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Re:	
Abstract	
Purpose	Adoption of proposed changes into P802.16e ~~Crossed-out indicates deleted text,~~ underlined blue indicates new text change to the Standard
Notice	
Release	
Patent Policy and Procedures	

Clarification on Vertically Encoded MIMO

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Abstract

Details for vertically encoded MIMO are not defined in D5a standard and only an exemplary figure is illustrated. Clarifications and slight modifications are proposed. The clarified structure supports open loop, closed loop, UBL, and ABL. It employs legacy interleavers designed for single-input single-output systems so that we do need to define new interleavers for vertical MIMO. Furthermore, the structure improves the system's frequency diversity by introducing a simple cyclic shift in logical subcarrier mapping. Finally, a bit loading table is proposed to reduce feedback overhead for modulation adaptation. In order to select a desired modulation coding scheme, it is sufficient to feed back a bit loading index and the average SNR of all streams instead of the SNRs for all streams, where the overhead of the first is about half of that of the second. Since feedback of average SNR is already in the standard, a bit loading table is introduced to reduce feedback overhead.

1 Introduction

On page 336, D5a, there is an exemplary figure for vertically encoded MIMO, which is shown in Figure 1. The major disadvantages of this structure are as follows. First, new interleavers need to be defined for the increased pay load sizes due to parallel spatial channels. For example, the interleaver size at the output of encoder needs to be doubled for two spatial channels. Second, frequency diversity is not maximized because the subchannel allocation for each spatial stream is the same. For example, one FEC block is interleaved and mapped into QAM symbols. The QAM symbols are alternately assigned to two subchannel blocks one per spatial channel by the demux. Because the subchannel allocation is exactly the same on both spatial channels, both subchannels are on the same subcarriers. This means that the FEC block is placed on the same physical subcarriers on both spatial channels. This limitation reduces the frequency diversity if the subchannel doesn't occupy all subcarriers allocated for the user. Frequency diversity can be improved by allowing the logical subchannels on different spatial channels to be placed on different sets of physical subcarriers. Finally, the structure in Figure 1 doesn't support adaptive bit loading because all code bits are mapped to the same modulation constellation before demux. The performance of closed loop is maximized when different modulation orders are employed for different spatial streams. Since the signal qualities on spatial channels can be different by more than 9 dB, which can not be compensated by FEC codes, the weakest spatial channel dominates the performance although there is excess signal power in the strong spatial channels.

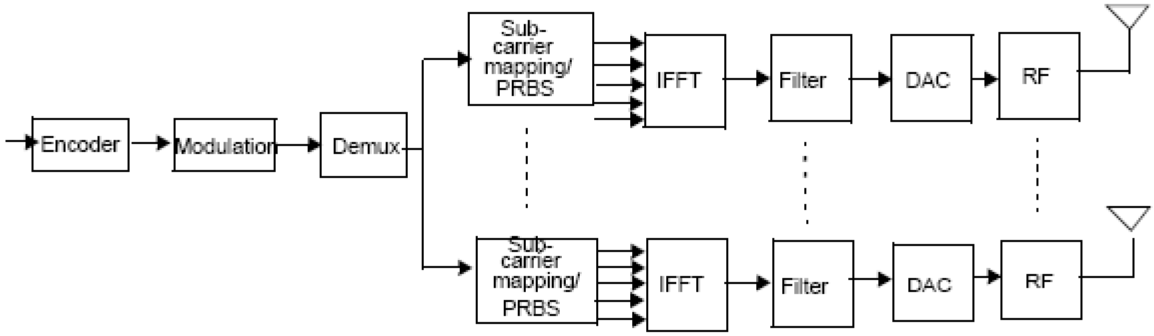

Figure 1 Exemplary structure for vertically encoded MIMO in D5a.

To demonstrate the advantage of adaptive bit loading (ABL), a simulation result is shown in Figure 2, where two data streams are sent using 2 transmit antennas with Matrix B over ITU, Pedestrian B, 2x2 channels, and packet error rate is plotted. The ABL scheme loads 6 and 2 bits on strong and weak spatial channels respectively while the uniform bit loading (UBL) scheme loads 4 bits on both spatial channels. Although the total number of bits per subcarrier is the same for both UBL and ABL, ABL outperforms UBL by more than 2 dB. More results for UBL and ABL comparison are documented in [2]. To simplify MAC signaling, we only propose per-stream ABL, where for a given spatial channel the modulation order is the same across all subcarriers.

