \frac{8^2 - 1}{M'^2 - 1} \triangleq 1.95\text{dB}$$

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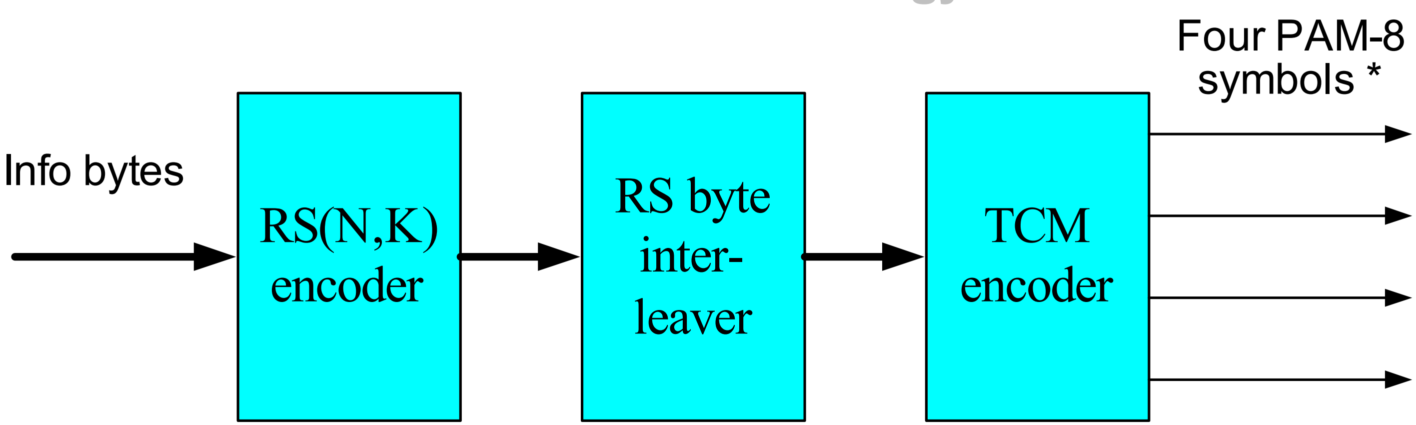
RS + TCM PAM-8

Well known technology



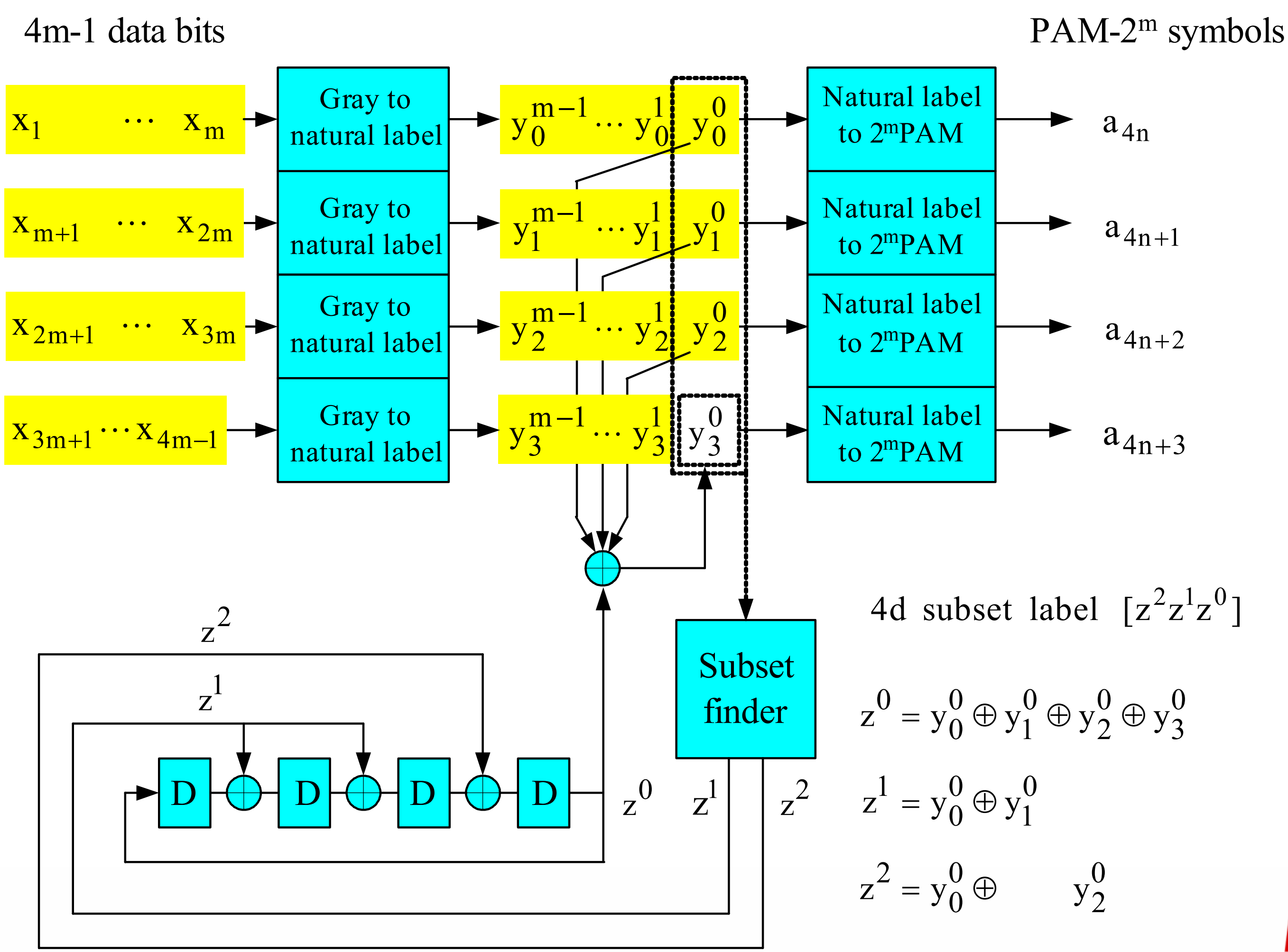
RS(255,239)
over GF(2^8)

