Turbo-Codes over Simple Blockcodes
and Turbo-Product Codes

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For high rate Turbo-Codes (TC) over convolutional codes, the typical steep descent of the error rate curves no longer can be observed. Additionally, many decoding iterations are necessary because of the high puncturing of the constituent codes. As an alternative approach, TC over short blockcodes have been proposed [1]. Here we discuss a division of the block of \( L \) information symbols of a TC-word into \( \mu \) parts, each corresponding to \( k_1 = L/\mu \) information symbols of \( \mu \) identical \((n_1, k_1)\) blockcodes. After permutation of the \( L \) symbols by the interleaver, the data sequence again is divided into \( \nu \) parts and encoded by \((n_2, k_2 = L/\nu)\) block codes. The partitioning offers following advantages: i) soft in/soft out symbol-by-symbol MAP decoding simply is implementable, ii) parallel processing can be applied, iii) separation of data symbols of one codeword into different codewords by interleaving is possible. Especially for \( \mu = k_2, \nu = k_1 \) a \( k_1 \times k_2 \) matrix interleaver or the well known structure of product codes but without parity of parity symbols, arises. We show that such a block interleaving slightly outperforms random interleaving. Only a small number of decoding iterations is necessary. A flattening of the error rate curve at moderate SNRs was not observed.

We propose a new design method for the interleaver based on following considerations: Usually, information symbols in a systematic linear blockcode are involved into different numbers of parity check equations, corresponding to the different weights of the columns of the parity-check matrix. Obviously, the quality of the extrinsic information on a symbol which is based on these equations, is affected by this number of equations. Therefore, symbols on which only small numbers of parity check equations are applied in both encoders, predominate the error rate of the TC-scheme. Thus, we propose an interleaving, by which not only the symbols of one codeword are spread into a maximum number of codewords, but also by which the sums of numbers of parity equation is equalized over all data symbols. We show, that the residual SNR-gap of the point error rate \( 10^{-5} \) to capacity limit can significantly be reduced by such a design.

Based on this criterion a construction of true product codes (including parity of parity symbols) is given and a corresponding modification of the iterative Turbo-decoding procedure is proposed. These "Turbo-Product Codes" offer very interesting tradeoffs between blocklength (data delay), implementation effort and error performance.