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Performance of differential Space-time Block Coded MIMO System using Cyclic Delay Diversity

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Abstract: Multi-input multi-output (MIMO) system can increase data rate, capacity and bit error rate (BER) performance compare to traditional single antenna system. However MIMO technique is pointed out the problem that has high complexity to design receiver. So a recent trend of research on the MIMO system pays more attention to simplified implementation of receiver structure. In this paper, we propose differential space time block code (STBC) for MIMO system with cyclic delay diversity (CDD). This structure can provide a very close performance to that of the conventional diversity scheme with maximum likelihood (ML) detection without channel estimation block while the receiver structure is highly simplified. Bit error rate (BER) performance of the proposed system is simulated for an AWGN channel by theoretical and simulated approaches. The results of this paper can be applicable to the 4G mobile multimedia communication systems.

Keyword: MIMO, diversity, cyclic delay, STBC

I. INTRODUCTION

Increasing demand for high-performance 4th generation (4G) broadband wireless communication system is enabled by the use of multiple antennas not only transmitter but also receiver ends. A multiple input multiple output (MIMO) system provides multiple independent transmission channels, thus, under certain conditions, leading to a channel capacity that increases linearly and diversity and coding gain with the number of antennas. [1].

So far, many kinds of signal encoding schemes that support multiple antenna systems have well been studied [2]. Among them, the primary ones include Bell Labs Layered Space Time (BLAST), space-time trellis codes (STTC), space-time block codes (STBC) and cyclic delay diversity (CDD) and so on. The BLAST employs spatial multiplexing where the signals are separated by several streams and then transmitted by a different antenna after each stream is modulated. However, this scheme has disadvantage of exponentially increased complexity as the number of transmit antennas. The STTC scheme includes Viterbi algorithm to decode the received signals. This guarantees diversity coding gain by use code sequences which are given by means of a trellis, but complexity of the decoder increases exponentially with the number of transmit antennas.

The STBC can be considered as a modulation scheme for multiple transmit antennas that provide full diversity by utilizing both time and space domain and very low complexity encoding and decoding. However unlike the STTC scheme, the STBC scheme does not guarantee diversity coding gain [3]. The CDD scheme employs arbitrary transmit antennas compared to the STBC scheme, and has disadvantage that requires a channel coding scheme for coding and diversity gains [4].

The above diversity schemes require independent pilot symbols transmission to each antenna for delivery of channel estimation information to the receiver. This aspect deteriorates bandwidth efficiency and increases implementation complexity in the receiver design. To prevent and relieve above problems, we propose differential modulation technique in [5] which the detected signal at time $t-1$ is utilized to estimate the channel at the receiver and these are used to estimate the transmitted data at time t . However, differential modulation scheme is a 3dB loss in BER performance due to the doubling of the effective noise for phase-shift-keying (PSK) modulation formats.

In this paper, we propose a novel diversity scheme which combines merits of differential STBC (DSTBC) and differential CDD (DCCD) schemes for the MIMO wireless multimedia communication systems. This scheme offers a very close performance to that of conventional diversity scheme while providing advantage of a simplified receiver structure.

The paper is organized as follows. Section II introduces the proposed system with the existing diversity scheme for DPSK, DSTBC and DCDD. In section III shows the simulation results and discussions. Finally, section IV draws some conclusion of the paper.

II. PROPOSED SYSTEM MODEL

In Fig.1, the transmitter and receiver block diagrams are depicted for the proposed novel diversity scheme. The DSTBC encoder makes input data bits orthogonal codeword and each stream fed to IFFT block. Since the delay of first antenna is zero, we simply insert the guard interval and transmit through first antenna. Unlike first antenna, data stream of the second antenna is cyclically shifted and then the guard interval is inserted. The receiver structure is a kind of combination of the DSTBC and the DCDD schemes. At the each receiver antenna, the arriving signals from each transmit antenna are summed, and the guard interval is removed from each

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stream. Then we find estimated signal $\hat{s}_1^l$ and $\hat{s}_2^l$ by through the DSTBC decoder. Finally, the estimated signals are fed to ML detector. In subsections of section II, each block is more reported in detail.

