Proceeding of the 2008 International Joint Conference in Engineering
IJSE2008, August 4-5, Jakarta, Indonesia

A Comparison of Channel Estimation on MIMO STBC 2x2 OFDM Systems Using Orthogonal STBC Properties Without and With Dimension Reduction Algorithm

Edrian Januar*, Budi Prasetya*, and Dharu Arseno*

* Departement of Electrical Engineering ITTelkom, Indonesia, Jln. Telekomunikasi No.1 Bandung 40257
Telp/Fax +6222-7565933, email: eboy_chiko@yahoo.com, bpy@ittelkom.ac.id, dha@stttelkom.ac.id

Abstract–**High speed data rate and bandwidth with good quality of service are world's main topic in wireless communications area. It was believed that Multiple Input Multiple Output-Orthogonal Frequency Division Multiplexing (MIMO-OFDM) technique were the answer for the problems before. The combination of MIMO-OFDM can improve the performance of system, but this combination is still cannot reach the best performance because the channel responses are changes with unpredictable that can cause error. Channel estimation technique defined as technique to known channel responses. Channel estimation technique that had many applied for MIMO system is done by using the orthogonal properties of Space Time Block Codes (STBC), meanwhile the dimension reduction algorithm had many applied in compression areas, such as picture compression.**

We compare the channel estimation using orthogonal STBC properties with out and with dimension reduction algorithm on IEEE 802.16e for WiMAX standardization. User in this research was assumed mobile with speed 0, 3, and 30 km/hour. From simulation results, adding dimension reduction algorithm can improve the MIMO-OFDM system performance about 1 dB on BER 10^{-4}, increasing the number of symbols as a pilot will reduce performance because it will reduce frame efficiency, User speed affect performance of both channel.

Keywords– MIMO-OFDM, STBC, Channel estimation, dimension reduction algorithm

I. INTRODUCTION

Wireless communications with high speed data rate are world's main topic now. But, as we know, there are many problems in wireless communication such as fading and multipath effect.

One of technique to combat the multipath effect was MIMO (Multiple-Input Multiple-Output). Using multi antennas both at transmitter and receiver can increase performance because probability, at least, one antenna received good signal was increased.

Meanwhile using OFDM technique can combat the effect of frequency selective fading. It divide wide bandwidth into several narrow bandwidth each sub-carrier. Using MIMO OFDM was believed as a key to achieve gigabit communication.

The consequence of using multi antennas was needed the channel response at receiver as part of decision criteria for symbols received. To know the channel response, we were using channel estimation technique using symbols as pilot

II. BASIC THEORY

2.1. MIMO *Space-Time Block Codes* (MIMO STBC)[1]

MIMO STBC 2x2 was introduced by Alamouti in 1998. Figure 1 shows the principle for MIMO 2x2. At *t* time slot, antenna Tx_1 will send S_0 symbol and antenna Tx_2 send S_1 symbol. When $t + T$ time slot, antenna Tx_1 will send - S_1* symbol and antenna Tx_2 send S_0* symbol.

From figure 1, we can obtain the received signals :

$$\begin{aligned} \mathbf{r}_0 &= \mathbf{h}_0\mathbf{s}_0 + \mathbf{h}_1\mathbf{s}_1 + \mathbf{n}_0 \\ \mathbf{r}_1 &= -\mathbf{h}_0\mathbf{s}_1^* + \mathbf{h}_1\mathbf{s}_0^* + \mathbf{n}_1 \\ \mathbf{r}_2 &= \mathbf{h}_2\mathbf{s}_0 + \mathbf{h}_3\mathbf{s}_1 + \mathbf{n}_2 \\ \mathbf{r}_3 &= -\mathbf{h}_2\mathbf{s}_1^* + \mathbf{h}_3\mathbf{s}_0^* + \mathbf{n}_3 \end{aligned} \tag{1}$$

Where h_0, h_1, h_2, h_3 are channel coeficients from *channel estimator* and n_0, n_1, n_2, n_3 are noise with random variables. Blok *combiner* from figure 1 build two signals into *maximum likelihood detector* :

$$\begin{aligned} \tilde{\mathbf{s}}_0 &= \mathbf{h}_0^*\mathbf{r}_0 + \mathbf{h}_1\mathbf{r}_1^* + \mathbf{h}_2^*\mathbf{r}_2 + \mathbf{h}_3\mathbf{r}_3^* \\ \tilde{\mathbf{s}}_1 &= \mathbf{h}_1^*\mathbf{r}_0 - \mathbf{h}_0\mathbf{r}_1^* + \mathbf{h}_3^*\mathbf{r}_2 - \mathbf{h}_2\mathbf{r}_3^* \end{aligned} \tag{2}$$

