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Title	**Enhanced HARQ technique using Self-Interference Cancellation Coding (SICC)**
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Re:	Response to the Call for Contributions IEEE 802.16m-08/016 — Hybrid ARQ
Abstract	This contribution proposes an enhanced HARQ technique for 802.16m system description document (SDD).
Purpose	To adopt the enhanced HARQ technique proposed herein into IEEE 802.16m system description document (SDD).
Notice	
Release	
Patent Policy	

Enhanced HARQ technique using Self-Interference Cancellation Coding(SICC)

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Abstract

The paper provides a method for combining HARQ along with Self-Interference Cancellation Coding (SICC) so that the reliability of HARQ with incremental redundancy can be improved. Additionally, the receiver structure is simplified. The simulation results show that significant gain is achieved over the existing Space Time code subpacket combining.

Background

The existing 802.16 standard allows for a HARQ scheme with incremental redundancy (HARQ-IR) in which the subpacket retransmissions are generated by using an Alamouti space time code [1]. We focus on the case of 4 transmit antennas where the encoding scheme is found in section 8.4.8.6 of [1]. The HARQ transmissions are defined as follows:

	Initial transmission	Odd retransmission	Even retransmission
Space time code incremental redundancy for Matrix C	$S_2^{(0)} = \begin{bmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \end{bmatrix}$	$S_2^{(odd)} = \begin{bmatrix} -S^*_2 \\ S^*_1 \\ -S^*_4 \\ S^*_3 \end{bmatrix}$	$S_2^{(even)} = \begin{bmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \end{bmatrix}$

Where we see that the transmitter's first two transmissions form a stacked 2 antenna Alamouti code. If decoding fails after the first *and* second transmissions then these transmissions are repeated and the repeated subpackets are chase combined with the appropriate (either the initial or second transmissions) received symbols. This transmission scheme allows the use of well known Alamouti decoding at the receiver. That is after the reception of the first and second subpackets the receiver can decode the S_1, S_2, by appropriate (linear) combining of the received subpackets on antennas 1 and 2 (we are assuming 4 receive antennas) and S_3, S_4, by appropriate combining of the received subpackets on antennas 3 and 4. However, in the case of simple linear receivers for the above scheme there will be self interference among the symbols after the linear combining. This interference is typically handle by either zero-forcing operation, where the receiver equalizes the effective MIMO channel as seen after the linear combing or by performing maximum likelihood detection among the two sets of antennas {1,2} and {3,4}.

Proposed SICC coding scheme

As an alternative coding scheme for the retransmission of subpackets consider the following sequence of 4 transmissions from 4 antennas

$$\mathbf{S} = \begin{bmatrix} S_1 & -S_2^* & S_1 & -S_2^* \\ S_2 & S_1^* & S_2 & S_1^* \\ S_3 & -S_4^* & -S_3 & S_4^* \\ S_4 & S_3^* & -S_4 & -S_3^* \end{bmatrix}.$$

Where each column represents a subpacket retransmission (except the first column which is the initial transmission). We see that the first retransmission (second column) is identical to the existing code in 802.16 and that after its reception a simple linear decoding can be attempted. What is new in this scheme are the 2nd and 3rd retransmission (3rd and 4th columns). This code enables a simple linear receiver that completely cancels self interference and can be seen by the following combing scheme for 4 transmissions.

