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Re:	
Abstract	**Enhancement of STC with Antenna Grouping**
Purpose	Adoption of proposed changes into P802.16e ~~Crossed-out indicates deleted text,~~ underlined blue indicates new text change to the Standard
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Enhancement of STC with Antenna Grouping

1. Introduction

Exploiting spatial diversity in systems with multiple antennas at the transmitter requires that the signal be pre-processed prior to transmission. Space-time coding (STC) is an example of such a processing. In the current IEEE802.16 system the base station shall use the channel state information. In this contribution we propose the enhanced STC schemes based on antenna grouping which utilizes the partial channel state information and exhibit better performance than the existing schemes for 3 and 4 transmit antennas.

Part I. Antenna Grouping for Matrix A

I-1. Antenna Grouping for 3 transmit-antenna STC Matrix A

A space-time-frequency code (over two OFDMA symbols and two sub-carriers) for 3Tx-Rate 1 configuration with diversity order 3 was introduced in the current standard [1]. Its matrix representation is the following.

$$A = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_3 & -\tilde{s}_4^* \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_s^* \end{bmatrix} \tag{I-1}$$

In above matrix A, antenna 2 will be used every time t1 and t2, every subcarriers f1 and f2. This approach offers a solution when the BS does not know the channel information. However, if the BS can use the partial channel information which is transmitted by the MS, the matrix A could be adapted based on channel quality.

$$A_1 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_3 & -\tilde{s}_4^* \\ \tilde{s}_2 & \tilde{s}_1^* & 0 & 0 \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_s^* \end{bmatrix}, \text{ where antenna 1 has the best associated channel.}$$

$$A_2 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_3 & -\tilde{s}_4^* \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_s^* \end{bmatrix}, \text{ where antenna 2 has the best associated channel.} \tag{I-2}$$

$$A_3 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ 0 & 0 & \tilde{s}_3 & -\tilde{s}_4^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_4 & \tilde{s}_s^* \end{bmatrix}, \text{ where antenna 3 has the best associated channel.}$$

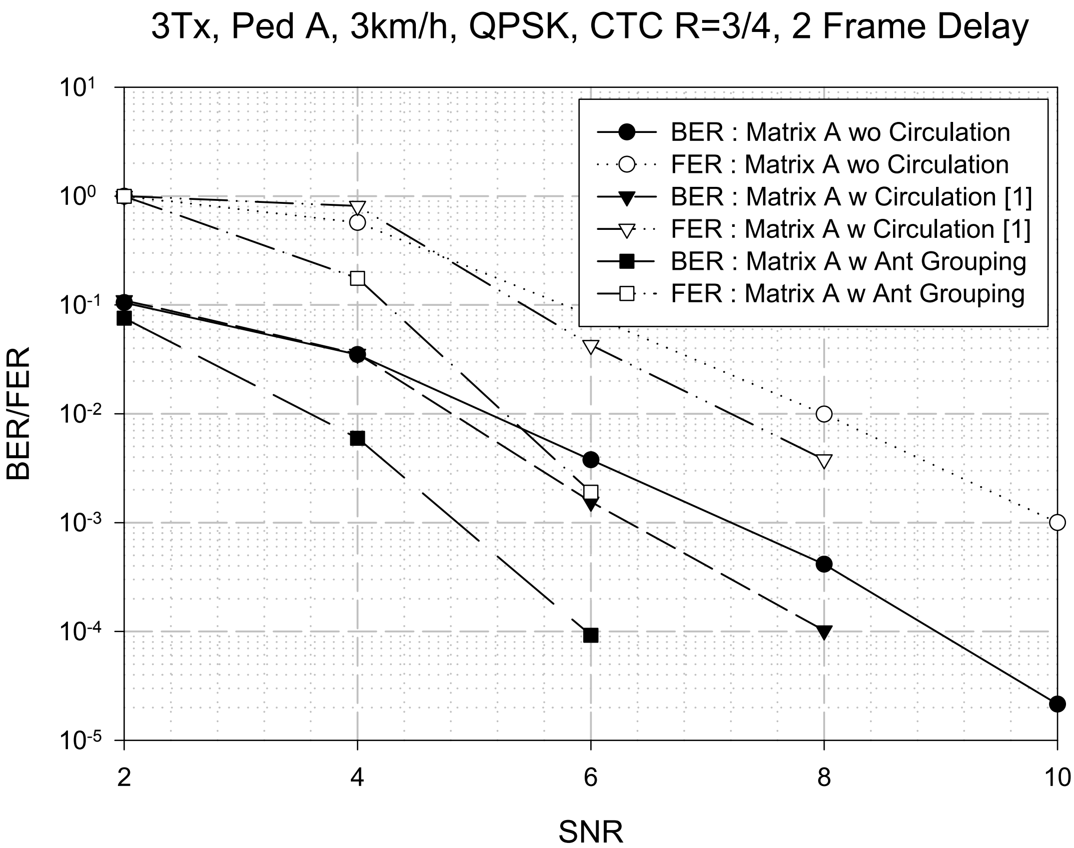

Fig I-1. BER/FER vs. SNR

The proposed scheme outperforms the existing Matrix A [1] by 2dB at FER=10-2.

I-2. Antenna Grouping for 4 transmit-antenna STC for Matrix A

The rate 1 transmission code for 4 Tx BS in the current standard [1] is

$$A = \begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ 0 & 0 & s_4 & s_3^* \end{bmatrix} \qquad \text{(I-3)}$$

Note that this scheme does not achieve full diversity.

Using the equivalent model,

$$A^H A = \begin{bmatrix} \rho_1 & 0 & 0 & 0 \\ 0 & \rho_1 & 0 & 0 \\ 0 & 0 & \rho_2 & 0 \\ 0 & 0 & 0 & \rho_2 \end{bmatrix} \qquad \text{(I-4)}$$

If the BS can use channel state information, the performance of the existing matrix A approaches the performance of the full diversity full rate STC

$$\arg \min_{antenna\_pair} |\rho_1 - \rho_2| \qquad \text{(I-5)}$$

Let $d_{\min}^2$ be the corresponding minimum distance of the normalized unit energy constellation. The 2^R-QAM Euclidean distance equation $d_{\min}^2 = 12/(2^R - 1)$ will be used, corresponding to QAM modulation for diversity. Using this Euclidean distance equation, we can estimate the error probability as.

$$P_e \le N_e Q\left(\sqrt{\frac{E_s}{N_0} d_{MIN}^2}\right) \tag{I-6}$$

where d_{MIN}^2 is the squared Euclidean distance of the received signal, N_e is the number of nearest neighbors in the constellation and can be found for each proposed mapping scheme based on the channel coefficient matrix H, $Q(x) = \frac{1}{2} erfc\left(x/\sqrt{2}\right)$, where *erfc* is the complementary error function. For STC, the minimum distance of the diversity constellation at the receiver can be shown to be

$$d_{MIN}^2(\mathbf{H}) \le \frac{\min\left(\|\mathbf{H}\|_F^2(a,b), \|\mathbf{H}\|_F^2(c,d)\right)}{N_T} d_{\min}^2 \tag{I-7}$$

where *(a,b)* and *(c,d)* are antenna grouping index and $\|\mathbf{H}\|_F$ is the Frobenius norm of matrix $\boldsymbol{H}$. The details for derivation follow the derivation procedure of the maximum SNR criterion for code design. [2]

Fig. I-2 shows the system block diagram which makes use of a grouper to select the antenna pair based on feedback channel information from the MS.

