PAM8 & FEC Options

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Supporters

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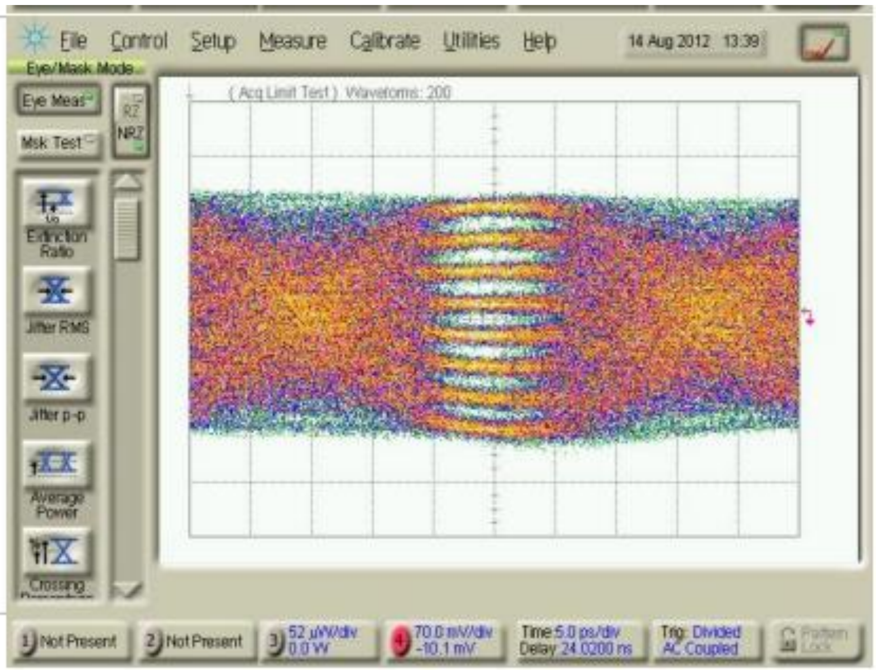
- Mark Nowell, Cisco
- Beck Mason, JDSU

PAM8 Introduction

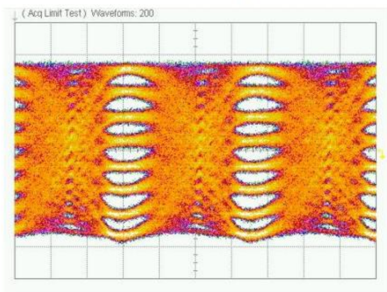
32 Gbaud, 8 PAM electrical eye, using DAC



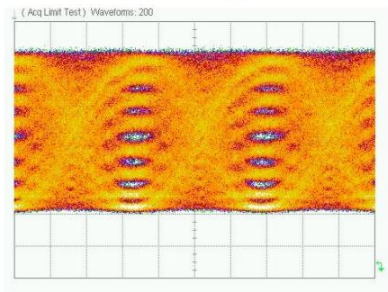
http://www.ieee802.org/3/bm/public/sep12/lewis_01_0912_optx.pdf