To obtain S_1 ,

$$\begin{bmatrix} r_{1,1} & r_{1,2}^* & r_{1,3} & r_{1,4}^* \end{bmatrix}\begin{bmatrix} h_{1,1}^* \\ h_{1,2} \\ h_{1,1}^* \\ h_{1,2} \end{bmatrix} + \begin{bmatrix} r_{2,1} & r_{2,2}^* & r_{2,3} & r_{2,4}^* \end{bmatrix}\begin{bmatrix} h_{2,1}^* \\ h_{2,2} \\ h_{2,1}^* \\ h_{2,2} \end{bmatrix}$$

$$+ \begin{bmatrix} r_{3,1} & r_{3,2}^* & r_{3,3} & r_{3,4}^* \end{bmatrix}\begin{bmatrix} h_{3,1}^* \\ h_{3,2} \\ h_{3,1}^* \\ h_{3,2} \end{bmatrix} + \begin{bmatrix} r_{4,1} & r_{4,2}^* & r_{4,3} & r_{4,4}^* \end{bmatrix}\begin{bmatrix} h_{4,1}^* \\ h_{4,2} \\ h_{4,1}^* \\ h_{4,2} \end{bmatrix}$$

$$= 2\left(|h_{1,1}|^2 + |h_{1,2}|^2 + |h_{2,1}|^2 + |h_{2,2}|^2 + |h_{3,1}|^2 + |h_{3,2}|^2 + |h_{4,1}|^2 + |h_{4,2}|^2\right)S_1 + n_1'$$

for S_2 ,

$$\begin{bmatrix} r_{1,1} & r_{1,2}^* & r_{1,3} & r_{1,4}^* \end{bmatrix}\begin{bmatrix} h_{1,2}^* \\ -h_{1,1} \\ h_{1,2}^* \\ -h_{1,2} \end{bmatrix} + \begin{bmatrix} r_{2,1} & r_{2,2}^* & r_{2,3} & r_{2,4}^* \end{bmatrix}\begin{bmatrix} h_{2,2}^* \\ -h_{2,1} \\ h_{2,2}^* \\ -h_{2,1} \end{bmatrix}$$

$$+ \begin{bmatrix} r_{3,1} & r_{3,2}^* & r_{3,3} & r_{3,4}^* \end{bmatrix}\begin{bmatrix} h_{3,2}^* \\ -h_{3,1} \\ h_{3,2}^* \\ -h_{3,1} \end{bmatrix} + \begin{bmatrix} r_{4,1} & r_{4,2}^* & r_{4,3} & r_{4,4}^* \end{bmatrix}\begin{bmatrix} h_{4,2}^* \\ -h_{4,1} \\ h_{4,2}^* \\ -h_{4,1} \end{bmatrix}$$

$$= 2\left(|h_{1,1}|^2 + |h_{1,2}|^2 + |h_{2,1}|^2 + |h_{2,2}|^2 + |h_{3,1}|^2 + |h_{3,2}|^2 + |h_{4,1}|^2 + |h_{4,2}|^2\right)S_2 + n_1'$$

for S_3 ,

$$\begin{bmatrix} r_{1,1} & r_{1,2}^* & r_{1,3} & r_{1,4}^* \end{bmatrix}\begin{bmatrix} h_{1,3}^* \\ h_{1,4} \\ -h_{1,3}^* \\ -h_{1,4} \end{bmatrix} + \begin{bmatrix} r_{2,1} & r_{2,2}^* & r_{2,3} & r_{2,4}^* \end{bmatrix}\begin{bmatrix} h_{2,3}^* \\ h_{2,4} \\ -h_{2,3}^* \\ -h_{2,4} \end{bmatrix}$$
$$+\begin{bmatrix} r_{3,1} & r_{3,2}^* & r_{3,3} & r_{3,4}^* \end{bmatrix}\begin{bmatrix} h_{3,3}^* \\ h_{3,4} \\ -h_{3,3}^* \\ -h_{3,4} \end{bmatrix} + \begin{bmatrix} r_{4,1} & r_{4,2}^* & r_{4,3} & r_{4,4}^* \end{bmatrix}\begin{bmatrix} h_{4,3}^* \\ h_{4,4} \\ -h_{4,3}^* \\ -h_{4,4} \end{bmatrix}$$
$$= 2\left(\left|h_{1,3}\right|^2 + \left|h_{1,4}\right|^2 + \left|h_{2,3}\right|^2 + \left|h_{2,4}\right|^2 + \left|h_{3,3}\right|^2 + \left|h_{3,4}\right|^2 + \left|h_{4,3}\right|^2 + \left|h_{4,4}\right|^2\right) S_3 + n_1'$$