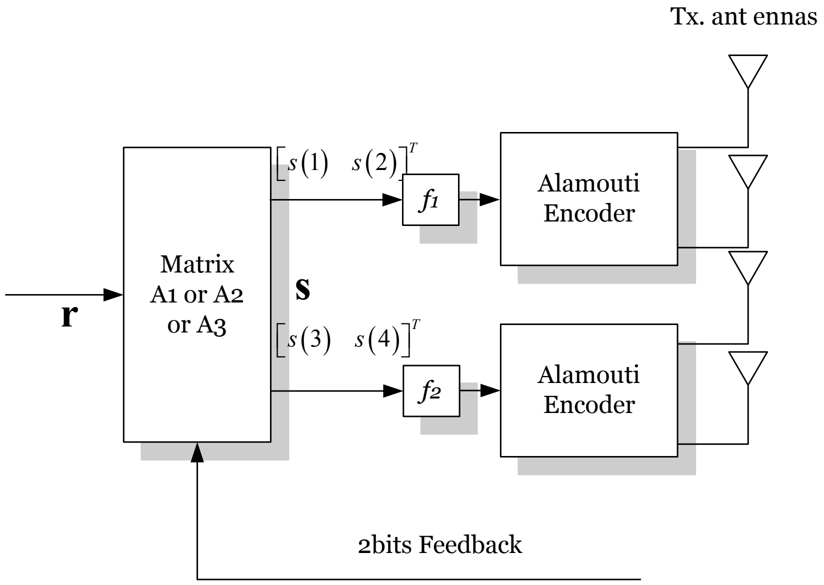

Fig. I-2. System Block Diagram

The performance of the proposed scheme is shown in Fig. I-3. At BER=10^{-3} point, the proposed scheme outperforms the conventional STC without antenna grouping by 3.5dB.

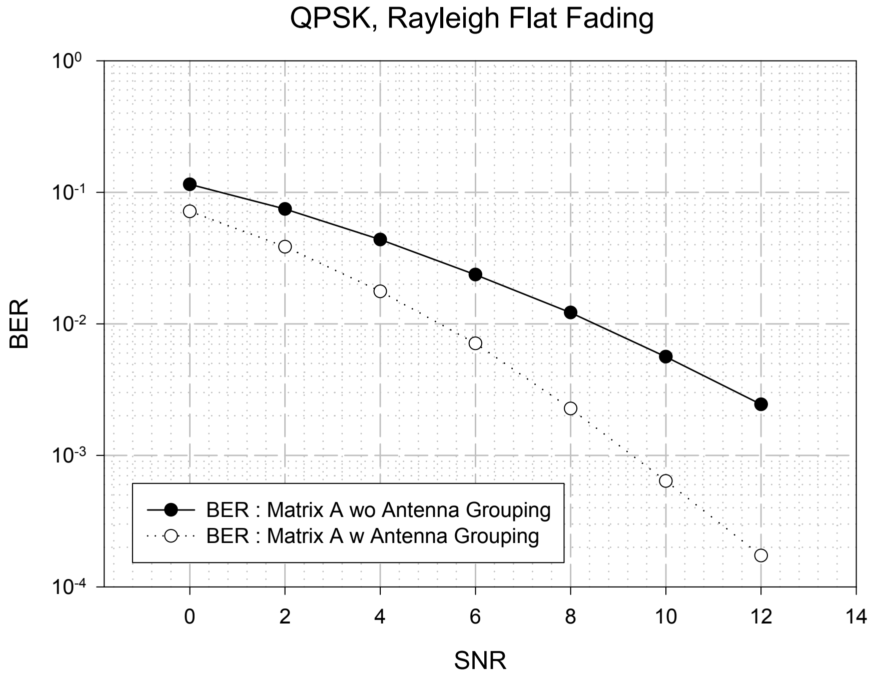

Fig I-3. BER vs. SNR with and without antenna grouping

In order to apply the current standards, parameters are set here according to band AMC mode. The number of bands per symbol is 24 and the number of bins per band and the number of subcarriers per bin are 4 and 9, respectively. The BS selects the best band based on feedback channel information from the MS. Fig. I-4 shows the coded BER/FER performance on band AMC mode. In this simulation, we use the CTC code as a channel codec.

Note that performance improvement is still kept in coded system although the gap is decreased. The main reason for decreasing gap (compared to Fig. I-3) is that the feedback information is not perfect when using band AMC mode. In fact, the MS just sends the mean channel power per each band to the BS.

The proposed scheme outperforms the existing Matrix A by 1.2dB at BER=10^{-3} and 1.2dB at FER 10^{-2}, respectively. (Ped A, 3km/h, QPSK, CTC R=1/2)

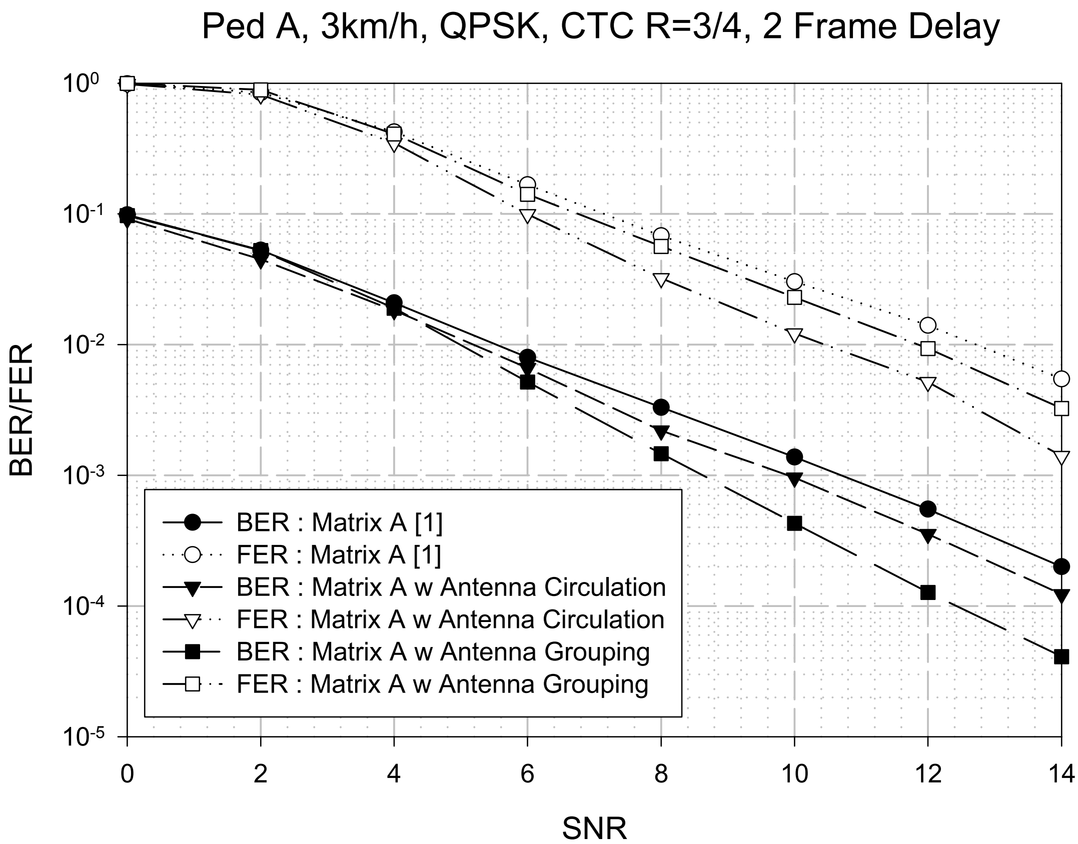

Fig I-2. Coded BER/FER vs. SNR with and without antenna grouping

Part II. Antenna Grouping for Matrix B

II-1. Antenna grouping for 3 transmit-antenna rate 2 STC

A space-time-frequency code (over two OFDMA symbols and two sub-carriers) for 3Tx-Rate 2 configuration was introduced in the current standard [1]. Its matrix representation is the following.

$$B_1 = \begin{bmatrix} \sqrt{\frac{3}{4}} & 0 & 0 \\ 0 & \sqrt{\frac{3}{4}} & 0 \\ 0 & 0 & \sqrt{\frac{3}{2}} \end{bmatrix} \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_5 & -\tilde{s}_6^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_6 & \tilde{s}_5^* \\ \tilde{s}_7 & -\tilde{s}_8^* & \tilde{s}_3 & -\tilde{s}_4^* \end{bmatrix}$$

$$B_2 = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix} B_1 \qquad \text{(II-1)}$$

and

$$B_3 = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} B_1$$

In above matrix B, s_3, s_4, s_7, and s_8 will be transmitted through only one antenna with diversity order of one while other symbols will be transmitted through two antennas with diversity order of two. This approach offers a solution when the BS does not know the channel information. However, if the BS can use the partial channel information which is transmitted by the MS, the matrix B could be adapted based on channel quality.