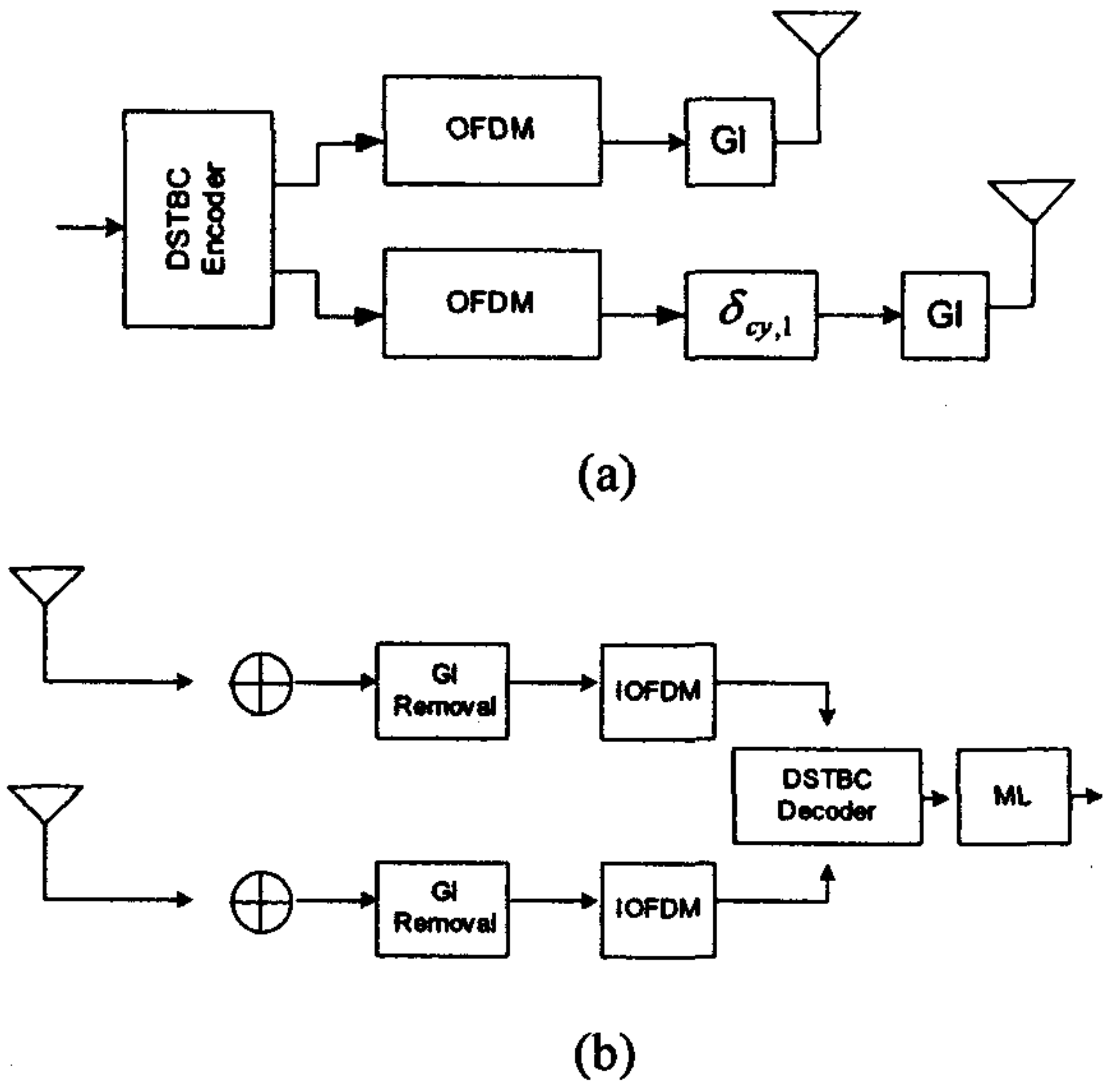

Fig. 1. Proposed diversity scheme.
(a)Transmitter (b) Receiver

II.1. Differential Phase Shift Keying (DPSK)

The DPSK encoder block diagram is depicted in Fig. 2. For DPSK modulation, the transmitter sends an arbitrary symbol c_0 at time zero. Then, at time t, if the input symbol s_t is 1, we leave the symbol c_t unchanged with respect to the previous symbol. However, when s_t is 0, c_t is changed. The procedure of generate the DPSK signal is shown in Table 1.

