Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Enhancing MIMO features for OFDMA PHY layer**
Date Submitted	**2004-04-25**
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Re:	Sponsor re-circulation Ballot
Abstract	Contribution elaborating of the MIMO enhancements for 802.16d OFDMA
Purpose	Adopt into IEEE 802.16 REVd/D4 - 2004
Notice	
Release	
Patent Policy and Procedures	

Consolidation and elaboration of the MIMO features for 802.16d OFDMA

1 Introduction

This contribution describes the MIMO enhancements to IEEE802.16REVd/D4 OFDMA PHY. The following PHY features are proposed:

- DL MIMO Preamble
- DL MIMO scattered pilot for FUSC, PUSC
- UL MIMO tile
- MIMO antenna configurations and transmission format
- MIMO soft packet combing
- MIMO DL fast signaling support

In addition, several basic OFDMA PHY features are described to enhance the performance for the interference limited multi-cell environment.

- DL PUSC scattered pilot planning
- Differential Modulation for range extension

1.1 Soft packet combing for MIMO

In the MIMO mode transmission, if the packet at receiver decoding is in error, then a re-transmission is requested, the MIMO transmitter can use the same STC format to re-send the packet. In this case, the packet can be re-transmitted using the same FEC encoded packet or can be re-transmitted using different FEC redundancy, the re-transmitted packet and erroneous packet can be combined in soft symbol form or can be decoded with the re-transmitted packet and erroneous packet as a code coming. This is so called hybrid ARQ. However, the benefit of the H-ARQ can be further extended to the space time domain in the MIMO mode. This is so called soft MIMO packet combining. The key advantage of the soft MIMO packet combining over the existing FEC based HARQ is that MIMO packet combing can further exploit the spatial diversity of the MIMO channel, this is particular effective when the channel fading is slow, since the conventional FEC based H-ARQ mainly relies on time diversity to improve the throughput. As we can see that the MIMO packet combing can significantly reduce the re-transmission number and reduce the packet re-transmission time. In what follows, we present a solution for IEEE802.16d. Assume the first transmit MIMO packet is a spatial multiplexing: $\begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$, if the re-transmission of the same packet is send in the form of $\begin{bmatrix} -s_2^* \\ s_1^* \end{bmatrix}$ then the 1st and 2nd transmission can be jointly decoded as an Alamouti space time block code. In additional to the soft combing gain, such a re-transmission allows to further exploit the space time block coding gain. If the 2nd transmission is still in error, then the 3rd re-transmission can be sent as $\begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$ such that the 2nd and 3rd transmission to form a space time block code, they can be jointly decoded. After STC decoding, the 1st STC decoding output and 2nd STC decoding output can be combing at FEC code symbol level by using Chase combing. The major advantage of this technique is in the slow fading case, where the coherent time is large; the temporal diversity of the conventional FEC based H-ARQ causes long packet retransmission delay, e.g. when in the deep fade. The issue associated with the STC based MIMO soft-packet combing is that in the fast fading, the channel can vary significantly between the re-transmission; therefore, the straightforward Alamouti decoding becomes not effective. To solve this problem, we could treat the re-transmission packet as additional virtual receive antennas and jointly decode the consecutive transmission as a zero-forcing receiver for the 2x4 spatial multiplexing mode.

$$\begin{bmatrix} r_{1,t_1} \\ r_{2,t_1} \\ r_{1,t_2}^* \\ r_{2,t_2}^* \end{bmatrix} = \begin{bmatrix} h_{11,t_1} & h_{12,t_1} \\ h_{21,t_1} & h_{22,t_1} \\ h_{12,t_2}^* & -h_{11,t_2}^* \\ h_{22,t_2}^* & -h_{21,t_2}^* \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$$

We have $\vec{r} = H\vec{s}$ then the soft MIMO packet combing output is $\vec{s} = \left(H^* H\right)^{-1} H^* \vec{r}$, note that here the soft combing is simply a re-use of the spatial multiplexing receiver. Figure 1 shows the performance advantages of the soft MIMO packet combing solution. In this case, the 5ms re-transmission delay and one re-transmission are assumed. It can be seen clearly that space time diversity improves significantly the packet re-transmission performance. For the 3km/h speed Alamouti decoder and zero-forcing SM decoder have the same performance. For the 100km/h speed, zero-forcing SM decoder is used.