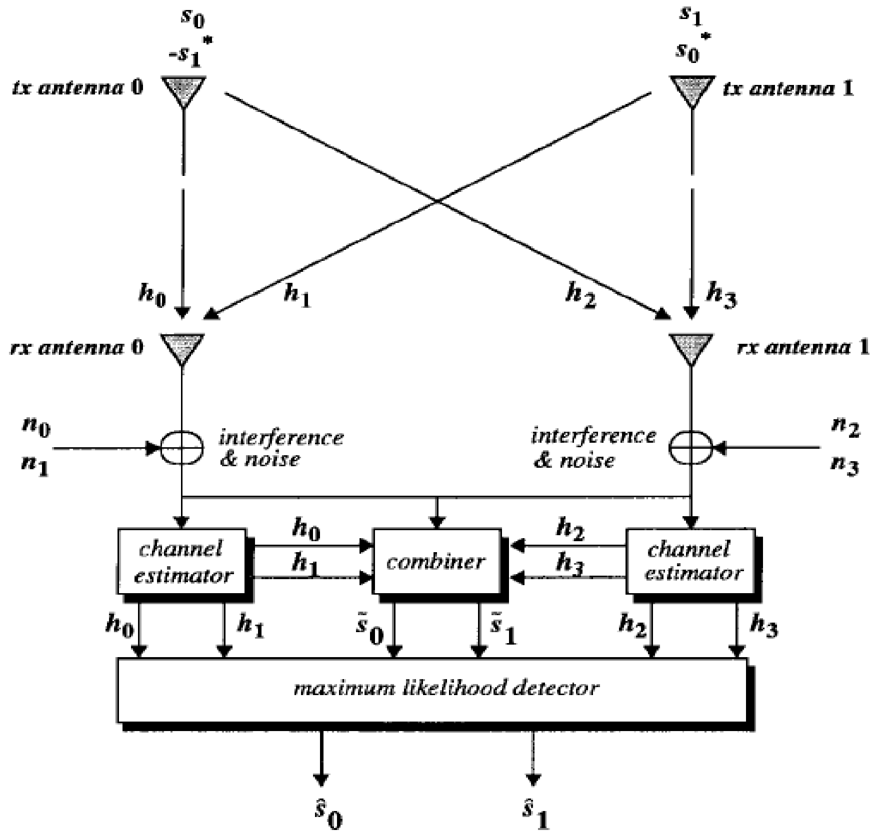


Figure 1 Space-Time Block Codes with 2x2 configurations

2.2. *Orthogonal Frequency Division Multiplex*

OFDM was multi-carrier modulation technique. It divides wide bandwidth into several narrow bandwidth and also with data rate. The benefits using OFDM is robust again frequency selective fading effect in each sub-carrier because bandwidth for each sub-carriers are very narrow comparing with bandwidth coherent. Also using OFDM can increase bandwidth efficiency caused each sub-carriers are allowed to overlap (orthogonal between sub-carriers).

IFFT was used to modulate each sub-carriers and FFT for de-modulation process.

IFFT :

$$x(n) = \frac{1}{N}\sum_{c=0}^{N-1} X(k) e^{j2\pi \frac{cn}{N}} \; ; n = 0,1,2,...,N-1 \quad (3)$$

FFT :

$$x_m = \sum_{n=0}^{N-1} X_n \exp\left\{-j\frac{2\pi mn}{N}\right\}, \quad 0 \le m \le N-1 \quad (4)$$

2.3. MIMO Channel Estimation

Channel estimation used to know channel responses, like amplitude and phase, from figure 1 we can see there are four path for signals, represented by h_0, h_1, h_2, h_3. The results of channel estimation used for decision criteris each signals received.

2.3.1. MIMO Channel Estimation using *Orthogonality-STBC*

The basic idea for this technique was using orthogonal symbols from STBC. But the problem is receiver doesn't know transmit symbols. To handle this problem, we are using symbols as pilot, symbols value must known both at transmitter and receiver, on each antennas.