When SS reports 0b110010 on its allocated CQICH, then BS shall transmit in the following transmission matrix

$$B_1 = \begin{bmatrix} \tilde{s}_7 & -\tilde{s}_8^* & \tilde{s}_3 & -\tilde{s}_4^* \\ \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_5 & -\tilde{s}_6^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_6 & \tilde{s}_5^* \end{bmatrix},\ \text{where antenna 1 has the best associated channel.}$$

When SS reports 0b110011 on its allocated CQICH, then BS shall transmit in the following transmission matrix

$$B_2 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_5 & -\tilde{s}_6^* \\ \tilde{s}_7 & -\tilde{s}_8^* & \tilde{s}_3 & -\tilde{s}_4^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_6 & \tilde{s}_5^* \end{bmatrix},\ \text{where antenna 2 has the best associated channel.}$$

When SS reports 0b110100 on its allocated CQICH, then BS shall transmit in the following transmission matrix

$$B_3 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_5 & -\tilde{s}_6^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_6 & \tilde{s}_5^* \\ \tilde{s}_7 & -\tilde{s}_8^* & \tilde{s}_3 & -\tilde{s}_4^* \end{bmatrix},\ \text{where antenna 3 has the best associated channel.}$$

II-2. Antenna grouping for 4 transmit-antenna rate 2 STC

The rate 2 transmission code for 4 transmit antennas in the current standard [1] is

$$B = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_2 & s_1^* & s_6 & -s_8^* \\ s_3 & -s_4^* & s_7 & s_5^* \\ s_4 & s_3^* & s_8 & s_6^* \end{bmatrix} \qquad \text{(II-2)}$$

The first two columns correspond to a subcarrier and the last two columns correspond to the adjacent subcarrier. Ttransmission matrix B for rate 2 may be improved with antenna grouping information which is fed back on a CQICH from SS:

When SS reports 0b110010 on its allocated CQICH, then BS shall group antenna 0 and 1 for the first diversity pair and antenna 1 and 2 for the second diversity pair. In matrix form, it shall be read as

$$B_1 = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_2 & s_1^* & s_7 & s_5^* \\ s_3 & -s_4^* & s_6 & -s_8^* \\ s_4 & s_3^* & s_8 & s_6^* \end{bmatrix}$$

When SS reports 0b110011 on its allocated CQICH, then BS shall transmit in the following transmission matrix

$$B_2 = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_2 & s_1^* & s_7 & s_5^* \\ s_4 & s_3^* & s_8 & s_6^* \\ s_3 & -s_4^* & s_6 & -s_8^* \end{bmatrix}$$

When SS reports 0b110100 on its allocated CQICH, then BS shall group antenna 0 and 2 for the first diversity pair and antenna 1 and 3 for the second diversity pair. In matrix form, it shall be read as

$$B_3 = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_3 & -s_4^* & s_6 & -s_8^* \\ s_2 & s_1^* & s_7 & s_5^* \\ s_4 & s_3^* & s_8 & s_6^* \end{bmatrix}$$

When SS reports 0b110101 on its allocated CQICH, then BS shall transmit in the following transmission matrix

$$B_4 = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_4 & s_3^* & s_8 & s_6^* \\ s_2 & s_1^* & s_7 & s_5^* \\ s_3 & -s_4^* & s_6 & -s_8^* \end{bmatrix}$$

When SS reports 0b110110 on its allocated CQICH, then BS shall group antenna 0 and 3 for the first diversity pair and antenna 1 and 2 for the second diversity pair. In matrix form, it shall be read as

$$B_5 = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_3 & -s_4^* & s_6 & -s_8^* \\ s_4 & s_3^* & s_8 & s_6^* \\ s_2 & s_1^* & s_7 & s_5^* \end{bmatrix}$$

When SS reports 0b110111 on its allocated CQICH, then BS shall transmit in the following transmission matrix

$$B_6 = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_4 & s_3^* & s_8 & s_6^* \\ s_3 & -s_4^* & s_6 & -s_8^* \\ s_2 & s_1^* & s_7 & s_5^* \end{bmatrix}$$

At the mobile, the optimum transmission matrix is determined based on the following criteria. Let $y_{r,i}$ be the received signal at the i-th symbol time at the r-th receive antenna, and $h_{t,r}$ denote the channel parameter between the t-th transmit and r-th receive antenna. When the number of receive antennas is two, the received signal can be represented as

$$\mathbf{y} = \mathbf{X}(\mathbf{HW})\mathbf{s} + \mathbf{v} \qquad \text{(II-5)}$$

where $\mathbf{y} = \begin{bmatrix} y_{1,1} & y_{1,2}^* & y_{2,1} & y_{2,2}^* \end{bmatrix}^T$, $\mathbf{s} = \begin{bmatrix} s_1 & s_2 & s_3 & s_4 \end{bmatrix}^T$, $\mathbf{v}$ is the noise vector, $\mathbf{H} = \begin{bmatrix} h_{1,1} & h_{2,1} & h_{3,1} & h_{4,1} \\ h_{1,2} & h_{2,2} & h_{3,2} & h_{4,2} \end{bmatrix}$, and $\mathbf{X}(\cdot)$ is a function of 2-by-4 input matrix which is defined as

$$\mathbf{X}\left(\begin{bmatrix} a & b & c & d \\ e & f & g & h \end{bmatrix}\right) = \begin{bmatrix} a & b & c & d \\ b^* & -a^* & d^* & -c^* \\ e & f & g & h \\ f^* & -e^* & h^* & -g^* \end{bmatrix} \quad . \tag{II-6}$$

At the mobile station, the index of the transmission matrix $\mathbf{B}_q$ is determined based on the following criteria:

$$q = \arg\min_{l=1,\cdots,6}\left[abs\left(\det(\mathbf{H}_{l,1}) + \det(\mathbf{H}_{l,2})\right)\right] \tag{II-7}$$

where $\mathbf{H}_{l,1}$ is the first two columns of $\mathbf{HW}_l$ and $\mathbf{H}_{l,2}$ is the last two columns of $\mathbf{HW}_l$. Note that the antenna grouping matrix selection rule in (6) is equivalent to the following rule:

$$q = \arg\min_{l=1,\cdots,6}\left[trace\left(\left[(\mathbf{X}(\mathbf{HW}_l))^H \mathbf{X}(\mathbf{HW}_l)\right]^{-1}\right)\right] \quad . \tag{II-8}$$

Alternate criteria for the antenna grouping can be applied to determine antenna group index. For example, minimize BER, minimum mean square error, etc.

II-3. Simulation results

We compare the proposed antenna grouping based closed-loop STC with open-loop STC for 4 transmit-antenna rate 2 STC. In Fig.II-1, packet error rates of the proposed antenna grouping method and the conventional open loop STC (matrix *B*) method are compared in the pedestrian A channel with 3km/h. One frame feedback delay is reflected in the simulation and MMSE linear detector is used at the receiver.

When the correlation coefficient is 0.7 (Fig. II-1), the proposed antenna grouping with 3bit feedback outperforms the conventional STC without antenna grouping more than 1.8 dB at PER = 10^{-2} (1.8 dB for 1/2 rate QPSK, 2.5 dB for 1/2 rate 16QAM, 2.4 dB for 1/2 rate 64QAM, and 3.2 dB for 2/3 rate 64QAM). As higher MCS level is used, the performance gain is increased.

