Proposed Text on MIMO HARQ for the IEEE 802.16m Amendment

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Venue:

In response to Call for Contributions and Comments on Project 802.16m Amendment Working Document

Base Contribution:

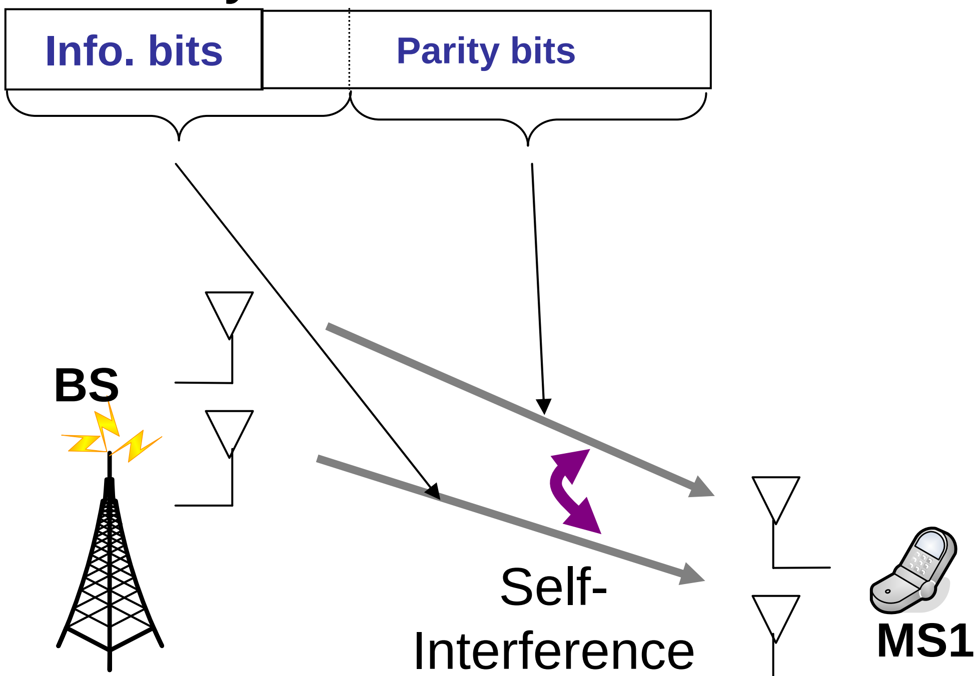
N/A

Purpose:

To be discussed and adopted by TGm for use in the IEEE 802.16m Amendment

Background

- MIMO stream 1 in a MxM SM causes self-interference between the spatial MIMO streams.
- Self interference between MIMO streams is repetitive instead of Gaussian. Retransmission and Chase combining can not improve the SIR corresponding to them effectively as Gaussian noise.



Introduction

- HARQ-CC for the MIMO stream 1 in a MxM SM has severe drawbacks due to self-Interference.
  - → STC code mapping can cancel the self-interference, then the performance is achieved to be optimal.
- HARQ-STC for the MIMO stream 1 in a MxM SM requires large memory for storing channel matrices for all initial- and re-transmission in the case of MRC receivers.
  - → MMSE+SLC* can achieve almost optimal performance despite of similar memory size as HARQ-CC case.

    (not necessary to use high complexity ML decoder)
- HARQ-STC for the MIMO stream 1 in a 4x4 SM on the 16e mapping still remain self-Interference.
  - → SICC + Alamouti code can cancel the self-interference.

SLC : Symbol level combining, MRC:Maximum Ratio Combining

SICC: Self-Interference Cancellation Coding

[EXAMPLE]

Table 1 illustrates the STC Code mappings per HARQ transmission for 2 transmit antennas.

Table 1. STC Code mapping for 2 transmit antennas.

	Initial Transmission	Odd Re-transmission	Even Re-transmission
Spatial time code incremental redundancy	$S_2^0 = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$	$S_2^{odd} = \begin{bmatrix} -s_2^* \\ s_1^* \end{bmatrix}$	$S_2^{even} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$

Note : ITRI's proposal should be investigated for 2Tx antennas case

Table 2 illustrates the STC Code mappings per HARQ transmission for 4 transmit antennas.

Table 2. STC Code mapping for 4 transmit antennas.

	Initial Transmission	First Re-transmission	Second Re-transmission	Third Re-transmission
Spatial time code incremental redundancy	$S_2^0 = \begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \end{bmatrix}$	$S_2^1 = \begin{bmatrix} -s_2^* \\ s_1^* \\ -s_4^* \\ s_3^* \end{bmatrix}$	$S_2^2 = \begin{bmatrix} s_1 \\ s_2 \\ -s_3 \\ -s_4 \end{bmatrix}$	$S_2^3 = \begin{bmatrix} -s_2^* \\ s_1^* \\ s_4^* \\ -s_3^* \end{bmatrix}$

Note : Huawei and Nortel proposals should be investigated for 3Tx antennas case.

HARQ-STC on 4x4 MIMO case analysis

- Current 802.16e STC subpacket combining on 4x4 MIMO cause **self-interference**

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

self-Interference

Proposed SICC/Alamouti scheme on 4x4 MIMO (1)

STC+SICC subpacket combining HARQ on 4x4 case

Let a channel response matrix for 4x4 MIMO (TX:4,RX:4) be H such that

$$H = \begin{bmatrix} h_{1,1} & h_{1,2} & h_{1,3} & h_{1,4} \\ h_{2,1} & h_{2,2} & h_{2,3} & h_{2,4} \\ h_{3,1} & h_{3,2} & h_{3,3} & h_{3,4} \\ h_{4,1} & h_{4,2} & h_{4,3} & h_{4,4} \end{bmatrix}$$

In the case of STC, The symbol transmissions (n^{th} column is n-th TX symbols) are

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

NO self-Interference

Hadamard matrix for sub-matrices based on Alamouti code is used as SICC.

So the received signals are

$$\mathbf{R}^{(1,2,3,4)} = \mathbf{HS} + \mathbf{n}^{(1,2,3,4)}$$

Proposed SICC/Alamouti scheme on 4x4 MIMO (2)

(1)MRC : linear combining [after 4th transmission] : Optimal, Plenty memory

For S_1,

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

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

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

Proposed SICC/Alamouti scheme on 4x4 MIMO (3)

(2)MMSE + linear combining [after 4th transmission] : sub-Optimal, Small memory

Let $\hat{S}_i^{(l)}$ be an estimated symbol for i - th antenna at l - th reception.