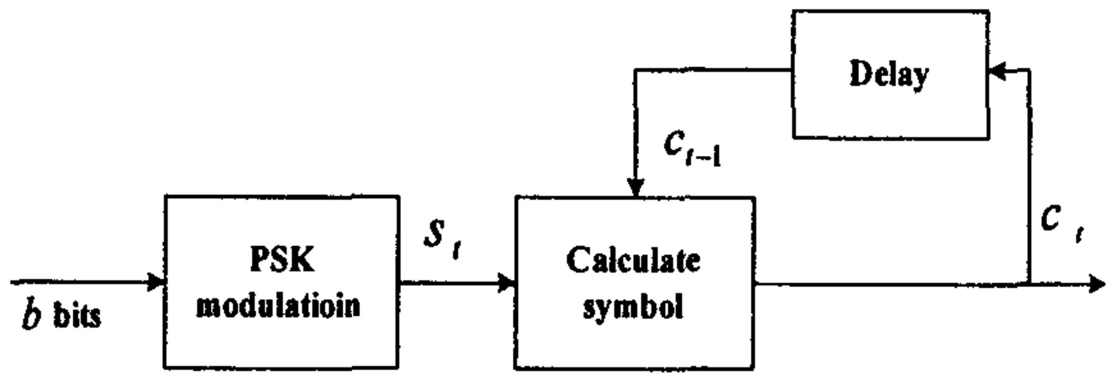

Fig. 2. DPSK encoder block diagram.

TABLE I
ILLUSTRATIGN THE GENERATION OF DPSK SIGNAL

s_k		1	0	1	0	0	1	0	1	1	1
c_{k-1}		1	1	0	0	1	0	0	1	1	1
c_k	1	1	0	0	1	0	0	1	1	1	1

In DPSK modulation, the decoder does not need to perform channel estimation because the transmitted symbols depend on the previous symbol and the decoder detects the data from successive symbols. The received signal is given by

$$r_t = \alpha c_t + \eta_t , \qquad (1)$$

where α is path gain between the transmitter and receiver and η_t is noise. To detect the transmitted data at time t, the receiver calculates $r_t r_{t-1}^*$. Then it estimates the calculated symbol by comparison with PSK constellation and finally estimates the transmitted symbol. The $r_t r_{t-1}^*$ is given by

$$\begin{aligned} r_t r_{t-1}^* &= |\alpha|^2 c_t c_{t-1}^* + \alpha c_t \eta_{t-1}^* + \eta_t \alpha^* c_{t-1}^* + \eta_t \eta_{t-1}^* \\ &\approx |\alpha|^2 c_{t-1} s_t c_{t-1}^* + \alpha c_t \eta_{t-1}^* + \eta_t \alpha^* c_{t-1}^* \qquad ,(2) \\ &= |\alpha|^2 s_t + \mathrm{N} \end{aligned}$$

where N is a Gaussian noise, the path gain α is assumed to remain the same at time $t-1$ and t, and $\eta_t \eta_{t-1}^*$ is ignored. Consequently, the optimal estimate of s_t is given by

$$\hat{s}_t = \arg \min_{s_t} \left| r_t r_{t-1}^* - |\alpha|^2 s_t \right|^2 . \qquad (3)$$

In (3), $|\alpha|^2$ is not changed due to PSK-series symbols have the same energy. Therefore, the equation (3) can be written as

$$\hat{s}_t = \arg \min_{s_t} \left| r_t r_{t-1}^* - s_t \right|^2 . \qquad (4)$$

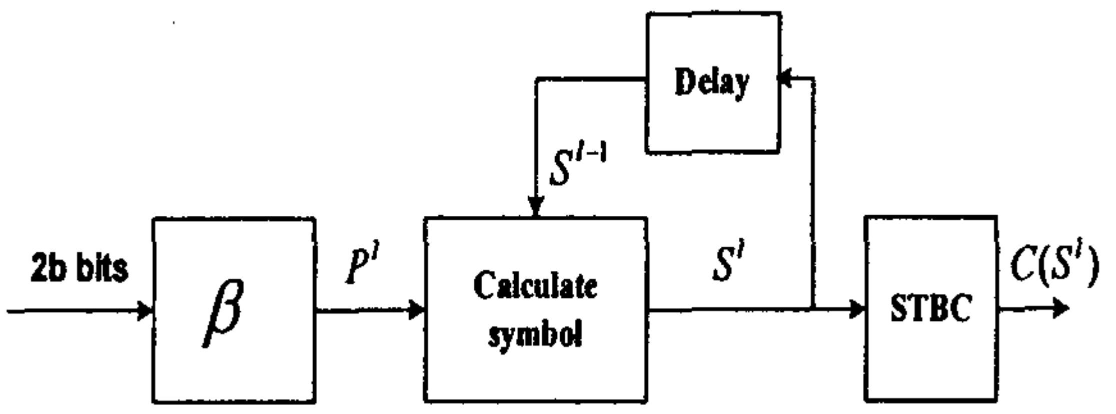

Fig. 3. DSTBC encoder block diagram.

