Forward Error Correction for High-Capacity Transmission Systems

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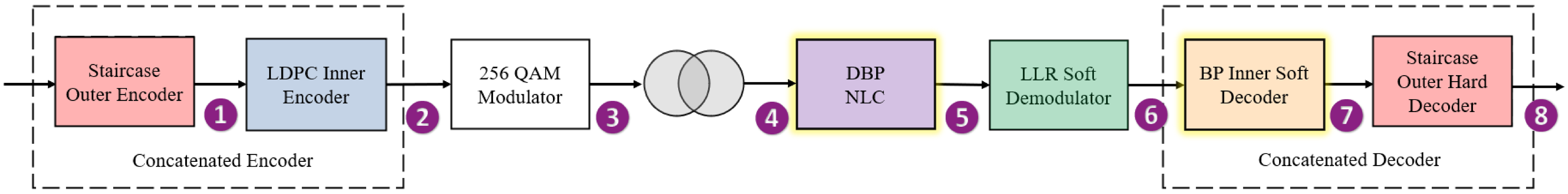
Introduction

Goals:

- Exploring the interplay between FEC and DBP.
- Combing suitable coded-modulation configurations with nonlinearity compensation to optimize spectral efficiency.
- Characterize the trade-off between DBP complexity and FEC overhead.



Coded –Modulation Design Choices

❖ **Scheme: Trivial Bit Interleaved Coded Modulation T-BICM.**

❖ **Staircase Outer Coding Scheme:**

- The outer coding scheme in the code-concatenation.
- Staircase code improves the BER from 4.7 x 10^{-3} to 10^{-15} with hard decoder.
- The overhead OH is **6.25%** for a **4.7 x 10^{-3}** threshold and **33.3%** for **2.12 x 10^{-2}**

❖ **LDPC Inner Encoder:**

- Low Density Parity Check LDPC from DVB-S2 of various OH configurations.
- Examined OH% are 11.11%, 20% and 33.33%.

❖ **LLR Soft Demodulator:**

- Demodulates 256 QAM signals (8 bits/symbol).
- Soft demodulation based on the Logarithmic Likelihood Ratio LLR is used:

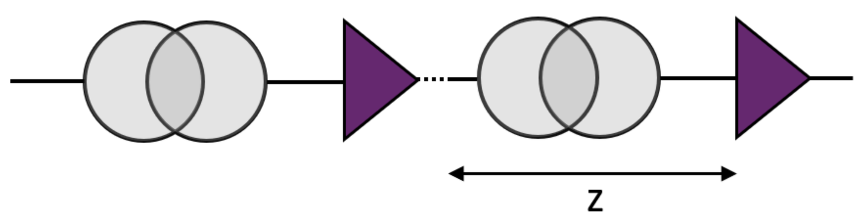
$$l_{b_j} = \log_{10} \frac{\sum_{i \epsilon I_{b_j=0}} p_{Y|x}(y|x_i)\, P_{X|b_j}(x_i|0)}{\sum_{i \epsilon I_{b_j=1}} p_{Y|x}(y|x_i)\, P_{X|b_j}(x_i|1)}$$

❖ **BP Inner Soft Decoder:**

- Decodes based on soft belief propagation BP characterized **with maximum number of iterations**.

