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Title	**Enhancement of the Rate 1 STC using Antenna Grouping**
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Re:	
Abstract	Enhancement of the Rate 1 STC using Antenna Grouping
Purpose	Adoption of proposed changes into P802.16e ~~Crossed-out indicates deleted text,~~ underlined blue indicates new text change to the Standard
Notice	
Release	
Patent Policy and Procedures	

Enhancement of the Rate 1 STC using Antenna Grouping

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1. Introduction

Exploiting spatial diversity in systems with multiple antennas at the transmitter requires that the signal be pre-processed or pre-coded prior to transmission. Space-time block coding (STBC) 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 diversity scheme based on antenna grouping which utilizes the partial channel state information and exhibits better performance than the existing schemes for 4 transmit antennas.

2. Antenna Grouping for 3 transmit-antenna STC

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.

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

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.

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

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

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

3. Antenna Grouping for 4 transmit-antenna STC

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

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

Note that this scheme does not achieve full diversity.

Using the equivalent model,

$$A^H A = \begin{bmatrix} \rho_1 & 0 & 0 & 0 \\ 0 & \rho_1 & 0 & 0 \\ 0 & 0 & \rho_2 & 0 \\ 0 & 0 & 0 & \rho_2 \end{bmatrix} \quad (4)$$

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

$$\arg \min_{antenna\_pair} |\rho_1 - \rho_2| \quad (5)$$

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.

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

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

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

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

Fig. 1 shows the system block diagram which makes use of a grouper to select the antenna pair based on feedback channel information from the MS.

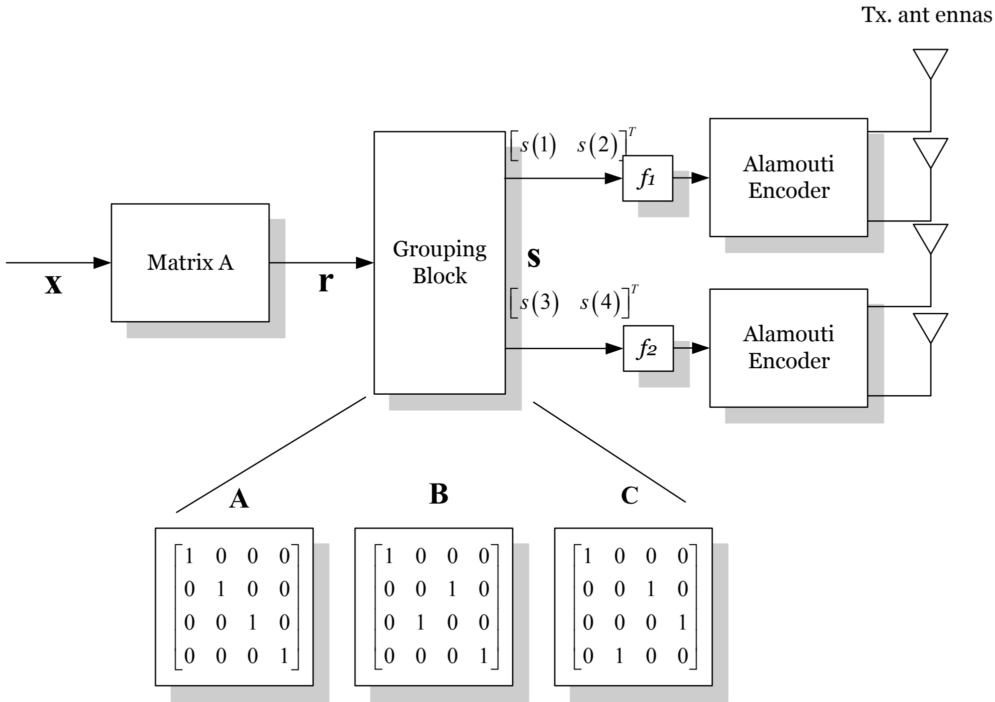


Fig 1. System Block Diagram

The performance of the proposed scheme is shown in Fig. 1. At BER=10^{-3} point, the proposed scheme outperforms the conventional STC without antenna grouping by 3.5dB.