For 1st recepsion,

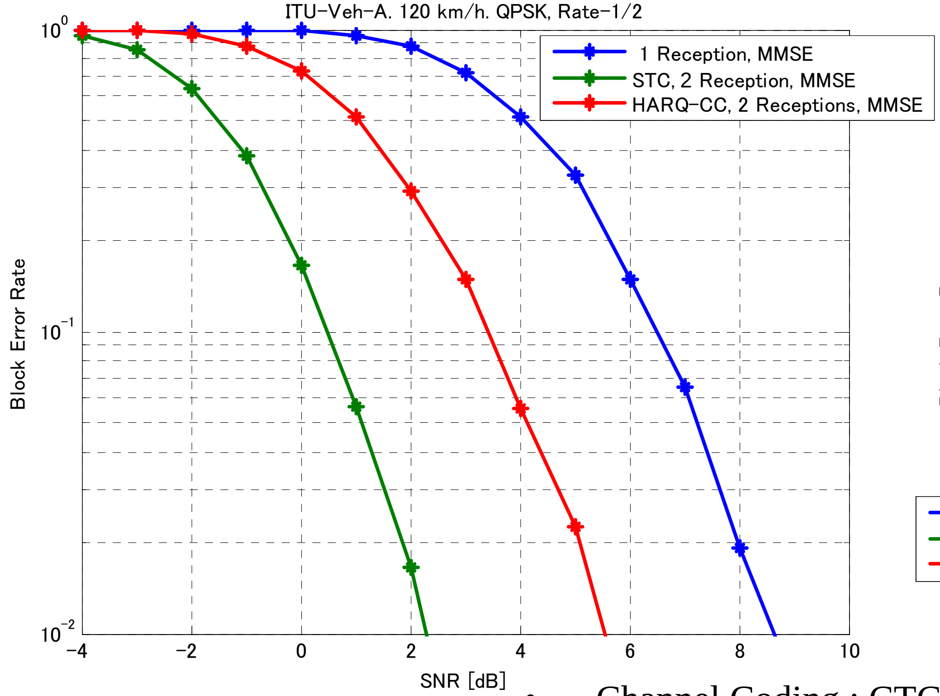
$$\begin{bmatrix} \hat{S}_1^{(1)} \\ \hat{S}_2^{(1)} \\ \hat{S}_3^{(1)} \\ \hat{S}_4^{(1)} \end{bmatrix} = \left(\mathbf{H}^H\mathbf{H} + \sigma^2 I\right)^{-1}\mathbf{H}^H \cdot \mathbf{y}^{(1)} = \left(\mathbf{H}^H\mathbf{H} + \sigma^2 I\right)^{-1}\mathbf{H}^H \cdot \left(\mathbf{H}\cdot\mathbf{S}^{(1)} + \tilde{\mathbf{n}}\right),$$

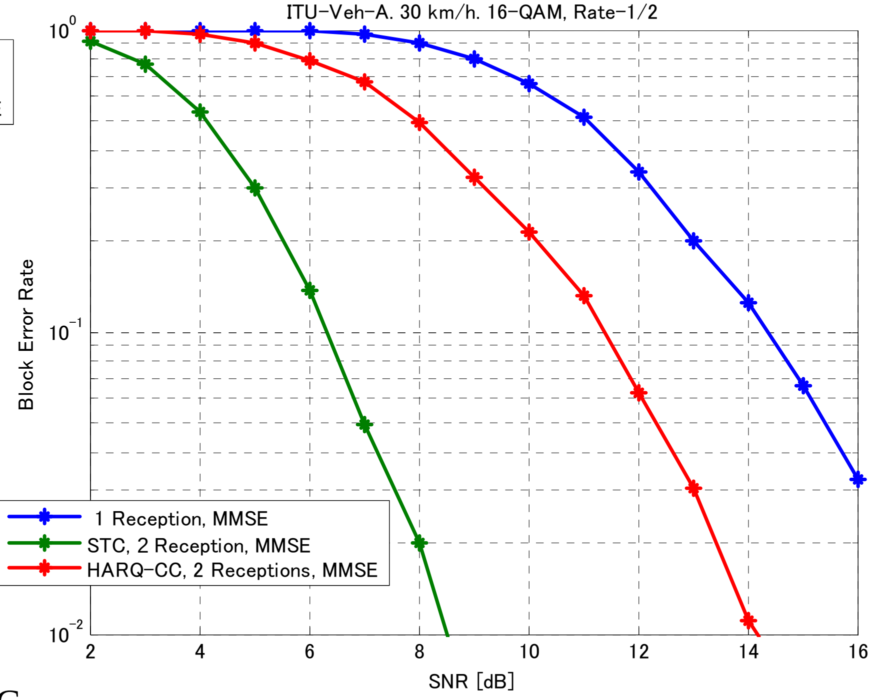
for 2nd ~ 4th reception same as 1st reception, estimated symbols can be gotten as,

$$\begin{bmatrix} -\hat{S}_2^{(2)*} \\ \hat{S}_1^{(2)*} \\ -\hat{S}_4^{(2)*} \\ \hat{S}_3^{(2)*} \end{bmatrix}, \begin{bmatrix} \hat{S}_1^{(3)} \\ \hat{S}_2^{(3)} \\ -\hat{S}_3^{(3)} \\ -\hat{S}_4^{(3)} \end{bmatrix}, \text{and} \begin{bmatrix} -\hat{S}_2^{(4)*} \\ \hat{S}_1^{(4)*} \\ \hat{S}_4^{(4)*} \\ -\hat{S}_3^{(4)*} \end{bmatrix}.$$

Individual estimated symbols can be gotten after MMSE decoding at each reception, so the symbol level combining could be done in the same memory.

Performance of MIMO HARQ (2Tx case)