In Fig.II-2, goodputs of the proposed antenna grouping and the conventional matrix B are compared. At the same SNR, the proposed antenna grouping outperforms a maximum of 1.7 bits/subcarrier over the conventional open loop scheme regardless of the value of antenna correlation.

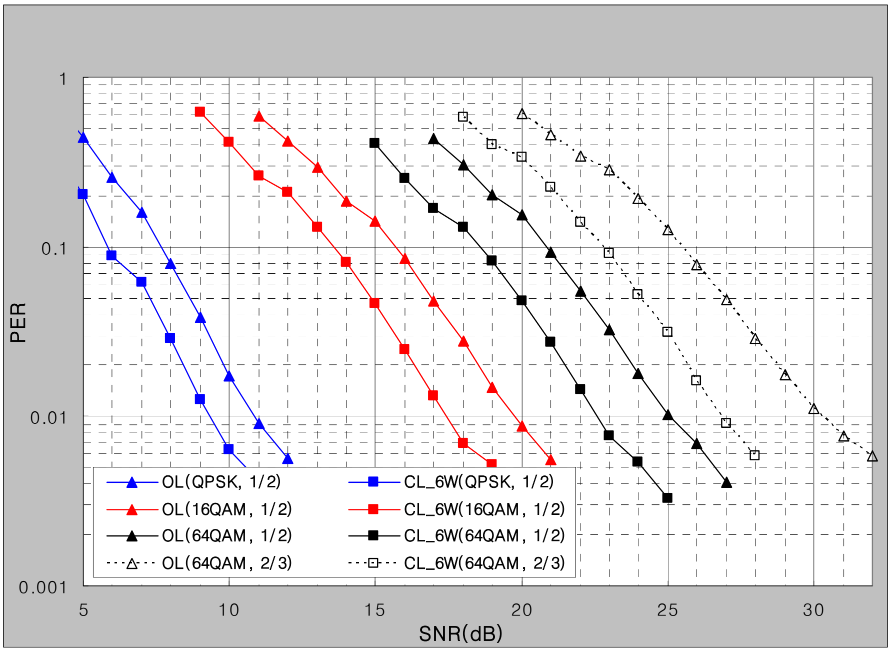

Fig.II-1. PER vs. SNR with and without antenna grouping when the correlation coefficient = 0.7.

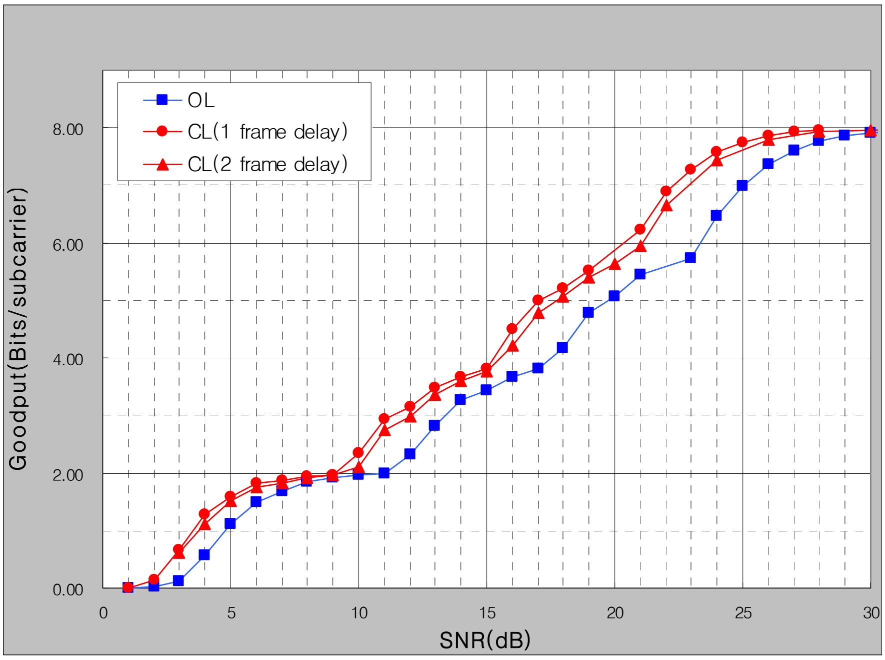

Fig.II-2. Goodput vs. SNR with and without antenna grouping when the correlation coefficient = 0.7 (OL denotes conventional open loop STC, CL denotes the proposed antenna grouping)

Part III. Antenna Grouping for Matrix C

III-1. Background

For the BS point to multi-point transmission, to exploit the multi-user diversity, the selection to schedule a burst can be based on the user with the best CQI for the particular AMC band, in addition, we can also select the number of antenna and the MIMO transmission formats. In this contribution, for a specific user assigned to a band AMC sub-channel, we discuss the strategy to perform the antenna selection and MIMO transmission format selection.

For a fixed SS, to further enhance the channel capacity, water-filling can be applied to each layer based on the eigenvalue distribution. However, for moving mobiles, it can be shown that equal power allocation is the optimum solution. In other words, when the feedback delay is long, water-filling will be no longer beneficial, and even be detrimental.

A MIMO system can be defined by

$$\vec{r} = H\vec{s} + \vec{n}, \tag{III-1}$$

then with equal power allocation, its channel capacity is given by

$$C = \sum_{i=1}^{L} \log_2\left(1 + \gamma_0 \lambda_i\right), \tag{III-2}$$

where $\gamma_0 = \frac{P}{M\sigma^2}$, P is the total transmitted power, σ^2 is the noise power (per receive antenna), L is the number of eigenvalues of HH'.

When the MIMO channel is perfectly know to the transmitter, the joint singular value decomposition (SVD) and water-filling power allocation provides the optimum solution. However, this is at the cost of a great amount of feedback in the UL. In addition, feedback quantization and sensitivity of SVD to channel aging will quickly diminish the SVD gain, and may even result in a loss (vs. an open-loop system due to mismatched power allocation).

In this contribution, we propose antenna selection for the closed-loop MIMO OFDMA system, the object of antenna grouping is to maintain the robustness of the channel condition at the price of reduced layers. The criterion in antenna selection is by eliminating the weakest layers, which is, equivalently, minimizing the condition of channel matrix.

Assuming that $\alpha_1, \alpha_2, \ldots, \alpha_L$ are L nonzero singular values of H_s, and $\lambda_1, \lambda_2, \ldots, \lambda_L$ are L eigenvalues of $H_s'H$, then $\lambda_i = \alpha_i^2$. Therefore, to select a subsystem from H is to find the sub-matrix Γ which maximizes

$$\Gamma = \arg\max_{H_s \in H} \sum_{i=1}^{L} \log_2\left(1 + \gamma_0 \alpha_i^2\right) \tag{III-3}$$

or equivalently

$$\Gamma = \arg\max_{H_s \in H} \prod_{i=1}^{L} \left(1 + \gamma_0 \alpha_i^2\right). \tag{III-4}$$

When SNR is high, equation (III-III-4) can be written as

$$\begin{aligned} \Gamma &\approx \arg\max_{H_s \in H} \prod_{i=1}^{L} \alpha_i^2 \\ &= \arg\max_{H_s \in H} \prod_{i=1}^{L} \lambda_i \end{aligned}. \tag{III-5}$$

Since

$$\det\left(H_s' H_s\right) = \prod_{i=1}^{L} \lambda_i, \tag{III-6}$$

Equation (III-III-5) can be written as

$$\Gamma = \arg\max_{H_s \in H} \det\left(H_s' H_s\right). \quad \text{(III-7)}$$

From equation (III-III-7), the selection process is very simple, and no SVD or eigen-value decomposition is required. Since $N \geq M$, $M > L$, and $H_s' H_s$ is a square matrix of size $L \times L$, the determinant calculation is limited to small size matrixes.

