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Title	**Per-Stream Bit Loading for MIMO Precoding**
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Re:	
Abstract	Per-Stream Bit Loading for MIMO Precoding
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	

Per-Stream Bit Loading for MIMO Precoding Systems

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Abstract

In this contribution, a per-stream adaptive bit loading (ABL) scheme is proposed. The SNR in the strongest and the weakest beamformed spatial channel is usually greater than 9 dB. This gap is hard to be compensated by FEC codes. Furthermore, this gap increases as the number of spatial channels and the accuracy of transmit beamforming. Simulation results demonstrate that closed-loop MIMO (i.e. MIMO precoding) provides only 0.5 dB gain over open loop MIMO for 2x2 and 4x4 MIMO at high SNR region using the uniform bit loading defined in the standard. To remedy this problem, adaptive bit loading (ABL) is required, which employs different constellations on different spatial channels. Since the exact ABL require large overhead to send the bit load table, per-stream ABL is proposed. The per-stream ABL employs one constellation per spatial channel, where the i-th spatial channel is formed by the i-th eigenmodes of all subcarriers. To further reduce the feedback overhead, we define a set of modulation coding schemes (MCSs), where each MCS specifies the modulation on each stream and the FEC code rate. Since the set for up to 4 streams has 38 entries, the infrequent MCS feedback only needs 6 bits.

In the D5 standard, there are 7 MCSs and up to 4 spatial streams, which defines 28 uniform bit loading MCSs. Therefore, it already requires 5 bits feedback to indicate which MCS and how many streams are employed. The proposed MCS table is just added 10 MCS with uneven bit loading after the 28 legacy MCSs and only 1 bit is added to the infrequent feedback.

1 Compact Feedback Scheme

The eigenvalue distributions of 4x1, 4x2, 4x3, and 4x4 are shown in Figure 1, and the means of the eigenvalues are listed in Table 1. The difference between the greatest and the smallest eigenvalues increases with the number of spatial streams, and it is greater than 17 dB for 4x4. This large difference is hard to be compensated by FEC coding and adaptive bit/power loading is required.

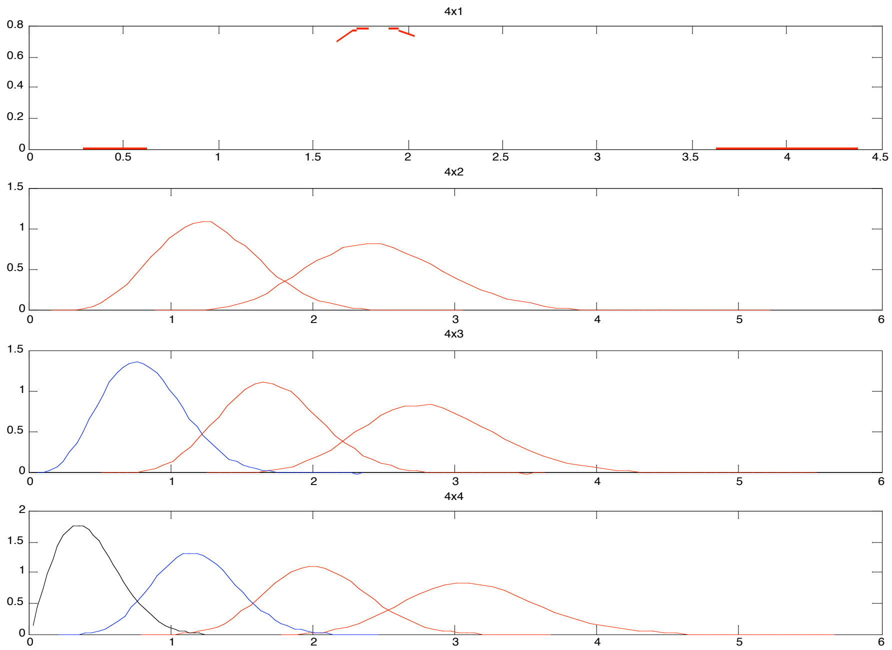

Figure 1. Eigenvalue distributions of spatial modes.

Table 1. Means of channel gain (i.e. sorted eigenvalues) of each spatial channel. The different between the greatest and smallest eigenvalues increases as number of spatial streams.