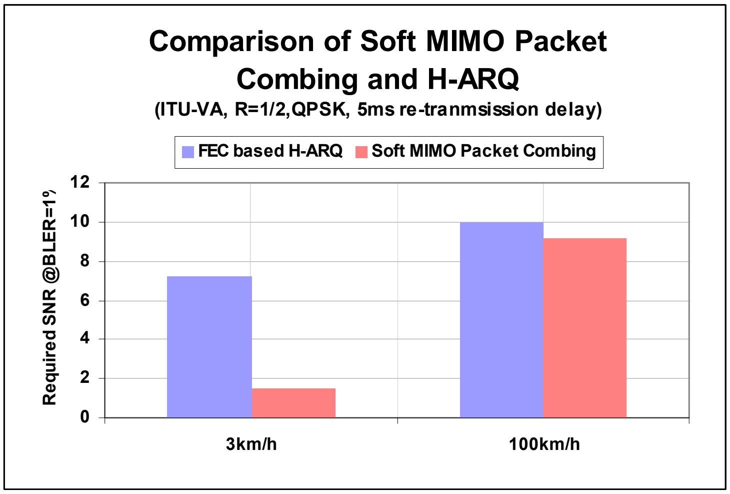

Figure 1 Performance for soft MIMO packet combing

1.2 Differential STC for non-coherent demodulation to improve the range

In the very low SNR level the coherent reception of OFDM signal becomes very difficult, in general, it requires pilot power boost. In the case of limited link budget, the range is limited. In order to extend the range, in addition to the repetition coding, non coherent demodulation will allow the reception of OFDM signal in the very low signal to noise level. We propose to introduce recursive type differential modulation for both MIMO and non-MIMO modes they are applicable to QPSK constellation. The STC code based differential modulation preserve fully the space time coding gain, with only 3dB penalty compared the coherent STC code. The encoding is $Z_i = \frac{1}{\sqrt{2}} Z_{i-1} X_i$ where $X_i = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix}$ and the element $x_1, x_2 \ldots$ is the input symbol. The decoding is $S_i = \frac{1}{\sqrt{2}} S_{i-1} Y_i$ where Y_i is the receiver matrix stacked from the received signal vectors, as we can see, both encoding and decoding is very simple. This is another advantage for the differential STC coding. The typical gain for 4x1 differential STC code v.s . the 2x1 differential STC code is about 12dB for QPSK at BER=10^{-3} . Therefore the differential STC can improve the range dramatically, even with single receive antenna for SS.

2 Specific text changes

2.1 MIMO H-ARQ

[Add new section 8.4.8.9]

---------Start text proposal-------

8.4.8.9 MIMO sub-packet generation for H-ARQ

In the MIMO transmission, for both downlink and uplink, the HARQ re-transmission sub-packet can be generated by using the Space time code incremental redundancy version. The transmission rule for space time coded incremental redundancy codes set is listed in Table aaa-2 and Table aaa-3.

Table aaa-2 H-ARQ Incremental Space time coding redundancy (2-transmit antenna case)

	initial transmission	odd re-transmission	even re-transmission
Space time code incremental redundancy	$S_{2xN_R}{}^{(0)} = \begin{bmatrix} s_1 & s_3 \\ s_2 & s_4 \end{bmatrix}$	$S_{2xN_R}{}^{(odd)} = \begin{bmatrix} -s_2{}^* & -s_4{}^* \\ s_1{}^* & s_3{}^* \end{bmatrix}$	$S_{2xN_R}{}^{(even)} = \begin{bmatrix} s_1 & s_3 \\ s_2 & s_4 \end{bmatrix}$

Table aaa-3 H-ARQ Incremental Space time coding redundancy (4-transmit antenna case)

	initial transmission	odd re-transmission	even re-transmission
Space time code incremental redundancy	$S_{4xN_R}{}^{(0)} = \begin{bmatrix} s_1 & s_5 \\ s_2 & s_6 \\ s_3 & s_7 \\ s_4 & s_8 \end{bmatrix}$	$S_{4xN_R}{}^{(odd)} = \begin{bmatrix} -s_2{}^* & -s_6{}^* \\ s_1{}^* & s_5{}^* \\ -s_4{}^* & -s_8{}^* \\ s_3{}^* & s_7{}^* \end{bmatrix}$	$S_{4xN_R}{}^{(even)} = \begin{bmatrix} s_1 & s_5 \\ s_2 & s_6 \\ s_3 & s_7 \\ s_4 & s_8 \end{bmatrix}$

The SS shall process the initial transmission, 1st re-transmission and 2nd re-transmission etc in the form of space time decoding. The re-transmission of FEC code word shall use the Chase combing re-transmission version, in this case, the sub-packet index is always set to zero in section 8.4.9.2.3.6.