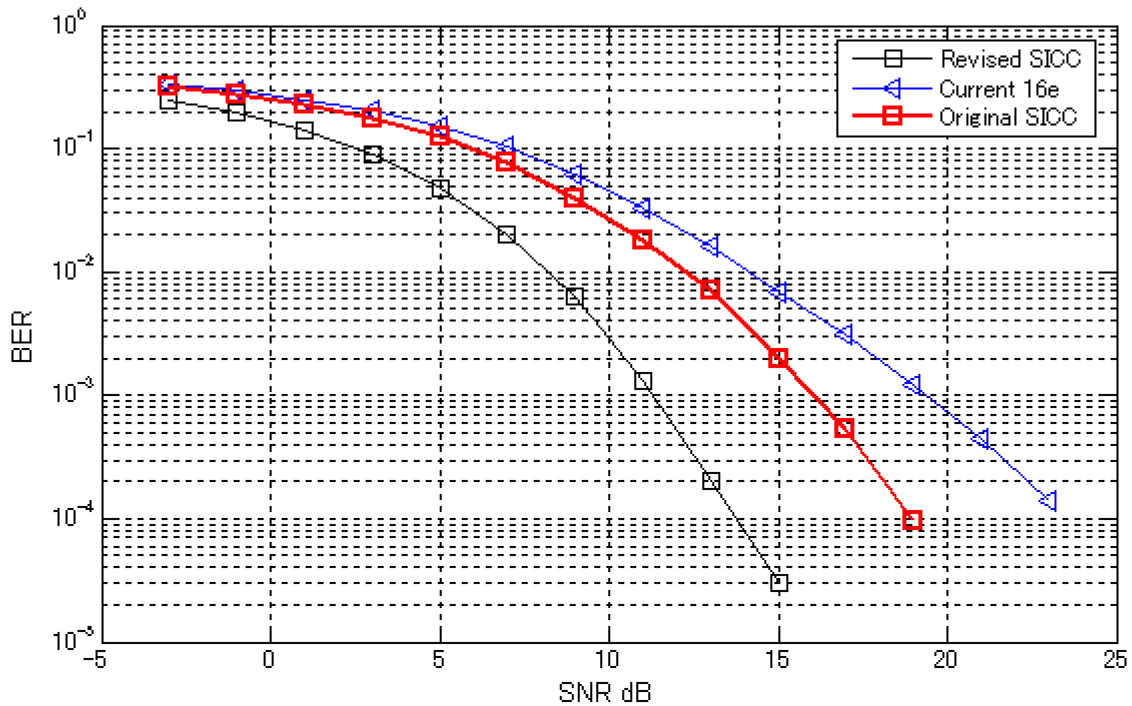
and for S_4,

$$\begin{bmatrix} r_{1,1} & r_{1,2}^* & r_{1,3} & r_{1,4}^* \end{bmatrix}\begin{bmatrix} h_{1,4}^* \\ -h_{1,3} \\ -h_{1,4}^* \\ h_{1,3} \end{bmatrix} + \begin{bmatrix} r_{2,1} & r_{2,2}^* & r_{2,3} & r_{2,4}^* \end{bmatrix}\begin{bmatrix} h_{2,4}^* \\ -h_{2,3} \\ -h_{2,4}^* \\ h_{2,3} \end{bmatrix}$$
$$+\begin{bmatrix} r_{3,1} & r_{3,2}^* & r_{3,3} & r_{3,4}^* \end{bmatrix}\begin{bmatrix} h_{3,4}^* \\ -h_{3,3} \\ -h_{3,4}^* \\ h_{3,3} \end{bmatrix} + \begin{bmatrix} r_{4,1} & r_{4,2}^* & r_{4,3} & r_{4,4}^* \end{bmatrix}\begin{bmatrix} h_{4,4}^* \\ -h_{4,3} \\ -h_{4,4}^* \\ h_{4,3} \end{bmatrix}$$
$$= 2\left(\left|h_{1,3}\right|^2 + \left|h_{1,4}\right|^2 + \left|h_{2,3}\right|^2 + \left|h_{2,4}\right|^2 + \left|h_{3,3}\right|^2 + \left|h_{3,4}\right|^2 + \left|h_{4,3}\right|^2 + \left|h_{4,4}\right|^2\right) S_4 + n_1'$$