Mt	Mr	$\overline{\lambda}_1$	$\overline{\lambda}_2$	$\overline{\lambda}_3$	$\overline{\lambda}_3$
2	2	1.81	0.61		
3	3	2.53	1.39	0.49	
4	4	3.14	2.03	1.17	0.43

The exact adaptive bit (or power) loading has the flexibility to put a different number of bits (or amount of power) on each OFDM subcarrier and each spatial channel. Since the loading table requires significant amount of overhead to feed back, the exact adaptive bit (or power) loading is not practical for 802.16e. In order to reduce the overhead, we propose per-stream adaptive bit loading as shown in Figure 2. It assigns the same number of bits on each spatial channel, where the *i*-th spatial channel is formed by the *i*-th eigenmodes of each subcarrier. To further reduce the feedback overhead, we define a set of modulation coding schemes (MCSs), where each MCS specifies the modulations on each stream and the FEC code rate (and suggested power ratio across streams). An MCS set is illustrated in Table 3. Since the whole set for up to 4 streams will have less than 64 entries, the infrequent MCS feedback only needs 6 bits.

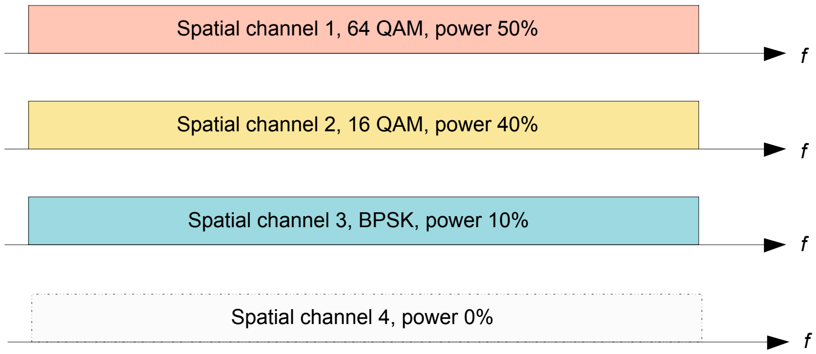

Figure 2. Illustration of per-stream adaptive bit loading. The horizontal axis is for subcarrier index while the vertical is for spatial channel index.

In 8.4.8.3.3 to 8.4.8.3.5 in [1], uniform bit loading (UBL) is defined, where there are 7 modulation coding schemes (MCSs) per stream. Since there are up to 4 streams, 28 MCSs are defined. To compensate for the SNR gap between beamformed streams, we define additional MCSs so that transmitter can load different numbers of bits to different precoded spatial streams according to the status of the spatial channels. The additional MCSs are listed in Table 2.

Table 2 Extended modulation coding schemes for closed-loop MIMO

ID#	Stream Count	Code Rate	Stream ID vs. Modulation			
			stream 1	stream 2	Stream 3	stream 4
29	2	1/2	16QAM	QPSK		
30	2	3/4	16QAM	QPSK		
31	2	3/4	64QAM	QPSK		
32	2	3/4	64QAM	16QAM		
33	3	1/2	16QAM	16QAM	QPSK	
34	3	3/4	64QAM	16QAM	16QAM	
35	3	3/4	64QAM	64QAM	16QAM	
36	4	1/2	16QAM	16QAM	QPSK	QPSK
37	4	1/2	16QAM	16QAM	16QAM	QPSK
38	4	3/4	64QAM	64QAM	16QAM	QPSK

The transmitter for per-stream ABL is illustrated in Figure 3. The only new component is a codebit distributor, which assigns bits to each stream with the amounts specified by the selected MCS. When the current uniform bit loading MCS is selected, the codebit distributor assigns interleavered codebits alternately into each stream. This operation is equivalent to the matrix operations defined in the standard.

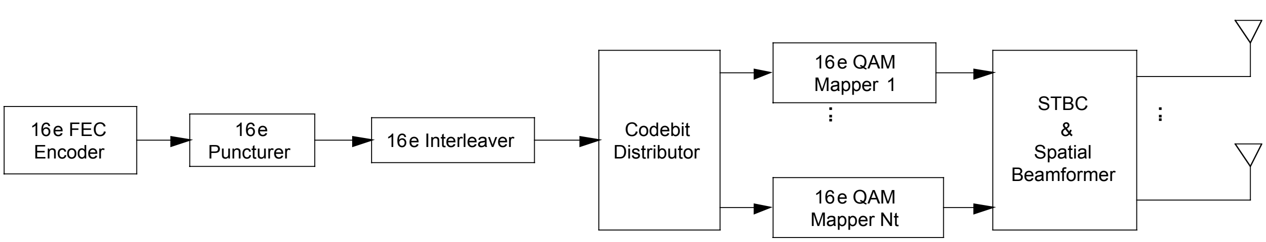

Figure 3 Transmitter architectures for per-stream adaptive bit loading using existing 16e building blocks and an additional bit distributor.