---------End text proposal-------

2.2 Differential Modulation for range extension

[Add the following text into section 8.4.9.2]

---------Start text proposal-------

Additional differential modulations for MIMO, SISO and SIMO are listed in table zzz-1

Table zzz-1 differential space time code for 1, 2 and 4 transmit antennas

Antenna Configuration	Modulation Rule	X_i
1-transmit antenna	$Z_i = \frac{1}{\sqrt{2}} Z_{i-1} X_i$	Table xxx-2
2-transmit antenna	$Z_i = \frac{1}{\sqrt{2}} Z_{i-1} X_i$	$X_i = \begin{bmatrix} x_1 & x_2 \\ -x_2{}^* & x_1{}^* \end{bmatrix}$

4-transmit antenna	$Z_i = \frac{1}{\sqrt{2}} Z_{i-1} X_i$	$X_i = \begin{bmatrix} x_1 & x_2 & \frac{x_3}{\sqrt{2}} & \frac{x_3}{\sqrt{2}} \\ -x_2^* & x_1^* & \frac{x_3}{\sqrt{2}} & -\frac{x_3}{\sqrt{2}} \\ \frac{x_3^*}{\sqrt{2}} & \frac{x_3^*}{\sqrt{2}} & \frac{-x_1 - x_1^* + x_2 - x_2^*}{2} & \frac{x_1 - x_1^* - x_2 - x_2^*}{2} \\ \frac{x_3^*}{\sqrt{2}} & -\frac{x_3^*}{\sqrt{2}} & \frac{x_1 - x_1^* + x_2 + x_2^*}{2} & \frac{-x_1 - x_1^* - x_2 + x_2^*}{2} \end{bmatrix}$

For single antenna transmission the input bit and symbol mapping is shown in Table zzz-2

Table zzz-2 π/4-DQPSK modulation

Codeword $b_0 b_1$	Modulation symbol, X_i
00	1
01	j
11	-1
10	-j

3 Updated Text

3.1 DL MIMO Preamble Construction and backward compatible with non-MIMO SS

[Add the following text into section 8.4.8.4]

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---------Start text proposal-------
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For each segment as defined in previous sections, two or four antennas are used to transmit the transmit diversity signals. Therefore from the definition in section 8.4.6.1.1, the following applies:

Each segment uses 2 types of preamble carrier-sets (one for each antenna or pair of antennas) out of the 6 sets in the following manner:

For two transmit MIMO:

Segment 0 - carrier set 0 used by antenna 0, ~~preamble~~ carrier set 3 used by antenna 1
Segment 1 - carrier set 1 used by antenna 0, ~~preamble~~ carrier set 4 used by antenna 1
Segment 2 - carrier set 2 used by antenna 0, ~~preamble~~ carrier set 5 used by antenna 1

For four transmit MIMO:

Segment 0 - carrier set 0 used by antenna 0 and 2, carrier set 3 used by antenna 1 and 3
Segment 1 - carrier set 1 used by antenna 0 and 2, carrier set 4 used by antenna 1 and 3
Segment 2 - carrier set 2 used by antenna 0 and 2, carrier set 5 used by antenna 1 and 3

The same PN series as defined in that 8.4.6.1.1 ~~section~~ is also used in the transmit diversity mode.

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---------End text proposal-------
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3.2 DL MIMO scattered pilot for FUSC and PUSC

[Add the following text into section 8.4.8.5]

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---------Start text proposal-------
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For 2 transmit, in FUSC all subchannles shall be used for MIMO transmission, the pilots within the symbols shall be divided between the antennas, antenna 0 uses VariableSet#0 and ConstantSet#0 for even symbols while antenna 1 uses VariableSet#1 and ConstantSet#1 for even symbols, antenna 0 uses VariableSet#1 and ConstantSet#0 for odd symbols while antenna 1 uses VariableSet#0 and ConstantSet#1 for odd symbols.
For 4 transmit, the FUSC configuration the pilots embedded within the symbol shall be further divided, the pilots shall be transmitted with a structure including 4 time symbol (repeating itself every 4 symbols) as follows:
Symbol 0: antenna 0 uses VariableSet#0 and ConstantSet#0, antenna 1 uses VariableSet#1 and ConstantSet#1
Symbol 1: antenna 2 uses VariableSet#0 and ConstantSet#0, antenna 3 uses VariableSet#1 and ConstantSet#1
Symbol 2: antenna 0 uses VariableSet#1 and ConstantSet#0, antenna 1 uses VariableSet#0 and ConstantSet#1
Symbol 3: antenna 2 uses VariableSet#1 and ConstantSet#0, antenna 3 uses VariableSet#0 and ConstantSet#1