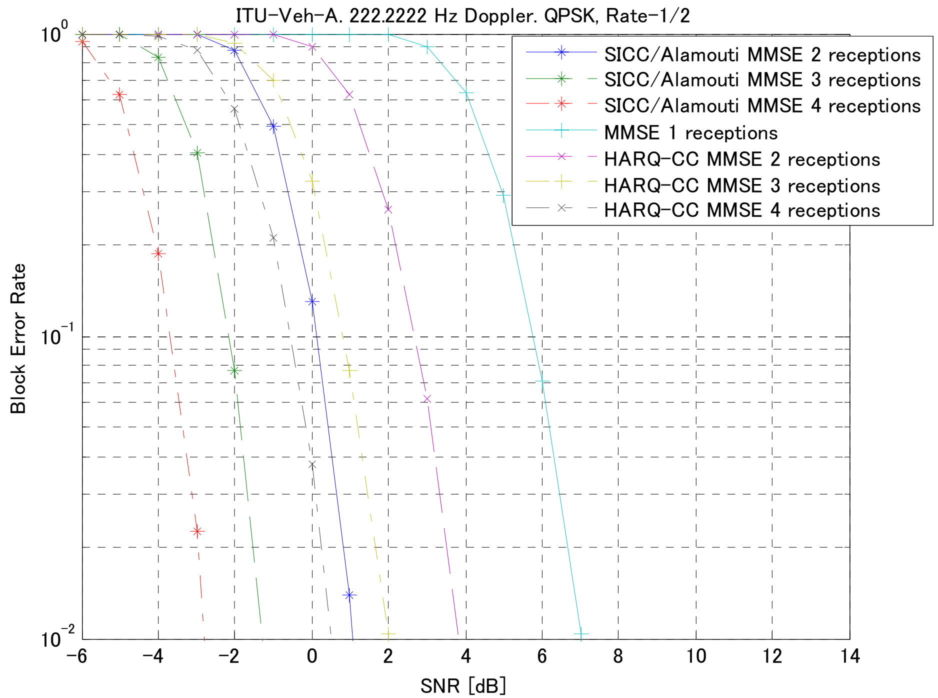


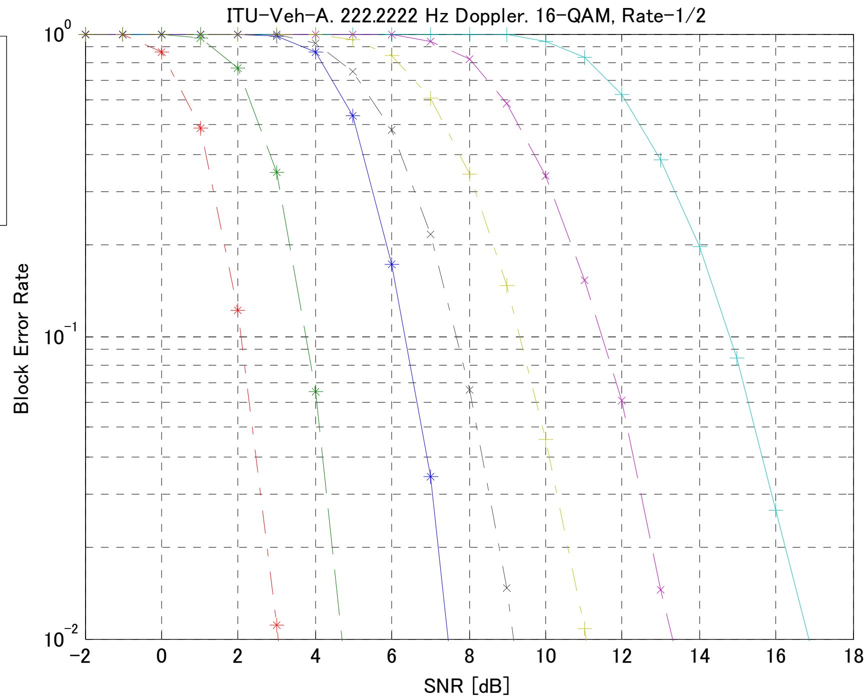


- Channel Coding : CTC
- Codeword length : 960bits
- 2x2 MIMO,
- SM (initial) + STC mapping (retransmission) : Table 1
- Decoder :
  MMSE + soft SLC (symbol level combining)
- Channel Estimation : Ideal

- 3.8dB gain(QPSK), 5.7dB gain(16QAM) using STC mapping

Performance of MIMO HARQ (4Tx case)



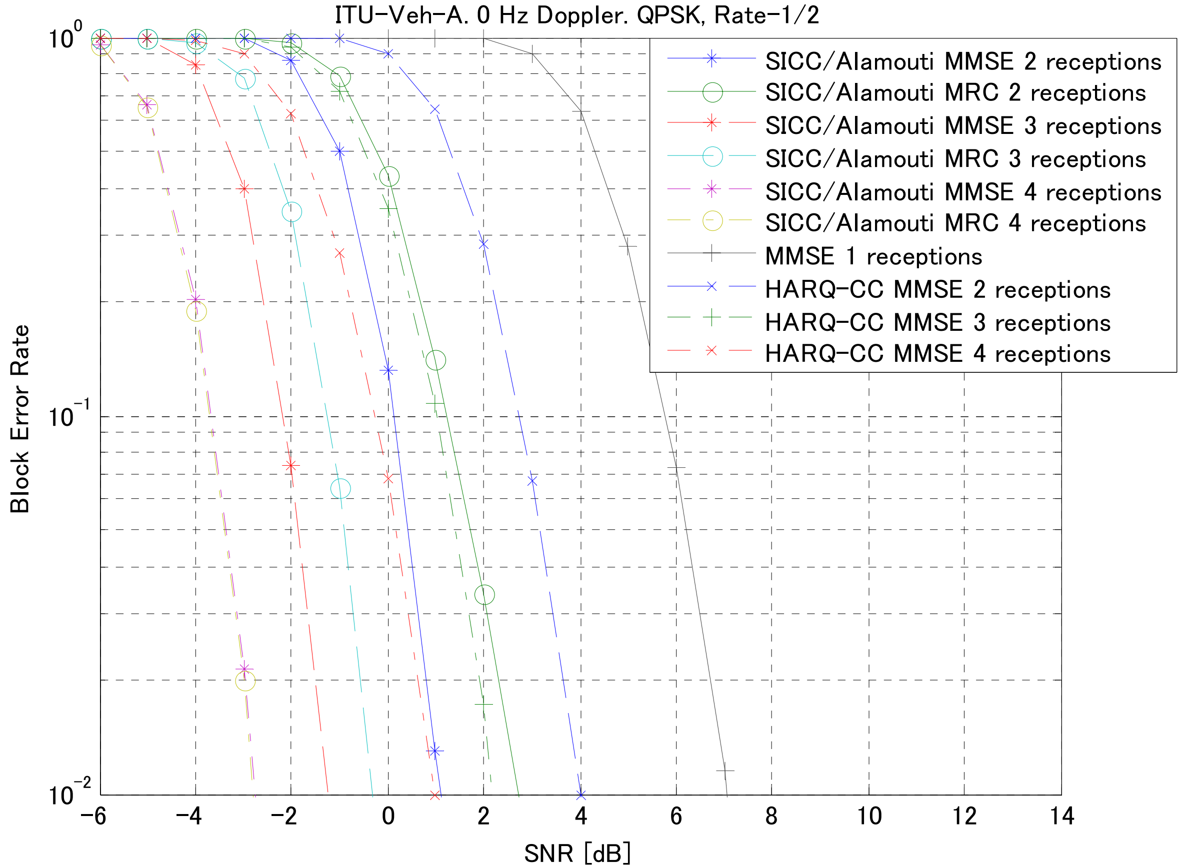


- Channel Coding : CTC , speed 120km/h
- Codeword length : 960bits
- 4x4 MIMO,
- SM (initial) + STC mapping (retransmission) : Table 2
- Decoder :
  MMSE + soft SLC (symbol level combining)
- Channel Estimation : Ideal

- 3~4dB gain(QPSK), 5~6.2dB gain(16QAM) using STC mapping

MMSE+SLC vs. MRC for MIMO HARQ

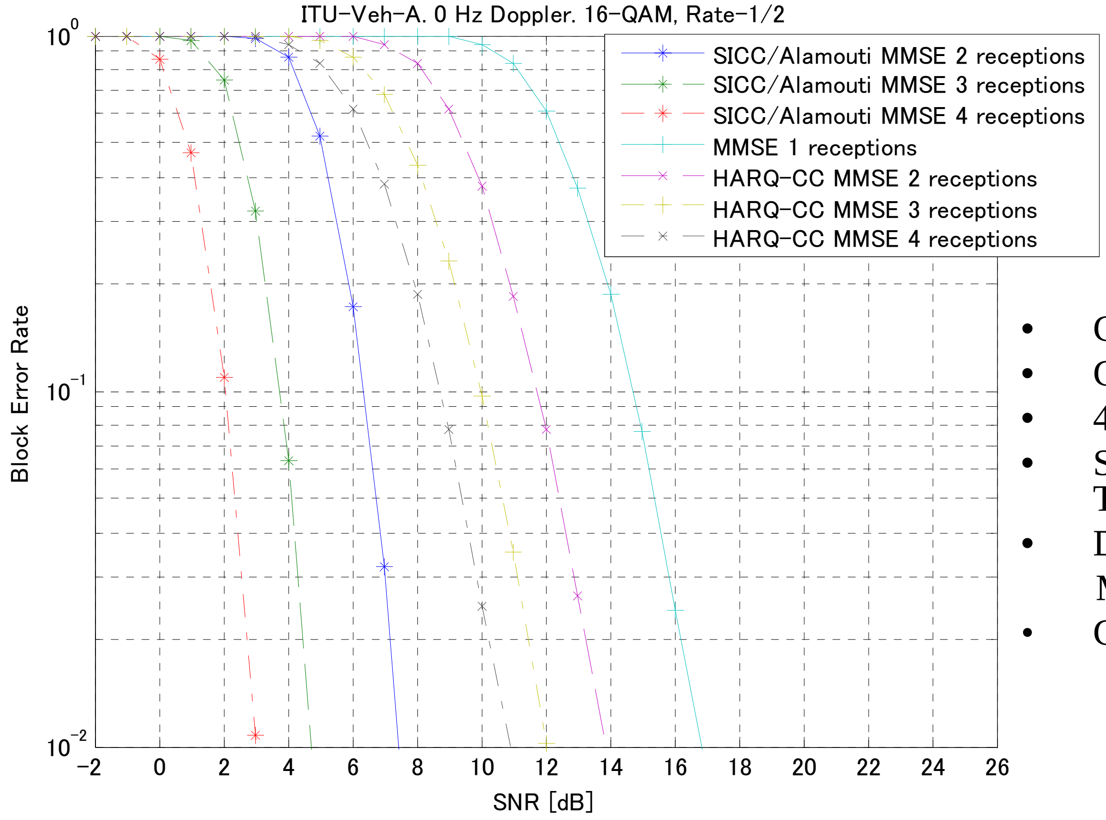
- MMSE+SLC decoder is good performance and low-complexity.