28 GBaud

electrical signal

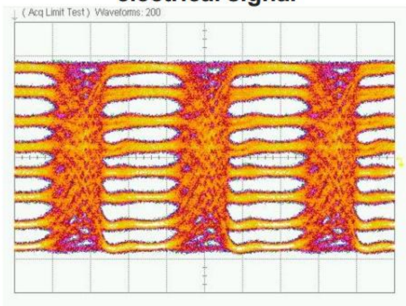


optical signal

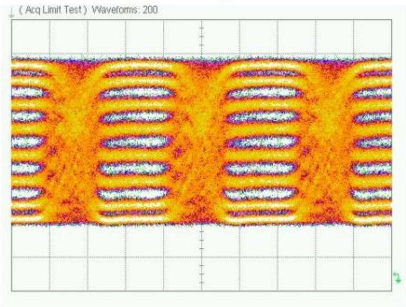


10 GBaud

electrical signal



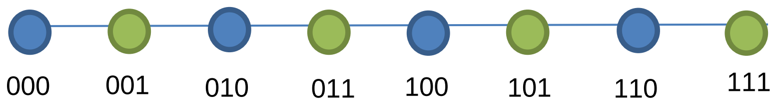
optical signal



http://www.ieee802.org/3/100GNGOPTX/public/jul12/schell_01_0712_optx.pdf

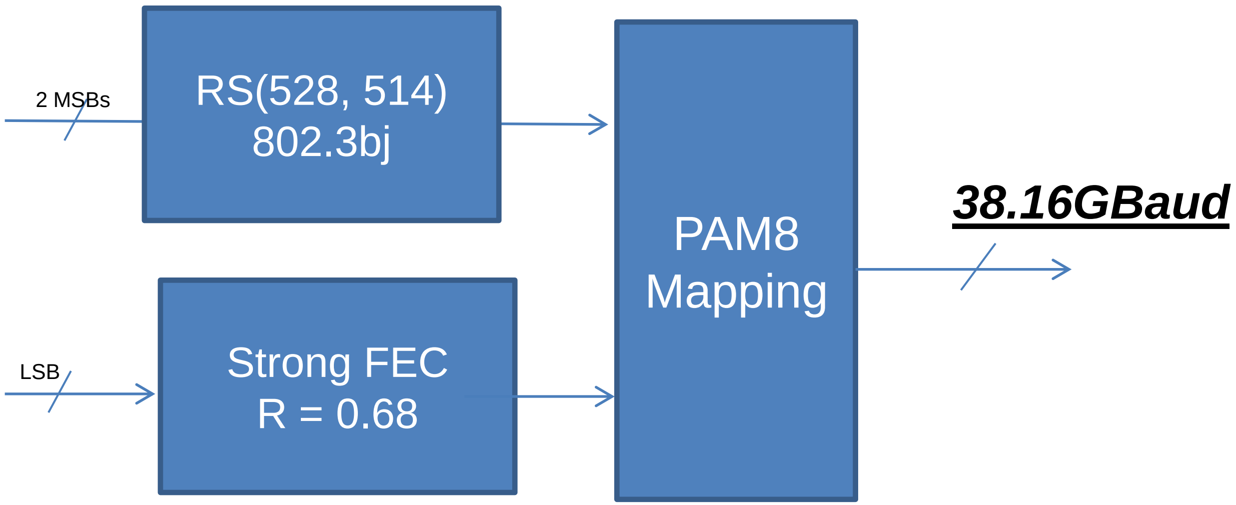
- PAM-8 measurements results have been presented at .bm
- EML is used as light source and external modulator
- In this presentation, we propose a mapping and FEC options for PAM8
    - ➢ Follow on to presentation from bhatt_01a_0912

Option 1: PAM8 Coded Modulation



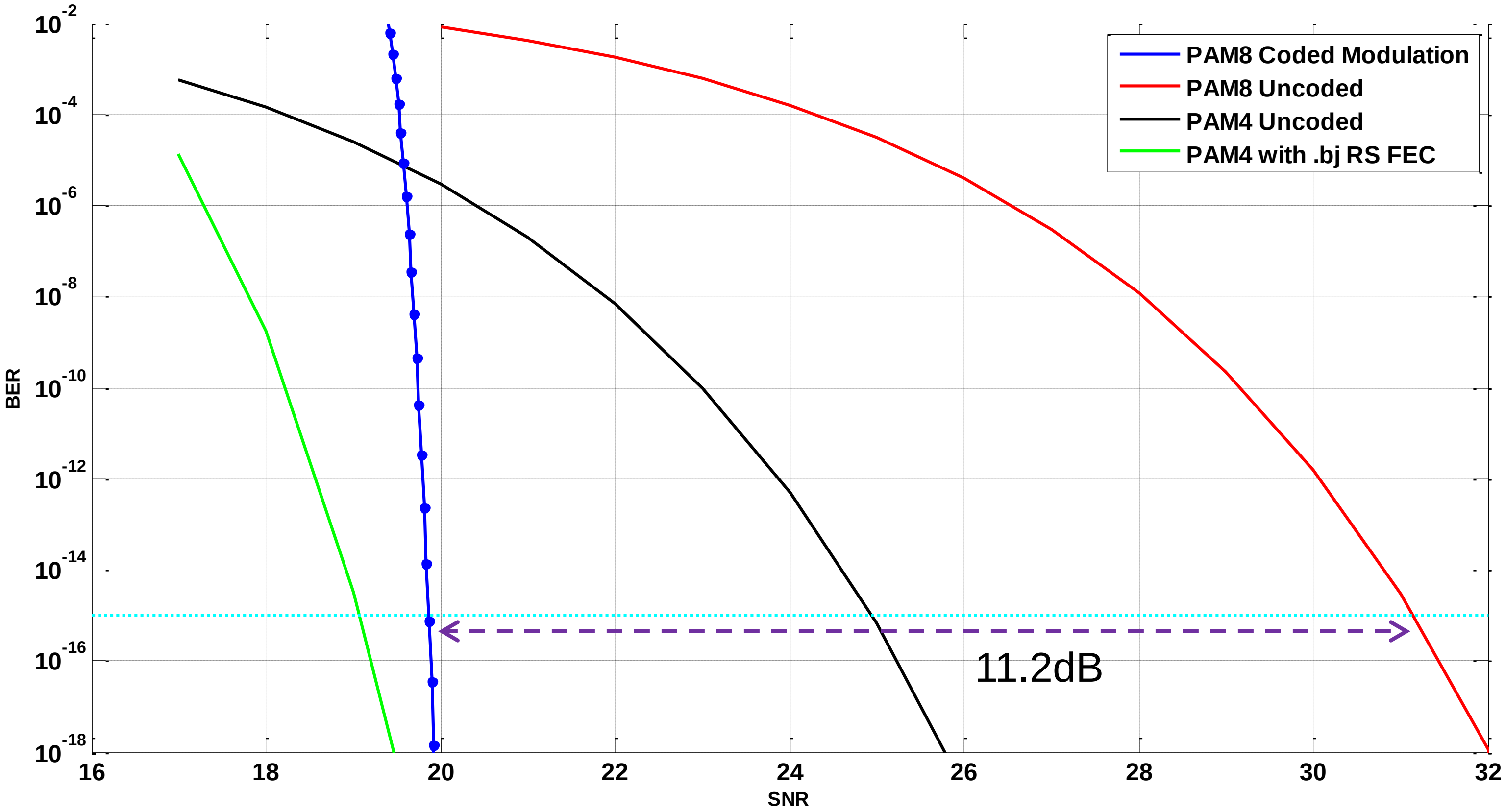
- PAM8 is partitioned into 2 subsets, Blue & Green
- High rate code is applied on the 2 MSB's.
  - .bj RS FEC for 2 out of 3 bits. Throughput 76Gb/s
  - Lower power than .bj FEC running at 100Gb/s
  - 2 MSB's gain 6dB in distance after set partitioning.
  - .bj FEC provides additional 5.7dB in addition to 6dB set partitioning gain
- LSB is coded with a low rate strong hard decision FEC
  - 11.2dB FEC code is applied at 38Gb/s

