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Leveraging 400G ZR FEC Technology

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OIF 400G ZR FEC Potential Benefits

1. Provides ~ 4 dB additional gain over KP4 => can be used to extend reach of 400GbE direct detect PAM4 to 40km and/or for lower cost optics

2. Increases FEC threshold from ~ 1.e-4 to ~ 1.e-2 => smaller penalties from Tx/Rx imperfections, RIN, dispersion, etc.

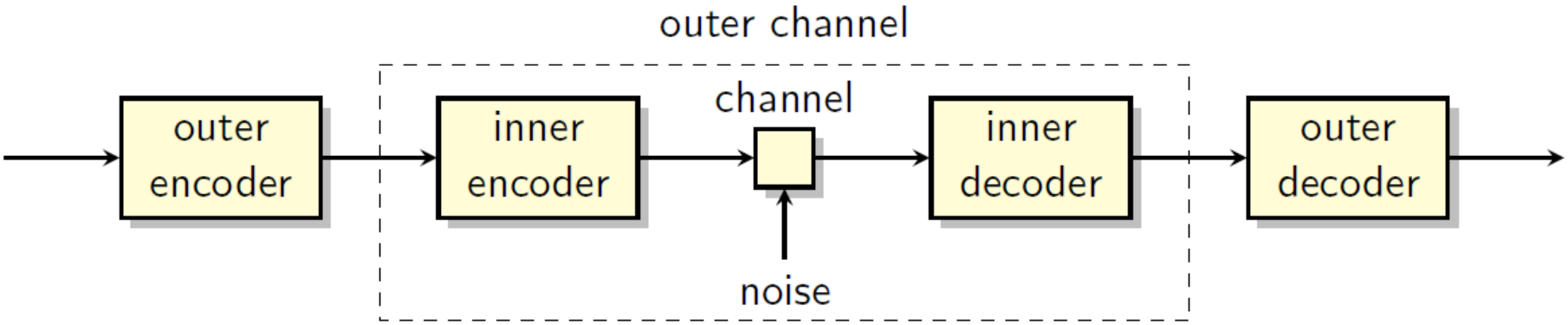
3. Enables a low cost 400GbE coherent solution for 80km (coherent QAM systems may have high error floors due to laser phase noise, DAC/ADC quantization noise, etc.)

4. Leverages industry investments in 400G ZR FEC

OIF 400G ZR FEC Overview

- Concatenated FEC
- Soft decision inner – Hamming (128,119) Code
- Hard decision outer – Staircase Code (255,239)
- 10.8dB NCG, 16QAM
- FEC overhead = 14.8 %
- Low Power

Concatenated Codes (Forney, 1966)