II.2. Differential Space-Time Block Codes (DSTBC)

Let us assume that we use a signal constellation with $2b$ bits, the encoder calculates two symbols and transmits them using an orthogonal STBC.
For example, the signals for the lth are given by

$$S^l = \begin{pmatrix} s_1^l \\ s_2^l \end{pmatrix} \qquad (5)$$

To describe how we generate S^l, we consider the following two vectors that construct orthogonal basis are given by

$$V_1(S^l) = \begin{pmatrix} s_1^l \\ s_2^l \end{pmatrix}, \quad V_2(S^l) = \begin{pmatrix} (s_2^l)^* \\ -(s_1^l)^* \end{pmatrix}. \qquad (6)$$

We use fix a set V which consists of 2^{2b} unit-length distinct vectors $P_1, P_2, \ldots, P_{2^{2b}}$ where each vector P_v is a 2 by 1 vector,

$$\mathrm{P}_V = (\mathrm{P}_{V1}, \mathrm{P}_{V2})^T. \tag{7}$$

The DSTBC encoding block is depicted in Fig. 3 [10]. In Fig. 3, we use an arbitrary one-to-one mapping $\beta(\cdot)$ which maps $2b$ bits on to V. Note that the choice of the set V and the mapping $\beta(\cdot)$ is completely arbitrary as long as vector P_V are unit-length. Finally, we find S^l by

$$S^l = P_1^l V_1(S^{l-1}) + P_2^l V_2(S^{l-1}). \tag{8}$$

Note that since $V_1(S^l)$ and $V_2(S^l)$ create an orthogonal basis, P_1^l and P_2^l can be derived from multiplying by $[V_1(S^{l-1})]^H$ and $[V_2(S^{l-1})]^H$, respectively. Therefore, we have

$$\begin{aligned} P_1^l &= [V_1(S^{l-1})]^H \cdot S^l = s_1^l (s_1^{l-1})^* + s_2^l (s_2^{l-1})^* \\ P_2^l &= [V_2(S^{l-1})]^H \cdot S^l = s_1^l s_2^{l-1} - s_2^l s_1^{l-1}\ . \end{aligned} \tag{9}$$

Above procedure starts with transmission of an arbitrary vector S^0. The receiver structure becomes very simple. Let us denote the two received signals by r_1^l and r_2^l. Then we have

$$\begin{cases} r_1^l = \alpha_1 s_1^l + \alpha_2 s_2^l + \eta_1^l \\ r_2^l = -\alpha_1 (s_2^l)^* + \alpha_2 (s_1^l)^* + \eta_2^l \end{cases}. \tag{10}$$

For estimation of the transmitted signals, we use the following equation.

$$\begin{cases} \hat{s}_1^l = (r_1^{l-1})^* r_1^l + (r_2^l)^* r_2^{l-1} \\ \hat{s}_2^l = (r_2^l)^* r_1^{l-1} - (r_2^{l-1})^* r_1^l \end{cases}. \tag{11}$$

These combine signals are forwarded maximum-likelihood decoder which $\hat{s}_1^l$, $\hat{s}_2^l$ are decide as following equation,

$$\begin{aligned} \tilde{s}_1^l &= \underset{s_1^l}{\operatorname{argmax}}\ \mathrm{Re}\{[(r_1^{l-1})^* r_1^l + (r_2^l)^* r_2^{l-1}] s_1^l\} \\ \tilde{s}_2^l &= \underset{s_2^l}{\operatorname{argmax}}\ \mathrm{Re}\{[(r_2^l)^* r_1^{l-1} - (r_2^{l-1})^* r_1^l] s_2^l\}. \end{aligned} \tag{12}$$

II.3. Differential Cyclic Delay Diversity (DCDD)

