Project	IEEE 802.16 Broadband Wireless Access Working Group <**http://ieee802.org/16**>
Title	Improved CTC Performance
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Re:	IEEE P802.16-2004/Cor1-D1 (2005-02-11)
Abstract	This contribution demonstrates that the convolutional turbo code (CTC) interleavers for block sizes 120 bytes and above were selected incorrectly. By selecting different interleaver parameters for these block sizes, the errors can be corrected without implementation impact. The difference between the propsed parameters and the existing parameters is at least 0.5 dB and in some cases up to 1.3 dB in AWGN at 10^{-4} FER.
Purpose	To correct CTC channel coding interleaver parameters when supporting H-ARQ.
Notice	
Release	
Patent Policy and Procedures	

Current CTC Performance

The convolutional turbo code (CTC), a parallel concatenation of two duo-binary tail-biting recursive systematic codes, is an optional error control coding mode in 802.16-2004. The CTC interleaver, defined in 8.4.9.2.3.1 and 8.4.9.2.3.2, uses an “almost regular” permutation (ARP) [1],

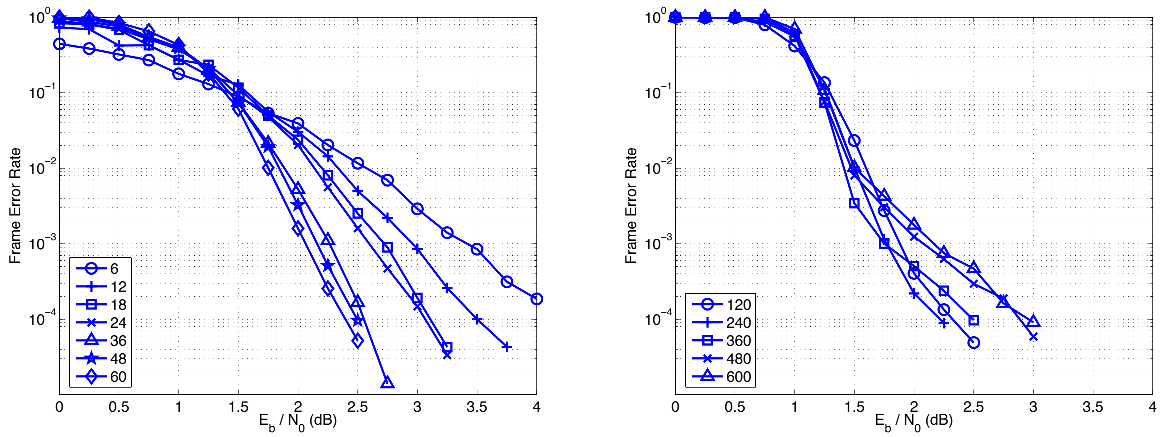
$$\pi(i) = (iP_0 + d(i)) \bmod N \tag{1}$$

where $0 \le i \le N-1$ is the sequential index, $\pi(i)$ is the permuted index, N is the information block size in bit couples, P_0 is a number that is relatively prime to N, and $d(i)$ is a “dither” vector. For all 802.16 block sizes, $d(i)$ assumes the form

$$d(i) = \begin{cases} 1, & i \bmod 4 = 0 \\ 1 + N/2 + P_1 & i \bmod 4 = 1 \\ 1 + P_2 & i \bmod 4 = 2 \\ 1 + N/2 + P_3 & i \bmod 4 = 3 \end{cases} \tag{2}$$

for $0 \le i \le N-1$. The values of P_0, P_1, P_2, and P_3 depend on N, and are listed in Tables 326 and 327. Henceforth, this document only considers block sizes contained in Table 325.

Figure 1 plots the simulated frame error rate (FER) versus E_b/N_0 using the current 802.16 CTC interleaver specification. The results assume a rate-1/2 code, binary modulation over a static additive white Gaussian noise (AWGN) channel, 7.5 decoding iterations, and perfect “genie” knowledge by the decoder of the encoder circulation states. Sub-figure (a) plots results for 6*n*-byte data block sizes (n = 1, 2, 3, 4, 6, 8, 10), and sub-figure (b) plots results for the larger 120*n*-byte data block sizes (n = 1, 2, 3, 4, 5).



(a) 6*n*-byte block sizes, n = 1, 2, 3, 4, 6, 8, 10 (b) 120*n*-byte block sizes, n = 1, 2, 3, 4, 5

Figure 1. FER performance for currently specified CTC interleavers.