- Channel Coding : CTC
- speed 0km/h
- Codeword length : 960bits
- 4x4 MIMO,
- SM (initial) + STC mapping (retransmission) : Table 2
- Decoder :
  - -MMSE + soft SLC (symbol level combining)
  - -MRC
- Channel Estimation : Ideal

- MMSE+SLC is better than MRC (2nd and 3rd Rx).
- MMSE+SLC and MRC are almost same performance(4th Rx).

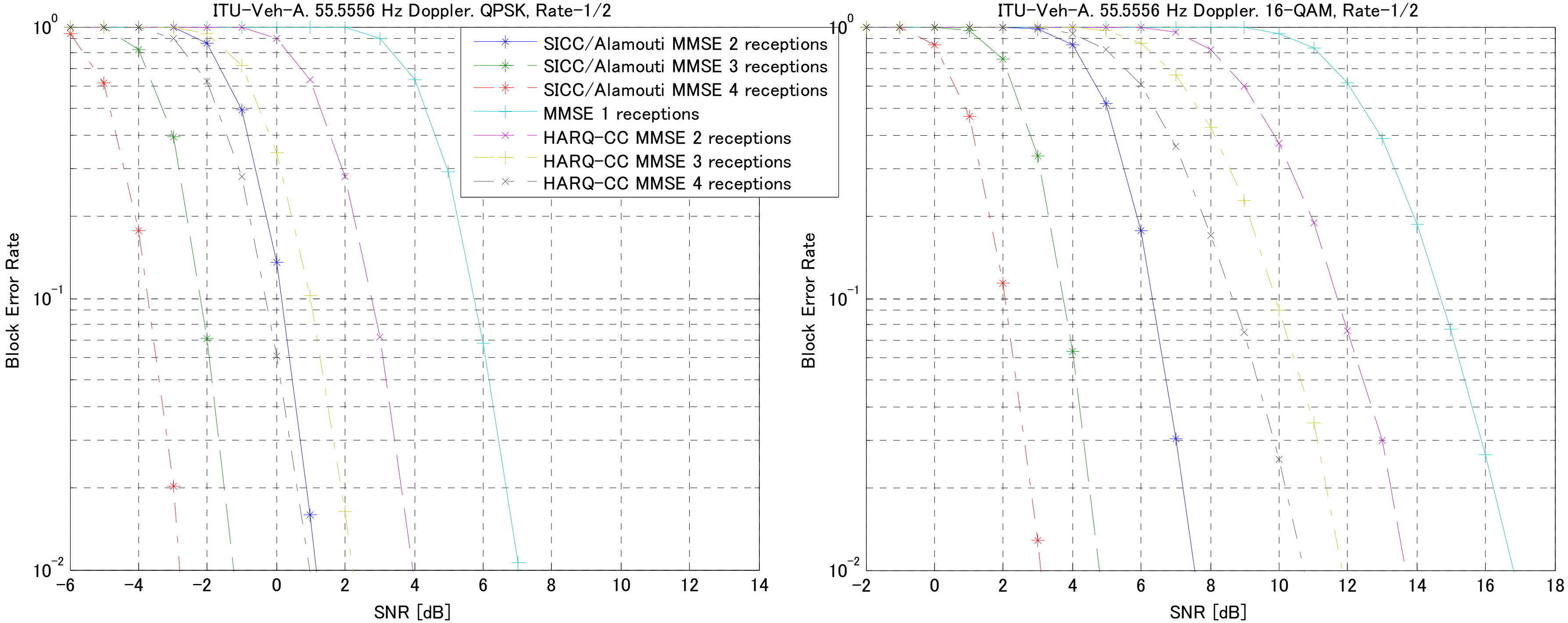
Appendix A (1/5)
Performance of MIMO HARQ (4Tx case)



- Channel Coding : CTC , speed 0 km/h
- Codeword length : 960bits
- 4x4 MIMO,
- SM (initial) + STC mapping (retransmission) : Table 2
- Decoder :
  MMSE + soft SLC (symbol level combining)
- Channel Estimation : Ideal

- 6.5dB~7.8dB gain(16QAM) using STC mapping

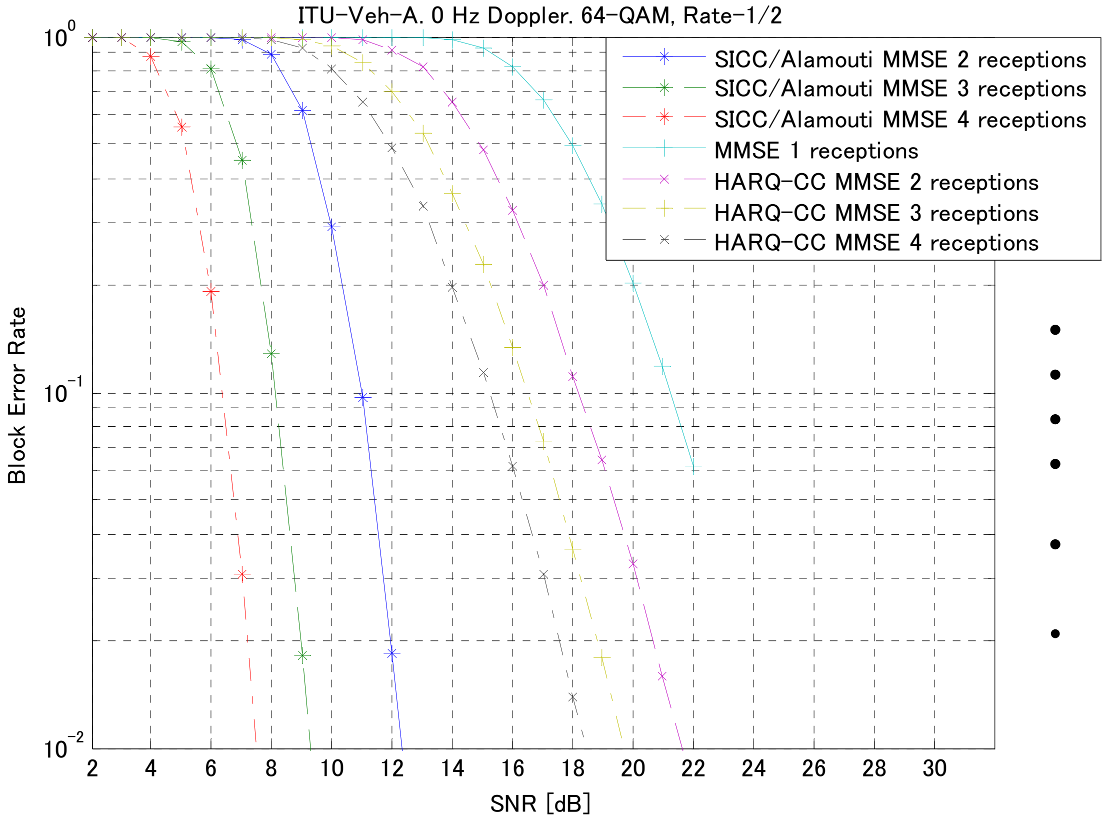
Appendix A (2/5)
Performance of MIMO HARQ (4Tx case)