PAM8 Coded Modulation Example



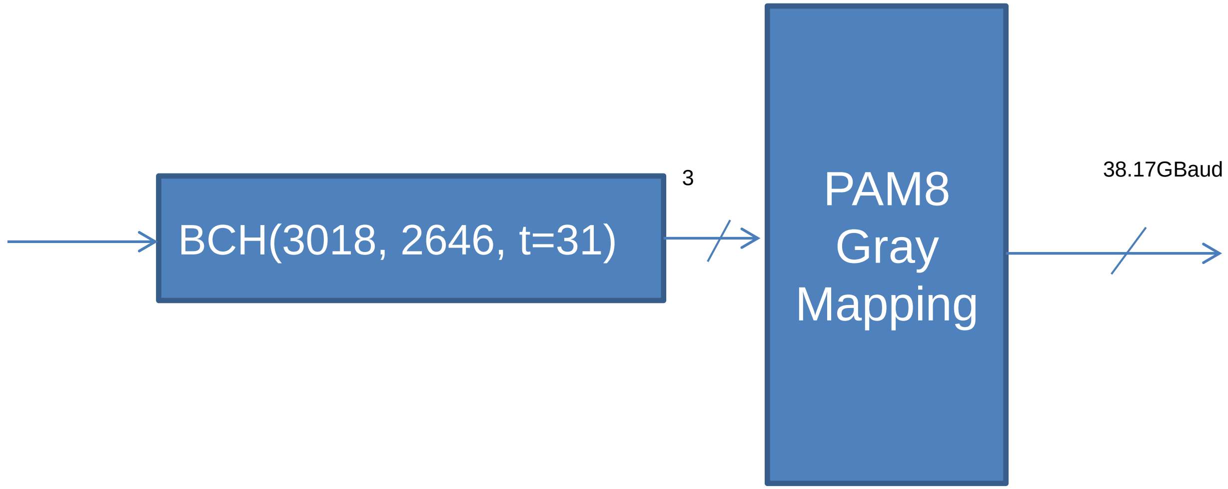
- Combined rate: (2 * 514/528 + 0.6836) / 3 = 0.8769
- Ethernet Rate = 100/3 * 257/256 * 1/0.8769 = 38.16 GBaud