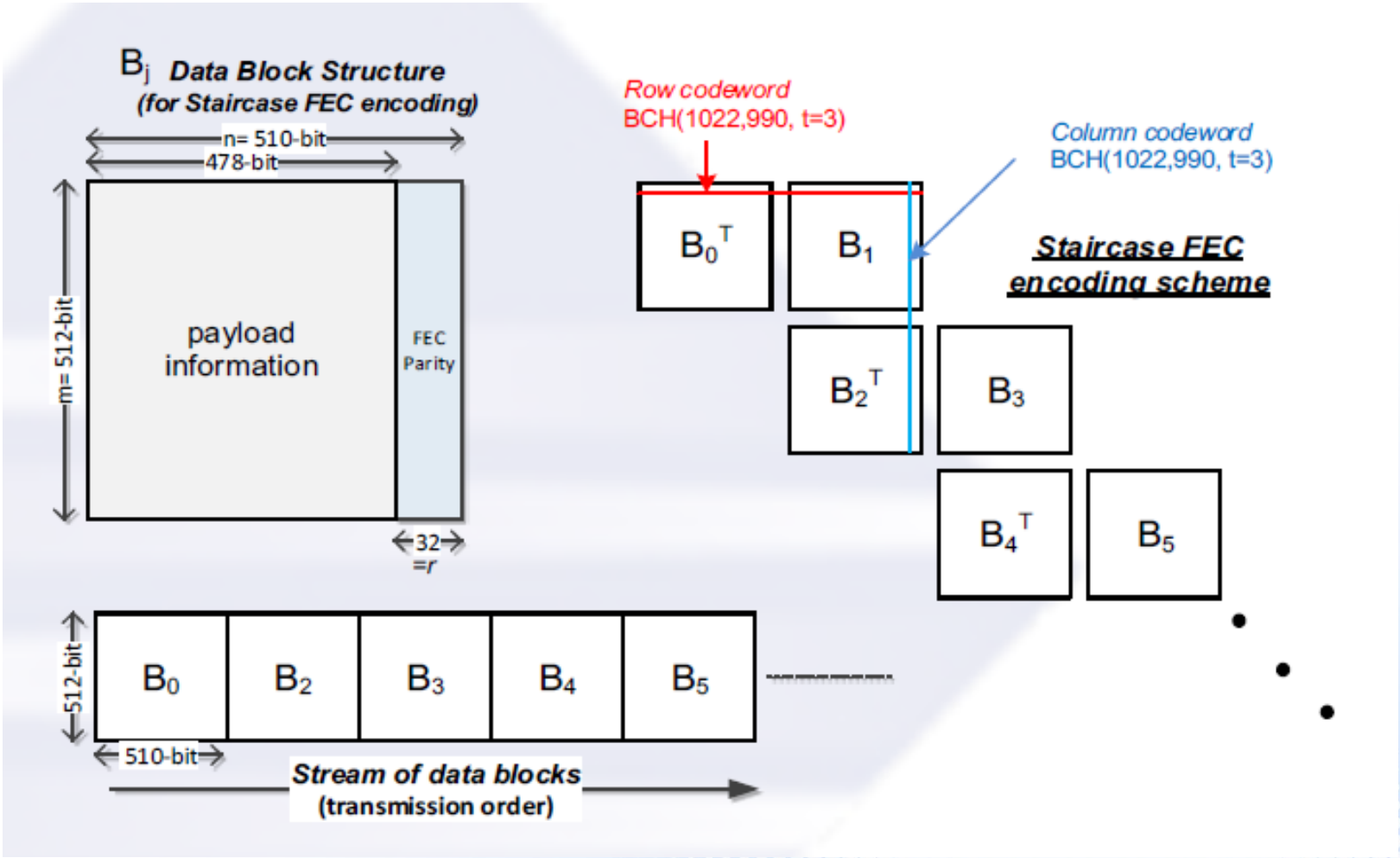


Concatenated codes: use two or more codes in tandem

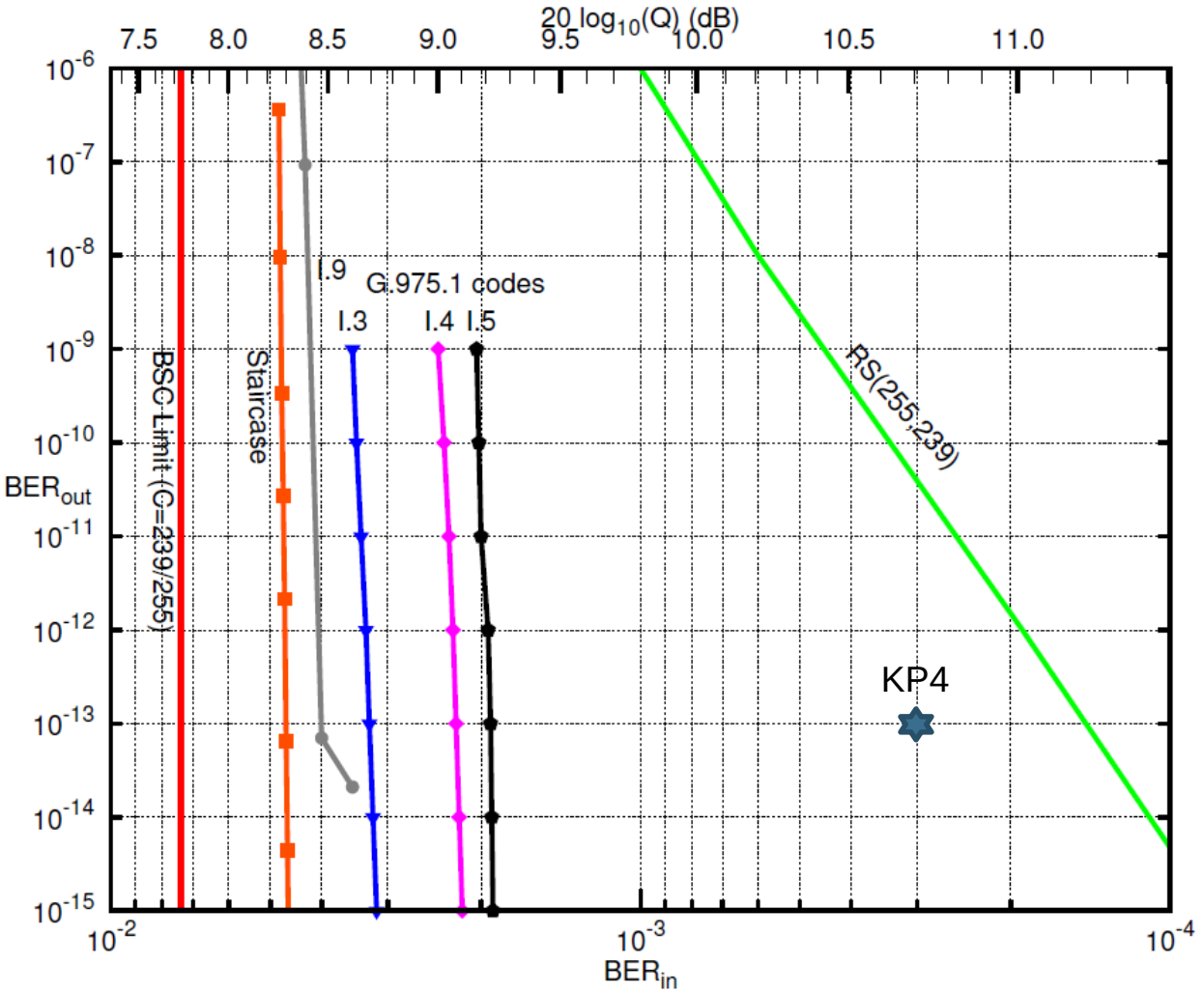
- **inner code** (code closest to the channel) is well-tuned for the particular channel
- **outer code** "cleans up" the errors left by the inner code
- overall rate $R = R_{\text{inner}} \cdot R_{\text{outer}}$
- often the inner code can perform soft-decision decoding