16-state 4-dim TCM,
feedback form with
Gray mapping

Code rate = 239/255 x 11/4 = 2.5775 bit/PAM symbol

* transmitted in parallel over four wire pairs

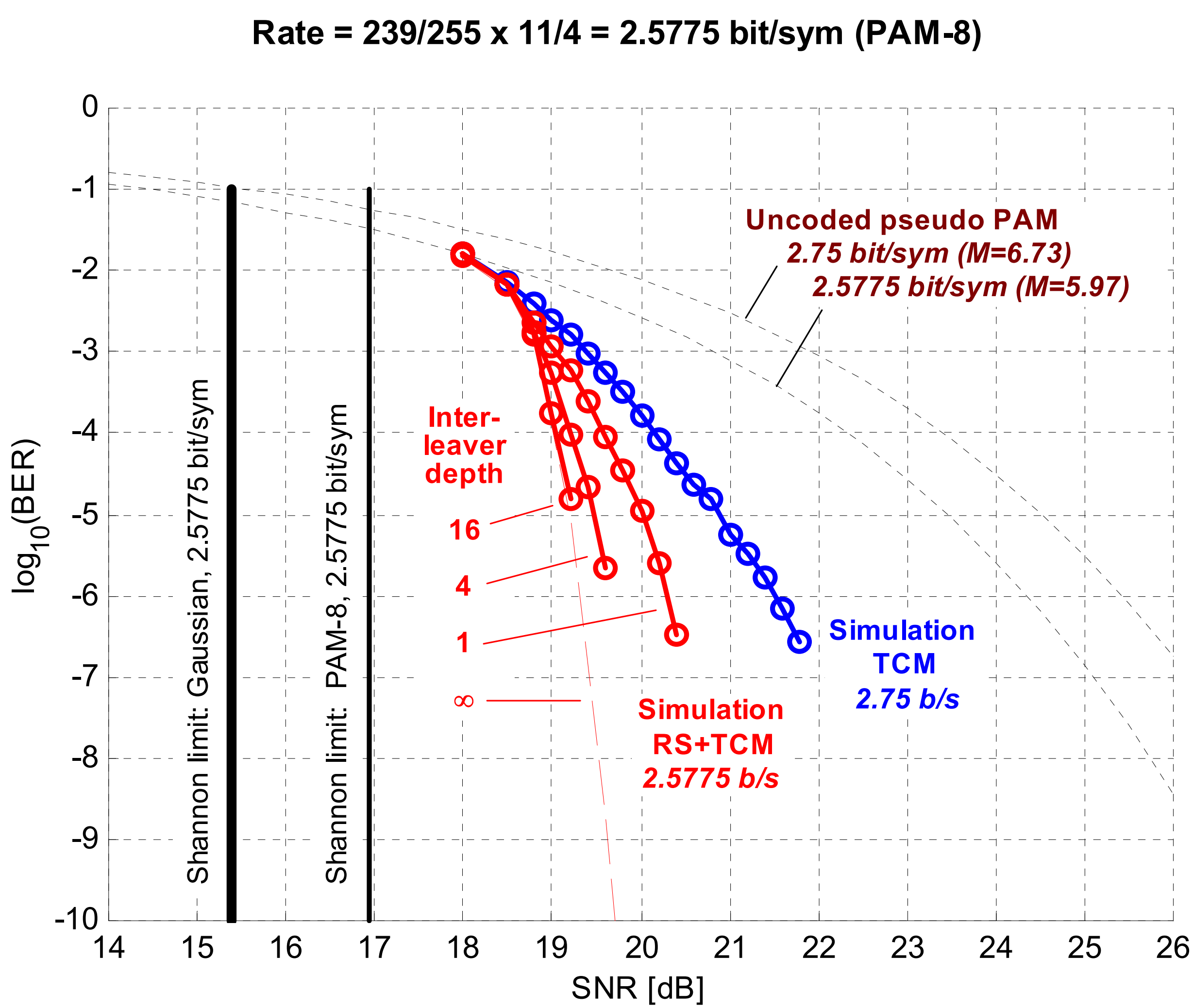
16st 4d TCM encoder for PAM-2^m: compact definition