Option 1: Coded Modulation Sim Results



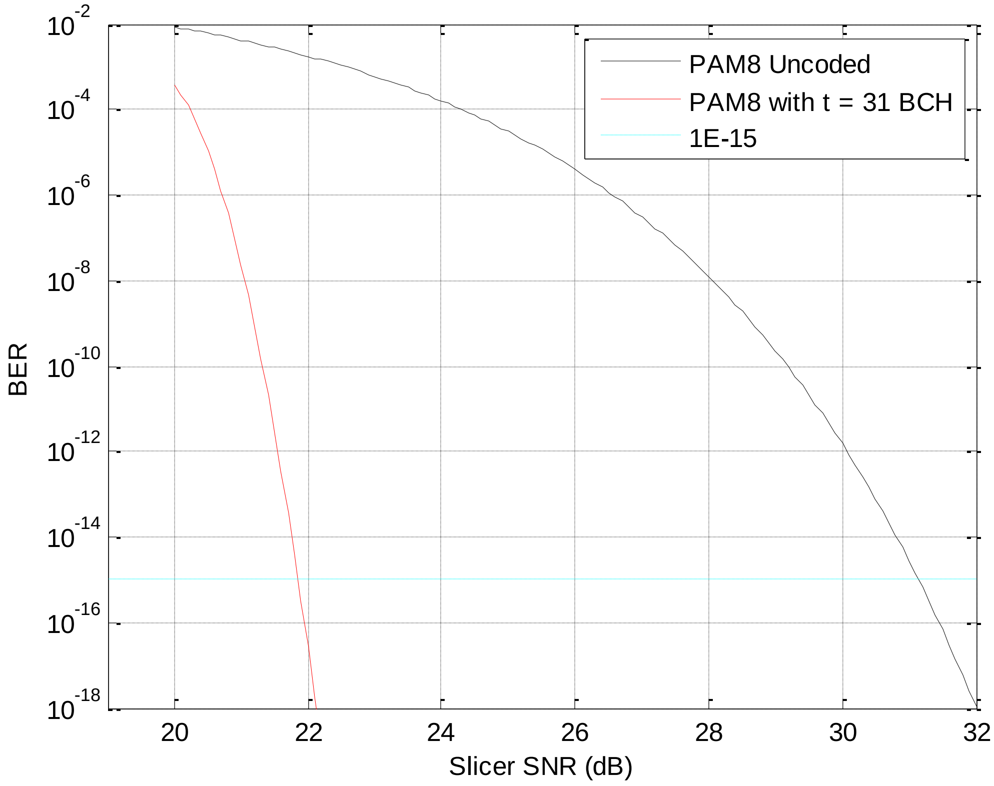
- PAM8 coded modulation FEC delivers 11.2dB coding gain

Option 2: PAM8 with low latency



- Gray Mapping
- Total FEC latency is 115ns. BCH targets 2E-3 input BER
- Ethernet Rate = 3018 / 2646 * 100 * 257/256 / 3 = 38.17G