Source: Frank Kschischang, "Introduction to Forward Error Correction," *OFC Short Course*, 2017

Outer Code: Hard Decision Staircase FEC

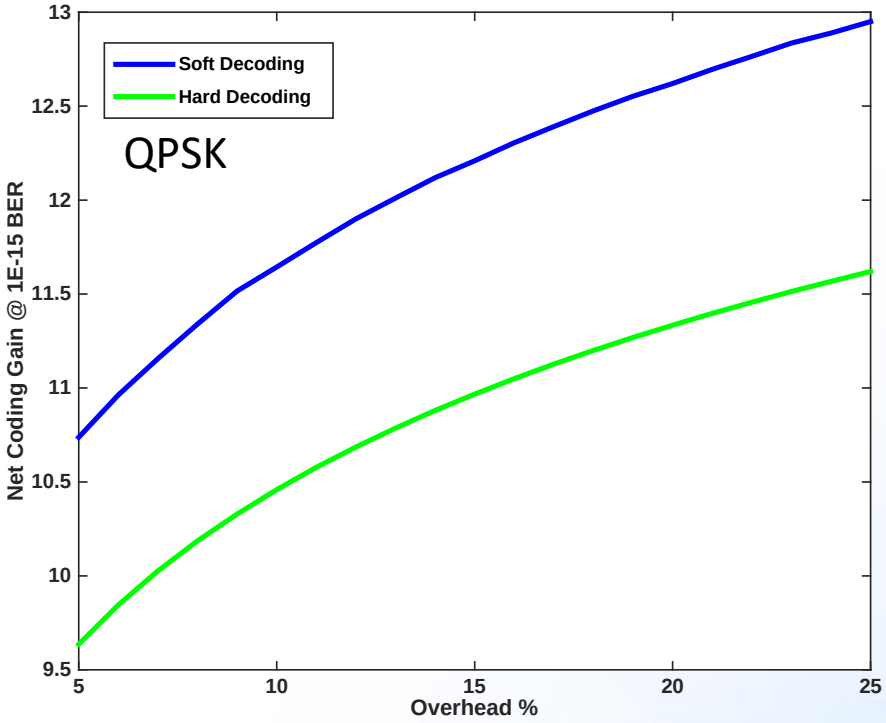


Comparison Hard Decision FECs



See: B. P. Smith, A. Farhood, A. Hunt, F. R. Kschischang, and J. Lodge, "Staircase Codes: FEC for 100 Gb/s OTN," *J. Lightwave Techn.*, vol. 30, January, 2012, pp. 110–117.

