# Rate-Matching Deep Polar Codes via Polar Coded Extension

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**Abstract**—We propose a novel rate-matching technique for deep polar codes using code extension, particularly effective when the desired code length slightly exceeds a power of two. Our approach leverages the layered structure of deep polar codes by concatenating polar codewords generated at each transformation layer, enabling flexible blocklengths while maintaining structural advantages of deep polar codes. We develop an efficient decoding algorithm using soft-output successive cancellation list decoding and provide comprehensive error probability analysis supporting our code design. Extensive simulations confirm that our approach delivers substantial coding gain over conventional rate-matching methods for polar codes, especially in medium to high code-rate regimes.

*Keywords—deep polar codes, rate-matching, code extension, short blocklength, URLLC*

Pre-transformed polar codes have emerged to coding schemes for short block lengths. Deep polar codes are a class of the pre-transformed polar codes that employ multi-layered polar kernel transformations to enhance code performance in short bloeklength regimes [1]. While deep polar codes address short blocklength limitations, they still require rate-matching techniques such as puncturing, shortening, or extension to support arbitrary code lengths. Extension-based methods can offer superior performance with reduced complexity when the desired code length exceeds a power of two by a small margin yet have received comparatively less attention in the literature [2].

We introduce a systematic extension method that leverages the hierarchical encoding structure of deep polar codes by concatenating partial codewords from different transformation layers. Our key innovation exploits the layered structure through a multi-layer configuration where information bits are partitioned into sub-messages that are independently encoded using different polar transform matrices. The encoding process generates multiple codewords from each layer, which are then concatenated to form a longer code, enabling flexible blocklengths that are not limited to powers of two.

We design an efficient LLR-combined successive cancellation list (SCL) decoding algorithm that incorporates soft information from pre-transform layers into the primary decoding process. The decoder first applies soft-output SCL decoding [3] to the extended segments to estimate soft information, then uses a modifed SCL decoder that combines both the original LLR values and the soft information from connection bits.

Extensive simulations across diverse code parameters demonstrate that our proposed extension method significantly outperforms conventional rate-matching techniques, particularly in medium to high code-rate regimes.

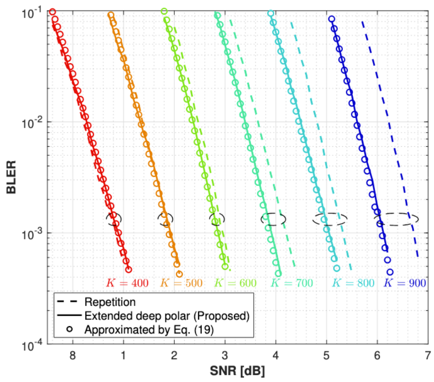


Fig. 1. BLER performance (Mother code length N=1024, Desired code length M=1024+64=1088), SC decoding

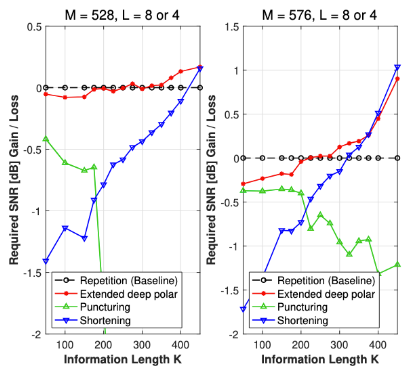


Fig. 2. Required SNR [dB] to achieve BLER $10^{-3}$ for each information length K. A point above the zero baseline indicates a performance gain over repetition.

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