Option 2: PAM8 with BCH



- PAM8 with BCH FEC delivers 9.2dB coding gain

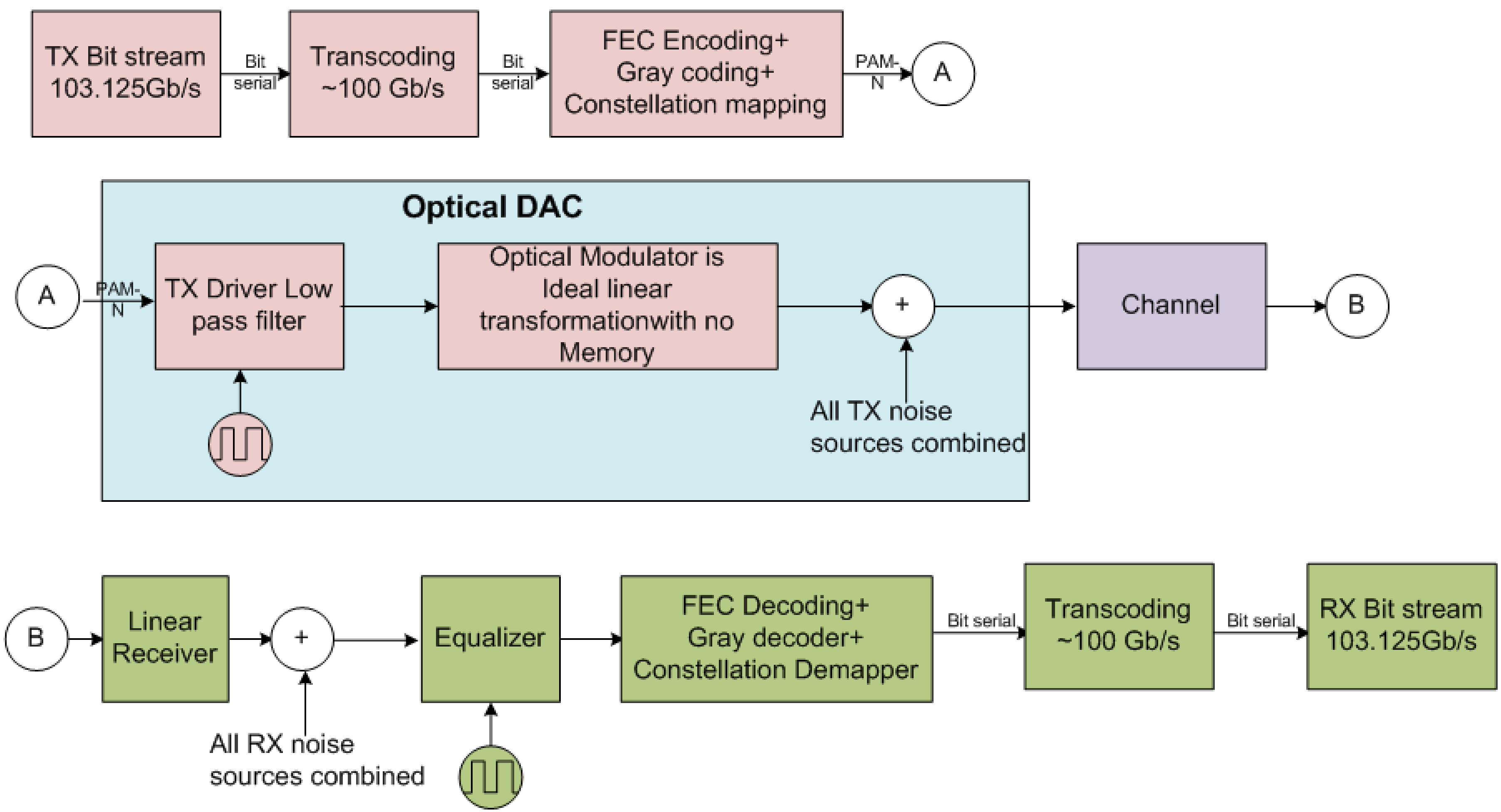
PAM8 Slicer SNR Summary

	PAM8 Option1 (Coded Mod)	PAM8 Option 2 with BCH	PAM4 with .bj RS
Baud rate	38.16G	38.17G	51.56G
FEC Target BERi for 1e-15 BERo	9E-3	2E-3	2.2E-5
FEC Latency	600ns	115ns	100ns
Ideal Required Slicer SNR	19.9dB	21.9dB	19.1dB
Relative SNR penalty	-0.8dB	-2.8dB	Ref
Relative Noise BW penalty	Ref	Ref	-1.27dB
Total Penalty	-0.8dB	-2.8dB	-1.27dB
Relative Margin	Ref	Ref-2dB	Ref-0.47dB

PAM Options Comparison

	PAM8 Coded Modulation	PAM8 BCH	PAM4 .bj RS
Baud rate	38.16G	38.17G	51.56G
FEC Target BERi for 1e-15 BERo	9E-3	2E-3	2.2E-5
Latency Target	<600ns	<115ns	<100ns
Coding Overhead	14.04%	14.04%	2.72%
Mapping / Coding gain	11.2dB	9.2dB	5.8dB

