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The 1st International Conference on Wireless System, Services, and Applications
(WSSA 2006)

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Invited Talks (Abstraction)

The Performance of Non Coherent Space Time Coding in MIMO-wireless Systems

Rina Pudji Astuti[1] , Andriyan B. Suksmono[2] Sugihartono[3], and Adit Kurniawan[4]
Affiliation 1 : Institut Teknologi Bandung; and STT Telkom-Indonesia, rina.p.a@plasa.com, 062 22 2501661
Affiliation 2 : Institut Teknologi Bandung-Indonesia, suksmono@yahoo.com, 062 22 2501661
Affiliation 3 : Institut Teknologi Bandung-Indonesia, sugi_sugihartono@yahoo.com, 062 22 2501661
Affiliation 4 : Institut Teknologi Bandung-Indonesia, adit@ltrgm.ee.itb.ac.id, 062 22 2501661

***Abstract*— In high mobility case, it is practical to develop modulation techniques that require no channel state information or non perfect channel state information, for example non coherent space time coding in MIMO. The objective of this paper is to investigate the performance of 3 non coherent space time schemes in wireless MIMO channel under similar conditions of mobile velocity, coding rate, frame size, modulation system, and channel condition. It is shown, the MIMO systems in Rayleigh fading condition with coherent space time code, especially STBC with perfect estimation has a better performance than all non coherent space time code scheme and STBC non perfect estimation. However, in general D-USTF encoding and STBC with perfect estimation have much better performance than D-unitary encoding, D-STBC, and STBC with non perfect estimation. Moreover, DUSTF encoding performance is better than STBC with perfect estimation in low Eb/No, and vice versa.**

***Index Terms*— MIMO, D-STBC, D-unitary encoding, D-unitary space time frequency.**

I. INTRODUCTION

IN the future, mobile broadband access systems are expected to operate at high vehicle speeds. Channel estimation, however, might be difficult or costly to estimate the channel accurately in high-mobility situations. Channel estimation over fast fading environment requires more training symbols and complex computation, hence higher power consumption. The perfect estimates of channel conditions assumption is acceptable if the channel changes slowly compared with the symbol rate, because the transmitters can send training symbols which allow the receiver to estimate the channel accurately. If multiple antennas are used, the path gains between each pair of transmit and receive antennas must be estimated too. In the frequency selective case, estimating the MIMO channels becomes significantly more difficult due to the presence in multipaths, which results in an increased number of channel coefficients.

One of the transmission techniques that can transmit information signal with or without channel estimation is differential modulation technique. Non coherent space time encoding is a differential modulation scheme applied in MIMO-wireless system. It is a common practice for fixed or low mobility wireless systems. It is still unknown, how high mobility affects the performance of non coherent space time encoding technique that is applied in MIMO wireless system.

The objective of this paper is to compare the performance of 3 types of non coherent space time encoding schemes over the wireless MIMO channel, i.e.: differential space time block code (D-STBC), differential unitary (D-unitary) encoding and differential unitary space time frequency (D-USTF) transmit diversity. The first two schemes are based on the group code and unitary matrices. The last one is based on the orthogonal where a differential space time encoding is applied to each subcarrier.

The selection of these 3 schemes in derived from various researches on non coherent space time schemes and based on the result of previous researches including the achieved performance, efficiency and the simplicity of proposed system (suboptimal condition). To keep our fairness judgment, these schemes are adapted and simulated under similar conditions, i.e. mobile velocity, coding rate, frame size, modulation system, channel state information, and 2x2 antennas system. The outcomes of this research will be used to develop a novel non coherent space time encoding technique, based on the unitary group code and differential space time frequency, which can be implemented in mobile broadband access system at high vehicle speed.

The paper is organized as follows. In Section 2, we investigate the space time coding schemes and decoding schemes for non coherent transmit diversity. Next, Section 3 we talk about the performance of MIMO wireless systems with non coherent space time coding. Finally, our main conclusions are summarized in Sections 4.

II. SPACE TIME CODING SCHEMES FOR NON COHERENT TRANSMIT DIVERSITY

A. Differential –STBC

Differential-STBC modeling in investigated quite often. This method can be divided into 2 types, the fist one is based on trellis code and decoded using Viterbi algorithm. The other type is based on spatial multiplexing of Alamouti encoded information streams [22],[14]. From the results of above mentioned research, despite its complexity, type I usually outperforms type II.