We are using hadamard code 2x2 for symbols as pilot and we assume that channel is under quasi-static condition. From received signals, we can obtain the equation for each channel responses :

$$\begin{bmatrix} \hat{\mathbf{h}}_0 \\ \hat{\mathbf{h}}_1 \end{bmatrix} = \frac{1}{|s_0|^2 + |s_1|^2} \begin{bmatrix} s_0 & s_1 \\ -s_1^* & s_0^* \end{bmatrix}^H \left[\begin{bmatrix} \mathbf{r_0} \\ \mathbf{r_1} \end{bmatrix} - \begin{bmatrix} n_0 \\ n_1 \end{bmatrix} \right] \quad (5)$$

$$\begin{bmatrix} \hat{\mathbf{h}}_2 \\ \hat{\mathbf{h}}_3 \end{bmatrix} = \frac{1}{|s_0|^2 + |s_1|^2} \begin{bmatrix} s_0 & s_1 \\ -s_1^* & s_0^* \end{bmatrix}^H \left[\begin{bmatrix} \mathbf{r_2} \\ \mathbf{r_3} \end{bmatrix} - \begin{bmatrix} n_2 \\ n_3 \end{bmatrix} \right] \quad (6)$$

From equation above, we assume that noise value is zero to make the equation easier because we don't know noise value. On the other hand, it can make error estimation. Change the symbols with pilot symbol and the equation will be :

$$\begin{bmatrix} \hat{\mathbf{h}}_0 \\ \hat{\mathbf{h}}_1 \end{bmatrix} = \frac{1}{|p|^2 + |p|^2} \begin{bmatrix} p & p \\ -p & p \end{bmatrix}^H \begin{bmatrix} \mathbf{r_0} \\ \mathbf{r_1} \end{bmatrix} \quad (7)$$

$$= \frac{1}{2p^2} \begin{bmatrix} p & -p \\ p & p \end{bmatrix} \begin{bmatrix} \mathbf{r_0} \\ \mathbf{r_1} \end{bmatrix}$$

For $\hat{\mathbf{h}}_2$ and $\hat{\mathbf{h}}_3$:

$$\begin{bmatrix} \hat{\mathbf{h}}_2 \\ \hat{\mathbf{h}}_3 \end{bmatrix} = \frac{1}{2p^2} \begin{bmatrix} p & -p \\ p & p \end{bmatrix} \begin{bmatrix} \mathbf{r_2} \\ \mathbf{r_3} \end{bmatrix} \quad (8)$$

2.3.2. MIMO Channel Estimation using Dimension Reduction Algorithm[3]

Process the estimation of canal MIMO with the dimension reduction early by signal transformation using Karhunen-Loeve Transform (KLT). KLT recognized by the name of transformation eigen vector proposed by Harold Hotelline (1933) and developed by Karl Kahnen (1947) and Michel Loeve (1948).

Algorithm for the process explainable as follows:

1. Input matrix beforehand made form square as according to size measure of block hereinafter.
2. Determine the covariance matrix using equation below.

   $$\mathbf{R}_{\hat{\mathbf{h}}} = E\{\hat{\mathbf{h}}\hat{\mathbf{h}}^H\} = [\hat{\mathbf{h}}\hat{\mathbf{h}}^H][\hat{\mathbf{h}}\hat{\mathbf{h}}^H]^*$$

3. Find the matrix eigenvector and matrix eigenvalue from the matrix covariance. This matrix Eigenvector named bases vektor to be used for the decorelate the component of input vector.
4. Karhunen-Loeve Transform can be implemented by using this equation to input matrix.

   $$\mathbf{z} = \mathbf{U}^H \hat{\mathbf{h}}$$

   Where $\mathbf{z}$ were Karhunen-Loeve matrix. $\mathbf{U}^H$ was hermitian matrix *eigenvector*.
5. Reduce the dimension done by throwing away component from matrix eigenvalue which do not significant value[4] so that reduce also matrix Karhunen-Loeve because every value of eigenvalue have correspondence with every column of matrix Karhunen-Loeve.
6. After getting optimum dimension value (L) hereinafter multiply the component with the matrix eigenvector so that got a new channel coefficient.

