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Title	Clarification of CTC Interleaver Definition
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Re:	IEEE P802.16-2004/Cor1/D4 (2005-08-07)
Abstract	The current CTC interleaver definition in Section 8.4.9.2.3.2 is ambiguous. This contribution identifies the correct definition after comparing the performance of two possible interpretations. A clear bit-by-bit definition is then provided for all three sections.
Purpose	To correct CTC channel coding interleaver definition.
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Release	
Patent Policy and Procedures	

Clarification of CTC Interleaver Definition

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Current Definition

The following is the CTC interleaver definition after combining the related text of Section 8.4.9.2.3.2 in two documents: IEEE Std 802.16-2004 and IEEE P802.16-2004/Cor1-D4 (2005-08-07).

The interleaver requires the parameters P0, P1, P2 and P3, shown in Table 326.
Step 1: Switch alternate couples
For j = 0 … N-1
  if (j mod 2 == 1) let (B,A) = (A,B) (i.e., switch the couple)
Step 2: $\boldsymbol{P_i(j)}$
The function $P_i(j)$ *provides the interleaved address i of the consider couple j (i.e. interleavedVec(j) = OriginalVec* $(P_i(j))$ *).*
For j = 0 … N-1
  Switch j mod 4:
  Case 0: $i = (P_0 \bullet j + 1) \bmod N$
  Case 1: $i = (P_0 \bullet j + 1 + N/2 + P_1) \bmod N$
  Case 2: $i = (P_0 \bullet j + 1 + P_2) \bmod N$
  Case 3: $i = (P_0 \bullet j + 1 + N/2 + P_3) \bmod N$

Ambiguities

The current definition shown above is ambiguous in at least two ways:

1. Variable *j* can be viewed as either (i) a dummy variable or (ii) the address after interleaving in both steps based on the description in Section 8.4.9.2.3.1;
2. *OriginalVec* can be viewed as the original vector before Step 1 or the vector produced after Step 1.

This ambiguity leads to two different ways of interpreting the interleaver definition:

(a) First interleave the couples based on function $P_i(j)$, then switch the even-indexed couples as defined.
(b) First interleave the couples based on function $P_i(j)$, then switch the odd-indexed couples. Since the odd-indexed couples after couple interleaving are located at even-indexed positions before couple interleaving, (b) is equivalent to switching even-indexed couples before couple interleaving.

To determine which interpretation, (a) or (b), performs better for the given CTC parameters, simulations were performed for all information block sizes K with rate 1/2 defined in Tables 326 and 327 of Section 8.4.9.2.3.1. The frame error rate (FER) results are shown in Figure 1 through Figure 4 in the Appendix. For most code sizes, (a) and (b) give almost identical performance, as shown in Figure 2 through Figure 4. However, as shown in Figure 1, (b) causes a severe error floor for K {18, 120} bytes. Thus interpretation (a) is better in terms of overall performance.

Note that two other editorial errors related to CTC are also corrected in the following.

Recommended Text Changes

To clarify the definitions of the CTC interleaver in Section 8.4.9.2.3.2, the following changes are proposed. Unambiguous definitions based on interpretation (a) are shown below. In addition, label "$\boldsymbol{P_i(j)}$" is changed to "$\boldsymbol{P(j)}$" since it refers to *i* in Step 2 and is not a function of *i*.

<Modify Section 8.4.9.2.3.2 of the merged text of
IEEE Std 802.16-2004, page 598, Section 8.4.9.2.3.2 and
IEEE P802.16-2004/ Cor1-D4 (2005-08-07), page 181, Section 8.4.9.2.3.2
as follows.>

The interleaver requires the parameters P0, P1, P2 and P3, shown in Table 326.

Step ~~2~~1: Interleave the couples ~~$P_i(j)$~~

Let the sequence u_0=[$(A_0, B_0), (A_1, B_1), (A_2, B_2), (A_3, B_3), \ldots, (A_{N-1}, B_{N-1})$] be the input to first encoding C_1.

The function $P_{i}(j)$ provides the ~~interleaved~~ address prior to interleaving ~~i~~ of the considered couple j ~~(i.e. interleavedVec (j) = OriginalVec($P_i(j)$))~~.

For j = 0 … N-1

Switch j mod 4:

Case 0: P(j)~~i~~ = $(P_0 \bullet j + 1) \bmod N$

Case 1: P(j)~~i~~ = $(P_0 \bullet j + 1 + N/2 + P_1) \bmod N$

Case 2: P(j)~~i~~ = $(P_0 \bullet j + 1 + P_2) \bmod N$

Case 3: P(j)~~i~~ = $(P_0 \bullet j + 1 + N/2 + P_3) \bmod N$

This step gives a sequence $u_1(j) = u_0(P(j))$ or u_1=[$(A_{P(0)}, B_{P(0)}), (A_{P(1)}, B_{P(1)}), (A_{P(2)}, B_{P(2)}), (A_{P(3)}, B_{P(3)}), \ldots, (A_{P(N-1)}, B_{P(N-1)})$].

Step ~~1~~2: Switch alternate couples

For j=0 … N-1

if (j mod 2 == ~~1~~0) let ~~(B,A) = (A,B)~~ (A_j,B_j) (B_j,A_j) (i.e., switch the couple)

This step gives a sequence u_2==[$(B_{P(0)}, A_{P(0)}), (A_{P(1)}, B_{P(1)}), (B_{P(2)}, A_{P(2)}), (A_{P(3)}, B_{P(3)}), \ldots, (A_{P(N-1)}, B_{P(N-1)})$]. Sequence u_2 is the input to second encoding C_2.

<Remove last sentence in the first paragraph of Section 8.4.9.2.3.1 in IEEE Std 802.16-2004, page 594>

~~Further, N shall be limited to 8 ≤ N/4 ≤ 1024.~~

<In Figure 257 of Section 8.4.9.2.3.1 in IEEE Std 802.16-2004, page 595, under label "Parity part":
Add label 'Y' to the arrow of the top output;
Add label 'W' to the arrow of the bottom output>

Appendix

The simulations were done for all rate 1/2 codes defined in Section 8.4.9.2.3.1 of IEEE Std 802.16-2004. QPSK modulation and an AWGN channel are assumed. In all figures, the red solid line indicates interleaving the couples before switching the even-indexed couple (interpretation (a)), and the blue dashed line indicates interleaving the couples before switching the odd-indexed couples (interpretation (b)).

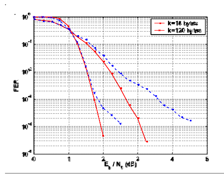

Figure 1. FER vs. E_b/N_0 (dB) information block size K {18, 120} bytes with rate-1/2 QPSK over an AWGN channel.

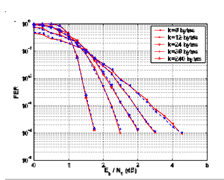

Figure 2. FER vs. E_b/N_0 (dB) information block size K {6, 12, 24, 36, 240} bytes with rate-1/2 QPSK over an AWGN channel.

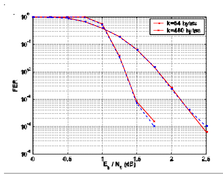

Figure 3. FER vs. E_b/N_0 (dB) information block size K {54, 480} bytes with rate-1/2 QPSK over an AWGN channel.

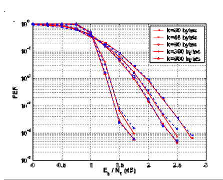

Figure 4. FER vs. E_b/N_0 (dB) information block size K {30, 48, 60, 360, 600} bytes with rate-1/2 QPSK over an AWGN channel.