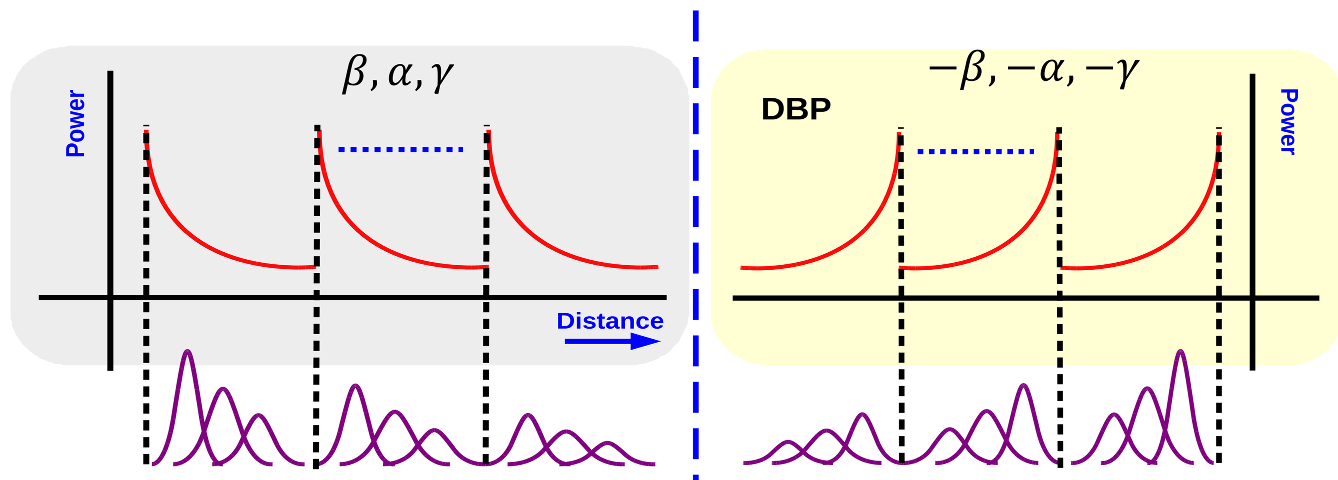
❖ **Total Overhead OH%:** $OH_T\% = 100\ \times (OH_{inner} OH_{outer} + OH_{inner} + OH_{outer})$

DBP Nonlinearity Compensation



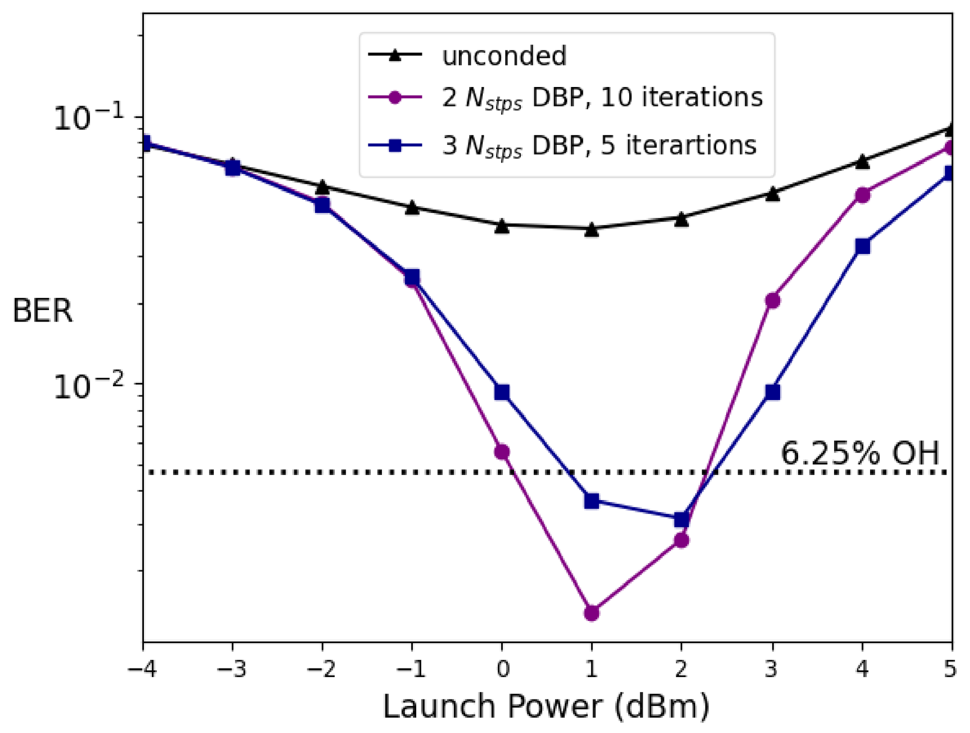
Nonlinear Schrödinger Equation (NLSE) $\frac{\partial A}{\partial z} + \frac{\partial^2 A}{\partial t^2} + \frac{\alpha}{2} A = i\gamma |A|^2 A$