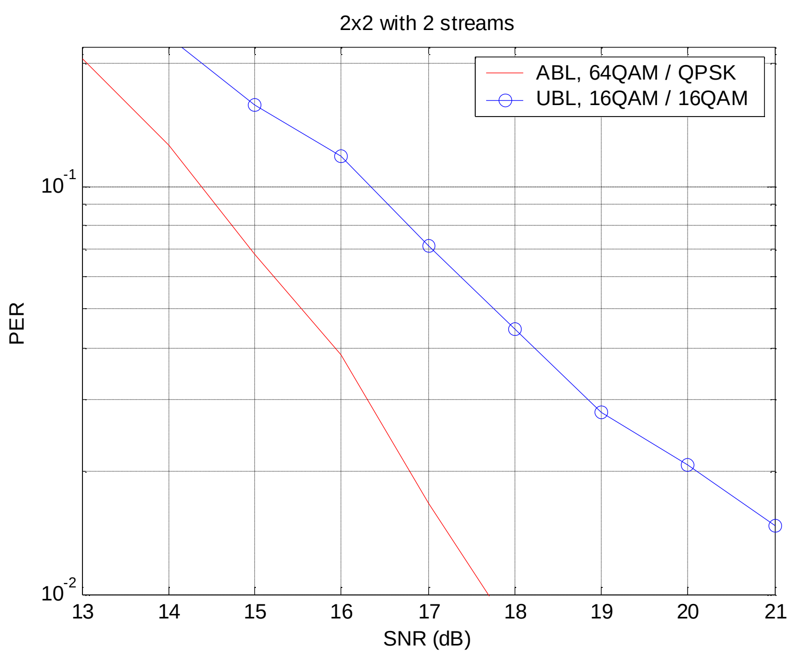

Figure 2 Comparison between ABL and UBL for 2x2 ITU, Pedestrian B with 0.7 Tx antenna correlation.

We propose slight modifications of the structure in Figure 1. The new structure supports open loop, closed loop, UBL, and ABL, as shown in Figure 3. It doesn't need to define new interleavers for MIMO and employs legacy interleavers designed for single-input single-output systems. The demux in Figure 1 is enhanced to support ABL and a cyclic shift is added at subcarrier mapping block to maximize frequency diversity. The transmitter works as follows. A block of data bits is first encoded by FEC encoder and the code bits are punctured to achieve a specified code rate. The punctured code bits are distributed to multiple streams according the modulation orders selected for the spatial channels. It should be noticed that the same modulation order is employed for all subcarrier for a given spatial channel. The distributed bits are interleaved by a legacy interleaver on each channel. The interleaved bits are mapped to QAM symbols and the QAM symbols are mapped to logical subcarriers. The mapped QAM symbols on the logical subcarriers are then circularly shifted by $j-1$ subcarrier for the j-th channel for $j=1,\cdots,M$ before they are finally mapped to physical subcarriers. The circular shift allows that the physical subchannel allocations on different spatial channels can be different so that frequency diversity is maximized for the FEC coded block. After the shift, the QAM symbols are STC encoded and may be beamformed. The beamformed symbols are finally mapped to physical subcarriers and are sent by antennas. Detailed description and simulation results of the cyclic shift are in [3]. Detailed operations of the demux are depicted next.

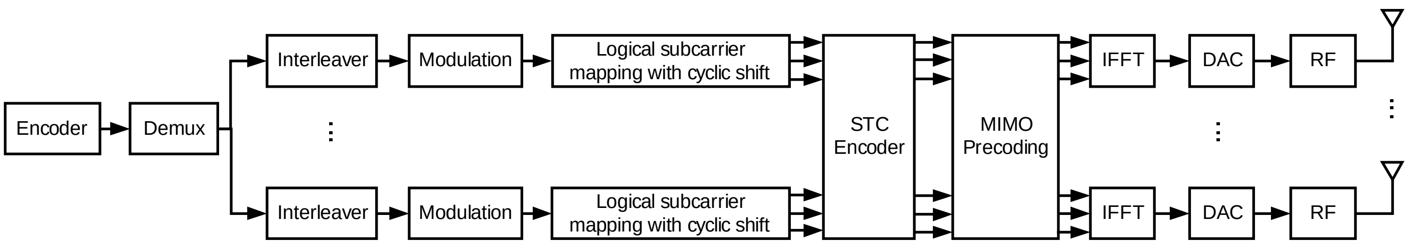

Figure 3 Proposed structure for vertically encoded MIMO.