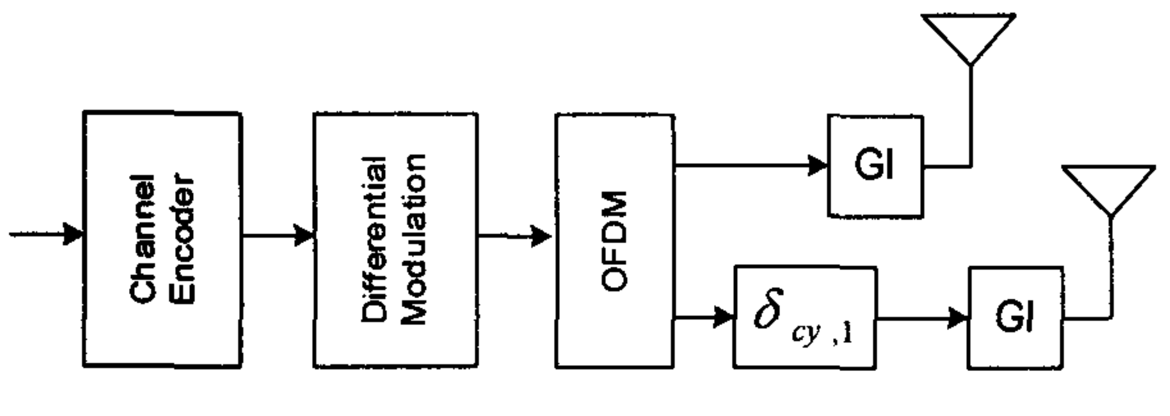

Fig. 4. DCCD OFDM encoder

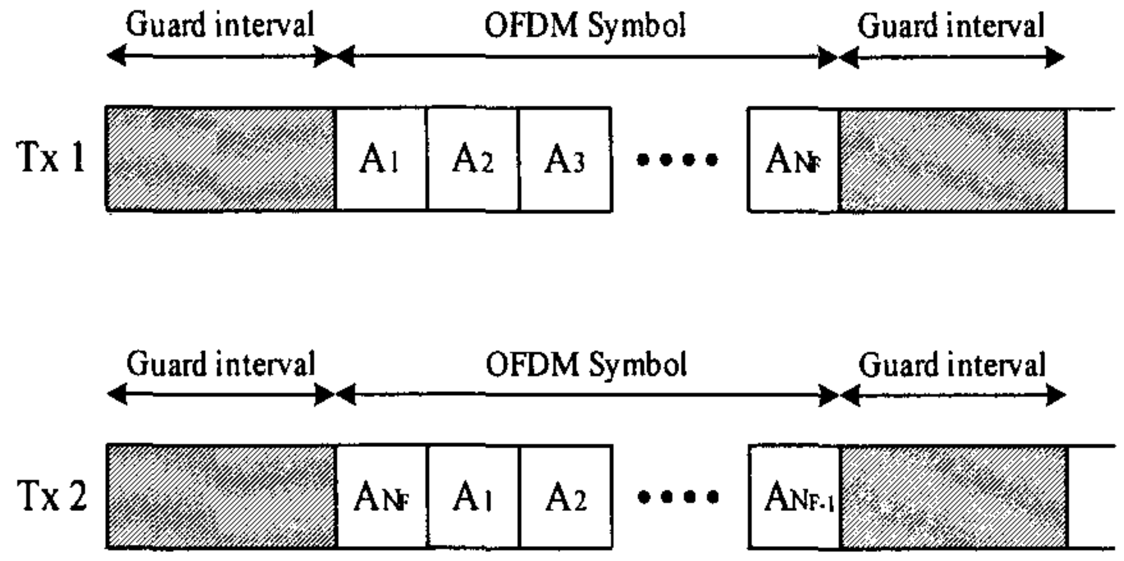

Fig. 5. Concept of CDD diversity scheme.

Fig. 4 shows the DCCD transmitter block diagram. The delay on the first antenna is zero [8,9]. For BPSK modulation, cyclic delay can be calculated as

$$\delta_{cy,l} = \frac{N_c}{M_{bpsk} \times (2^{l-1})} \quad l = 1,2,\ldots,N_{T-1}, \tag{13}$$

where N_T denotes the number of transmit antennas, N_c is number of sub-carriers and M_{BPSK} is the modulation index. Figure 5, illustrates the concept of CDD diversity scheme for OFDM system.

III. SIMULATION RESULTS

Follow Figures show comparative results of the proposed diversity scheme with other conventional diversity schemes in terms of BER.