- Channel Coding : CTC , speed 30km/h
- Codeword length : 960bits
- 4x4 MIMO,
- SM (initial) + STC mapping (retransmission) : Table 2
- Decoder :
  MMSE + soft SLC (symbol level combining)
- Channel Estimation : Ideal

- 2.8~3.8dB gain(QPSK), 6~7.8dB gain(16QAM) using STC mapping

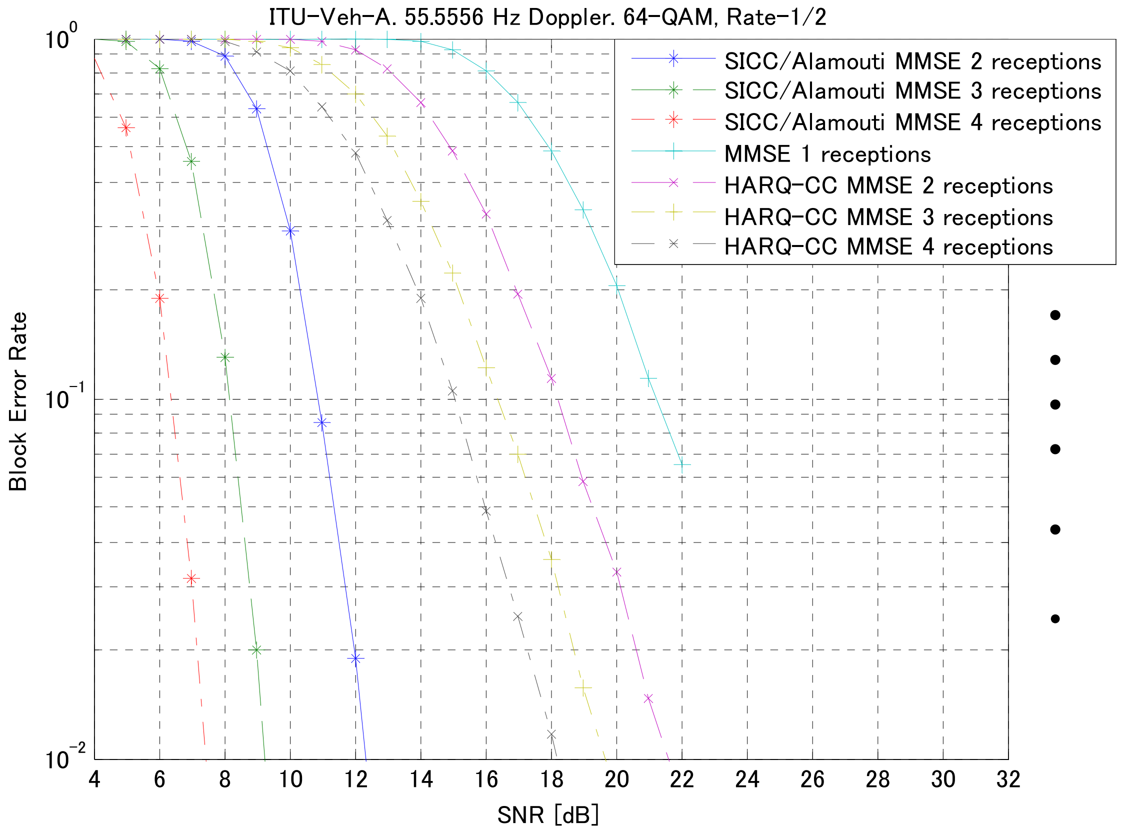
Appendix A (3/5)
Performance of MIMO HARQ (4Tx case)



- Channel Coding : CTC , speed 0 km/h
- Codeword length : 960bits
- 4x4 MIMO,
- SM (initial) + STC mapping (retransmission) : Table 2
- Decoder :
  MMSE + soft SLC (symbol level combining)
- Channel Estimation : Ideal

- 9dB~11dB gain(64QAM) using STC mapping

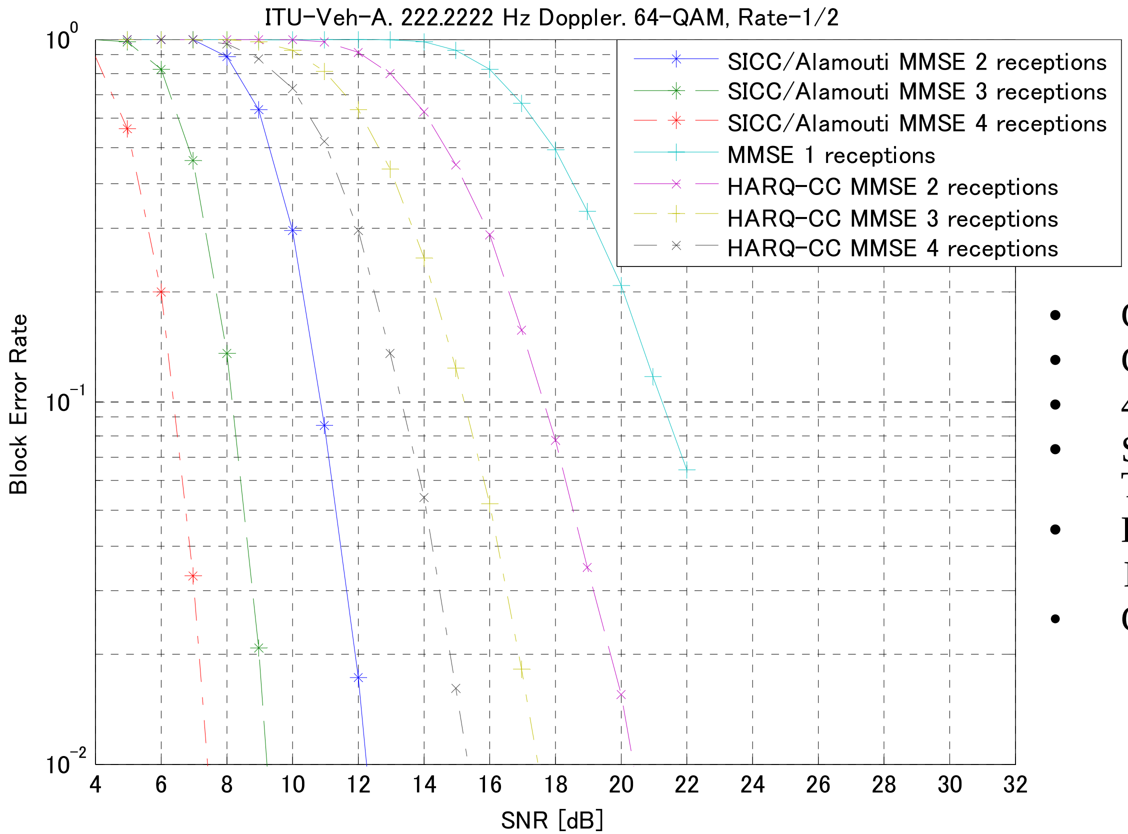
Appendix A (4/5)
Performance of MIMO HARQ (4Tx case)