The demux extracts bits for M spatial channels one by one in descending order of the channels' modulation order. It first evenly extracts the bits for the spatial channel with the greatest modulation order from the input bit sequence. Namely, the i-th extracted bit is the k-th bit in the original input bit sequence, where $k=\text{round}\left(\frac{i}{L_1}\sum_{j=1}^{M}L_j\right)$; M is the number of spatial channels; and L_j is the number of bits on the j-th spatial channel assuming $L_1\geq\cdots\geq L_M$. For example, if the first and second channels employ 64QAM and QPSK, $L_1=6$ and $L_2=2$. The term $\frac{1}{L_1}\sum_{j=1}^{M}L_j$ is the nominal spacing between two extracted bits in the original bit sequence. Seen from the computation of index k, the extracted bits are evenly located in the original sequence. After extracting bits for the first spatial channel from the input sequence, the demux extracts bits for the second spatial channel from the remaining bits. Similarly, the i-th extracted bit is the k-th bit in the remaining bits, where $k=\text{round}\left(\frac{i}{L_2}\sum_{j=2}^{M}L_j\right)$. For the extraction for the p-th channel, the i-th extracted bit is the k-th bit in the remaining bits, where $k=\text{round}\left(\frac{i}{L_p}\sum_{j=p}^{M}L_j\right)$. This process repeats until there is only one channel left and all the remaining bits are assigned to the channel. For UBL, the demux process above becomes a simple serial-to-parallel conversion.

For modulation coding adaptation of MIMO with multiple streams, it is sufficient to feed back a bit loading index and the average SNR of all streams instead of the SNRs for all streams, where the overhead of the first is about half of that of the second. Since the feedback of average SNR is already in D5a standard, a bit loading table with 25 entries is listed below for MIMO with multiple streams. The bit loading table specifies the modulation order employed by each active spatial stream. With the table, the subscriber station can feed back the index of a desired bit loading and the average SNR of all streams in order to indicate the desired modulation coding scheme. The first 12 entries in the table are for UBL.

Table 1 Bit loading options

ID#	Stream Count	Stream ID vs. Modulation			
		stream 1	stream 2	Stream 3	stream 4
1	1	QPSK			
2	1	16QAM			
3	1	64QAM			
4	2	QPSK	QPSK		
5	2	16QAM	16QAM		
6	2	64QAM	64QAM		
7	3	QPSK	QPSK	QPSK	
8	3	16QAM	16QAM	16QAM	
9	3	64QAM	64QAM	64QAM	
10	4	QPSK	QPSK	QPSK	QPSK
11	4	16QAM	16QAM	16QAM	16QAM
12	4	64QAM	64QAM	64QAM	64QAM
13	2	16QAM	QPSK		
14	2	64QAM	QPSK		
15	2	64QAM	16QAM		
16	3	16QAM	QPSK	QPSK	
17	3	16QAM	16QAM	QPSK	
18	3	64QAM	16QAM	16QAM	
19	3	64QAM	64QAM	QPSK	
20	3	64QAM	64QAM	16QAM	
21	4	16QAM	16QAM	QPSK	QPSK
22	4	16QAM	16QAM	16QAM	QPSK
23	4	64QAM	16QAM	16QAM	QPSK
24	4	64QAM	64QAM	16QAM	QPSK
25	4	64QAM	64QAM	64QAM	QPSK