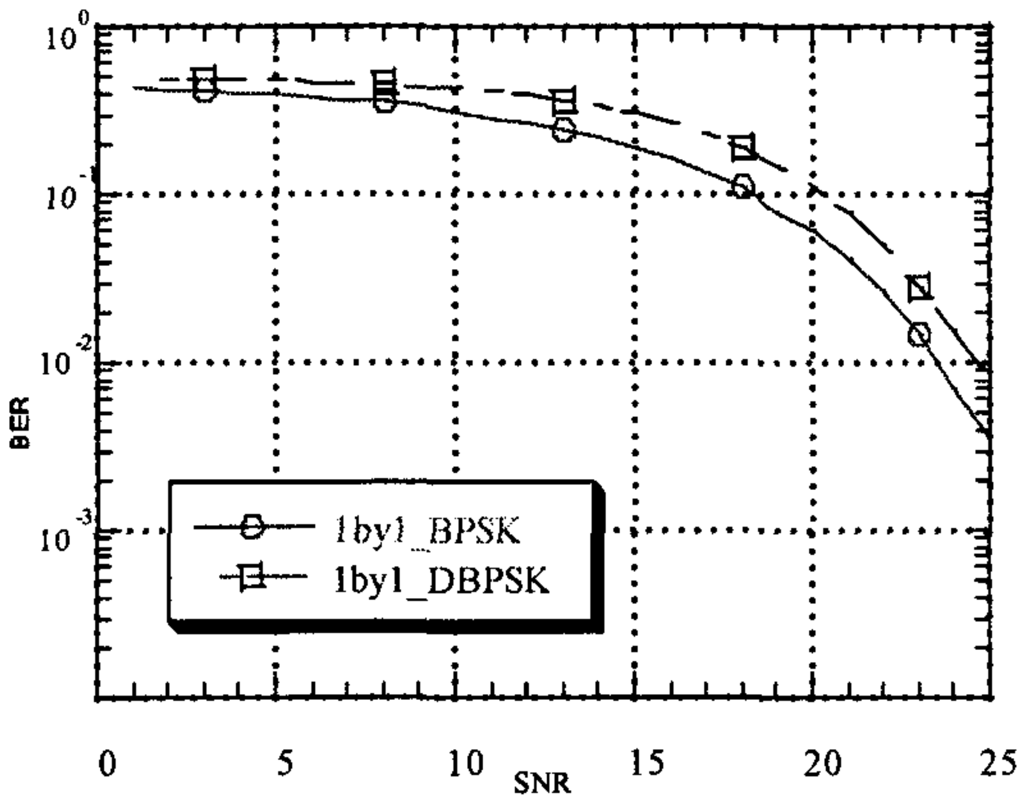

Fig. 6. BPSK and DBPSK with 1Tx-1Rx antenna.