16st 4d TCM PAM: features

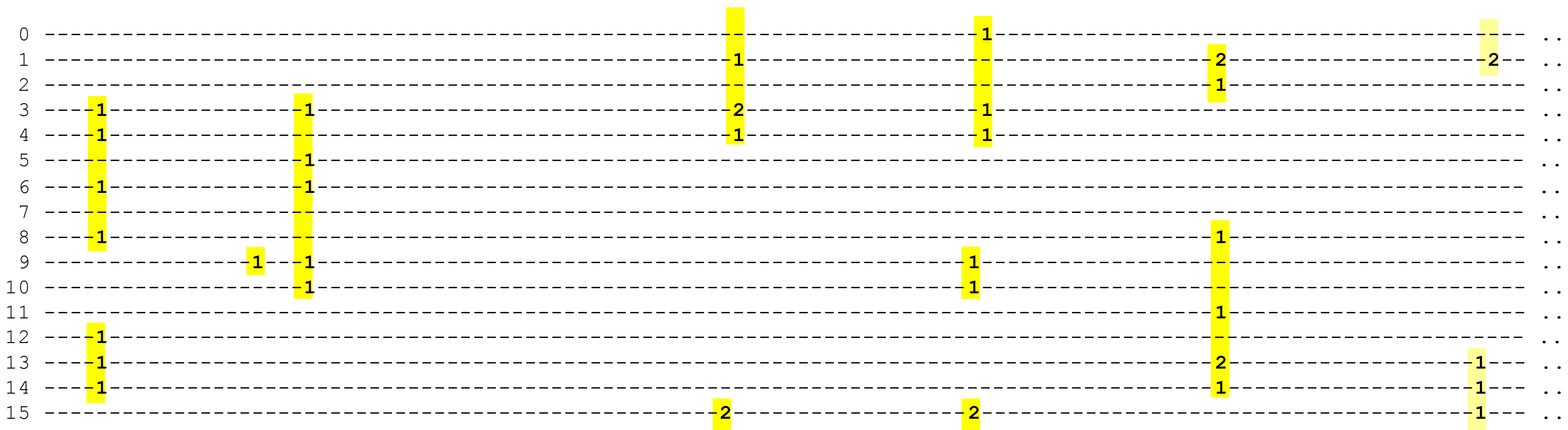
- Feedback form permits separation of trellis diagram (FSM) from mapping of info bits to symbols …
- hence allows for Gray mapping $\rightarrow$ few bit errors per error event.
- Symbol mapping is compactly defined in algebraic form; 4d symbol mapping is based on 1d symbol mappings with a translation from Gray mapping to natural mapping.
- Code differs from as TCM codes of V.34/V.90 and ADSL, but achieves same performance; asymptotic coding gain 4.5 dB.