- Channel Coding : CTC , speed 30 km/h
- Codeword length : 960bits
- 4x4 MIMO,
- SM (initial) + STC mapping (retransmission) : Table 2
- Decoder :
  MMSE + soft SLC (symbol level combining)
- Channel Estimation : Ideal

- 9dB~11dB gain(64QAM) using STC mapping

Appendix A (5/5)
Performance of MIMO HARQ (4Tx case)



- Channel Coding : CTC , speed 120 km/h
- Codeword length : 960bits
- 4x4 MIMO,
- SM (initial) + STC mapping (retransmission) : Table 2
- Decoder :
  MMSE + soft SLC (symbol level combining)
- Channel Estimation : Ideal

- 7.5dB~8dB gain(64QAM) using STC mapping

Appendix B(1/2)
HARQ-STC decoding method for 2x2 MIMO [example]

- MMSE + linear combining [after 2nd transmission]

For example in the case of 2x2 MIMO,

For 1st transmission and 2nd transmission, we use the STBC mapping in the table 1.

Let $H^{(1)}$ and $H^{(2)}$ be channel matrices for 1st transmission and 2nd transmission, respectively, such that

$$H^{(1)} = \begin{bmatrix} h_{1,1}^{(1)} & h_{1,2}^{(1)} \\ h_{2,1}^{(1)} & h_{2,2}^{(1)} \end{bmatrix}, H^{(2)} = \begin{bmatrix} h_{1,1}^{(2)} & h_{1,2}^{(2)} \\ h_{2,1}^{(2)} & h_{2,2}^{(2)} \end{bmatrix}.$$

Estimated symbols by STC MMSE decoding are calculated as follows,

Let $\hat{S}_i^{(l)}$ be an estimated symbol for i-th index at l-th reception.

For 1st reception,

$$\begin{bmatrix} \hat{S}_1^{(1)} \\ \hat{S}_2^{(1)} \end{bmatrix} = A^{(1)} H^{(1)H} \left(H^{(1)} \begin{bmatrix} S_1 \\ S_2 \end{bmatrix} + n^{(1)} \right) = A^{(1)} \begin{bmatrix} h_{1,1}^{(1)*} & h_{2,1}^{(1)*} \\ h_{1,2}^{(1)*} & h_{2,2}^{(1)*} \end{bmatrix} \begin{bmatrix} h_{1,1}^{(1)} & h_{1,2}^{(1)} \\ h_{2,1}^{(1)} & h_{2,2}^{(1)} \end{bmatrix} + AH^{(1)H} n^{(1)},$$

$$= A^{(1)} \begin{bmatrix} \left|h_{1,1}^{(1)}\right|^2 + \left|h_{2,1}^{(1)}\right|^2 & h_{1,1}^{(1)*} h_{1,2}^{(1)} + h_{2,1}^{(1)*} h_{2,2}^{(1)} \\ h_{1,2}^{(1)*} h_{1,1}^{(1)} + h_{2,2}^{(1)*} h_{2,1}^{(1)} & \left|h_{2,1}^{(1)}\right|^2 + \left|h_{2,2}^{(1)}\right|^2 \end{bmatrix} \begin{bmatrix} S_1 \\ S_2 \end{bmatrix} + A^{(1)} H^{(1)H} n^{(1)}, \quad \text{where } A^{(1)} = \left(H^{(1)H} H^{(1)} + \sigma^2 I \right)^{-1}.$$

For 2nd reception, same as the 1st reception case,

$$\begin{bmatrix} -\hat{S}_2^{(2)*} \\ \hat{S}_1^{(2)*} \end{bmatrix} = A^{(2)} \begin{bmatrix} \left|h_{1,1}^{(2)}\right|^2 + \left|h_{2,1}^{(2)}\right|^2 & h_{1,1}^{(2)*} h_{1,2}^{(2)} + h_{2,1}^{(2)*} h_{2,2}^{(2)} \\ h_{1,2}^{(2)*} h_{1,1}^{(2)} + h_{2,2}^{(2)*} h_{2,1}^{(2)} & \left|h_{2,1}^{(2)}\right|^2 + \left|h_{2,2}^{(2)}\right|^2 \end{bmatrix} \begin{bmatrix} -S_2^* \\ S_1^* \end{bmatrix} + A^{(2)} H^{(2)H} n^{(2)}, \quad \text{where } A^{(2)} = \left(H^{(2)H} H^{(2)} + \sigma^2 I \right)^{-1}.$$

and then $\hat{S}_1 = \left(\hat{S}_1^{(1)} + \left(\hat{S}_1^{(2)*} \right)^* \right) \Big/ 2, \hat{S}_2 = \left(\hat{S}_1^{(2)} - \left(-\hat{S}_1^{(2)*} \right)^* \right) \Big/ 2.$

Appendix B(2/2)
HARQ-STC decoding method for 2x2 MIMO [example]

- Self-Interference Cancellation

  If $H^{(1)}$ and $H^{(2)}$ are assumed to be same as static channel, self-interference can be cancelled perfectly, such that,

$$\hat{S}_1 = \left(\hat{S}_1^{(1)} + \left(\hat{S}_1^{(2)*}\right)^*\right)\Big/2 = \frac{A^{(1)}}{2}\left(\left|h_{1,1}^{(1)}\right|^2 + \left|h_{2,1}^{(1)}\right|^2 + \left|h_{1,2}^{(2)}\right|^2 + \left|h_{2,2}^{(2)}\right|^2\right)S_1 + \boxed{\frac{A^{(1)}}{2}\left(\left(h_{1,1}^{(1)*}h_{1,2}^{(1)} + h_{2,1}^{(1)*}h_{2,2}^{(1)}\right) - \left(h_{1,2}^{(2)}h_{1,1}^{(2)*} + h_{2,2}^{(2)}h_{2,1}^{(2)*}\right)\right)S_2} + \frac{A^{(1)}}{2}\mathrm{H}^{(1)H}\left(n^{(1)} + n^{(2)}\right)$$

$$= \frac{A^{(1)}}{2}\left(\left|h_{1,1}^{(1)}\right|^2 + \left|h_{2,1}^{(1)}\right|^2 + \left|h_{1,2}^{(2)}\right|^2 + \left|h_{2,2}^{(2)}\right|^2\right)S_1 + \frac{A^{(1)}}{2}\mathrm{H}^{(1)H}\left(n^{(1)} + n^{(2)}\right),$$

Interference Term =0

  Even If mobility channel is assumed, self-interference can be reduced as our simulation results.

Individual estimated symbols can be calculated by only the channel matrix at each transmission, so the previous channel matrix can be abandoned.

Appendix C(1/3)
HARQ-CC, HARQ-IL, HARQ-STC decoding methods for 2x2 MIMO

For example in the case of 2x2 MIMO,

For 1st transmission and 2nd transmission, we use the STBC mapping in the table 1.