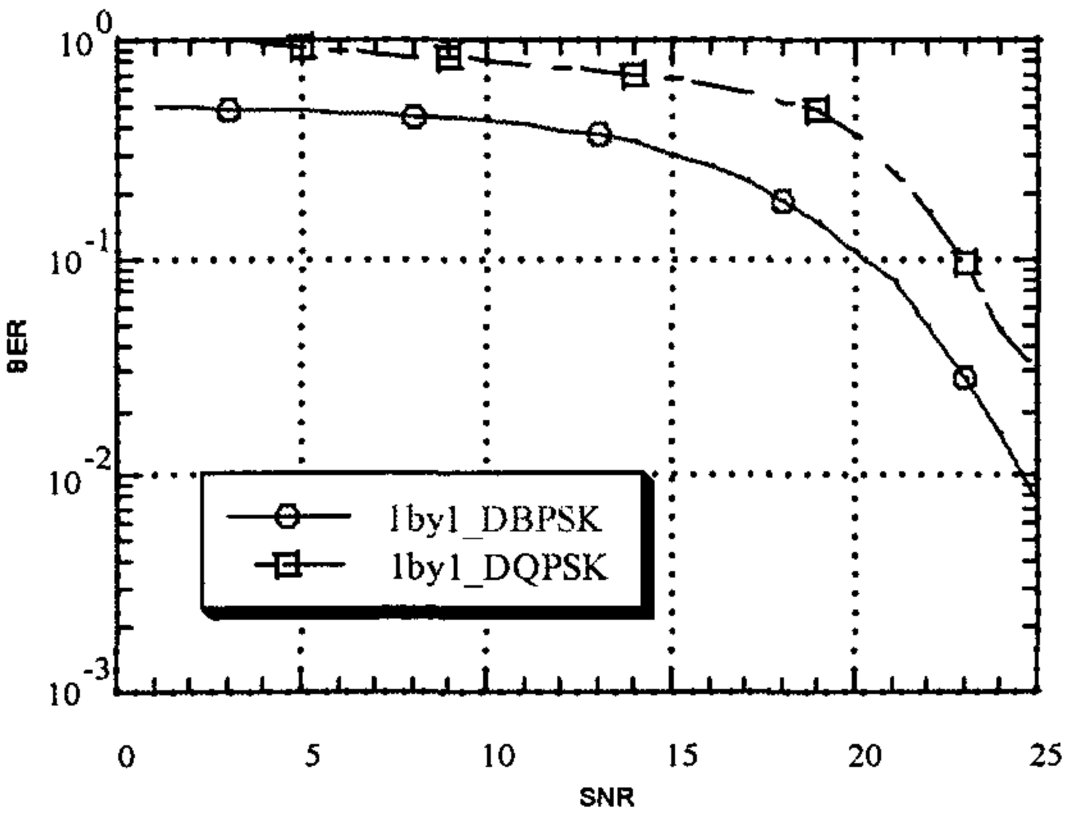

Fig. 7. Comparison of DBPSK and DQPSK with 1Tx-1Rx antenna.

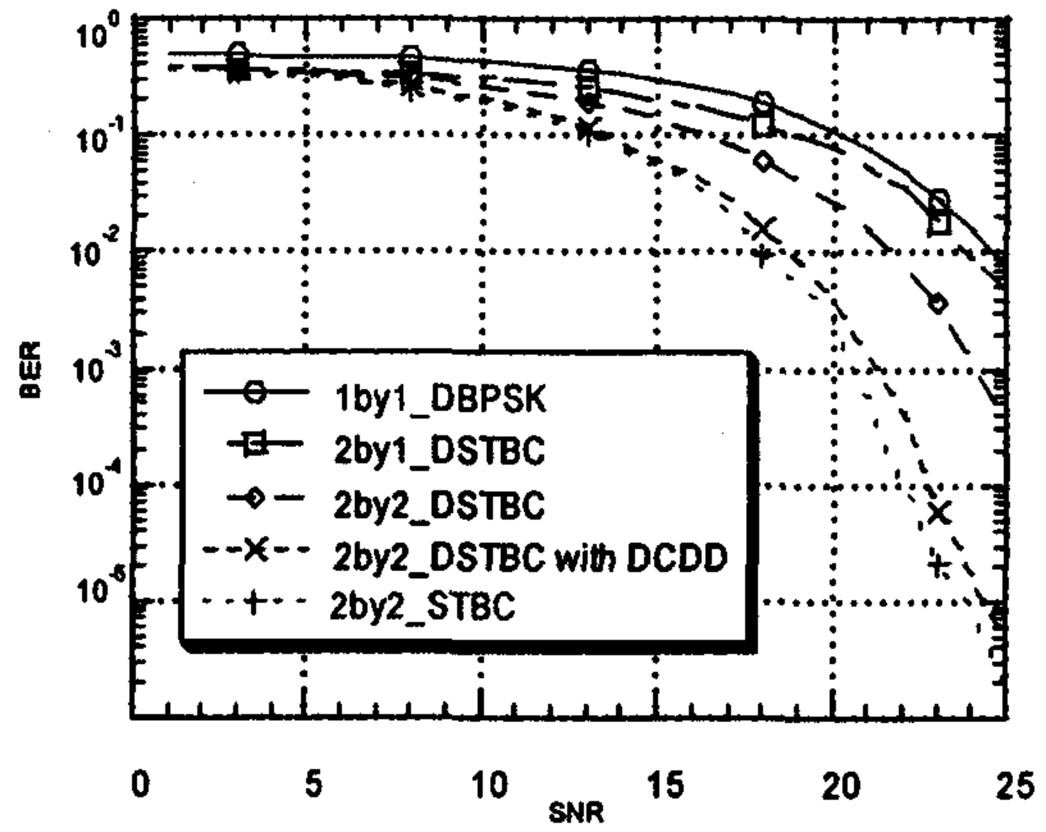

Fig. 8. BER performance of the proposed scheme compared with conventional schemes.