2 Simulations

We evaluate the throughput performance of the proposed per-stream ABL by simulations. Two antenna configurations for closed-loop MIMO, i.e. 2x2 and 3x3, are simulated. We employed 10 MHz bandwidth with equivalent optional FUSC frequency permutation and modulation (using convolutional codes). MMSE receiver is assumed at the receiver. ITU-R channel model, pedestrian B [3] with antenna correlations 0.2 is employed. The packet size is 1000 bytes. In the legend, 'Current MCSs' are the uniform bit loading schemes and 'Extended MCS' includes the 'Current MCSs' and the extended ones in Table 2. The system throughput with slow link adaptation is computed for both sets of MCSs for each antenna configurations, whose results are shown in Figure 4 and Figure 5. The extended MCS set outperforms the current set in the standard by 1-2 dB at medium and high SNR regions.

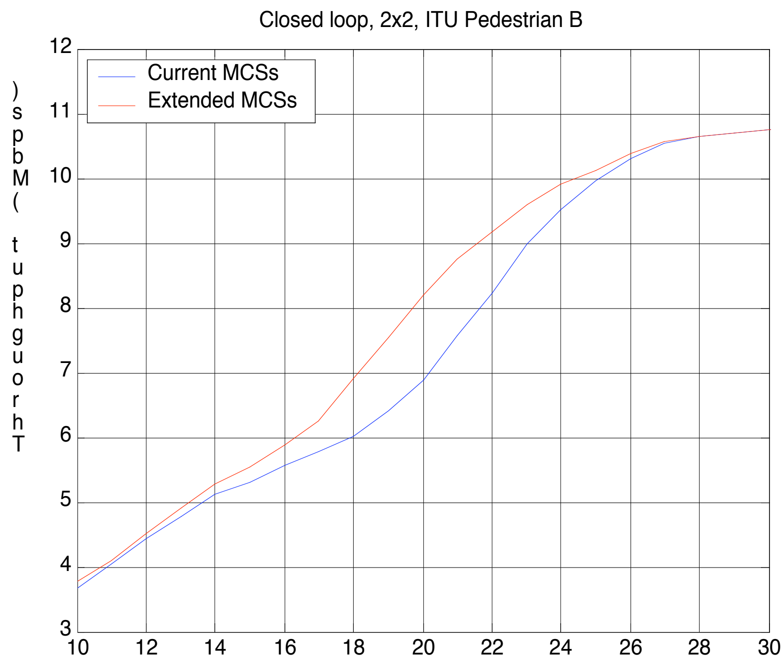

Figure 4 Throughput of 2x2 closed-loop MIMO with current MCSs and extended MCSs.

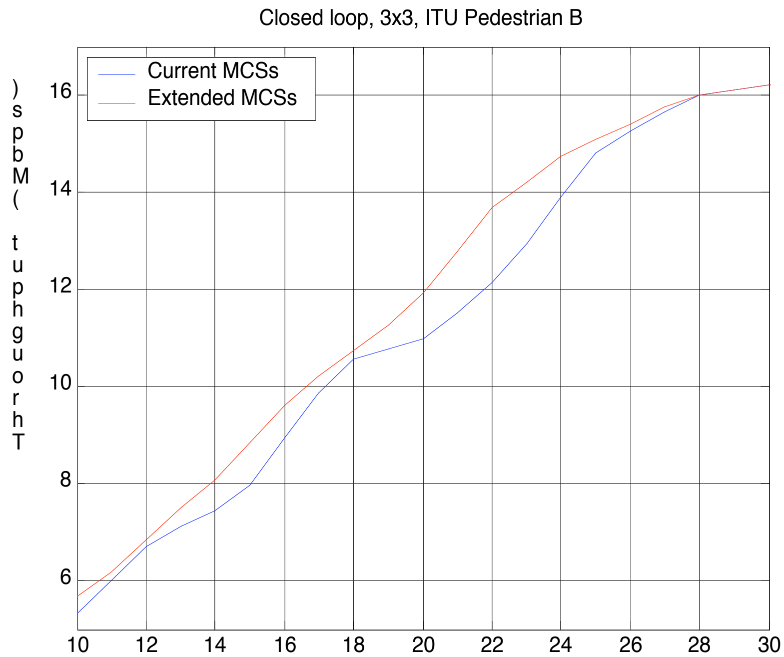

Figure 5 Throughput of 3x3 closed-loop MIMO with current MCSs and extended MCSs

3 Conclusion

A per-stream adaptive bit loading scheme is proposed for MIMO precoding. Ten uneven bit loading schemes are defined. The slightly extended MCS outperforms the current MCS by 1-2 dB at medium and high SNR regions.