In the above equations, r_{ij}, is the received symbol at the i^{th} antenna at j^{th} reception time and h_{ij} is the channel coefficient from the j^{th} transmit antenna to the i^{th} receive antenna. We see that the linear combing of the 4 subpackets results in the complete cancellation of self-interference terms.

Performance

We have simulated the HARQ-IR schemes over a Rayleigh fading channel to compare there performance. For the STC coding scheme it is assumed that subpackets are chase combined and then a Zero-forcing MIMO receiver is employed after Alamouti combing. In the SICC scheme the linear combing receiver as described above is used. Bit error rates are shown below and we see that after 4 retransmissions the proposed SICC scheme (Revised SICC) out performs the existing scheme by about 7-8 dB. (Original SICC is old version as mentioned in IEEE C802.16m-08/385r1.)



Proposed text for SDD

11.x Physical layer

11.x.y Hybrid ARQ

HARQ scheme with STC and/or SICC (Self-Interference Cancellation Coding) should be used for 802.16m systems. The proposed encoding rule of retransmitted packet is shown in the Tables.

Table 1 STC HARQ combining **(2-transmit antenna case) :same as 8.4.8.6 of [1]**

	Initial transmission	**Odd re-transmission**	**Even re-transmission**
Space time code incremental redundancy for matrix A	$\mathbf{S}^{(0)}=\begin{bmatrix}S_1\\S_2\end{bmatrix}$	$\mathbf{S}^{(odd)}=\begin{bmatrix}-S_2^*\\S_1^*\end{bmatrix}$	$\mathbf{S}^{(even)}=\begin{bmatrix}S_1\\S_2\end{bmatrix}$

Table 2 STC HARQ combining **(3-transmit antenna case) :same as 8.4.8.6 of [1]**

	Initial transmission	**Odd re-transmission**	**Even re-transmission**
Space time code incremental redundancy for matrix C	$\mathbf{S}^{(0)}=\begin{bmatrix}S_1\\S_2\\S_3\end{bmatrix}$	$\mathbf{S}^{(odd)}=\begin{bmatrix}-S_2^*\\S_1^*\\S_3^*\end{bmatrix}$	$\mathbf{S}^{(even)}=\begin{bmatrix}S_1\\S_2\\S_3\end{bmatrix}$

Table 3 STC/SICC HARQ combining **(4-transmit antenna case):new**

	Initial transmission	**2^{nd} transmission**	**3rd transmission**	**4^{th} transmission**

Space time code incremental redundancy for matrix C	$\mathbf{S}^{(0)} = \begin{bmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \end{bmatrix}$	$\mathbf{S}^{(1)} = \begin{bmatrix} -S_2^* \\ S_1^* \\ -S_4^* \\ S_3^* \end{bmatrix}$	$\mathbf{S}^{(2)} = \begin{bmatrix} S_1 \\ S_2 \\ -S_3 \\ -S_4 \end{bmatrix}$	$\mathbf{S}^{(3)} = \begin{bmatrix} -S_2^* \\ S_1^* \\ S_4^* \\ -S_3^* \end{bmatrix}$

References

1. *Standard for Local and metropolitan area networks Part 16: Air Interface for Broadband Wireless Access Systems*, P802.16Rev2/D4 (April 2008)