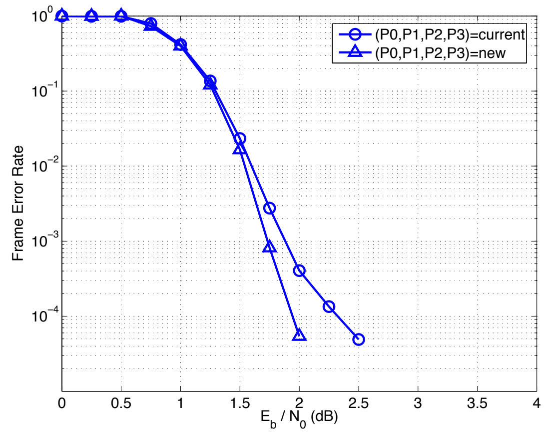
The performance of the 6*n*-byte block sizes displays the expected turbo code behavior of improving performance with increasing block size. Furthermore, no error floor is discernable down to a FER of 10^{-4}. However, the performance of the 120*n*-byte block sizes displays the opposite. Here, the performance degrades with increasing block size (above 240-byte) and a distinct error floor is present.

CTC Performance with New Interleaver Parameters

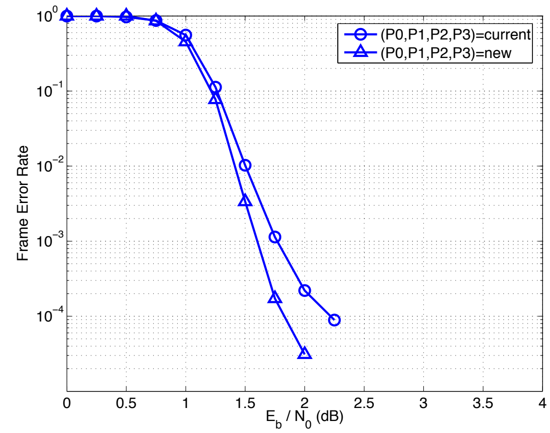
A new set of CTC interleaver parameters was designed to correct the performance deficiencies of the 120*n*-byte block sizes. The new parameters were selected according to guidelines prescribed in [1]. The FER performance (rate-1/2, binary modulation, static AWGN channel, 7.5 decoding iterations, and “genie” circulation state knowledge) with the new parameters is plotted in Figure 2. The figure shows that the new parameters correct the performance deficiencies of the current parameters. At FER = 10^{-4} the performance with the new parameters is at least 0.5 dB and in some cases up to 1.3 dB better than with the current parameters.

The proposed interleaver parameters have been independently tested by Nortel in comparison to the existing parameters. Their results in Figure 3 further support the significant improvement achieved by the proposed parameters.

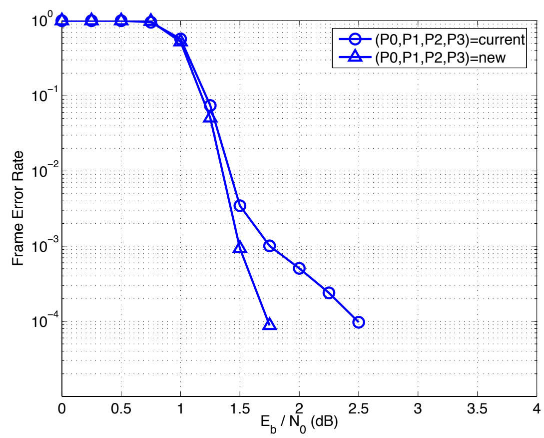
In addition, a search conducted by France Telecom showed that the proposed parameters are among the best that could be found.