Performance of RS(255,239) + 16st 4d TCM PAM-8



16st 4d TCM PAM-8: byte error events

- 16 RS(255,236) codewords interleaved (I = 16)
- bytes are transmitted column-wise
- numbers indicate # wrong bits in errored bytes



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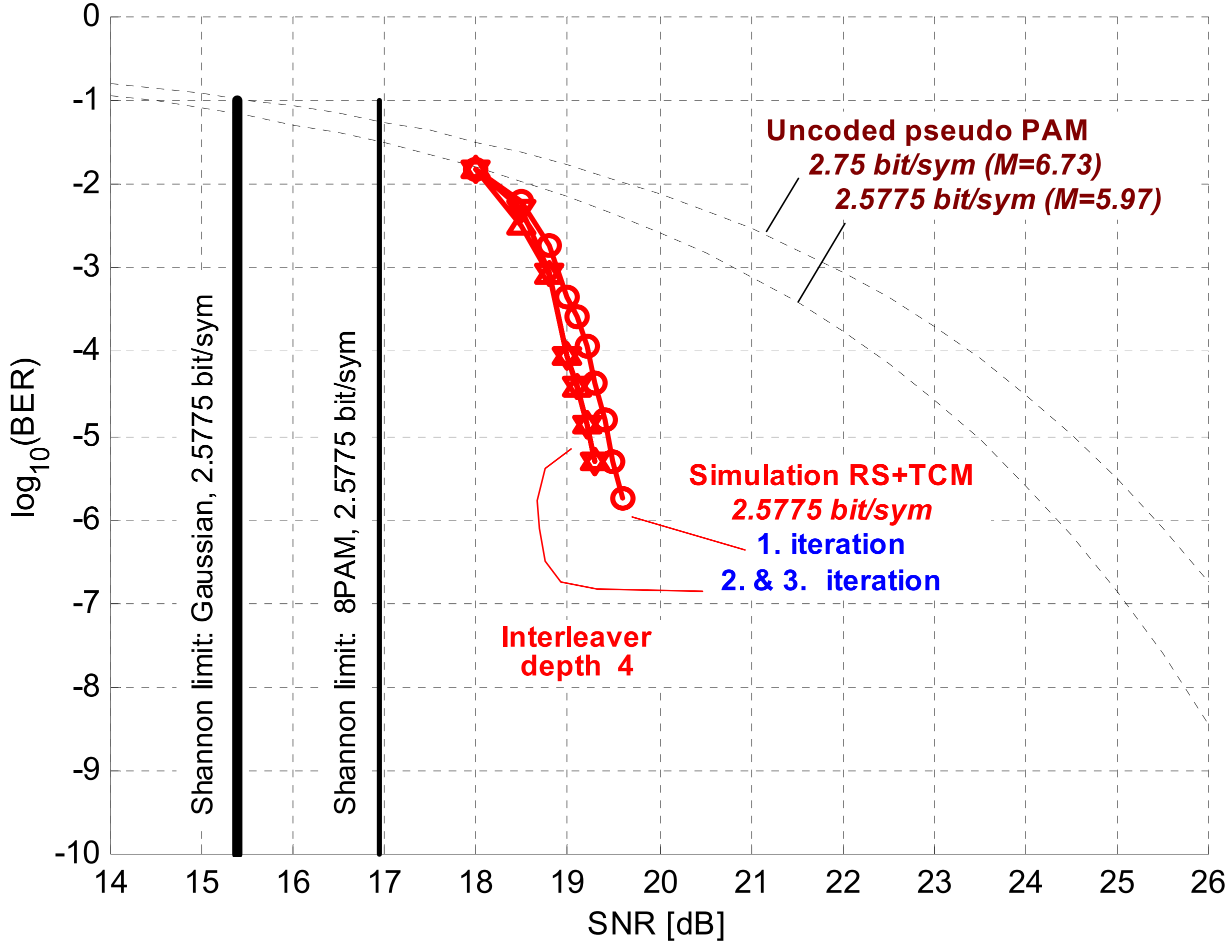
Performance of RS(255,239) + 16st 4d TCM PAM-8