The matrix H_s is a matrix consists of L columns of H . The number of candidate sets is

$$\mathrm{K} = \frac{M!}{L!(M-L)!}. \quad \text{(III-8)}$$

III-2. Proposed Solution

The MSS compute the antenna grouping criterion by computing the sub-MIMO channel determinants of all possible antenna group combinations. And select the sub-MIMO channel for the antenna grouping with the maximum determinant value. The un-selected antennas are muted from transmission for a particular sub-channel and for a particular user. The power is add onto the active antennas with boosted power.

Advantages

The proposed antenna grouping based SM has the following advantages:

- Very light feedback is needed
  - only antenna group index is fed back maximum 3 bits
- No channel/pre-coding matrix quantization error.
- Resistant to channel aging
  - due to even layer energy distribution and equal transmit power allocation
- Applicable to *all* the sub-channelization

III-3. Simulation Results

The simulation methodology is compliant with the CL-MIMO harmonization group requirements.

Simulation Set Up

The simulation parameters and conditions are listed in Table III-1.

Table III-1 Simulation Set Up

Configurations	Parameters	Comments
Optional BAND AMC sub-channel		The band allocation in time-direction shall be fixed at center band
Coding Modulation Set	CC coding , K=3, TB	Coded Symbol Puncture for MIMO Pilot
	QPSK ½, QPSK, ¾, 16QAM ½, 16QAM R=¾, 64QAM R=1/2, 64QAM R= 3/4	
Code Modulation Mapping	Single encoder block with uniform bit-loading	
MIMO Receiver	MMSE-one-shot for SVD	

	MLD receiver for OL and CL SM	
FFT parameters	Carrier 2.6GHz, 10MHz, 1024-FFT Guard tone 79 left, 80 right CP=11.2ms, Sampling rate = 8/7, Sub-carrier spacing = 11.2kHz	
Frame Length	5ms frame, DL:UL=2:1	
Feedback delay	2 frames	
MIMO Configurations	4x2	
Channel Model	ITU-PA, 3km/h, ITU-VA, 30km/h Antenna Correlation: 20% Perfect Channel Estimation	
Feedback	SVD: perfect pre-coding matrix V without quantization SM: antenna selection matrix index	

The simulation results are shown in Fig. III-1, where the open loop SM, the antenna grouping 4x2 SM and the 4x2 perfect SVD are presented in the hull curve representation.

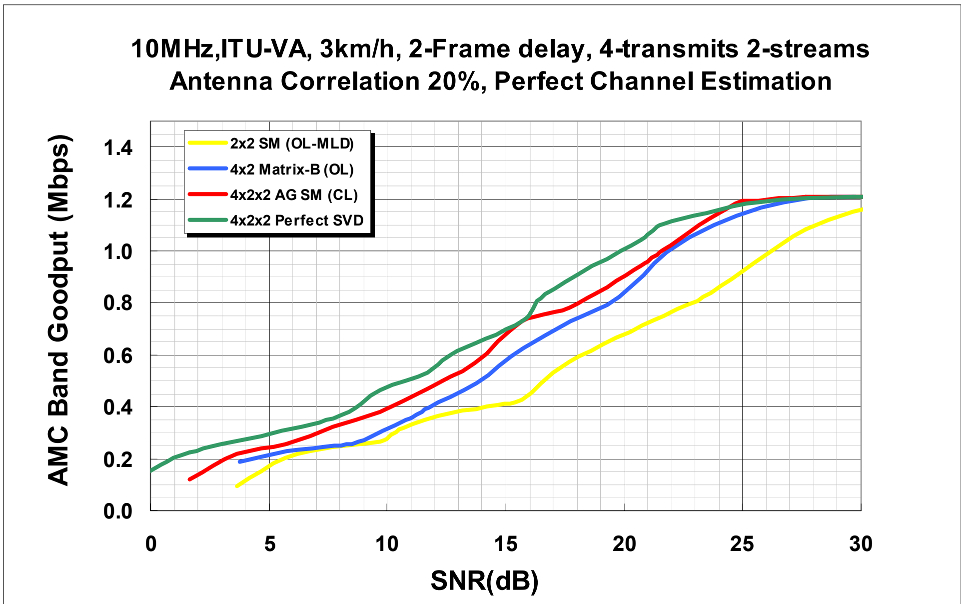

Fig. III-1 Hull curve PA-3km/h (20% correlation, CC coding case)

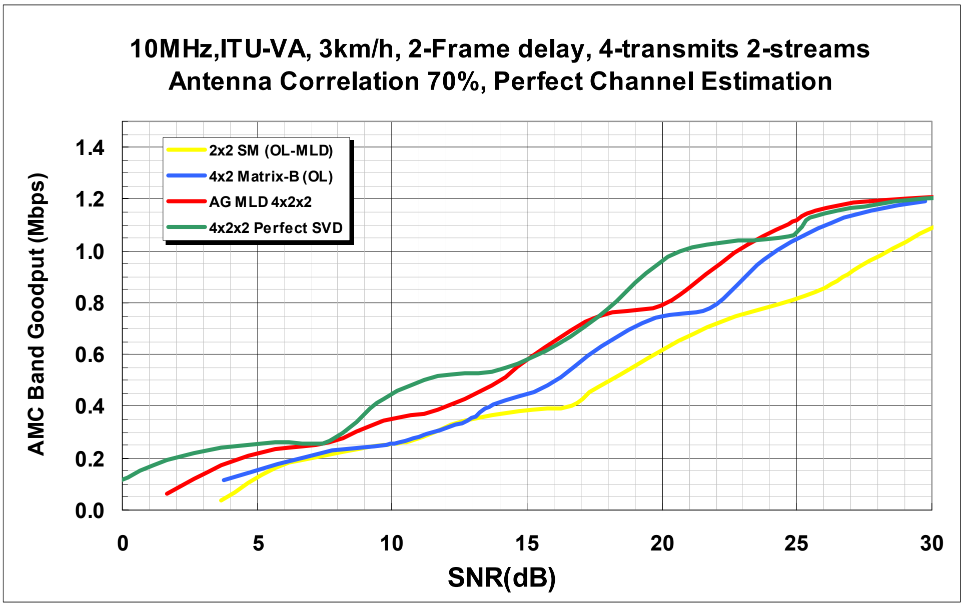

Fig. III-1 Hull curve PA-3km/h (70% correlation, CC coding case)

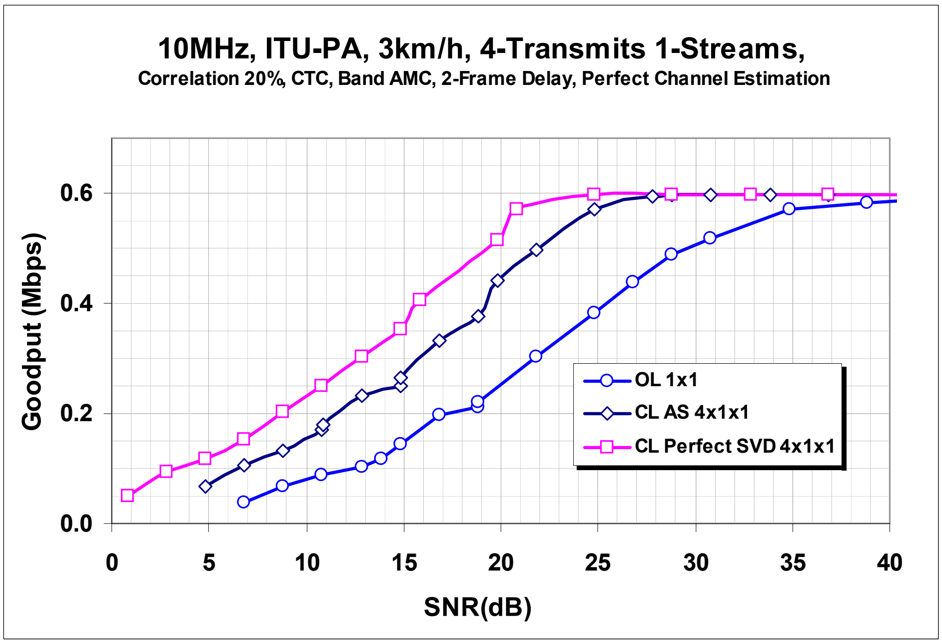

Fig. III-1 Hull curve PA-3km/h (20% correlation, CC coding case)