Let $\mathrm{H}^{(1)}$ and $\mathrm{H}^{(2)}$ be channel matrices for 1st transmission and 2nd transmission, respectively, such that

$$\mathrm{H}^{(1)} = \begin{bmatrix} h_{1,1}^{(1)} & h_{1,2}^{(1)} \\ h_{2,1}^{(1)} & h_{2,2}^{(1)} \end{bmatrix}, \mathrm{H}^{(2)} = \begin{bmatrix} h_{1,1}^{(2)} & h_{1,2}^{(2)} \\ h_{2,1}^{(2)} & h_{2,2}^{(2)} \end{bmatrix}.$$

Estimated symbols by MRC and MMSE decoding are calculated as follows,

Let $\hat{\mathbf{S}}^{(l)}$, $\mathbf{y}^{(l)}$, and $\mathbf{S}^{(l)}$ be an estimated symbol vector, a received symbol vector, and a transmitted symbol vector for i-th index at l-th reception.

For l – th reception,

$$\hat{\mathbf{S}}^{(l)} = A_{\mathrm{xxx}}^{(l)} \mathrm{H}^{(l)H} \mathbf{y}^{(l)} = A_{\mathrm{xxx}}^{(l)} \mathrm{H}^{(l)H} \left(\mathrm{H}^{(l)} \mathbf{S}^{(l)} + \mathrm{n}^{(1)} \right), \quad \text{where } A_{MRC}^{(l)} = \left(\mathrm{H}^{(l)H} \mathrm{H}^{(l)} \right)^{-1}, A_{MMSE}^{(l)} = \left(\mathrm{H}^{(l)H} \mathrm{H}^{(l)} + \sigma^2 I \right)^{-1}.$$

Let us assume 3 type of symbols for HARQ-CC, HARQ-IL, and HARQ-STC such that,

	HARQ-CC	HARQ-IL (symbol interleaving)	HARQ-STC
Transmitted symbols	$\mathbf{S}^{(1)} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}, \mathbf{S}^{(2)} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$	$\mathbf{S}^{(1)} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}, \mathbf{S}^{(2)} = \begin{bmatrix} s_2 \\ s_1 \end{bmatrix}$	$\mathbf{S}^{(1)} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}, \mathbf{S}^{(2)} = \begin{bmatrix} -s_2^* \\ s_1^* \end{bmatrix}$

Appendix C(2/3)
HARQ-CC, HARQ-IL, HARQ-STC decoding methods for 2x2 MIMO

For l=2 reception on a static channel,

- HARQ-CC

Diversity order=2 | Interference Term

$$\hat{S}_1 = \left(\hat{S}_1^{(1)} + \hat{S}_1^{(2)}\right)/2 = \boxed{\frac{A^{(1)}}{2}\cdot 2\left(\left|h_{1,1}^{(1)}\right|^2 + \left|h_{2,1}^{(1)}\right|^2\right)S_1} + \boxed{\frac{A^{(1)}}{2}\cdot 2\left(h_{1,1}^{(1)*}h_{1,2}^{(1)} + h_{2,1}^{(1)*}h_{2,2}^{(1)}\right)S_2} + \frac{A^{(1)}}{2}\mathrm{H}^{(1)H}\left(n^{(1)} + n^{(2)}\right)$$

Same as the Interference at 1st reception

- HARQ-IL

Diversity order=4 | Interference Term

$$\hat{S}_1 = \left(\hat{S}_1^{(1)} + \left(\hat{S}_1^{(2)*}\right)^*\right)/2 = \boxed{\frac{A^{(1)}}{2}\left(\left|h_{1,1}^{(1)}\right|^2 + \left|h_{2,1}^{(1)}\right|^2 + \left|h_{1,2}^{(2)}\right|^2 + \left|h_{2,2}^{(2)}\right|^2\right)S_1} + \boxed{\frac{A^{(1)}}{2}\left(\left(h_{1,1}^{(1)*}h_{1,2}^{(1)} + h_{2,1}^{(1)*}h_{2,2}^{(1)}\right) + \left(h_{1,2}^{(2)}h_{1,1}^{(2)*} + h_{2,2}^{(2)}h_{2,1}^{(2)*}\right)\right)S_2} + \frac{A^{(1)}}{2}\mathrm{H}^{(1)H}\left(n^{(1)} + n^{(2)}\right)$$

$$\text{for } l\text{-th reception, } \frac{A^{(1)}}{l}\sum_{i=1}^{l} I_{self}^{i}$$

Interference energy can be reduced as $-10\log_{10}(l)$dB

- HARQ-STC

Diversity order=4 | Interference Term

$$\hat{S}_1 = \left(\hat{S}_1^{(1)} + \left(\hat{S}_1^{(2)*}\right)^*\right)/2 = \boxed{\frac{A^{(1)}}{2}\left(\left|h_{1,1}^{(1)}\right|^2 + \left|h_{2,1}^{(1)}\right|^2 + \left|h_{1,2}^{(2)}\right|^2 + \left|h_{2,2}^{(2)}\right|^2\right)S_1} + \boxed{\frac{A^{(1)}}{2}\left(\left(h_{1,1}^{(1)*}h_{1,2}^{(1)} + h_{2,1}^{(1)*}h_{2,2}^{(1)}\right) - \left(h_{1,2}^{(2)}h_{1,1}^{(2)*} + h_{2,2}^{(2)}h_{2,1}^{(2)*}\right)\right)S_2} + \frac{A^{(1)}}{2}\mathrm{H}^{(1)H}\left(n^{(1)} + n^{(2)}\right)$$

=0

Appendix C(3/3)
HARQ-CC, HARQ-IL, HARQ-STC decoding methods for 2x2 MIMO

For l=2 reception,

If $H^{(1)}$ and $H^{(2)}$ are assumed to be same as static channel, self-interference can be cancelled perfectly.

		HARQ-CC	HARQ-IL (such as various Interleavers or ant. hopping)	HARQ-STC
Diversity order		$\in [2,4]$	4	4
Interference Term $\alpha \cdot I_{self}$ (α : ratio to the 1st reception I_{self})	Static channel	1	$1/2(\text{ave.})$	0
	Dynamic channel	$\in [1/2(\text{ave.}),1)$	$1/2(\text{ave.})$	$\in (0,1/2(\text{ave.})]$

Even If dynamic channel is assumed, self-interference can be reduced more than other schemes.
The performance in the worst case of HARQ-STC may be similar as the performance in the best case of HARQ-IL or HARQ-CC.

Appendix D(1/3)
Performance comparison on 2x2 MIMO

Table .D.1 2x2 MIMO case (Nre=1) 10% FER rate=1/2

	Gain vs. Chase Combining(dB)					
	VehA-30 QPSK	VehA-120 QPSK	VehA-30 16QAM	VehA-120 16QAM	VehA-30 64QAM	VehA-120 64QAM
STC-HARQ	3.1	3.2	4.9	4.7	6.0	5.8
HARQ-IR*	?	?	1.4	1.55	?	?
CoRe*	-	-	1.7	1.9	3.9	3.9

* Reference: IEEE C802.16m-09/0345,"Mapping rule for Constellation Rearrangement".