Since our research takes into account the system complexity, we focus on type II, especially the method that has been developed by [2], with several adjustments. The Alamouti STBC has two main limitations. First, it requires channel knowledge at the receiver by using training sequences at the expense of rate overhead. In high mobility scenarios, it becomes very costly and impractical to estimate and track large number of channel parameters accurately. The second limitation is achievable rate, i.e. one, achieved from 2 information symbols transmitted over 2 symbol periods using 2 transmit antennas. It is half the maximum possible rate, i.e. two, achieved in this scenario using spatial multiplexing due to the 2 inserted redundant symbols of full spatial diversity gains.

A transmission scenario is considered, where the full spatial diversity is obtained using 2 Tx antennas and 2 Rx antennas. Neither the transmitter nor the receiver has access to channel state information. The detection scheme can use equal energy constellations with low decoding complexity [22]. By means of the transmission scenario, in this paper we applied this scenario on 2 x 2 antenna system as Fig.1.

In this paper, the constellation C_{cons} will be restricted by 2^b-PSK for MIMO-wireless system. Set a pair of 2b-PSK constellation symbols, e.g. b = 1 or BPSK scheme, p_1 and p_2. The complexes vectors $(p_1 \quad p_2)$ and $\left(-p_2^* \quad p_1^*\right)$ are orthogonal to each other and have unit lengths. Any two dimensional vectors $\mathbf{P}=\left(p_1 \quad p_2\right)$ can be represented in the orthonormal basis, a unique complex vector $U_p=(A_p \quad B_p)$, as follows:

$$(p_3 \quad p_4)=A_p\left(p_1 \quad p_2\right)+B_p\left(-p_2^* \quad p_1^*\right) \qquad (1)$$

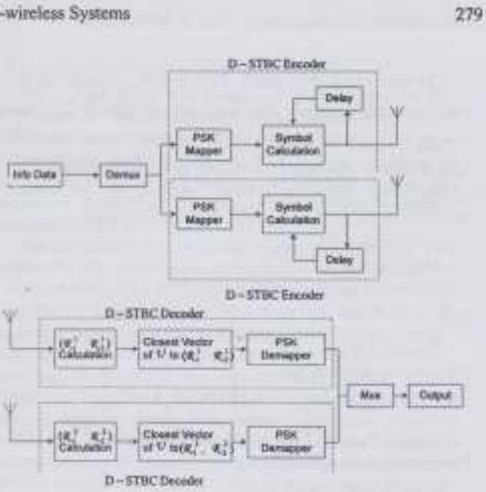

Figure 1. Differential-STBC transmitter-receiver block scheme of MIMO-wireless system

where

$$A_p = p_3 p_1^* + p_4 p_2^* \qquad (2)$$

$$B_p = -p_3 p_2 + p_4 p_1 \qquad (3)$$

The set $\mathcal{U}_p$ is defined as all the vectors U_p, $\mathbf{P} \in C_{cons} \times C_{cons}$. Then, an arbitrary mapping $\mathcal{M}$ of blocks of $2b$ bits will map onto $\mathcal{U}$. Known a block $\mathcal{B}$ of $2b$ bits, the first b bits are mapped into a constellation symbol s_3 and the second b bits are mapping into a constellation symbol s_4 using Gray mapping.

Let $s_1 = s_2 = 1/\sqrt{2}$, then $\mathcal{M}(\mathcal{B}) = \left(A(\mathcal{B}) \quad B(\mathcal{B})\right)$ is defined by:

$$A(\mathcal{B}) = s_3 s_1^* + s_1 s_2^* \qquad (4)$$

$$B(\mathcal{B}) = -s_3 s_2 + s_4 s_1 \qquad (5)$$

On the other hand, let $\left(A(\mathcal{B}) \quad B(\mathcal{B})\right)$, then the pair $(s_3 \quad s_4)$ is recovered by:

$$(s_3 \quad s_4) = A(\mathcal{B})(s_1 \quad s_2) + B(\mathcal{B})(-s_2^* \quad s_1^*) \qquad (6)$$