For 2-transmit the PUSC cluster pilot locations are shown in Figure x-1. When 4-transmit antennas are used, the pilots for antenna 2 and 3 pilots are punctured into corresponding data carrier locations as shown in Figure x-1

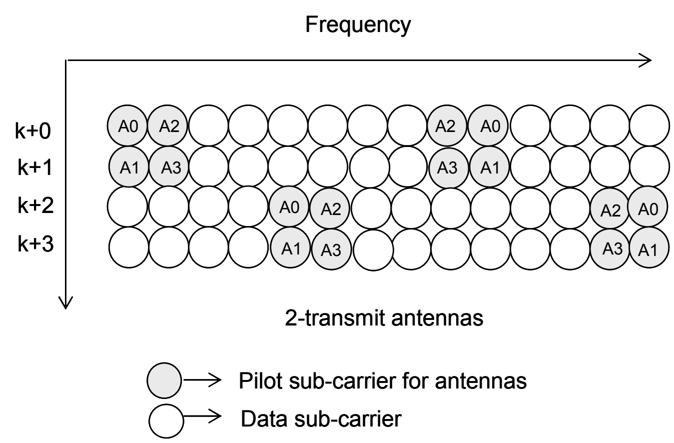

Figure x1

---------End text proposal-------

3.3 UL MIMO tile

[Add the following text into section 8.4.8.6]

---------Start text proposal-------

8.4.8.6 Uplink MIMO

~~Not changed compared to the regular mode of operation.~~
A two transmit MIMO burst in the uplink is defined as MIMO tile and uplink bin, 2-transmit diversity data or 2-transmit spatial multiplexing data can be mapped onto each subcarrier, each MIMO tile is composed of 4-continuous subcarriers and 3-continuous time symbols. It's configuration is illustrated in Figure xxx-1. One subchannel is constructed from 8 uplink MIMO tiles, within each burst, there are 64 data subcarriers and 32 fixed-location pilot subcarrier.

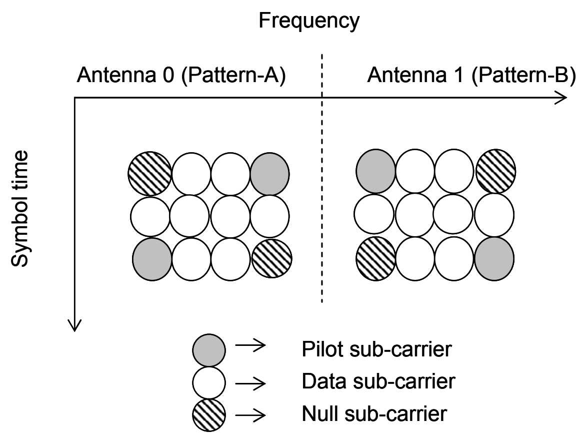

Figure x-3 UL MIMO collaborative spatial multiplexing tilte

Two single transmit antenna SS's can perform collaborative spatial multiplexing onto the same subcarrier. In this case, the one SS should use the uplink tile with pattern-A, and the other SS should use the uplink tile with pattern-B. Figure x-3 depicts the uplink tile

---------End text proposal-------

3.4 MIMO antenna configurations and transmission format

[Add the following text into section 8.4.8.8]

---------Start text proposal-------

~~8.4.8.8 Transmission through 4 antennas (possible enhancement)~~

~~The Transmit diversity schemes could be further enhanced by using 4 antennas at the transmission site. Two antennas are now being used in order to transmit each symbol (the first antenna transmits the signal as defined in 8.4.8.2 and 8.4.8.3, and the second transmits the same signal with a complex vector rotation), this transmission shall create additional multipaths received by the user, these multipaths aim are to reduce the effect of the Rayleigh channel variation. This method gives the space diversity associated with the STC/FHDC with an additional multipath creation caused by another antenna; this scheme is presented in Figure 237:~~