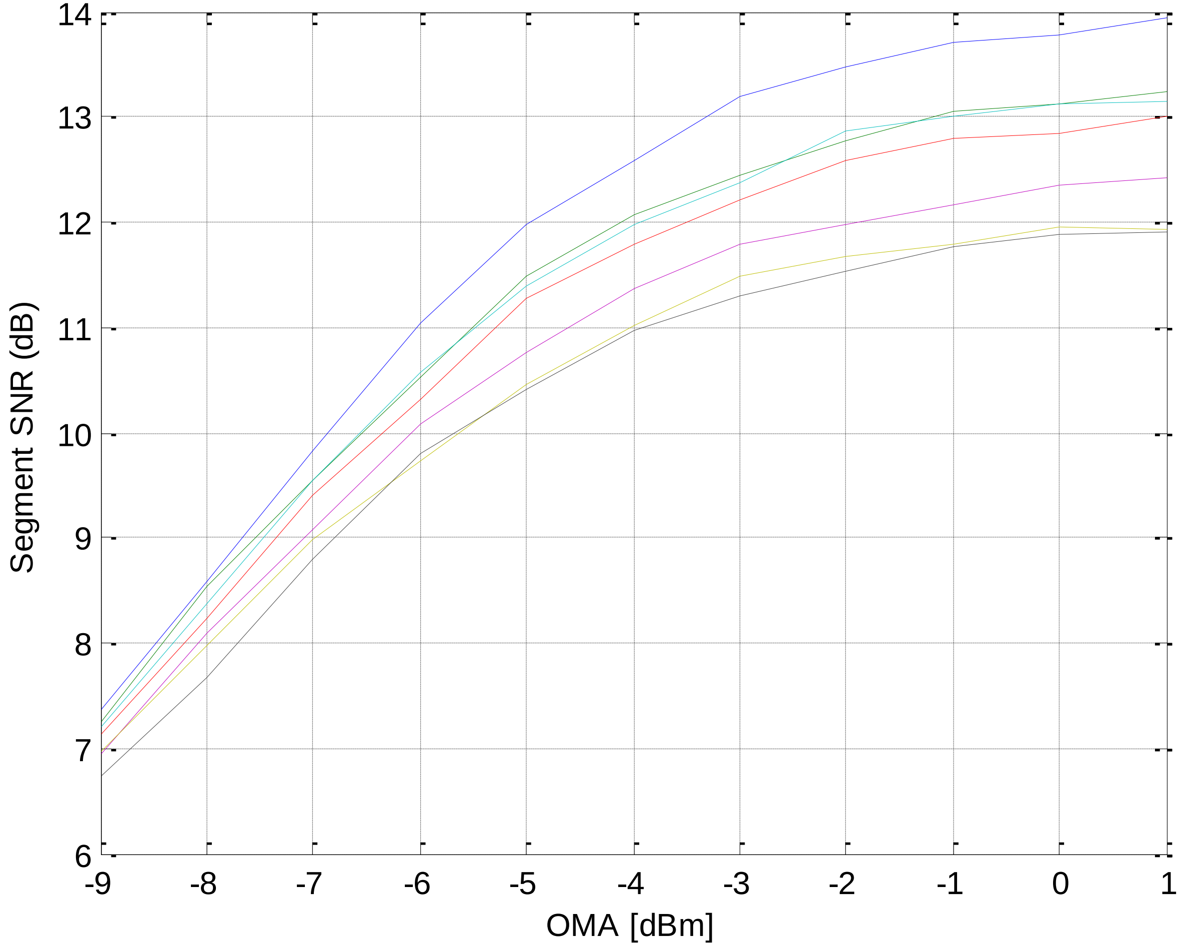
Unipolar PAM-N High-Level Block Diagram



Simulation Parameters

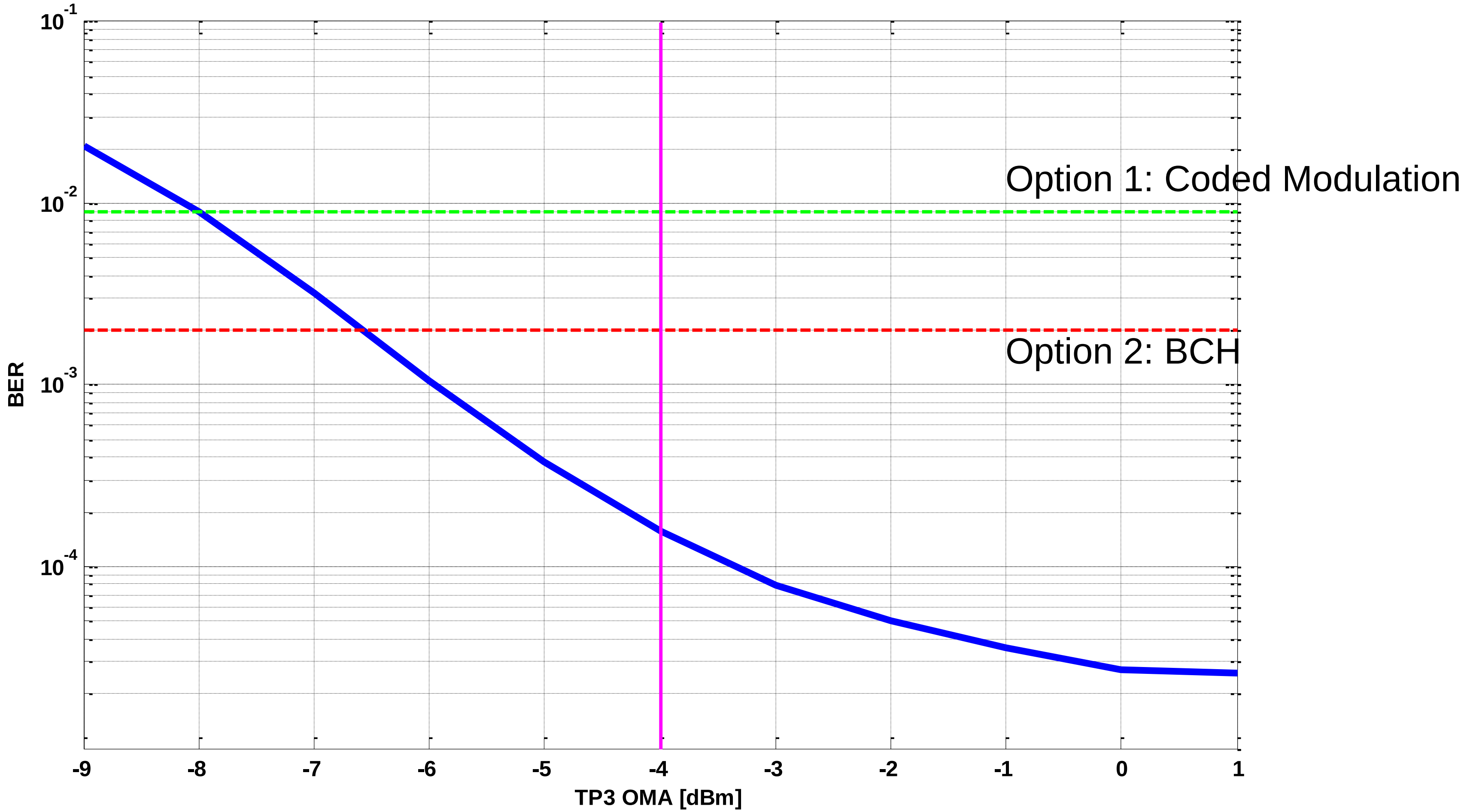
- Tx_RJ = 150fS
- Tx_BW = 22GHz
- ER = 6dB
- Tx_SNR = 30dB
- RIN = -144 dB/Hz
- Resp = 0.85 A/W
- NEP = 15 pA/sqrt(Hz)
- Rx_BW = 18GHz
- Rx_RJ = 150fS
- OMA = 0dBm
- PJ = 2ps @ 100MHz