4 Specific Text Changes

Add section 8.4.8.3.6.1 on page 242 of [1] as follows

8.4.8.3.7 Transmitter structure and bit loading scheme for MIMO Precoding

Transmitter loads the interleaved coded bits to each data stream according to Table 3 and Figure 6.

Table 3 Modulation coding schemes for MIMO precoding

ID#	Stream Count	Code Rate	Stream ID vs. Modulation			
			stream 1	stream 2	Stream 3	stream 4
1	1	1/2	QPSK			
2	1	3/4	QPSK			
3	1	1/2	16QAM			
4	1	3/4	16QAM			
5	1	1/2	64QAM			
6	1	2/3	64QAM			
7	1	3/4	64QAM			
8	2	1/2	QPSK	QPSK		
9	2	3/4	QPSK	QPSK		
10	2	1/2	16QAM	16QAM		
11	2	3/4	16QAM	16QAM		

12	2	1/2	64QAM	64QAM		
13	2	2/3	64QAM	64QAM		
14	2	3/4	64QAM	64QAM		
15	3	1/2	QPSK	QPSK	QPSK	
16	3	3/4	QPSK	QPSK	QPSK	
17	3	1/2	16QAM	16QAM	16QAM	
18	3	3/4	16QAM	16QAM	16QAM	
19	3	1/2	64QAM	64QAM	64QAM	
20	3	2/3	64QAM	64QAM	64QAM	
21	3	3/4	64QAM	64QAM	64QAM	
22	4	1/2	QPSK	QPSK	QPSK	QPSK
23	4	3/4	QPSK	QPSK	QPSK	QPSK
24	4	1/2	16QAM	16QAM	16QAM	16QAM
25	4	3/4	16QAM	16QAM	16QAM	16QAM
26	4	1/2	64QAM	64QAM	64QAM	64QAM
27	4	2/3	64QAM	64QAM	64QAM	64QAM
28	4	3/4	64QAM	64QAM	64QAM	64QAM
29	2	1/2	16QAM	QPSK		
30	2	3/4	16QAM	QPSK		
31	2	3/4	64QAM	QPSK		
32	2	3/4	64QAM	16QAM		
33	3	1/2	16QAM	16QAM	QPSK	
34	3	3/4	64QAM	16QAM	16QAM	
35	3	3/4	64QAM	64QAM	16QAM	
36	4	1/2	16QAM	16QAM	QPSK	QPSK
37	4	1/2	16QAM	16QAM	16QAM	QPSK
38	4	3/4	64QAM	64QAM	16QAM	QPSK

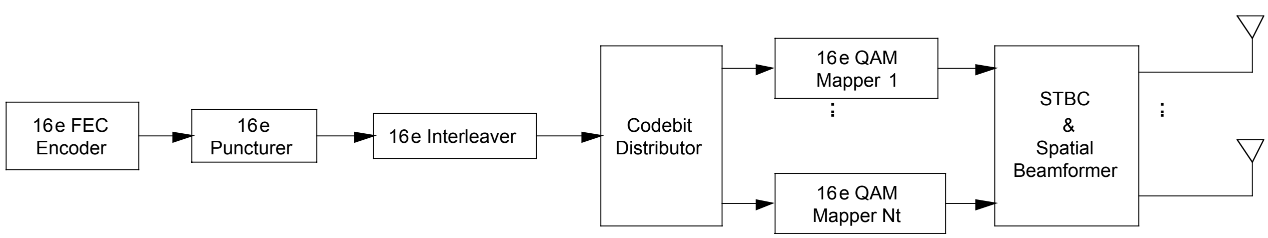

Figure 6 Transmitter structure for MIMO precoding

References:

[1] IEEE P802.16e/D5 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] IEEE P802.16-REVd/D5-2004 Draft IEEE Standards for local and metropolitan area networks, Part 16: Air interface for fixed broadband wireless access systems, 2004.

[3] Recommendation ITU-R M.1225, Guidelines for Evaluation of Radio Transmission Technologies for IMT-2000, 1997.