Soft Decision Decoding



BSC	Hard	Soft	Extra NCG
7%	10	11.1	1.1
15%	10.95	12.2	1.25
20%	11.3	12.6	1.3
25%	11.6	12.9	1.3

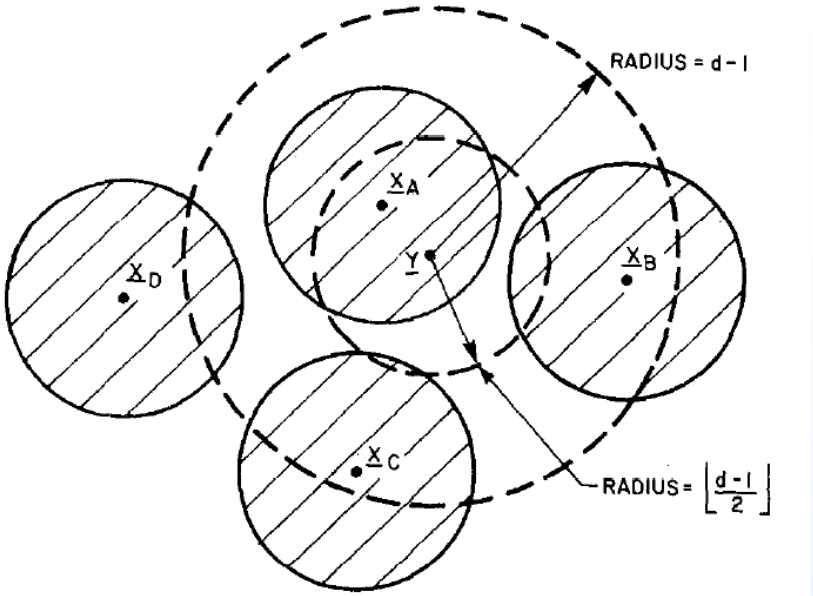
- Soft FEC operating at 15% OH provides 0.6dB higher NCG than HDFEC at 25% OH
- SFEC at 15% OH helps lower the baud rate
- Lower baud rate reduces power consumption

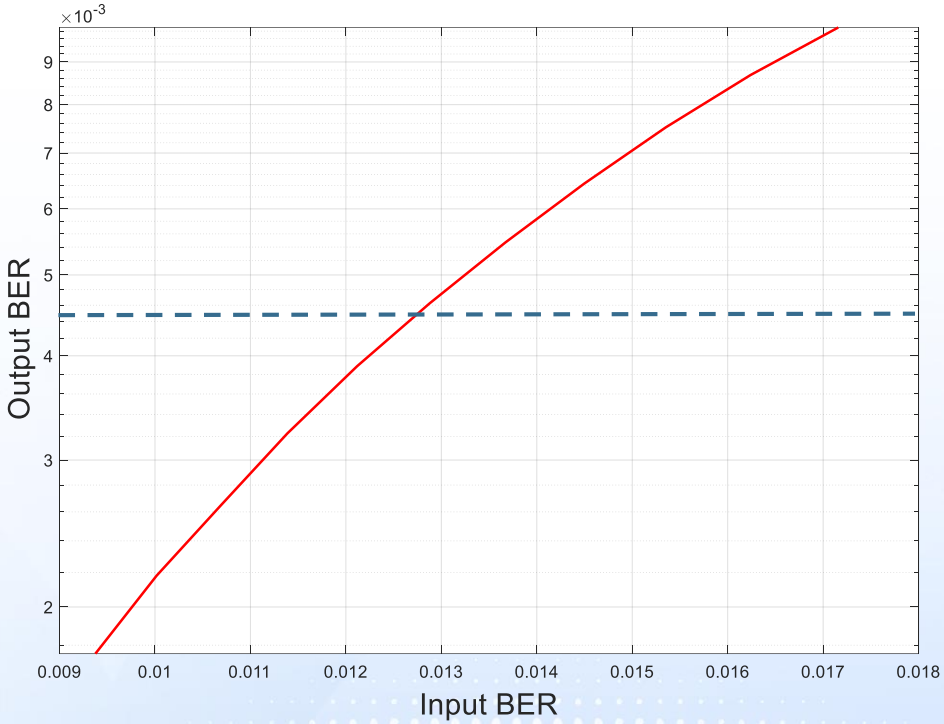
Inner Code: Soft Decision Hamming

Double-Extended (128,119) Hamming Code

Chase Algorithm Soft Decoding

Low-Complexity, Near-ML





David Chase, "A Class of Algorithms for Decoding Block Codes with Channel Measurement Information," *IEEE Trans. Inf. Theory*, 1972

FEC Comparison

FEC type	KP4 RS(544,514,15)	Staircase FEC	Concatenated Hamming + Staircase FEC
Overhead	5.8%	6.7%	14.8%
NCG (PAM4/16QAM)	6.9 dB	9.76 dB	10.8 dB
FEC Threshold (BER = 1.e-15)	2.3e-4	4.5e-3	1.25e-2
Power	P	~ 2.5*P	~ 3*P
Latency	t	~ 100*t	~ 100*t

Conclusion

- Presented an overview of OIF 400G ZR FEC architecture
- 4 dB higher coding gain, and 2 orders of magnitude higher BER threshold compared with KP4
- Low power “strong FEC”
- Leverages industry investments in OIF 400G ZR project