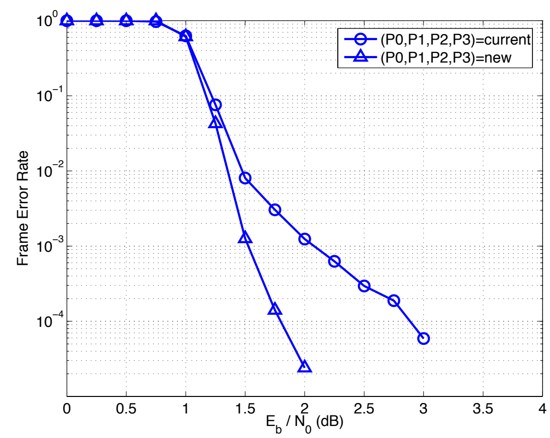
(a) 120-byte block



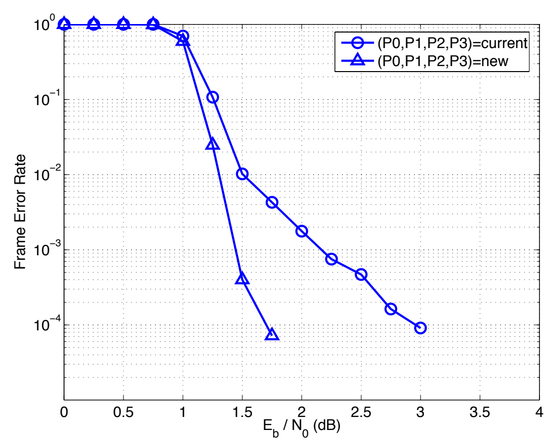
(b) 240-byte block



(c) 360-byte block



(d) 480-byte block



(e) 600-byte block

Figure 2. Performance with new CTC interleaver parameters.

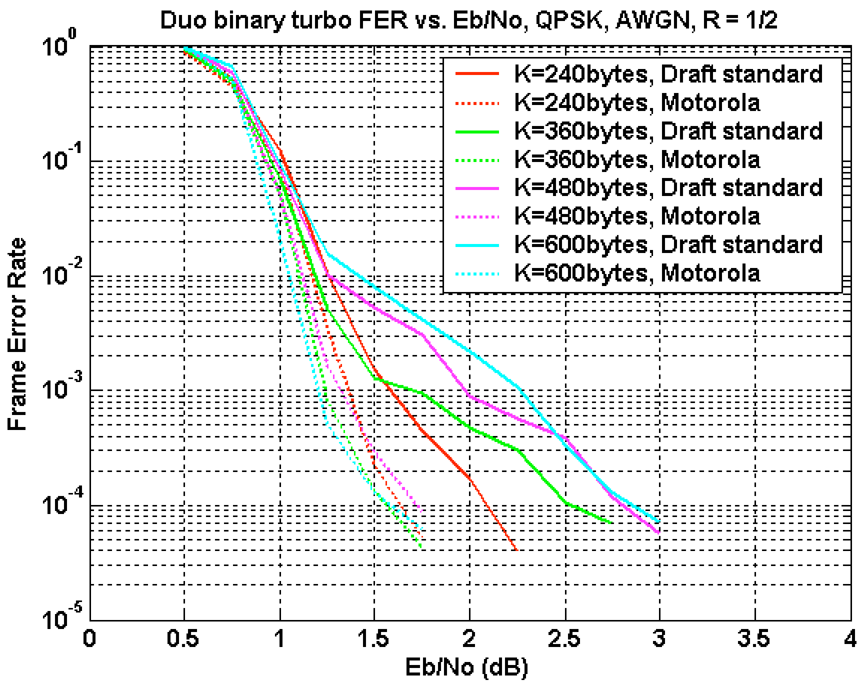


Figure 3. Cross simulation provided by Nortel on the existing and new CTC interleaver parameters.

References

[1] C. Berrou *et al.*, "Designing good permutations for turbo codes: towards a single model," in *Proceedings of the 2004 IEEE International Conference on Communications*, vol. 1, pp. 341-345.

Recommended Text Changes:

<Insert the following to IEEE P802.16-2004/Cor1-D1 (2005-02-11) section 8.4.9.2.3.1 p.110 line 59>
Change the entries of Table 327 as indicated.

Table 327 – Optimal CTC channel coding per modulation when supporting H-ARQ

Data block size (bytes)	**N**	P0	P1	P2	P3
6	24	5	0	0	0
12	48	13	24	0	24
18	72	11	6	0	6
24	96	7	48	24	72
36	144	17	74	72	2
48	192	11	96	48	144
60	240	13	120	160	180
120	480	~~13~~ 53	~~240~~ 62	~~120~~ 12	~~360~~ 2
240	960	~~13~~ 43	~~480~~ 64	~~240~~ 300	~~720~~ 824
360	1440	~~17~~ 43	720	360	540
480	1920	~~17~~ 31	~~960~~ 8	~~480~~ 24	~~1440~~ 16
600	2400	~~17~~ 53	~~1200~~ 66	~~600~~ 24	~~1800~~ 2