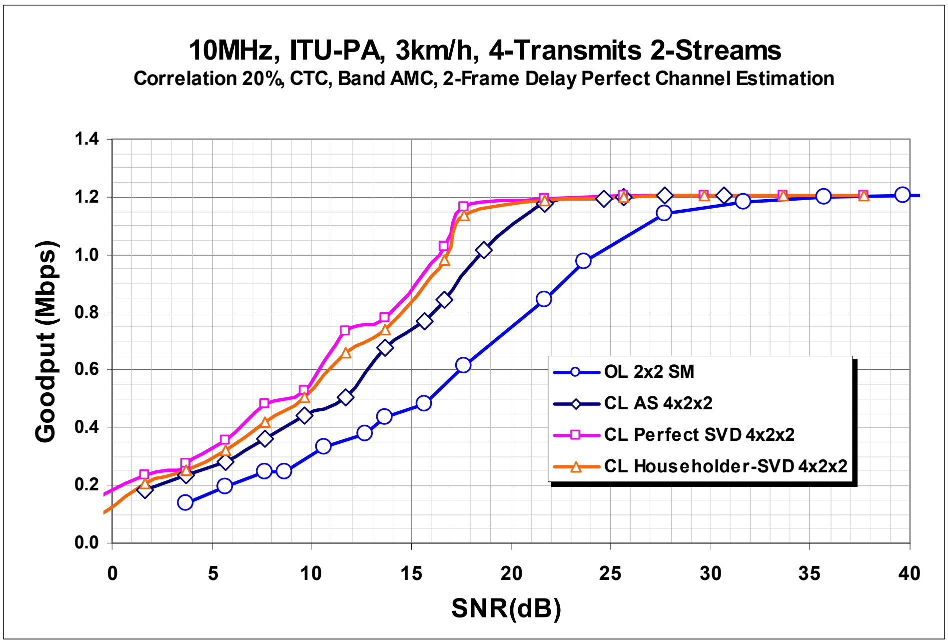

Fig. III-1 Hull curve PA-3km/h (20% correlation, CC coding case)

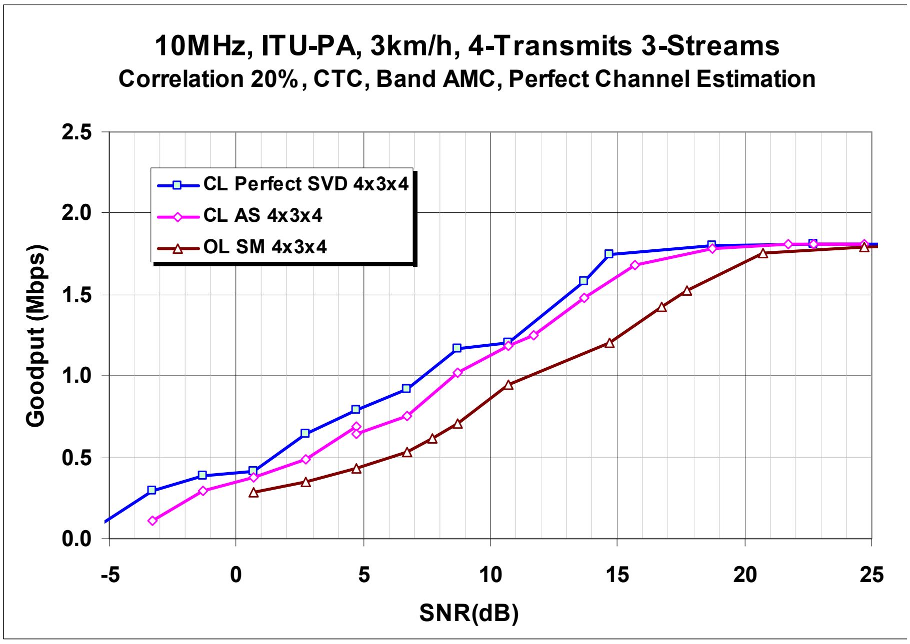

Fig. III-1 Hull curve PA-3km/h (20% correlation, CC coding case)

It can be seen that for the fixed and slow nomadic case, antenna grouping MIMO and the closed loop SVD have about 4~6dB gain over the basic open loop 2x2 SM. In addition, the performance of antenna grouping SM is very close to the perfect SVD closed loop SM. The practical SVD requires compression of the pre-coding V matrix in general will introduce the quantization loss, for the antenna grouping, such a loss can be avoided.

Impact of Mobility Speed

The mobility has a significant impact on the performance of closed loop based MIMO, especially on the SVD based methods, In Fig. III-4, the significant ~3dB loss of closed loop perfect SVD is observed at 30km/h mobility (if the mobility speed is higher than 10km/h, the SVD closed loop performance gain is diminished).

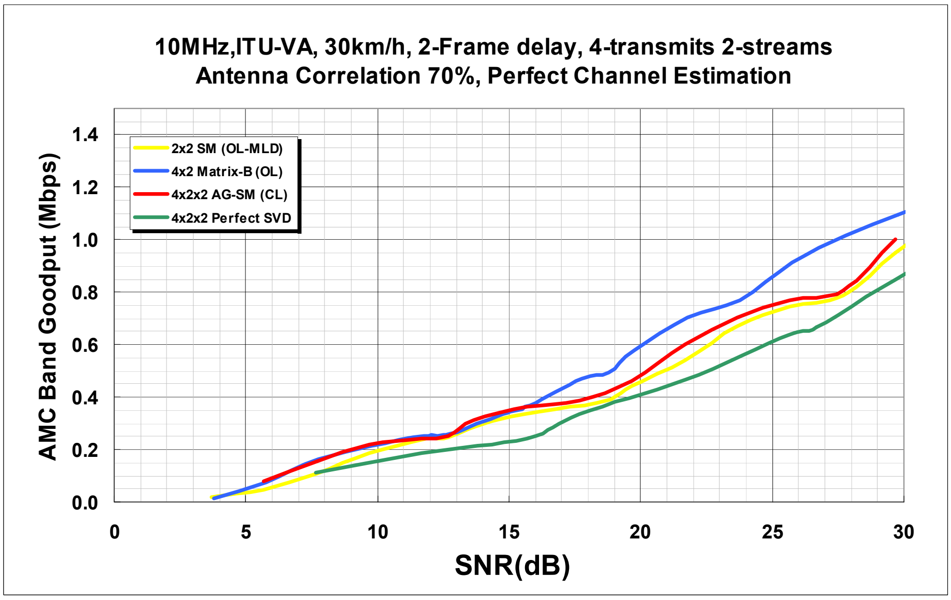

Fig. III-2 Comparison of Aging Effect (70% correlation)

As we can see, the most the gain of the closed loop MIMO can be achieved by simple antenna grouping while avoiding the pre-coding matrix feedback penalty in the UL. In addition, the antenna grouping based closed loop MIMO requires a small among addition computing complexity.