Suppose that s_{2t-1} and s_{2t} are transmitted, respectively, from antennas one and two at time $2t-1$. Then, $-s_{2t}^*$, s_{2t-1}^* are transmitted, respectively, from antennas one and two at time $2t$. At time $2t+1$, a block of $2b$ bits $\mathcal{B}_{2t+1}$ arrives at encoder. The transmitter employs the mapping $\mathcal{M}$ and computes $\mathcal{M}(\mathcal{B}_{2t+1}) = \left(A(\mathcal{B}_{2t+1}) B(\mathcal{B}_{2t+1})\right)$. Next, it computes $\left(s_{2t+1} \quad s_{2t+2}\right)$

$$= A(\mathcal{B}_{2t+1})(s_{2t-1} \quad s_{2t}) + B(\mathcal{B}_{2t+1})(-s_{2t}^* \quad s_{2t-1}^*) \qquad (7)$$

The transmitter then sends s_{2t+1} and s_{2t+2}, respectively, from transmit antennas one and two at time $2t+1$, and $-s^*_{2t+2}$, s^*_{2t+1} from antennas one and two at time $2t+2$. This process in repeated until the end of the transmission.

Assuming only one receive antenna, let the signals received are r_{2t-1}, r_{2t}, r_{2t+1} and r_{2t+2}. Allow with:

$$\mathbf{H}(h_1,h_2)=\begin{pmatrix} h_1 & h_2^* \\ h_2 & -h_1^* \end{pmatrix} \tag{8}$$

and

$$W_{2t-1}=(w_{2t-1} \quad w^*_{2t}) \tag{9}$$

The receiver reminds that

$$\left(r_{2t-1} \quad r^*_{2t}\right)=\left(s_{2t-1} \quad s_{2t}\right)\mathbf{H}(h_1,h_2)+W_{2t-1} \tag{10}$$

$$(r_{2t+1} \quad r^*_{2t+2})=(s_{2t+1} \quad s_{2t+2})\mathbf{H}(h_1,h_2)+W_{2t+1} \tag{11}$$

For notational simplicity, let

$$\begin{aligned}\mathcal{R}_1 &= r_{2t+1}r^*_{2t-1}+r^*_{2t+2}r_{2t} \\ &=\left(|h_1|^2+|h_2|^2\right)A(\mathcal{B}_{2t-1})+W_1\end{aligned} \tag{12}$$

and

$$\mathcal{R}_2=\left(|h_1|^2+|h_2|^2\right)B(\mathcal{B}_{2t-1})+W_2 \tag{13}$$

Thus, we can write

$$\begin{aligned}&(\mathcal{R}_1 \quad \mathcal{R}_2) \\ &=\left(|h_1|^2+|h_1|^2\right)\left(A(\mathcal{B}_{2t-1}) \quad ?(\mathcal{B}_{2t-1})\right)+(W_1 \quad W_1)\end{aligned} \tag{14}$$

Since the elements of $\mathcal{U}$ have equal length, the receiver now computes $\left(A(\mathcal{B}_{2t-1}) \quad B(\mathcal{B}_{2t-1})\right)$ by searching the closest vector of $\mathcal{U}$ to $(\mathcal{R}_1 \quad \mathcal{R}_2)$. Then, the inverse mapping of $\mathcal{M}$ is applied and the transmitted bits are recovered.

The similar procedure can be employed for another receive antenna. For each receive antenna i, assuming only receive antenna i exist, $\mathcal{R}^i_1$ and $\mathcal{R}^i_2$ can computed using the same method for $\mathcal{R}_1$ and $\mathcal{R}_2$ given before. After that the closet vector of $\mathcal{U}$ to $\left(\sum_{i=1}^{n_r}\mathcal{R}^i_1 \quad \sum_{i=1}^{n_r}\mathcal{R}^i_2\right)$ be computed. Later, the transmitted bits are computed by applying the inverse mapping of $\mathcal{M}$.

B. Differential Unitary Coding

A general approach to differential modulation for multiple antennas is based on group structure code, for example differential unitary coding. Unitary space time signals are orthonormal in time across the antennas and have been shown to be reliable in a Rayleigh fading channel where neither the transmitter nor the receiver knows the fading coefficients. The signal can achieve low probability of error by exploiting multiple antenna diversity.

The unitary space time codes have to have a condition as follows [13]:

$$C_u C_u^* = n_s I \qquad \text{for all } u=1,\cdots,U \tag{15}$$

where $(\ )^*$ is the conjugate transpose, n_s is number of symbols.