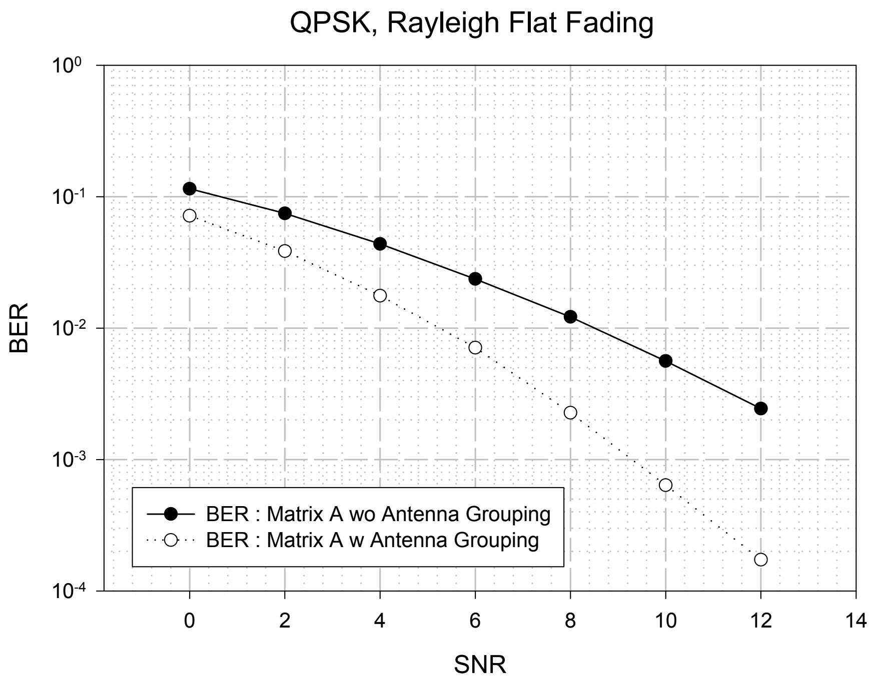
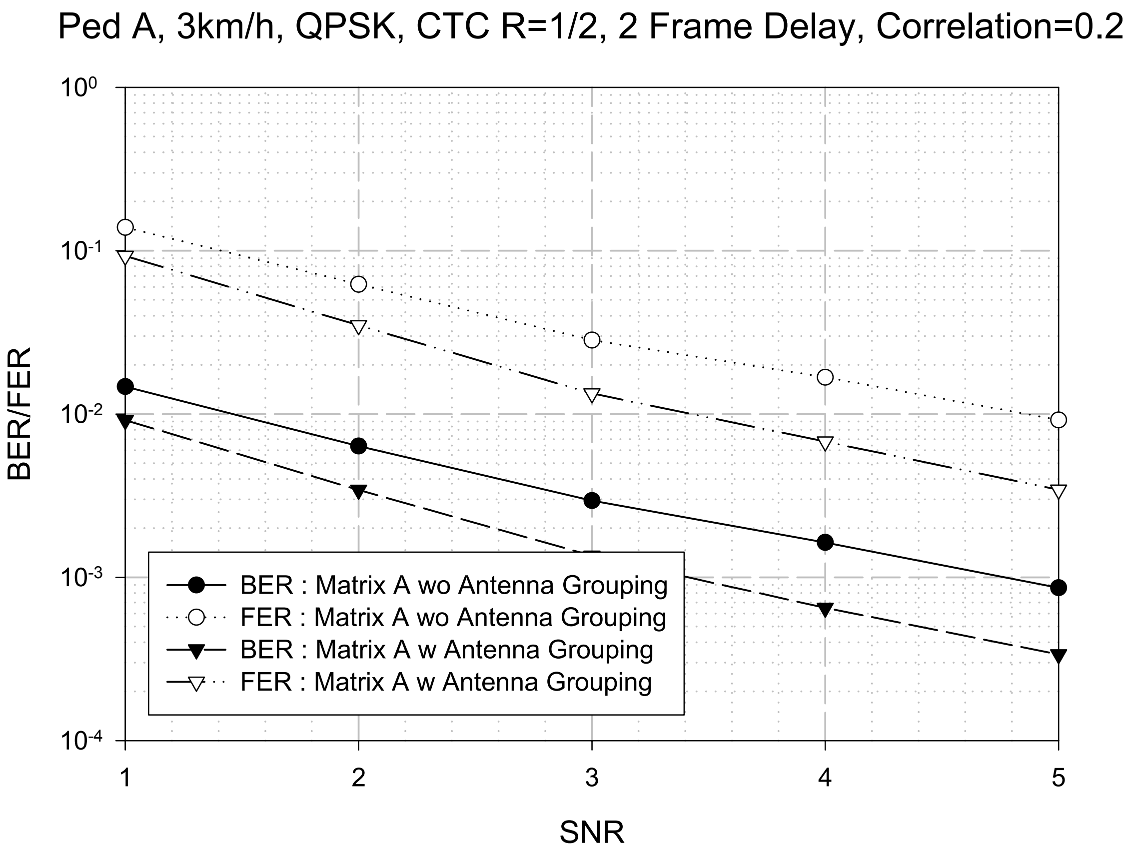


