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Performance of hybrid turbo codes

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encoding by an extended BCH code. This new matrix (N_c columns of N symbols) is used as an interleaver. Every row is encoded by the RSC code, with code memory v , as illustrated in Fig. 1. The redundancy Y of this code can be punctured: it is organised as N_y columns of N symbols. The code rate R of the hybrid turbo code is

$$R = \frac{KN_c}{N(N_c + N_y)}$$

where $K/N = R_{BCH}$ is the BCH code rate and $N_c/[N_c + N_y] = R_{RSC}$ is the RSC code rate.

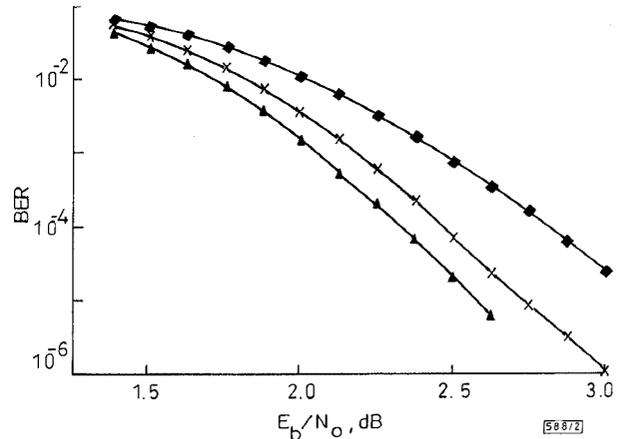


Fig. 2 BER for BCH (32, 26, 4) and RSC (23, 35) with $q = 4$, $R = 1/2$ and after four iterations

- ◆ iteration 2
- × iteration 3
- ▲ iteration 4

Bit error rate (BER) against signal to noise ratio on a Gaussian channel: Iterative decoding requires reliability information at the decoder outputs: for RSC codes, the Viterbi-based algorithm described in [6] is used and for extended BCH codes, the measurement of reliability is obtained from the log likelihood ratio estimation (LLR) [3]. Fig. 2 gives the BER of the hybrid turbo code built with extended BCH (32, 26, 4) and RSC (23, 35) code. The symbols are encoded using $q = 4$ bits (one bit for the sign and three for its reliability) and the global code rate is $R = 1/2$.

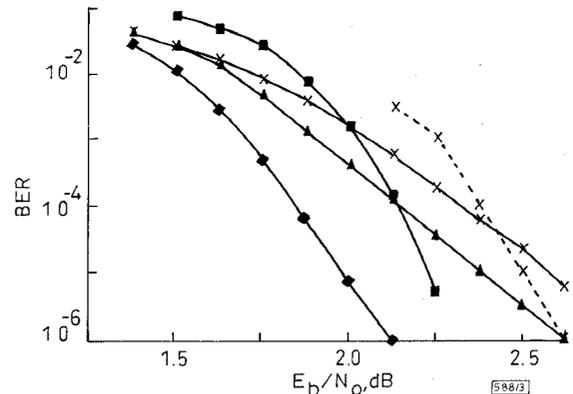


Fig. 3 Performance of different hybrid turbo codes with $q = 4$, $R = 1/2$ and after four iterations

- ◆ CC (133, 171) and BCH (64, 57, 4)
- CC (133, 171) and BCH (64, 51, 6)
- ▲ CC (23, 35) and BCH (64, 57, 4)
- × CC (23, 35) and BCH (32, 26, 4)
- ×- CC (133, 171) and BCH (255, 233, 16)

Using the same code rate, we can associate different extended BCH coding with RSC $v = 4$ (23, 35) or $v = 6$ (133, 171). The results are reported in Fig. 3. The signal to noise ratio for a BER of 10^{-5} at iteration 4 is 2dB from Shannon's theoretical limit for the serial concatenation of BCH (64, 57, 4) and RSC (133, 171). We compared this association with the serial concatenation of the Reed-Solomon code RS (255, 223, $t = 16$) and convolutional code CC (133, 171) [7] (in this case, the code rate is lower: 0.43). The coding gain is ~ 0.5 dB for the hybrid turbo code.

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Indexing terms: Turbo codes, Convolutional codes, Block codes

The authors present the latest results on turbo codes which are built from a serial concatenation between a block code (BCH) and a recursive systematic convolutional code. The performance on a Gaussian channel with QPSK modulation is evaluated.

Introduction: In 1993, Berrou *et al.* [1] showed that it was possible to transmit digital information at a rate close to channel capacity as predicted by Shannon in 1948 [2]. For this, a coding scheme based on the parallel concatenation of two recursive systematic convolutional (RSC) codes was used, associated with an original iterative decoding algorithm. This iterative decoding algorithm uses soft input and output decoding of the component codes. In 1994, Pyndiah *et al.* [3] proposed a new iterative decoding algorithm for decoding product codes, introduced by Elias [4] in 1954. This iterative decoding algorithm is also based on soft input and output decoding of the component codes. This new coding scheme showed exceptional performance for high code rates, typically for $R > 0.75$. This new concept is known as a 'turbo-code' and is widely accepted [5]. In this Letter, we investigate the performance of iterative decoding in the case of a block code (extended BCH) serially concatenated with a convolutional code (RSC).