A system with m transmit antennas and constellation C_{con} is considered. For any $n_s \geq m$, allow $\mathcal{G}$ be any group of $n_s \times n_s$ unitary matrices and let C_D be a $m \times n_s$ matrix such that $C_D G \in C_{con}^{m \times n_s}$ for all $G \in \mathcal{G}$. So the collection of matrices of a group code of length n_s over constellation C_{con} can be expressed as:

$$C_D\mathcal{G} \overset{\Delta}{=} \{C_D G : G \in \mathcal{G}\} \tag{16}$$

The cardinality of $\mathcal{G}$ is denoted by $|\mathcal{G}|$, so the rate of this code is written as:

$$R=\frac{1}{n_s}\log_2|\mathcal{G}| \text{ Bit/s/Hz} \tag{17}$$

By means of the coding model, in this paper we apply this coding on 2 x 2 antennas system as follows:

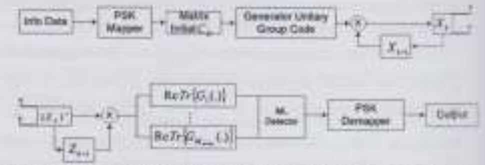

Figure 2. Non coherent MIMO-unitary group code scheme.

There are many classes of group code, including codes from reflection groups [18], all binary linear codes with BPSK modulation [6], and block-circulant unitary codes [12]. It is clear that group codes can be constructed for any number of transmit antennas and any constellation.

In this paper, in particular, we will investigate the structure and performance of differentially encoded group codes with two assumptions [11], but this scheme is adapted for two receive antennas system. Firstly, we assume that $C_D\mathcal{G}$ is a unitary code. Clearly, $C_D\mathcal{G}$ is unitary if and only if $C_D C_D^* = n_s I$. Secondly, we assume for simplicity that $n_s = m$. The group codes can be differentially encoded in a way similar to PSK [19].

Let us consider $\mathcal{G}$ to be the set of possible messages. To initialize transmission, the transmitter sends $X_0 = C_D$. Then, to send $G_k \in \mathcal{G}$ in block k, the transmitter sends messages with differentially encoded as follows:

$$X_k = X_{k-1}G_k \quad k=1,\cdots,K \tag{18}$$

In the absence of Channel State Information, the receiver with $n_s = m$ applies the ML detector for the sequence in the equation above. It consists of the quadratic receiver as:

$$\hat{u} = \arg\max_{u} p(Z|C_u) = \arg\max_{u} Tr\{ZC_u^{+}C_u Z^{+}\} \quad (19)$$

This is applied to the entire received sequence $Z = [Z_0 : \cdots : Z_K]$, where

$$Z_k \overset{\Delta}{=} \sqrt{(SNR)_m}\,\mathbf{H}X_k + W_k \qquad k = 1, \cdots, K \quad (20)$$

where $(SNR)_m$ is signal-to-noise ratio per receive antenna, and $H = \{h_{ij}\}$ is the $n \times m$ fading matrix. Even for moderate values of m transmit antennas and K block code, this receiver is quite complex.

So, we prefer a simpler suboptimal receiver. For example of DPSK, it is usual to look for a receiver that estimates G_k using only the last two received blocks.

$$\widetilde{Z}_k \overset{\Delta}{=} [Z_{k-1} : Z_k] \quad (21)$$

As $G_k = G$, the code matrices that affect $\widetilde{Z}_k$ is:

$$\widetilde{C}_G \overset{\Delta}{=} [X_{k-1} : X_{k-1}G] \quad (22)$$

For $n_s = m$ and $C_D C_D^{+} = n_s I$ it is implicit that $C_D^{+}C_D = mI$. So $XX^{+} = X^{+}X = mI$ for all $X \in C_D\mathcal{G}$. Then, It satisfies that $\widetilde{C}_G\widetilde{C}_G^{+} = 2mI$ for all $X_{k-1} \in C_D\mathcal{G}$ with the $m \times 2m$ matrices and $(\widetilde{C}_G : G \in \mathcal{G})$. Thus, that is a unitary block code of length $\widetilde{n}_s = 2m$.