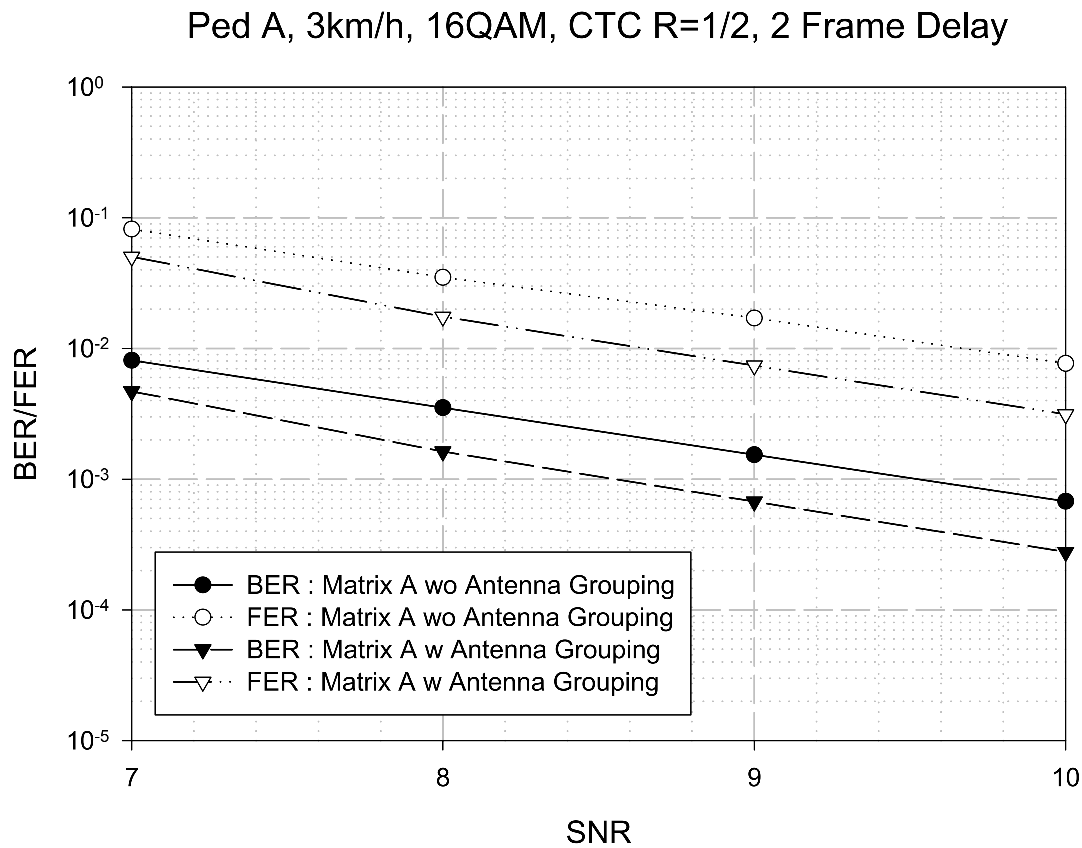
Fig 2. BER vs. SNR with and without antenna grouping

In order to apply the current standards, parameters are set here according to band AMC mode. The number of bands per symbol are 24 and the number of bins per band and the number of subcarriers per bin are 4 and 9, respectively. The BS select the best band based on feedback channel information from the MS. Fig. 3 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. 2) 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)




Ped A, 3km/h, 16QAM, CTC R=1/2, 2 Frame Delay
BER/FER
SNR
BER : Matrix A wo Antenna Grouping
FER : Matrix A wo Antenna Grouping
BER : Matrix A w Antenna Grouping
FER : Matrix A w Antenna Grouping