PAM8 Simulation Results



Segment SNR is defined in Backup

PAM8 Simulation Results



- Allocate 1dB MPI penalty allocation for -35dB RL (See farhood_01_1112_optx)
- 3dB Optical margin for Option 1 Coded Modulation FEC
- 1.5dB Optical margin for Option 2 BCH FEC

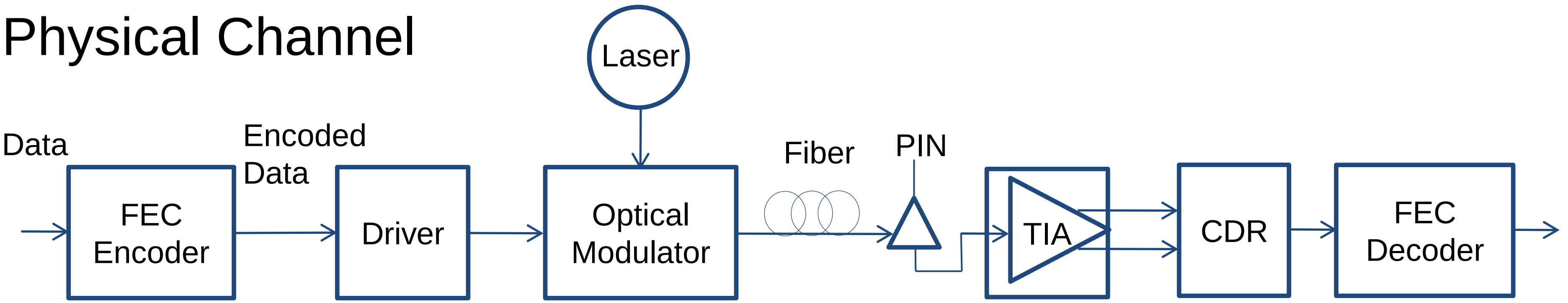
Summary

- We have proposed two options for coding and mapping of 38G PAM8
- PAM8 coded modulation with 600ns latency solution provides a robust optical link with 3dB margin
- PAM8 and BCH with 115ns latency offers a lower latency solution with 1.5dB margin
- We have a high degree of confidence in technical feasibility for -35dB Return Loss cable plant