2 Specific Text Changes

Added section 8.4.8.10 at line 33 on page 362 of [1] as follows

8.4.8.10 Vertically encoded MIMO

Figure 254a illustrates a transmitter for vertically encoded MIMO, where there are M data streams. The punctured code bits are distributed into M modulation chains by the demultiplexer. The demultiplexer extracts bits for the chains one by one from its input bit sequence. The bits to the chain with higher modulation order are extracted before those with lower modulation order. Denote the number of bits per subcarrier on the j-th chain as L_j, where $L_1 \geq \cdots \geq L_M$. The demultiplexer first extracts the bits for the chain with the greatest modulation order from as follows. The i-th extracted bit is the k-th bit in the original input bit sequence, where $k = \text{round}\left(\frac{i}{L_1}\sum_{j=1}^{M} L_j\right)$. For the p-th chain, the i-th extracted bit is the k -th bit in the remaining bits after the extractions for the previous $p-1$ chains, where $k=\text{round}\left(\frac{i}{L_p}\sum_{j=p}^{M}L_j\right)$.

Each chain interleaves and modulates the distributed bits using the interleaving schemes specified for SISO transmission. After mapped to logical subcarriers, the modulated symbols are circularly shifted by $j-1$ logical subcarriers for the j -th chain for $j=1,\cdots,M$. The circularly shifted symbols are then sent to STC encoder.

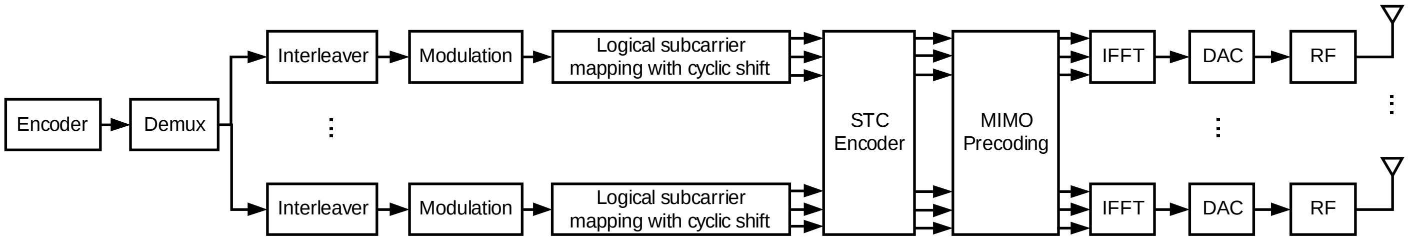

Figure 254a Illustration of vertically encoding for optional zones in DL.

The bit loading options of the chains are listed in Table 2.

Table 2 Bit loading options

ID#	Stream Count	Stream ID vs. Modulation			
		stream 1	stream 2	Stream 3	stream 4
1	1	QPSK			
2	1	16QAM			
3	1	64QAM			
4	2	QPSK	QPSK		
5	2	16QAM	16QAM		
6	2	64QAM	64QAM		
7	3	QPSK	QPSK	QPSK	
8	3	16QAM	16QAM	16QAM	
9	3	64QAM	64QAM	64QAM	
10	4	QPSK	QPSK	QPSK	QPSK
11	4	16QAM	16QAM	16QAM	16QAM
12	4	64QAM	64QAM	64QAM	64QAM
13	2	16QAM	QPSK		
14	2	64QAM	QPSK		
15	2	64QAM	16QAM		
16	3	16QAM	QPSK	QPSK	
17	3	16QAM	16QAM	QPSK	
18	3	64QAM	16QAM	16QAM	
19	3	64QAM	64QAM	QPSK	
20	3	64QAM	64QAM	16QAM	
21	4	16QAM	16QAM	QPSK	QPSK
22	4	16QAM	16QAM	16QAM	QPSK
23	4	64QAM	16QAM	16QAM	QPSK
24	4	64QAM	64QAM	16QAM	QPSK
25	4	64QAM	64QAM	64QAM	QPSK

References:

[1] IEEE P802.16e/D5a Air Interface for Fixed and Mobile Broadband Wireless Access Systems – Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, 2004.

[2] Q. Li, *et al*., "Per-Stream Bit Loading for MIMO Precoding," IEEE C80216-04_529r5, Nov. 2004.

[3] S. Sandhu, *et al*., "Space-frequency bit-interleaved coded modulation for MIMO-OFDM/OFDMA systems," IEEE C80216-04_533r4, Jan. 2005.