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Title	**Subpacket retransmission with spatial diversity schemes in MIMO channel**
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Source(s)	Ryohei KIMURA[*], Takaaki KISHIGAMI[*], Isamu YOSHII[*] Katsuhiko HIRAMATSU[*] Lei HUANG [*] Matsushita Electric (Panasonic) [+]Panasonic Singapore Laboratories Voice: +81-50-3687-6584 E-mail: kimura.ryohei@jp.panasonic.com kishigami.takaaki@jp.panasonic.com yoshii.isamu@jp.panasonic.com
Re:	IEEE 802.16m-08/016 - Call for Contributions on Project 802.16m System Description Document (SDD), shoot for “Hybrid ARQ (PHY aspects)” topic.
Abstract	In this contribution, we discuss HARQ subpacket retransmission with multi-antenna transmission. STC has already been decided to apply to subpacket retransmission in IEEE802.16e as an optional extra. Other spatial diversity schemes(e.g., precoding, CDD and antenna selection) can be also applied.
Purpose	For 802.16m discussion and adoption
Notice	
Release	
Patent Policy	

Subpacket Retransmission with Spatial Diversity Schemes in MIMO Channel

Ryohei KIMURA, Takaaki KISHIGAMI, Isamu YOSHII, and Katsuhiko HIRAMATSU

Matsushita Electric (Panasonic)

Lei HUANG

Panaosnic Singapore Laboratories

1. Introduction

Space time coding (STC) is adopted as an option in IEEE 802.16e for HARQ subpacket retransmission in MIMO channel [1]. Changing subpacket retransmission format according to STC principle can prominently improve HARQ performance due to the introduction of spatial diversity. Naturally, in addition to STC, other spatial diversity schemes (e.g., precoding, cyclic delay diversity (CDD), and antenna selection) can also be applied to HARQ subpacket retransmission. In this contribution, the application of various spatial diversity schemes to HARQ subpacket retransmission in IEEE 802.16m is addressed.

2. Subpacket Retransmission in MIMO Channel

In IEEE 802.16m, various spatial diversity schemes should be considered for HARQ subpacket retransmission to reduce the number of HARQ retransmissions by improving the diversity gain. For simplifying presentation, the spatial diversity schemes for HARQ subpacket retransmission are addressed only with two transmit antenna case through the contribution. Following the similar spirit, these spatial diversity schemes can be adapted to the case of more than three transmit antennas.

2.1. Space Time Coding

The STC subpacket retransmission schemes specified in IEEE 802.16e should be reused in IEEE 802.16m. According to IEEE 802.16e, for two transmit antennas, the STC subpacket retransmission can be generated according to the principle of Alamouti coding. The transmission rule for STC subpacket retransmission is listed in Table 1.

Table 1. STC subpacket retransmission rule (2-Tx antenna/rank 2 case)

	1st transmission	2nd transmission	Further transmission
Retransmission vector	$\mathbf{s}^{(1)} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$	$\mathbf{s}^{(2)} = \begin{bmatrix} -s_2^* \\ s_1^* \end{bmatrix}$	Alternatively using 1st and 2nd transmission vectors

2.2. Precoding

Precoding is used for multi-layer beamforming, which can maximize the throughput performance of MIMO systems. Precoding should be considered for subpacket retransmission in IEEE 802.16m. The precoding subpacket retransmission can be generated by using the precoding vector (for rank 1) or the precoding matrix (for rank 2). The transmission rules for rank 1 and rank 2 precoding subpacket retransmission are listed in Table 2 and Table 3, respectively.