~~**Figure 237—Illustration of Transmit diversity using 4 antennas**~~

~~This method does not change the channel estimation process of the user, therefore this scheme could be implemented without any changes made to the Transmit diversity user.~~

8.4.8.8 MIMO antenna configurations and transmission format

Assuming that the N_T is the number of transmit antenna at BS and N_R is the number of receive antennas at terminal SS. The MIMO configuration is denoted as N_TxN_R. For the MIMO down link transmission, the space time coding is employed, Assuming the MIMO transmission and reception can be expressed by $Y=HS$, where Y^{1xM} is the output of MIMO channel and H^{MxNT} is the MIMO channel and S denotes the space time coding matrix., with the row index indicate the antenna number and column index indicate the symbol time

8.4.8.8.1 4x1 configuration: (space time coding rate = 1)

$$S_{4x1} = \begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ 0 & 0 & s_4 & s_3^* \end{bmatrix}$$

8.4.8.8.2 4x2 configuration: (space time coding rate = 2)

By in-time puncturing the columns 3&4, 7&8 and 11&12 of S_{4x1}

$$S_{4x2} = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_2 & s_1^* & s_6 & -s_8^* \\ s_3 & -s_4^* & s_7 & s_5^* \\ s_4 & s_3^* & s_8 & s_6^* \end{bmatrix}$$

8.4.8.8.3 4x4 configuration (space time coding rate = 4)

By in-time puncturing the columns 2, and 4 of S_{4x2}.

$$S_{4x4} = \begin{bmatrix} s_1 & s_5 \\ s_2 & s_6 \\ s_3 & s_7 \\ s_4 & s_8 \end{bmatrix}$$

8.4.8.8.4 2x1 configuration: (space time coding rate = 1)

By in-space puncturing antenna 3&4 and in-time puncturing columns 3&4 of S_{4x2}

$$S_{2x1} = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}$$

8.4.8.8.5 2x2, 2x4 configurations: (space time coding rate = 2),

By in-time puncturing the even columns of S_{2x1}:

$$S_{2x2,2x4} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$$

The MIMO transmission formats S_{4x1}, S_{4x2} and S_{2x1} generate space time transmit diversity (STTD), and the formats S_{4x4} and $S_{2x2,2x4}$ generate the vertical spatial multiplexing (SM)

---------End text proposal-------

3.5 Fast DL signaling channel support

[Add new section 8.4.4.8]

---------Start text proposal-------

8.4.4.8 MIMO fast signaling zone

The AAS diversity MAP zone is used for the MIMO mode to transmit MIMO specific compressed DL_MAP such as MIMO DL Enhanced IE format. The construction of this zone is as follows: the message with QPSK rate ½ with 4 repetitions is denoted as $s_{m,n}$ where *m* denotes subcarrier number *n* denotes the OFDM symbol number. MIMO_DL_Config_IE message is then differentially space time encoded in the OFDM symbol direction as: $Z_n = \frac{1}{\sqrt{2}} Z_{n-1} X_n$ where, $X_i = \begin{bmatrix} s_{m,n} & s_{m,n+1} \\ -s_{m,n}^{*} & s_{m,n+1}^{*} \end{bmatrix}$ for $m = N_{offset}, N_{offset}+1, \ldots$, where the 1st row of Z_n is mapped onto 1st transmit antenna and 2nd row of Z_n is mapped onto 2nd transmit antenna and the N_{offset} is the sub-carrier offset.

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---------End text proposal-------
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3.6 DL FUSC scattered pilot planning

[Add the following text into section 8.4.6.1.2.1.1]

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---------Start text proposal-------
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8.4.6.1.2.1.1 Downlink subchannels subcarrier allocation

Each subchannel is composed of 48 subcarriers. The subchannel indices are formulated using a RS series, and is allocated out of the data subcarriers domain. The data subcarriers domain includes 48*32=1536 subcarriers, which are the remaining subcarriers after removing from the subcarrier's domain (0-2047) all possible pilots and zero subcarriers (including the DC subcarrier). The allocated vlaues of the variableSet pilot defined in Table 271 shall add an offset (ID_{Cell})mod12, and since the down link transmission is OFDMA symbol pairs based therefore the allocated of the variableSet pilot shall be based on the OFDMA symbol pair. After allocating the data subcarriers domain, the procedure of partitioning those subcarriers into subchannels shall be as specified in section 8.4.6.1.3.

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---------End text proposal-------
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