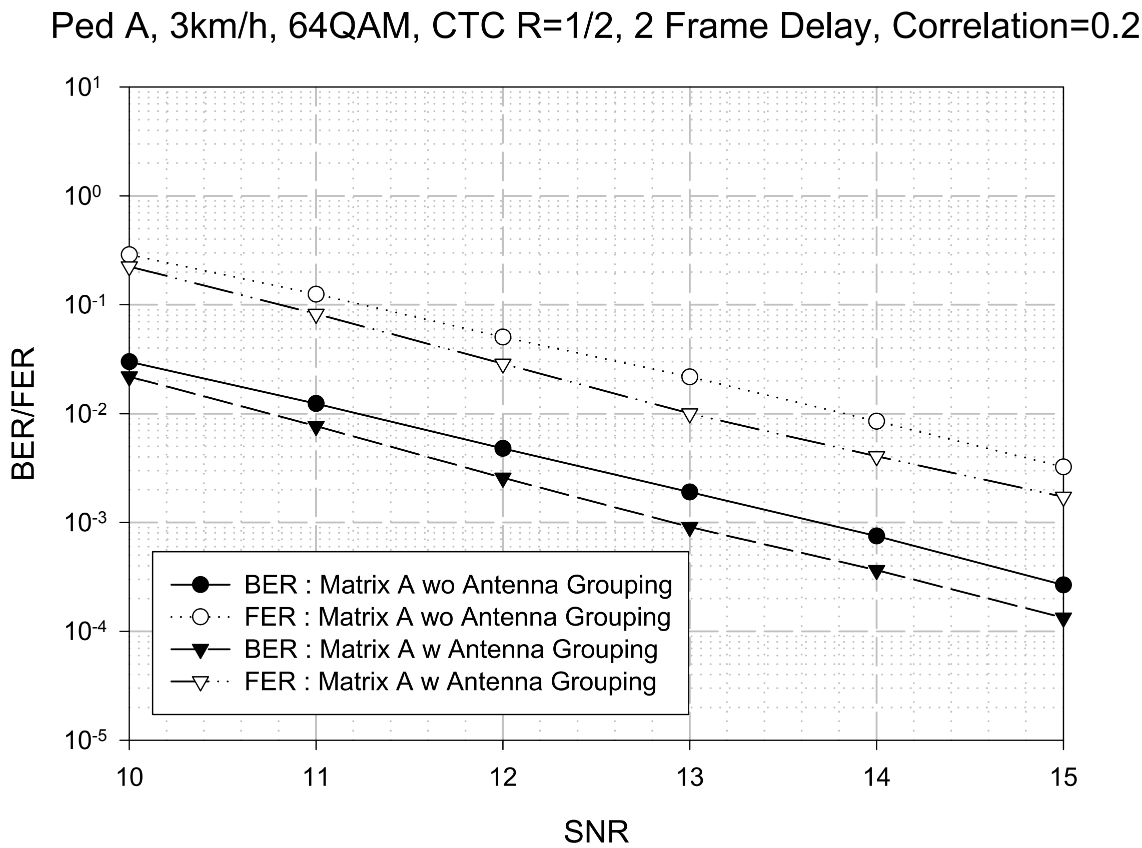

Ped A, 3km/h, 64QAM, CTC R=1/2, 2 Frame Delay, Correlation=0.2
BER/FER
SNR
BER : Matrix A wo Antenna Grouping
FER : Matrix A wo Antenna Grouping
BER : Matrix A w Antenna Grouping
FER : Matrix A w Antenna Grouping

Fig 3. Coded BER/FER vs. SNR with and without antenna grouping

4. Specific Text Changes

Add a new section 8.4.8.3.5.1 as follows]

8.4.8.3.4.1 Enhanced 3 Tx Transmission Schemes with Antenna Grouping

For 3 Tx antenna BS, transmission matrix A in 8.4.8.3.5 may be improved with adaptive antenna grouping which is fed back from SS.

When MS 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 MS 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 MS 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

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

where the ML decoding can be achieved by symbol-by-symbol decoding.

[Add a new section 8.4.8.3.5.1 as follows]

8.4.8.3.5.1 Enhanced 4 Tx Transmission Schemes with Antenna Grouping

For 4 Tx antenna BS, transmission matrix A in 8.4.8.3.4 may be improved with adaptive antenna grouping which is fed back from SS.

When MS 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 MS 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 MS 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

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

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