Table 2. Precoding subpacket retransmission rule (2-Tx antenna/rank 1 case)

	1st transmission	2nd transmission	3rd transmission	4th transmission	Further transmission
Retransmission vector	$\mathbf{p}^{(1)} = \frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$	$\mathbf{p}^{(2)} = \frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$	$\mathbf{p}^{(3)} = \frac{1}{\sqrt{2}}\begin{bmatrix}1\\j\end{bmatrix}$	$\mathbf{p}^{(4)} = \frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$	Repeatedly using 1st, 2nd, 3rd and 4th transmission vectors

Table 3. Precoding subpacket retransmission rule (2-Tx antenna/rank 2 case)

	1st transmission	2nd transmission	Further transmission
Retransmission matrix	$\mathbf{P}^{(1)} = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$	$\mathbf{P}^{(2)} = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\j & -j\end{bmatrix}$	Alternatively using 1st and 2nd transmission matrices

2.3. Cyclic Delay Diversity

The CDD is a diversity scheme which can transform spatial diversity into frequency diversity avoiding inter symbol interference. The CDD should also be a promising technique for subpacket retransmission in IEEE 802.16m. The CDD subpacket retransmission can be generated by using the CDD matrix (for both rank 1 and rank 2). The transmission rules for rank 1 and rank 2 CDD subpacket retransmission are listed in Table 4 and Table 5, respectively, where k indexes the subcarrier number.

Table 4. CDD subpacket retransmission rule (2-Tx antenna/rank 1 case)

	1st transmission	2nd transmission	Further transmission
Retransmission matrix	$\mathbf{D}^{(1)} = \begin{bmatrix}1 & 0\\0 & e^{-i\pi}\end{bmatrix}$	$\mathbf{D}^{(2)} = \begin{bmatrix}e^{i\pi/2} & 0\\0 & e^{-i\pi/2}\end{bmatrix}$	Alternatively using 1st and 2nd transmission matrices

Table 5. CDD subpacket retransmission rule (2-Tx antenna/rank 2 case)

	1st transmission	2nd transmission	Further transmission
Retransmission matrix	$\mathbf{D}^{(1)} = \begin{bmatrix}1 & e^{i\pi/2}\\e^{-i\pi} & e^{-i\pi/2}\end{bmatrix}$	$\mathbf{D}^{(2)} = \begin{bmatrix}e^{i\pi/2} & 1\\e^{-i\pi/2} & e^{i\pi}\end{bmatrix}$	Alternatively using 1st and 2nd transmission matrices

2.4. Antenna Selection

Antenna selection can realize the diversity benefits of MIMO systems, while keep the potentially prohibitive hardware cost and complexity low. Antenna selection should be a potential candidate for subpacket retransmission in IEEE 802.16m. The antenna selection subpacket retransmission can be generated by using the antenna selection vector (for rank 1) or the antenna selection matrix (for rank 2). The transmission rules for rank 1 and rank 2 antenna selection subpacket retransmission are listed in Table 6 and Table 7, respectively.

Table 6. Antenna selection subpacket retransmission rule (2-Tx antenna/rank 1 case)

	1st transmission	2nd transmission	Further transmission
Retransmission vector	$\mathbf{a}^{(1)} = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$	$\mathbf{a}^{(2)} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$	Alternatively using 1st and 2nd transmission vectors

Table 7. Antenna selection packet retransmission rule (2-Tx antenna/rank 2 case)

	1st transmission	2nd transmission	Further transmission
Retransmission matrix	$\mathbf{A}^{(1)} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$	$\mathbf{A}^{(2)} = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$	Alternatively using 1st and 2nd transmission matrices

3. Conclusion

In this contribution, various spatial diversity schemes for HARQ subpacket retransmission in MIMO channel are proposed for IEEE 802.16m, including STC, precoding, CDD, and antenna selection. Rearranging subpacket retransmission format according to the proposed spatial diversity schemes can improve HARQ performance due to the introduction of spatial diversity.

Although only two transmit antennas case is addressed in this contribution, the proposed spatial diversity schemes can be adapted easily to the case of more than 3 transmit antennas, which will be detailed at stage 3.

Note that the signal constellation rearrangement in the case of 2^M-QAM with M larger than 2 can be used together with the proposed subpacket retransmission schemes and can dramatically improve HARQ performance [2]. Therefore, subpacket retransmission based on spatial diversity shall be included in the IEEE 802.16m SDD.