   $$\tilde{\mathbf{h}} = \sum_{i=1}^{L} \mathbf{U}_i \mathbf{z}_i$$

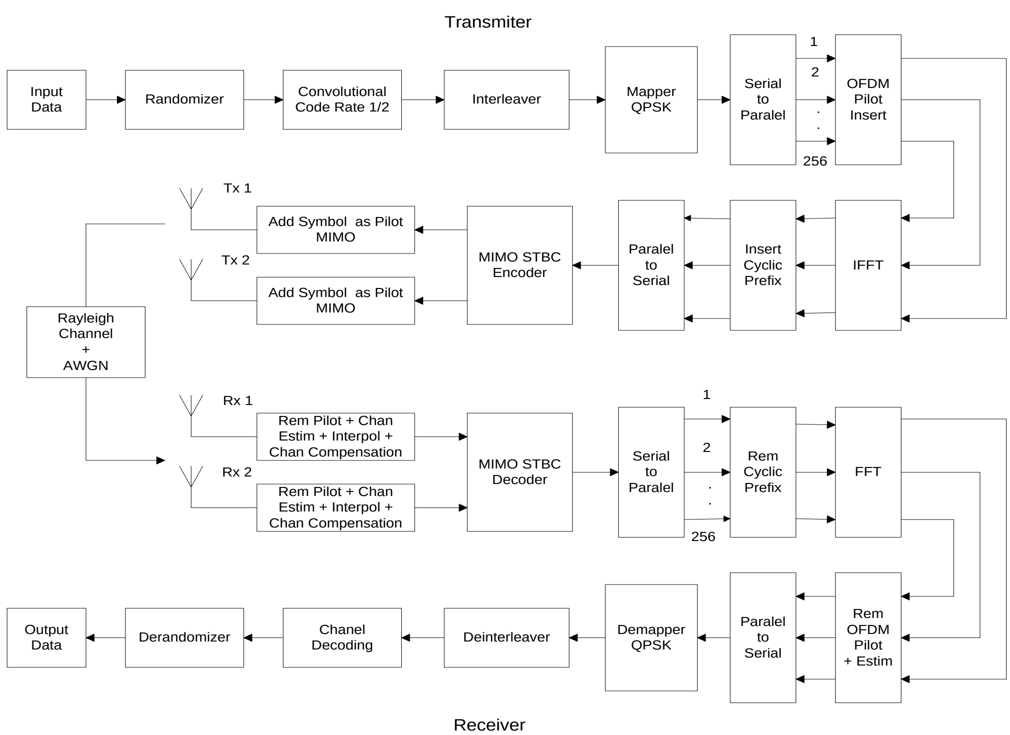
   If there are more than one value eigenvalue which significant hence long election of optimum dimension can be done by using method MSE, formulated with.

   $$\varepsilon_{\tilde{\mathbf{h}}}^2 = \left\| \mathbf{h} - \tilde{\mathbf{h}} \right\|_F^2$$

   $\left\| \; \right\|_F^2$ was Frobenius normalized.

III. SIMULATION RESULTS

3.1. Simulation Model



3.2. Analysis of Simulation Results

3.2.1. Performance of OSTBC Method

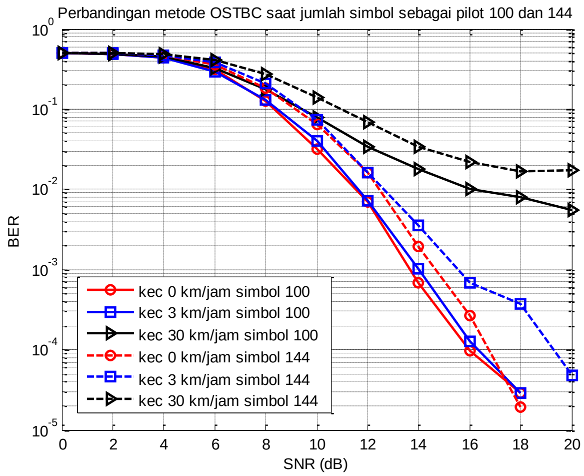


Figure 2 OSTBC performance using 100 and 144 symbols as a pilot with mobile user

From figure 2 we can see that performance when number of symbols as pilot 100 (solid line) are better than performance when number of symbols as a pilot 144 (dash line), this is because increasing number of symbols as a pilot reducing frame efficiency. Also performance are getting worse when user speed are increase because also increasing Doppler effect.