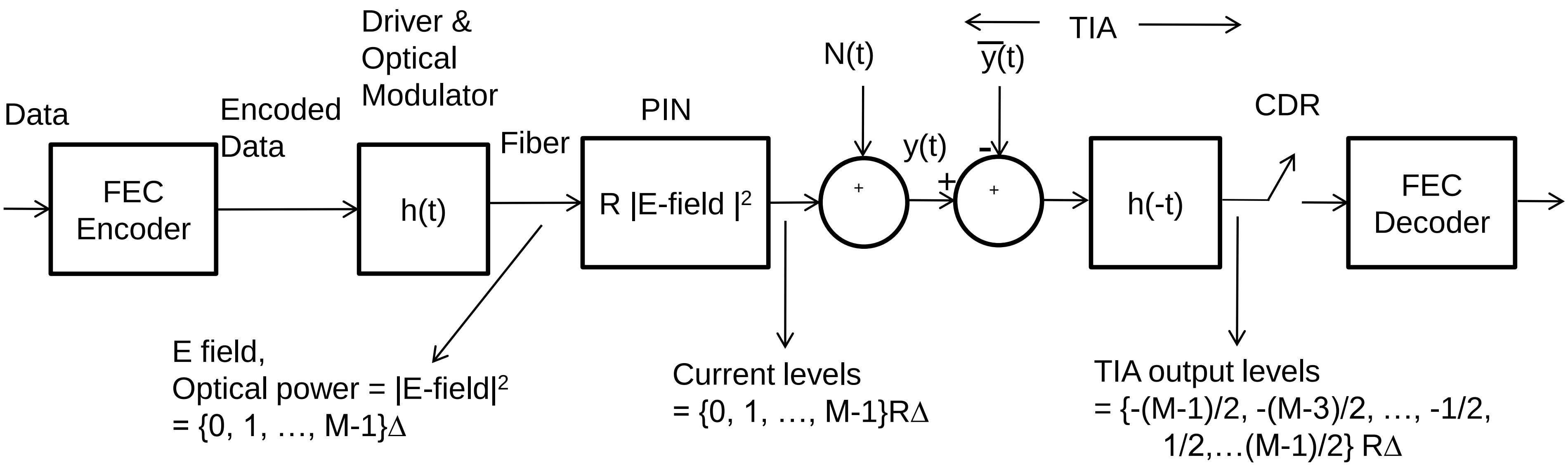
Backup

SNR Channel Model

Physical Channel



Equivalent AWGN Channel Model



General Case SNR

N(t) is a white Gaussian random process which has both signal independent thermal noise and signal dependent components due to laser RIN and shot noise. For optimum receiver thresholds, the symbol error probability is:

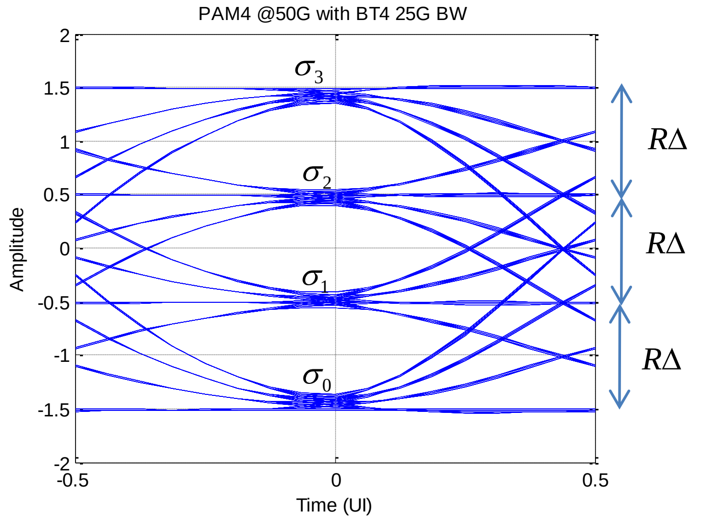
$$Q(k) = R\Delta / (\sigma_{k+1} + \sigma_k),\ k = 0,\dots,M-2$$

$$R\Delta = \begin{cases} \dfrac{2RP_{avg,optical}}{M-1} \\ \sqrt{\dfrac{6P_{avg,electrical@TIAinput}}{(M-1)(2M-1)}} \\ \sqrt{\dfrac{12P_{avg,electrical@TIAoutput}}{(M^2-1)}} \end{cases},$$

$$\sigma_k^2 = (N_{Th} + 2qRk\Delta + 10^{\frac{RIN}{10}}(Rk\Delta)^2)W \ \ (\mathrm{W = Rx\ bandwidth})$$

$$P(k) = erfc\left(\frac{Q(k)}{\sqrt{2}}\right)$$

$$P_s = \frac{1}{M-1}\sum_{k=0}^{M-2} P(k)$$



A single sigma is not valid

Each individual level has its own noise variance

Define Segment SNR for each eye, Q(k)