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X. HARQ

Various spatial diversity schemes shall be used for HARQ subpacket retransmission in MIMO channel to reduce the number of retransmission. These spatial diversity schemes include STC, precoding, CDD, and antenna selection. The transmission rules for subpacket retransmission with these spatial diversity schemes are listed in Table x.1 to Table x.7.

Table x.8. STC subpacket retransmission rule (2-Tx antenna/rank 2 case)

	1st transmission	2nd transmission	Further transmission
Retransmission vector	$\mathbf{s}^{(1)} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$	$\mathbf{s}^{(2)} = \begin{bmatrix} -s_2^* \\ s_1^* \end{bmatrix}$	Alternatively using 1st and 2nd transmission vectors

Table x.9. Precoding subpacket retransmission rule (2-Tx antenna/rank 1 case)

	1st transmission	2nd transmission	3rd transmission	4th transmission	Further transmission
Retransmission vector	$\mathbf{p}^{(1)} = \frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$	$\mathbf{p}^{(2)} = \frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$	$\mathbf{p}^{(3)} = \frac{1}{\sqrt{2}}\begin{bmatrix}1\\j\end{bmatrix}$	$\mathbf{p}^{(4)} = \frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$	Repeatedly using 1st, 2nd, 3rd and 4th transmission vectors

Table x.10. Precoding subpacket retransmission rule (2-Tx antenna/rank 2 case)

	1st transmission	2nd transmission	Further transmission
Retransmission matrix	$\mathbf{P}^{(1)} = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$	$\mathbf{P}^{(2)} = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\j & -j\end{bmatrix}$	Alternatively using 1st and 2nd transmission matrices

Table x.11. CDD subpacket retransmission rule (2-Tx antenna/rank 1 case)

	1st transmission	2nd transmission	Further transmission
Retransmission matrix	$\mathbf{D}^{(1)} = \begin{bmatrix}1 & 0\\0 & e^{-i\pi}\end{bmatrix}$	$\mathbf{D}^{(2)} = \begin{bmatrix}e^{i\pi/2} & 0\\0 & e^{-i\pi/2}\end{bmatrix}$	Alternatively using 1st and 2nd transmission matrices

Table x.12. CDD subpacket retransmission rule (2-Tx antenna/rank 2 case)

	1st transmission	2nd transmission	Further transmission
Retransmission matrix	$\mathbf{D}^{(1)} = \begin{bmatrix}1 & e^{i\pi/2}\\e^{-i\pi} & e^{-i\pi/2}\end{bmatrix}$	$\mathbf{D}^{(2)} = \begin{bmatrix}e^{i\pi/2} & 1\\e^{-i\pi/2} & e^{i\pi}\end{bmatrix}$	Alternatively using 1st and 2nd transmission matrices

Table x.13. Antenna selection subpacket retransmission rule (2-Tx antenna/rank 1 case)

	1st transmission	2nd transmission	Further transmission
Retransmission vector	$\mathbf{a}^{(1)} = \begin{bmatrix}1\\0\end{bmatrix}$	$\mathbf{a}^{(2)} = \begin{bmatrix}0\\1\end{bmatrix}$	Alternatively using 1st and 2nd transmission vectors

Table x.14. Antenna selection packet retransmission rule (2-Tx antenna/rank 2 case)

	1st transmission	2nd transmission	Further transmission
Retransmission matrix	$\mathbf{A}^{(1)} = \begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$	$\mathbf{A}^{(2)} = \begin{bmatrix}0 & 1\\1 & 0\end{bmatrix}$	Alternatively using 1st and 2nd transmission matrices

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4. Reference

[1] IEEE Std 802.16e™-2005, "IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems - Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands"

[2] IEEE 802.16m-07/292r1, ITRI, "Enhanced HARQ Technique Using Constellation Rearrangement"