Iterative TCM-RS-TCM-RS … decoding



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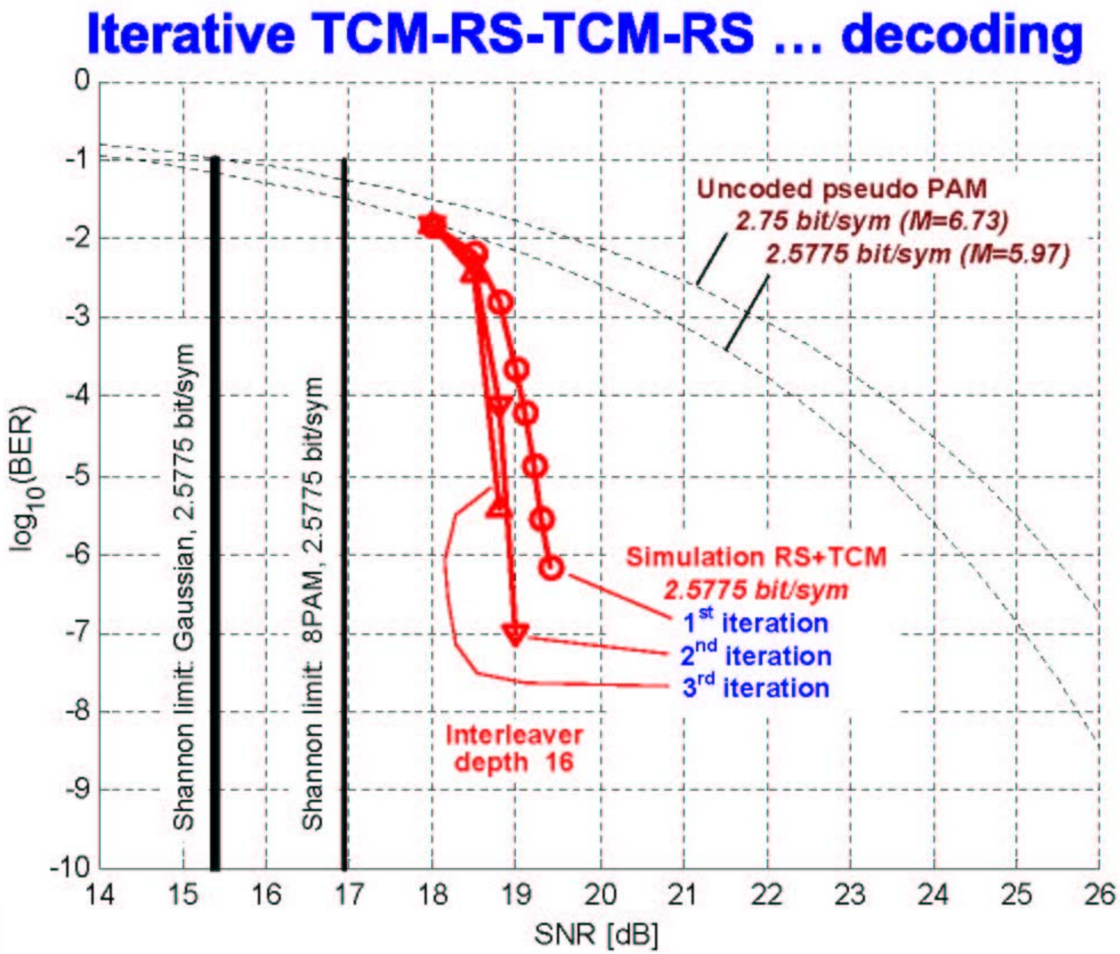
Performance of RS(255,239) + 16st 4d TCM PAM-8



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Latency

Latency = β (>1) $\times$ block length (BL) + decoding time + filter delays + signal processing delays + propagation delay + …

- **LDPC 8-PAM**

  BL = 2747 info bits / 10Gbps = 275 ns

- **RS(255,239) + Intleav (I) + 16st 4d TCM PAM-8**

  I = 1 : BL = 239 x 8 info bits / 10Gbps = 191 ns

  I = 8 : BL = 239 x 8 info bits / 10Gbps = 1530 ns

Conclusions

- LDPC PAM-8 has short block length (BL), hence potentially lower latency.
- RS + TCM PAM-8 with sufficient byte interleaving achieves equal or better coding gain, has simpler and well-understood decoding, and proven absence of error floor (additional coding gain can be obtained through decoding iterations).
- RS + TCM PAM-8 permits by-passing in a receiver with sufficient SNR (short links) de-interleaving and RS decoding, thus achieving low latency with TCM coding gain only.
- Latency in 10GBASE-T transceivers is likely dominated by signal-processing delay.