3.2.2. Performance OSTBC+dimension reduction with user speed 0 kmph

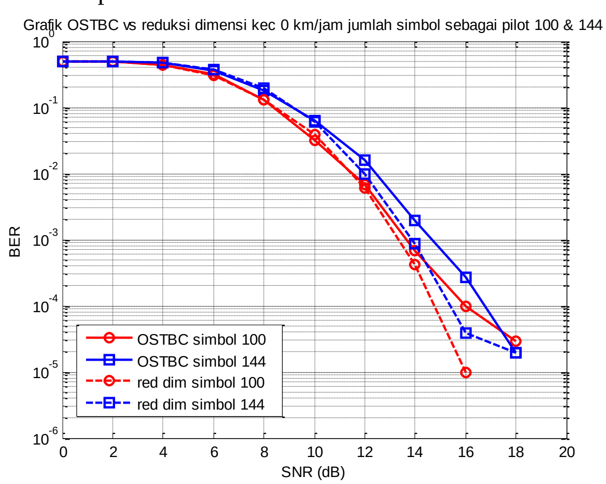


Figure 3 Performance comparison when user speed 0 kmph

Figure 3 shows that adding dimension reduction algorithm (dash line) can increase performance about 1.2 dB on BER 10^{-4} both for number symbols as a pilot 100 and 144. As explained before, dimension reduction can reduce noise level that still corrupt after OSTBC method by discarding eigenvalue with unsignificant value (comparing to noise variance)

3.2.3. Performance OSTBC+dimension reduction with user speed 3 kmph

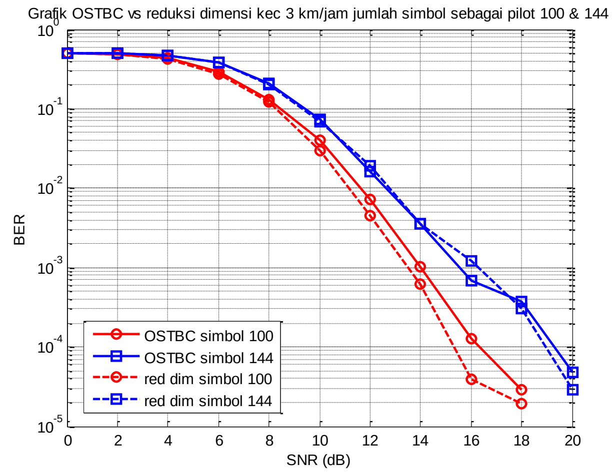


Figure 4 Performance comparison when user speed 3 kmph

Figure 4 shows performance when user increase their speed into 3 kmph, still adding dimension reduction algorithm (dash line) can increase performance about 1 dB on BER 10^{-4}. If we compare figure 3 and figure 4, performance is getting worse caused by Doppler effect.

IV. CONCLUSIONS

1. Adding dimension reduction algorithm can increase performance about 1 dB on BER 10^{-4}.
2. Number symbols as a pilot affect the performance. Increasing the number of symbols as a pilot will reduce performance because it will reduce frame efficiency.
3. User speed affect performance of both channel estimation method caused by Doppler affect.

REFERENCES

[1] Alamouti, M Siavash. "*A Simple Transmit Diversity Technique for Wireless Communications*". IEEE journal on select areas in communications Vol 16, no 8, October 1998.

[2] Saan-Maw, Maung. "Multi Input Multi Output Technology", SASASE LAB, 2006.

[3] Stege Matthias, Zillmann Peter, Fettweis Gerhard. "*MIMO Channel Estimation with Dimension Reduction*". Dresden University of Technology, 2002.

[4] Jellito Jens, Fettweis Gerhard. "*Reduced Dimension Space-Time Processing for Multi-Antenna Wireless Systems*". IEEE Wireless Communications, December 2002.

[5] IEEE Standar for local and metropolitan area network : 802.16^{TM}, part 16 : *Air Interface for Fixed Broadband Wireless Access Systems*, 2004.

[6] Paltenghi, Giovanni, "*Functional spesifications of the adaptive modem IEEE 802.16*", Multichannel adaptive Information System, 2004.

[7] M. C. Valenti, D. A. Baker. "*The Impact of Channel Estimation Errors on Space Time Block Codes*". Wireless Communications Research Lab West Virginia University