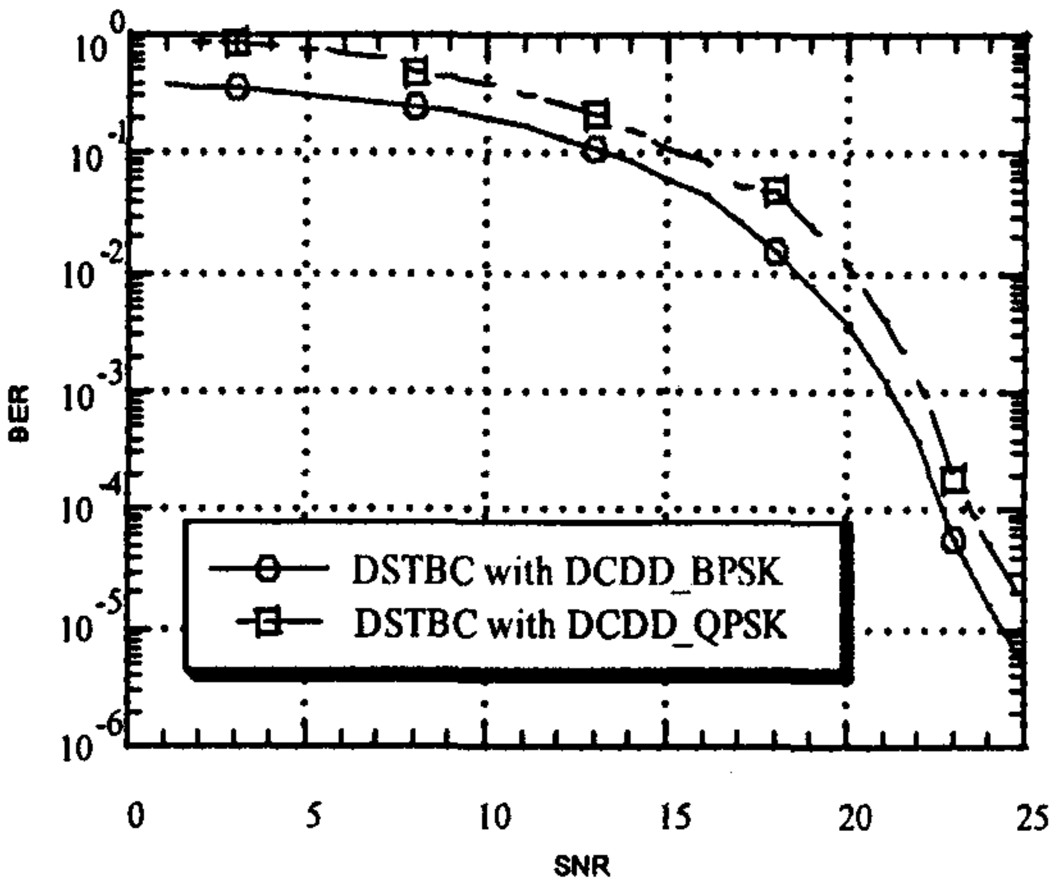

Fig. 9. Comparison of the proposed scheme for BPSK and QPSK transmission

It is found that there are two distinct advantages in our proposed scheme: 1) receiver structure becomes very simpler compared to other conventional diversity schemes. 2) In spite of use differential modulation, its performance almost the same as the conventional one in 2 by 2 STBC scheme.

IV. CONCLUSION

In this paper, we proposed novel diversity scheme which combines the DSTBC scheme with the DCDD scheme. For the DSTBC scheme with orthogonal signal design, we have employed Alamouti diversity scheme. From the simulation results, it is well confirmed that there are obvious advantages on its simple receiver structure and BER performance compared with the existing transmit diversity schemes. The results of the paper can be applied to the MIMO-OFDM wireless multimedia communication systems which support very high transmission rate.

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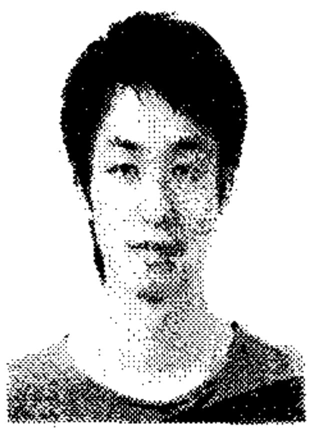

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