The optimal decoder for this block code, if X_{k-1} were known at the receiver, would be the quadratic receiver as expressed in the equation before, which depends only on the cross-product matrices:

$$\widetilde{C}_G^{+}\widetilde{C}_G = \begin{bmatrix} mI & mG \\ mG^{+} & mI \end{bmatrix} \quad (23)$$

These matrices do not depend on X_{k-1}, so the receiver does not require knowledge of the past in order to decode the current message. Furthermore, this receiver is reduced to a simple form as:

$$\begin{aligned} \widetilde{G} &= \arg\max_{G \in \mathcal{G}} Tr\left(\widetilde{Z}_k \widetilde{C}_G^{+} \widetilde{C}_G \widetilde{Z}_k^{+}\right) \\ &= \arg\max_{G \in \mathcal{G}} Tr\left([Z_{k-1} : Z_k]\begin{bmatrix} mI & mG \\ mG^{+} & mI \end{bmatrix}[Z_{k-1} : Z_k]^{+}\right) \\ &= \arg\max_{G \in \mathcal{G}} \operatorname{Re} Tr\left(Z_{k-1} G Z_k^{+}\right) \\ &= \arg\max_{G \in \mathcal{G}} \operatorname{Re} Tr\left(G Z_k^{+} Z_{k-1}\right) \end{aligned} \quad (24)$$

The receiver is much simpler than ML detection based on $Z_0, \cdots, Z_K$. Its complexity raises exponentially with m and R, as $M_{array} = 2^{mR}$ comparisons are required.

C. Differential Unitary Space Time Frequency

Differential space time frequency transmit diversity (D-STF) from orthogonal design in OFDM systems is derived. In OFDM, with a sufficient guard interval each sub-carrier gives a flat fading MIMO channel. The transmit symbols of differential transmit diversity can be allocated in time and frequency conditional to time variation and frequency-selectivity of the channel.

The differential encoding can be done separately for each sub-carrier [4], space time transmit diversity. In broadband communication, the OFDM symbol duration may be relatively long due to a large number of sub-carriers and fading may become relatively fast due to a high carrier frequency and fast vehicular speed. But the coherent time may still be sufficiently too long. So the block size will be relatively short in time direction. Therefore, a training matrix in each sub-carrier will cause a high overhead. This means a significant overhead particularly in broadband communications where it anticipates a large number of sub-carriers but relatively short number of OFDM symbols per frame. Then, it is necessary to do the differential encoding in frequency direction. The D-STF scheme is done both in time and frequency direction in continuous stream through sub-carriers and OFDM symbols [4].

The entries of a matrix $\mathbf{X}_k$ are transmitted on adjacent sub-carriers of the same OFDM symbol rather than on the same sub-carrier of subsequent OFDM symbols. This scheme can reduce the transmission delay. However, the channel needs to be constant over the adjacent sub-carriers which transmit entries of two successive matrices. This is true in channels with low frequency-selectivity or might be able by using a large number of sub-carriers in order to make the sub-carrier spacing very narrow. On the other hand, differential space frequency block codes will suffer in heavy frequency selective channels.

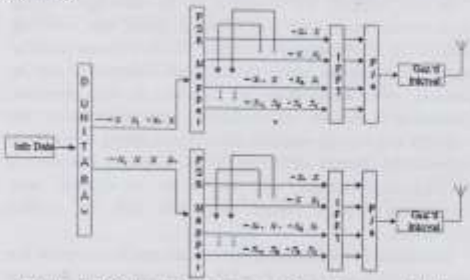

Figure 3. Differential unitary space time frequency block code in OFDM

This paper is focused on differential unitary space time frequency (DUSTF) encoding. STF modeling is based on the modeling in [4], with several changes, i.e. differential transmit diversity from orthogonal designs using differential space time modulation scheme, that is unitary encoding [11]. Whereas modeling in [4] uses simple DSTBC. The modification of this scheme takes into account our previous research results.

Unitary encoding has better performance in low Eb/No, whereas STF prefers in higher Eb/No. In addition, in this DUSTF encoding scheme, 2 receive antennas are applied.

Then, as can be seen from Fig. 3, for $m_T = 2$ where the elements of one 2x2 transmit matrix are transmitted in different time slots on the same sub-carrier but the differential encoding is done across frequency. After that, the next matrix is transmitted in two successive time slots of the adjacent sub-carrier.