Impact of Multi-User Closed-Loop Antenna Selection

On of the key advantages of the antenna grouping is that this method allows configuring the multi-user transmission. In this case, we can select one user with two active antennas transmission, and the other un-used antennas can be used for another user which has the best antenna selection. Figure III-3 show that by combining the two user transmission the BS has a better utilization of the antenna recourse and higher aggregated throughput. In Figure III-4 we can select one user with one active BS antennas transmission, and the other un-used antennas can be used for other users which has the best antenna selection

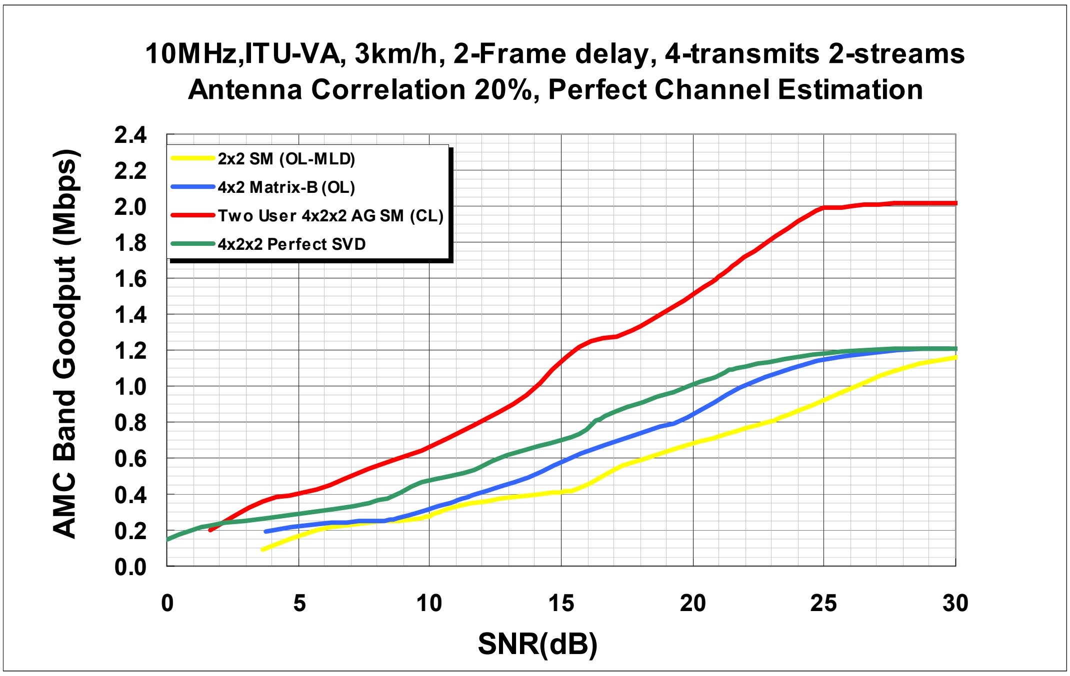

Figure III-3 Multi-user Closed Loop AS (CC coding)

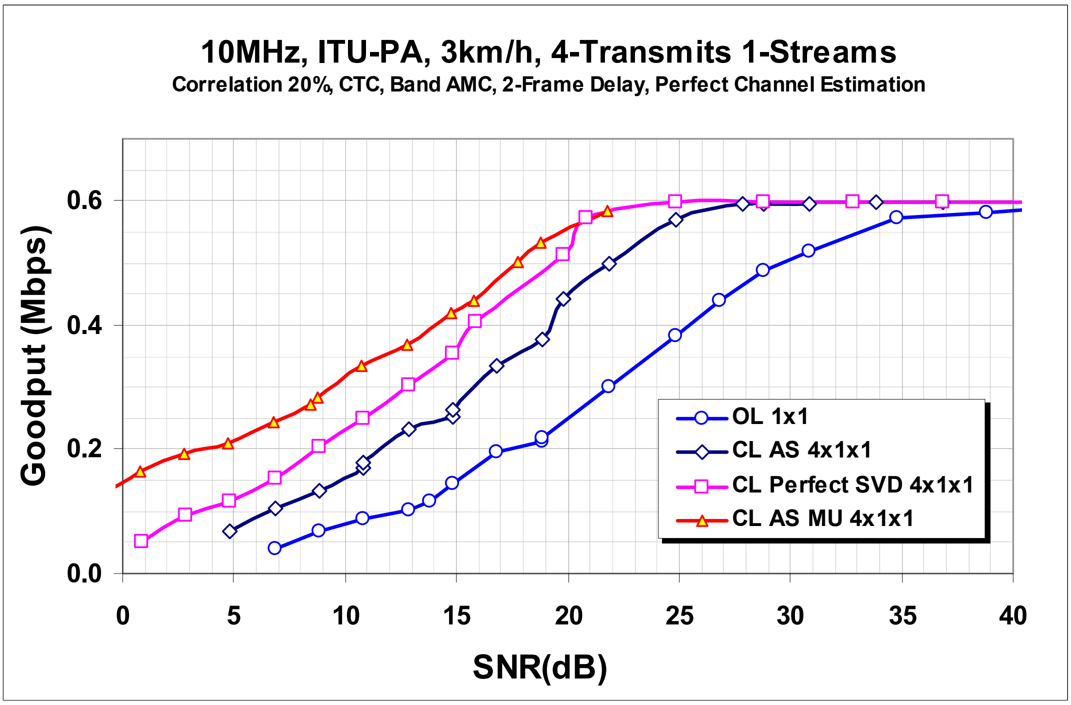

Figure III-4 Multi-user Closed Loop AS (CTC coing)

III-4. Feedback Requirement

2~3 bit are required per AMC band

III-5. Complexity

The complexity of antenna selection mainly consists of the computing the determinant defined by equation (III-III-7). For 4x2 antenna grouping case, maximum108 multiplications are required.

III-6. Summary

The proposed antenna grouping SM can achieve the performance gain close to the perfect channel feedback SVD pre-coding with the following merits:

- Requires small feedback resource
- Applicable to all the sub-channelization
- Robust t feedback aging and no performance degradation worse than open loop transmission
    - However for the SVD based pre-coding, significant performance loss for the mobility speed larger than 10km/h

Part IV. Specific Text Changes

[Add a new section 8.4.8.3.4.1 as follows]

8.4.8.3.4.1 Enhanced 3 Tx Matrix A with Antenna Grouping

For 3 Tx antenna BS, transmission matrix A in 8.4.8.3.4 may be employed with adaptive antenna grouping which is fed back from MSS.

When MSS reports 0b101111 on its CQICH (See 6.x.x), then BS shall group antenna 0 and 1 for the first subcarrier and antenna 0 and 2 for the second subcarrier. In matrix form, it shall be read as

$$A_1 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_3 & -\tilde{s}_4^* \\ \tilde{s}_2 & \tilde{s}_1^* & 0 & 0 \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_s^* \end{bmatrix}$$

When MSS reports 0b110000 on its CQICH, then BS shall group antenna 0 and 1 for the first subcarrier and antenna 1 and 2 for the second subcarrier. In matrix form, it shall be read as

$$A_2 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_3 & -\tilde{s}_4^* \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_s^* \end{bmatrix}$$

When MSS reports 0b110001 on its CQICH, then BS shall group antenna 0 and 2 for the first subcarrier and antenna 1 and 2 for the second subcarrier. In matrix form, it shall be read as

$$A_3 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ 0 & 0 & \tilde{s}_3 & -\tilde{s}_4^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_4 & \tilde{s}_s^* \end{bmatrix}$$

[Add a new section 8.4.8.3.4.2 as follows]

8.4.8.3.4.2 Enhanced 3 Tx Matrix B with Antenna Grouping

For 3 Tx antenna BS, transmission matrix B for rate 2 may be employed with antenna grouping information which is fed back on a CQICH from MSS.

When MSS reports 0b110010 on its allocated CQICH, then BS shall transmit in the following transmission matrix

$$B_1 = \begin{bmatrix} \tilde{s}_7 & -\tilde{s}_8^* & \tilde{s}_3 & -\tilde{s}_4^* \\ \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_5 & -\tilde{s}_6^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_6 & \tilde{s}_5^* \end{bmatrix}$$

When MSS reports 0b110011 on its allocated CQICH, then BS shall transmit in the following transmission matrix

$$B_2 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_5 & -\tilde{s}_6^* \\ \tilde{s}_7 & -\tilde{s}_8^* & \tilde{s}_3 & -\tilde{s}_4^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_6 & \tilde{s}_5^* \end{bmatrix}$$

When MSS reports 0b110100 on its allocated CQICH, then BS shall transmit in the following transmission matrix

$$B_3 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_5 & -\tilde{s}_6^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_6 & \tilde{s}_5^* \\ \tilde{s}_7 & -\tilde{s}_8^* & \tilde{s}_3 & -\tilde{s}_4^* \end{bmatrix}$$

8.4.8.3.4.3 Enhanced 3 Tx Matrix C with Antenna Grouping

For the transmission matrix C, when k sub-streams are configured, $x_i=[s_1,s_2,..s_k]$, k=1,2,.M, M=3,4, Transmission matrix is adaptively changed according to the CQICH.For 3-transmit antennas BS, the transmission matrix is listed in Table xxx, where the mapping of the matrix C_n to the CQICH is shown. The active antenna is power boosted.