Digital Backpropagation DBP: Single Channel DBP based on Symmetric SSFM



Characterization is based on number of steps/span N_{stps}

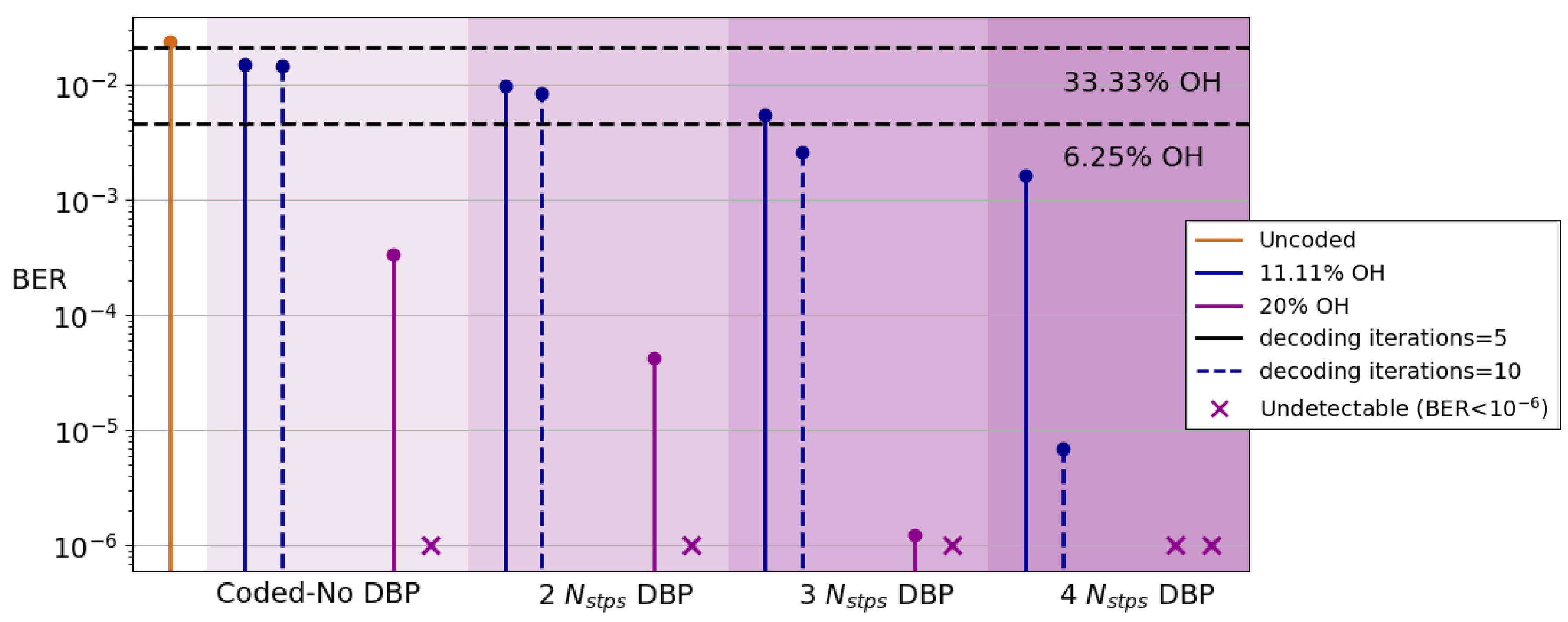
Results



Configurations with Identical Spectral Efficiency (256-QAM, 400km)

Assessing Overhead Across System Configurations

Distance (km)	Configuration: DBP (N_{stps}) x	2	3	4	Decoder Iterations 5	10	Overhead OH%: Inner Code	Outer Code	Total
300			■			■	11.11%	6.25%	18.06%
				■	■				
	■				■		20%		27.5%
400		■				■			
			■		■				
	■				■		33.33%		41.67%



The Impact of Coding and DBP in 256-QAM Fibre Channel Over 300km

Simulation Setups

Parameter	Value
α (dB/km)	0.2
D (ps/nm/km)	17
γ (rad/W/km)	1.4
Noise figure (dB)	5
Oversampling (SpS)	8
Span Length (km)	100
Number of Spans	3, 4
Symbol Rate (Gbaud)	60
Pulse Shaping (filter, roll-off factor, span)	RRC, 25%, 256

Conclusions

- DBP integration increases the coded channel reach by 33% without compromising spectral efficiency.
- A 300km coded channel extends to 400km with consistent spectral efficiency, by either incorporating a 2 N_{stps} DBP with 5 decoding iterations or 3 with 10.
- Extending the channel reach from 300km to 400km is possible by either compromising the spectral efficiency by 14.17% or integrating DBP.

Future research:

- Comparative computational complexity estimation.
- Examine different equalization methods and multichannel scenarios.

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