The differential encoding can be made as continuous stream through frequency and time if only one training matrix per frame is needed. Consequently, the channel has to be constant over two OFDM symbols in time domain and two sub-carriers in frequency domain rather than four OFDM symbols as in D-STBC or four sub-carriers as in differential space frequency block codes. D-Unitary encoding is applied in to make an orthogonal design in time, which is based on the modeling in section 2.2.

In order to make orthogonal designs by mapping in time and frequency, measures of coherent time and coherent bandwidth are used. $T_{s,OFDM\_gi}$ is the OFDM symbol duration including th^ guard interval, P_{row} is number of rows of the orthogonal design, and $1/T_{sr,OFDM}$ is the sub-carrier spacing. So the coherent time of the channel of DSTBC and the coherent bandwidth of space frequency block codes can be expressed as follows:

$$T_{coh} > 2P_{row}T_{s,OFDM\_gi} \tag{25}$$

$$B_{coh} > 2P_{row}/T_{sr,OFDM} \tag{26}$$

III. MIMO-WIRELESS PERFORMANCE WITH NON COHERENT SPACE TIME CODING

In this section, the objective is to investigate signal performance from three non coherent space time encoding schemes in MIMO-wireless systems. These schemes could be applied in condition where channel state information and no channel state information are known. In this research, simulation is focused on no-channel state information. We consider that in high mobility situations, it might be costly to estimate the channel accurately. STBC model by Alamouti is selected as reference, with knowledge of channel state information that is perfect estimation and non perfect estimation.

Simulation is conducted to provide comparison between the downlink BER performance and the results of all non coherent space time coding schemes in MIMO wireless systems with 2 transmit antennas and 2 receive antennas. In all simulation scenarios, we use frequency of 5 GHz, convolutional code rate of ½, Viterbi decoder at receiver, and 512 bits per block data. Modulation system could be any scheme, MPSK or MQAM, but in our simulation BPSK is implemented, with power efficiency consideration. It is assumed that the simulation results of all non coherent space time coding schemes are acquired in Rayleigh fading channel condition by applying suboptimal ML detection at receiver. Exception is for space time coding, STBC, where optimal ML is applied. It is in accordance with Alamouti modeling, where its estimation technique is simple as proposed by [Valenti].

We make some observations for various speeds of mobility, i.e. motionless, low speed (80 km/hour), medium speed (150 km/hour), and high speed (500 km/hour). Firstly, we consider that all non coherent space time coding schemes is applied in the fixed MIMO-wireless system. The performance is compared to STBC with knowledge of channel state information.

Fig. 4 shows simulation results, i.e. the BER performance comparison between D-unitary encoding, D-SF encoding, D-STBC, and coherent space time code, especially STBC with CSI of MIMO-wireless system with velocity= 0 km/hour or motionless. In this simulation we do not take into account DUSTF encoding performance, proposed in section 2.3, due to the unbalanced result compared with other encoding schemes. Hence, differential space frequency without differential time is selected. The combination of D-STBC and space time encoding is based on the modeling in [4], but without differential time. From Fig. 4, it is apparent that differential space frequency with 8 subcarriers has similar performance as STBC with perfect CSI. On the other hand, D-STBC has the worst performance.

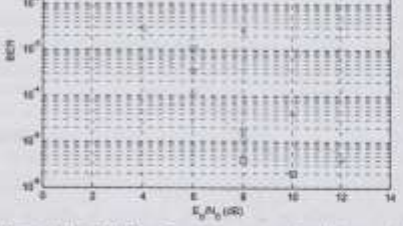

Figure 4. The BER performance comparison between 3 non coherent STC schemes (D-unitary, D-SF, and D-STBC) and coherent space time code, especially STBC with CSI of MIMO-wireless systems with velocity = 0 km/hour, motionless.

Fig. 5 presents the BER performance comparison between D-unitary encoding, D-USTF encoding, D-STBC, and coherent space time code, especially STBC (with perfect and non perfect estimation). The simulation is conducted in MIMO wireless system with velocity 80 km/hour, where DUSTF encoding is applied with 256 subcarries. In this speed condition, it can be seen that DUSTF encoding outperforms the other non coherent space time codes. This is because the proposed DUSTF has 2 advantages, i.e. good processing gain due to differential unitary encoding scheme, and also selective fading resiliency due to differential space time encoding.