Table xxx The Mapping of the Transmission Matrix and CQICH for 3 Transmit Antennas

	CQICH			Power boosting
Streams, k	0b110000	0b110001	0b110010	
1	$C_1 = c\begin{bmatrix} s_1 \\ 0 \\ 0 \end{bmatrix}$	$C_2 = c\begin{bmatrix} 0 \\ s_1 \\ 0 \end{bmatrix}$	$C_3 = c\begin{bmatrix} 0 \\ 0 \\ s_1 \end{bmatrix}$	$c = 1$
2	$C_1 = c\begin{bmatrix} s_1 \\ s_2 \\ 0 \end{bmatrix}$	$C_2 = c\begin{bmatrix} s_1 \\ 0 \\ s_2 \end{bmatrix}$	$C_3 = c\begin{bmatrix} 0 \\ s_1 \\ s_2 \end{bmatrix}$	$c = 1/\sqrt{2}$

[Add a new section 8.4.8.3.5.1 as follows]

8.4.8.3.5.1 Enhanced 4 Tx Matrix A with Antenna Grouping

For 4 Tx antenna BS, transmission matrix A in 8.4.8.3.5 may be employed with adaptive antenna grouping which is fed back from MSS.

When MSS reports 0b101111 on its CQICH (See 6.x.x), then BS shall group antenna 0 and 1 for the first subcarrier and antenna 1 and 2 for the second subcarrier. In matrix form, it shall be read as

$$A_1 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ \tilde{s}_2 & \tilde{s}_1^* & 0 & 0 \\ 0 & 0 & \tilde{s}_3 & -\tilde{s}_4^* \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_3^* \end{bmatrix}$$

When MSS reports 0b110000 on its CQICH, then BS shall group antenna 0 and 2 for the first subcarrier and antenna 1 and 3 for the second subcarrier. In matrix form, it shall be read as

$$A_2 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ 0 & 0 & \tilde{s}_3 & -\tilde{s}_4^* \\ \tilde{s}_2 & \tilde{s}_1^* & 0 & 0 \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_3^* \end{bmatrix}$$

When MSS reports 0b110001 on its CQICH, then BS shall group antenna 0 and 3 for the first subcarrier and antenna 1 and 2 for the second subcarrier. In matrix form, it shall be read as

$$A_3 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ 0 & 0 & \tilde{s}_3 & -\tilde{s}_4^* \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_3^* \\ \tilde{s}_2 & \tilde{s}_1^* & 0 & 0 \end{bmatrix}$$

[Add a new section 8.4.8.3.5.2 as follows]

8.4.8.3.5.2 Enhanced 4 Tx Matrix B with Antenna Grouping

For 4 Tx antenna BS, transmission matrix B for rate 2 may be employed with antenna grouping information which is fed back on a CQICH from MSS.

When MSS reports 0b110010 on its allocated CQICH, then BS shall group antenna 0 and 1 for the first diversity pair and antenna 1 and 2 for the second diversity pair. In matrix form, it shall be read as

$$B_1 = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_2 & s_1^* & s_7 & s_5^* \\ s_3 & -s_4^* & s_6 & -s_8^* \\ s_4 & s_3^* & s_8 & s_6^* \end{bmatrix}$$

When MSS reports 0b110011 on its allocated CQICH, then BS shall transmit in the following transmission matrix

$$B_2 = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_2 & s_1^* & s_7 & s_5^* \\ s_4 & s_3^* & s_8 & s_6^* \\ s_3 & -s_4^* & s_6 & -s_8^* \end{bmatrix}$$

When MSS reports 0b110100 on its allocated CQICH, then BS shall group antenna 0 and 2 for the first diversity pair and antenna 1 and 3 for the second diversity pair. In matrix form, it shall be read as

$$B_3 = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_3 & -s_4^* & s_6 & -s_8^* \\ s_2 & s_1^* & s_7 & s_5^* \\ s_4 & s_3^* & s_8 & s_6^* \end{bmatrix}$$

When MSS reports 0b110101 on its allocated CQICH, then BS shall transmit in the following transmission matrix

$$B_4 = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_4 & s_3^* & s_8 & s_6^* \\ s_2 & s_1^* & s_7 & s_5^* \\ s_3 & -s_4^* & s_6 & -s_8^* \end{bmatrix}$$

When MSS reports 0b110110 on its allocated CQICH, then BS shall group antenna 0 and 3 for the first diversity pair and antenna 1 and 2 for the second diversity pair. In matrix form, it shall be read as

$$B_5 = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_3 & -s_4^* & s_6 & -s_8^* \\ s_4 & s_3^* & s_8 & s_6^* \\ s_2 & s_1^* & s_7 & s_5^* \end{bmatrix}$$

When MSS reports 0b110111 on its allocated CQICH, then BS shall transmit in the following transmission matrix

$$B_6 = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_4 & s_3^* & s_8 & s_6^* \\ s_3 & -s_4^* & s_6 & -s_8^* \\ s_2 & s_1^* & s_7 & s_5^* \end{bmatrix}$$

[Add a new section 8.4.8.3.5.3 as follows]

8.4.8.3.5.3 Enhanced 4 Tx Matrix C with Antenna Grouping

For 4-transmit antennas BS, the transmission matrix is listed in Table yyy, where the mapping of the matrix C_n to the CQICH is shown. The active antenna is power boosted.

Table yyy The Mapping of the Pre-coding matrix and CQICH for 4 Transmit Antennas

Streams, k	CQICH						Power boosting
	0b110000	0b110001	0b110010	0b110011	0b110100	0b110101	

1	$C_1 = c\begin{bmatrix} s_1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$	$C_2 = c\begin{bmatrix} 0 \\ s_1 \\ 0 \\ 0 \end{bmatrix}$	$C_3 = c\begin{bmatrix} 0 \\ 0 \\ s_1 \\ 0 \end{bmatrix}$	$C_4 = c\begin{bmatrix} 0 \\ 0 \\ 0 \\ s_1 \end{bmatrix}$			$c = 1$
2	$C_1 = c\begin{bmatrix} s_1 \\ s_2 \\ 0 \\ 0 \end{bmatrix}$	$C_2 = c\begin{bmatrix} s_1 \\ 0 \\ s_2 \\ 0 \end{bmatrix}$	$C_3 = c\begin{bmatrix} s_1 \\ 0 \\ 0 \\ s_2 \end{bmatrix}$	$C_4 = c\begin{bmatrix} 0 \\ s_1 \\ s_2 \\ 0 \end{bmatrix}$	$C_5 = c\begin{bmatrix} 0 \\ s_1 \\ 0 \\ s_2 \end{bmatrix}$	$C_6 = c\begin{bmatrix} 0 \\ 0 \\ s_1 \\ s_2 \end{bmatrix}$	$c = 1/\sqrt{2}$
3	$C_1 = c\begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ 0 \end{bmatrix}$	$C_2 = c\begin{bmatrix} s_1 \\ s_2 \\ 0 \\ s_4 \end{bmatrix}$	$C_3 = c\begin{bmatrix} s_1 \\ 0 \\ s_2 \\ s_3 \end{bmatrix}$	$C_4 = c\begin{bmatrix} 0 \\ s_1 \\ s_2 \\ s_3 \end{bmatrix}$			$c = 1/\sqrt{3}$

End text proposal

References:

[1] 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

[2] C.B.Chae *et al*, “Adaptive Spatial Modulation for MIMO-OFDM,” *IEEE WCNC,* 2004