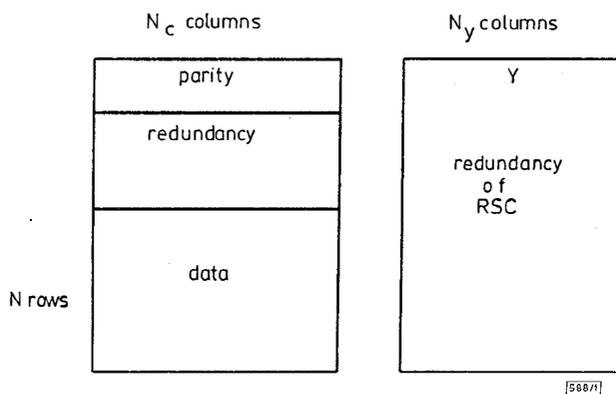


Fig. 1 Construction of hybrid turbo code

Construction of encoder: We consider the extended BCH (N, K, δ). The hybrid turbo code is obtained by placing $N_c K$ information bits in an array of K rows and N_c columns. The N_c columns are

Variations with size of frame: If N_c is modified, the size of the frame changes. Fig. 4 gives the BER for two hybrid turbo codes:

(i) BCR (32, 26, 4) and RSC (23, 35) with 416 and 832 bit frame sizes

(ii) BCH (16, 11, 4) and RSC (23, 35) with 88, 176 and 264 bit frame sizes

For a 176 bit frame size, we have added the curve which gives the frame error rate (FER). Thus, hybrid turbo codes can be used for short blocks.

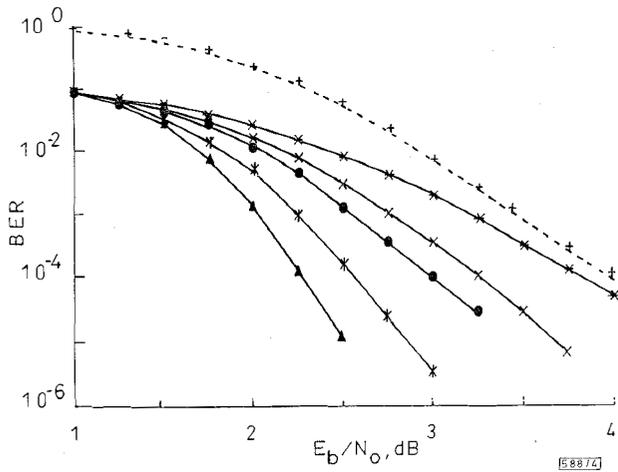


Fig. 4 BER against frame size and signal to noise ratio with $q = 4$, $R = 1/2$ and after four iterations

- $K \times N_c = 416$
- ▲ $K \times N_c = 832$
- × $K \times N_c = 88$
- * $K \times N_c = 176$
- $K \times N_c = 264$
- - × - FER = (176)

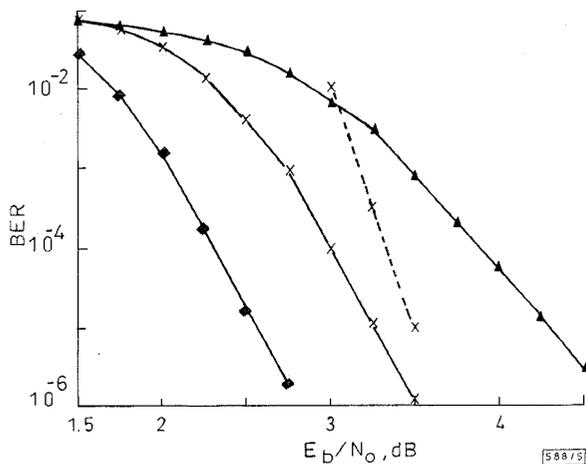


Fig. 5 BER against code rate and signal to noise ratio for BCH (32, 26, 4) and RSC (23, 35) with $q = 4$ and after four iterations ($R = 1/2, 2/3$ and $3/4$)

- ◆ $R = 1/2$
- × $R = 2/3$
- ▲ $R = 3/4$
- - × - CC (133, 171 and $R = 3/4$) and RSC (255, 239, 8)

Variations with N_c : By puncturing Y , it is possible to change R_{RSC} (and R). Fig. 5 gives the BER of the concatenation of BCH (32, 26, 4) and RSC (23, 35), against different code rates. The results of the hybrid turbo code are compared with the serial concatenation of CC ($v = 6$, $R = 3/4$) and RS code (255, 239, $t = 8$), used for digital HDTV [8].

Conclusion: We have given some results concerning the performances of hybrid turbo codes. They indicate that this serial concatenation can favourably replace the 'standard scheme' built with a CC and RS code. We also showed that they could be used for short blocks.

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