However, at high Eb/No, its performance is worse than STBC with perfect estimation.

Figure 5. The BER performance comparison between 3 non coherent STC schemes (D-unitary, D-USTF, and D-STBC) and coherent space time code, especially STBC (with perfect and non perfect estimation) of MIMO-wireless systems with velocity = 80 km/hour.

Fig. 6 presents the BER performance comparison between D-unitary encoding, D-USTF encoding, D-STBC, and coherent space time code, especially STBC (with perfect and non perfect estimation) of MIMO-wireless system with velocity = 150 km/hour. DUSTF encoding is implemented with 256 subcarriers.

In speed condition, it can be seen that, in general DUSTF and STBC with perfect estimation has much better performance than D-unitary, D-STBC, and STBC with non perfect estimation. Like in low speed, DUSTF encoding performance is better than STBC with perfect estimation in low Eb/No and vice versa.

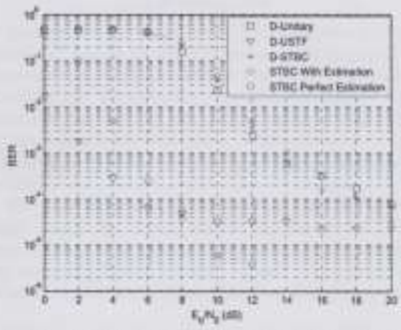

Figure 6. The BER performance comparison between 3 non coherent STC schemes (D-unitary, D-USTF, and D-STBC) and coherent space time code, especially STBC (with perfect and non perfect estimation) of MIMO-wireless systems with velocity = 150 km/hour.

Fig. 7 presents the BER performance comparison between 4 non coherent space time code schemes (especially D-unitary encoding, D-USTF encoding, D-SF, and D-STBC) and coherent space time code, especially STBC (with perfect estimation and with non coherent estimation) of MIMO-wireless systems with velocity = 500 km/hour. D-USTF encoding and D-SF encoding are applied with 256 subcarriers.

In this high speed condition, the simulation employs D-SF, which is a combination of D-STBC and differential space frequency without differential time. Its performance is compared with the proposed D-USTF encoding, which is a combination between D-unitary encoding and differential space time frequency. This scenario is intended to observe the effect of D-unitary encoding scheme and differential time encoding at high speed. In general, D-SF encoding performance is better than D-unitary, D-STBC, and STBC with non perfect estimation. Yet, it is worse than D-unitary encoding scheme, particularly at low Eb/No.

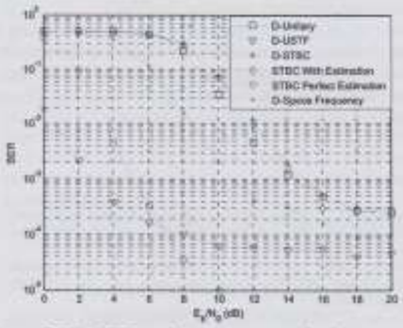

Figure 7. The BER performance comparison between 4 non coherent STC schemes (D-unitary, D-USTF, D-SF, and D-STBC) and coherent space time code, especially STBC (with perfect and non perfect estimation) of MIMO-wireless systems with velocity = 500 km/hour.

IV. CONCLUSION

In general, the MIMO systems in Rayleigh fading condition with coherent space time code, especially STBC with perfect estimation gives better performance than all non coherent space time code systems and STBC with non perfect estimation. However, in the motionless MIMO-wireless system, D-SF encoding is better than D-unitary and D-STBC.

Furthermore, at all speed conditions (80 km/hour, 150 km/hour, and 500 km/hour), the performance of D-unitary encoding, D-STBC, and STBC with non perfect estimation are similar, yet worse than D-USTF encoding and STBC with perfect estimation.

Moreover , in MIMO-wireless system with user movement (low, medium, and high speed) and non CSI, it is obvious that the implementation of 2 differential schemes in D-USTF (D-unitary encoding and D-STF encoding) gives performance improvement compared with that of single differential scheme (D-SF encoding, D-unitary encoding, D-STBC).

Founded on all of those results, we have been exploring a new space time code. To accommodate higher data rate, that is based on differential space time frequency block code combined with differential unitary group code. Multilevel space time encoding scheme is also considered.

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