Appendix D(2/3)
Performance comparison on 4x4 MIMO

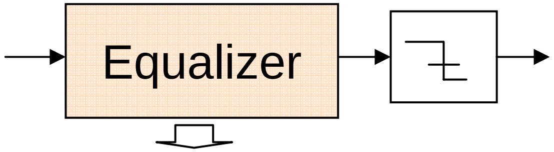
Table .D.2 4x4 MIMO case (Nre=1) 10% FER rate=1/2

	Gain vs. Chase Combining(dB)					
	VehA-30 QPSK	VehA-120 QPSK	VehA-30 16QAM	VehA-120 16QAM	VehA-30 64QAM	VehA-120 64QAM
STC-HARQ	3.0	2.6	5.5	5.2	7.3	6.9
HARQ-IR	?	?	?	?	?	?
CoRe	-	-	?	?	?	?

Appendix E
ML Decoding and MMSE decoding

MIMO STC can be decoded by both MMSE and MLD. Please remind that MLD needs equalizer. Equalizer and MMSE complexity are almost same as follows, and Equalizer complexity is very low in comparison with MLD one.

- Equalizer + hard decision (most simplest receiver)

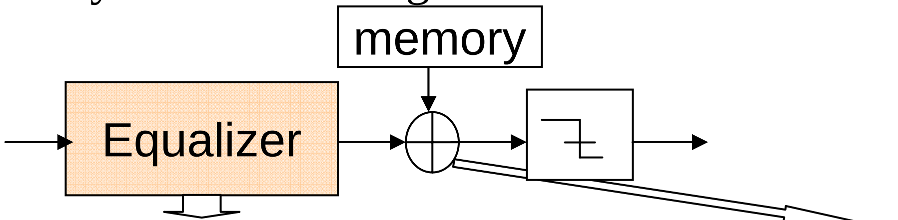


$$\hat{S}^{(l)} = A^{(l)} H^{(l)H} \left(H^{(l)}\hat{S}^{(l)} + n^{(l)}\right), \quad \text{where } A^{(l)} = \left(H^{(l)H} H^{(l)}\right)^{-1}.$$

Small circuit

Large circuit

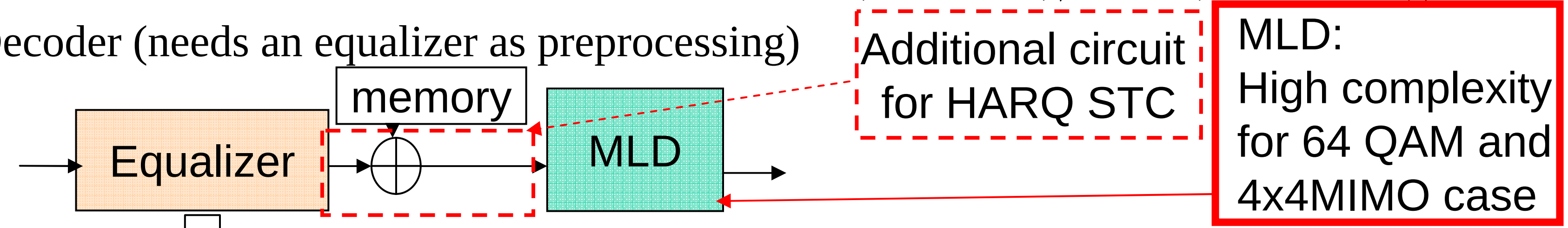
- MMSE+ Symbol combining + hard decision



$$\hat{S}^{(l)} = A^{(l)} H^{(l)H} \left(H^{(l)}\hat{S}^{(l)} + n^{(l)}\right), \quad \text{where } A^{(l)} = \left(H^{(l)H} H^{(l)} + \sigma^2 I\right)^{-1}.$$

$$\hat{S}_1 = \left(\hat{S}_1^{(1)} + \left(\hat{S}_1^{(2)*}\right)^*\right)/2, \hat{S}_2 = \left(\hat{S}_1^{(2)} - \left(-\hat{S}_1^{(2)*}\right)^*\right)/2.$$

- ML Decoder (needs an equalizer as preprocessing)



$$\hat{S}^{(l)} = A^{(l)} H^{(l)H} \left(H^{(l)}\hat{S}^{(l)} + n^{(l)}\right), \quad \text{where } A^{(l)} = \left(H^{(l)H} H^{(l)} + \sigma^2 I\right)^{-1}.$$

$$\hat{S}_1 = \left(\hat{S}_1^{(1)} + \left(\hat{S}_1^{(2)*}\right)^*\right)/2, \hat{S}_2 = \left(\hat{S}_1^{(2)} - \left(-\hat{S}_1^{(2)*}\right)^*\right)/2.$$

Text Proposal for SDD(1/3)

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• ***15.3.xx MIMO HARQ***

For HARQ subpacket retransmission, the mapping of bits or modulated symbols to spatial streams may be applied to exploit spatial diversity with given mapping pattern, depending on the type of IR. In this case, the predefined set of mapping patterns should be known to both transmitter and receiver.

• 15.3.xx.xx **STC Code Mapping**

In the STC transmission, for both DL and UL, the STC subpacket retransmission 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 Tables 1 through Table 3.

The MS shall process the initial transmission, first retransmission, and second retransmission, etc., in the form of space time decoding.

Table 1 illustrates the STC Code mappings per HARQ transmission for 2 transmit antennas..

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Text Proposal for SDD(2/3)

--- *Start of the Text* ---

Table 1 illustrates the STC Code mappings per HARQ transmission for 2 transmit antennas.

Table 1. STC Code mapping for 2 transmit antennas.

	Initial Transmission	Odd Re-transmission	Even Re-transmission
Spatial time code incremental redundancy	$S_2^0 = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$	$S_2^{odd} = \begin{bmatrix} -s_2^* \\ s_1^* \end{bmatrix}$	$S_2^{even} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$

Table 2 illustrates the STC Code mappings per HARQ transmission for 3 transmit antennas.

Table 2. STC Code mapping for 3 transmit antennas.

	Initial transmission	First Re- transmission	Second Re-transmission	Third Re-transmission
Spatial time code incremental redundancy	$S_2^0 = \begin{bmatrix} s_1 \\ s_2 \\ s_3 \end{bmatrix}$	$S_2^1 = \begin{bmatrix} -s_2^* \\ s_1^* \\ s_3^* \end{bmatrix}$	$S_2^2 = \begin{bmatrix} s_1 \\ s_2 \\ -s_3 \end{bmatrix}$	$S_2^3 = \begin{bmatrix} -s_2^* \\ s_1 \\ -s_3^* \end{bmatrix}$

--- *End of the Text* ---

Text Proposal for SDD(3/3)

--- *Start of the Text* ---

Table 3 illustrates the STC Code mappings per HARQ transmission for 4 transmit antennas.

Table 3. STC Code mapping for 4 transmit antennas.

	Initial transmission	First Re- transmission	Second Re-transmission	Third Re-transmission
Spatial time code incremental redundancy	$S_2^0 = \begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \end{bmatrix}$	$S_2^1 = \begin{bmatrix} -s_2^* \\ s_1^* \\ -s_4^* \\ s_3^* \end{bmatrix}$	$S_2^2 = \begin{bmatrix} s_1 \\ s_2 \\ -s_3 \\ -s_4 \end{bmatrix}$	$S_2^3 = \begin{bmatrix} -s_2^* \\ s_1^* \\ s_4^* \\ -s_3^* \end{bmatrix}$

--- *End of the Text* ---