Improvement of FER using Differential Space-Time Block Code

K. Meena Anusha, Ch. Santhi Rani

Abstract: Over recent years, various modulation and coding techniques have been proposed in MIMO wireless communication systems. A MIMO system uses the concept of spatial diversity which is very successful and promising technique. When a coherent transmission system is considered, the estimation of radio channel impulse response is done precisely. In MIMO systems, the radio channel is estimated among every transmitting and receiving antennas such that the complexity can be increased. For this reason, in MIMO systems differential modulation schemes are estimated. A Differential Space-Time Block Code (DSTBC) is useful in the Raleigh fading channel as they do not require channel estimates. Space-time coding with MIMO antennas at transmitting and receiving reduces the consequences of fading in multiple paths and therefore the performance of digital transmission throughout wireless radio channel can be improved. So it has been presumed that perfect CSI is available at the receiver and coherent detection is employed. This paper presents improvement of Frame Error Rate (FER) for differential space-time block code using various Doppler spectra. When the channels estimates are not available the DSTBC system noticed that at SNR of 10 dB, for two transmitting and four receiving antennas the FER is 0.0067 for rounded Doppler spectrum. The differential schemes attains full transmit diversity owing to orthogonal designs. However, the receiver or the transmitter needs the channel state information so these differential schemes are 3 dB worse than the STBC with coherent detection.

Keywords: DSTBC, FER, DOPPLER SPECTRA, MIMO.

I. INTRODUCTION

A MIMO system uses the concept of spatial diversity which is very successful and promising technique. When a coherent transmission system is considered, the estimation of radio channel impulse response is done precisely. The radio channel is estimated in MIMO systems among every transmitting and receiving antennas such that the complexity can be increased. This is why differential modulation schemes are estimated for MIMO systems. Test signal overhead can be avoided and the computation complexity is reduced significantly. A differential space-time block code (DSTBC) does not require channel estimates and it is useful in the Raleigh fading channel.

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Space-time turbo trellis code emerges as the code that combines the benefits of coding gain for turbo coding with the diversity advantage of space-time coding and the effective bandwidth of coded modulation. Space-time coding with MIMO antennas at transmitting and receiving reduces the consequences of fading in multiple paths and therefore the performance of digital transmission throughout wireless radio channel can be improved.
Therefore it was assumed that the ideal CSI is available to the receiver and a coherent detection is used to compared the symbol rate, the channel slowly changes and the transmitter sends sequences of pilot symbols so that the receiver can estimate the channel accurately. In some situations high mobility environment conditions changes rapidly, which is difficult to estimate the channel accurately. For such situations at the receiver or transmitter, it is useful to modernize space-time coding techniques that are not required for the channel estimates.

S. M. Alamouti[1] suggested STBC which increases transmission rate in mobile communications. The main feature of STBC is to improve the system capacity and provides diversity gain and requires channel estimation methods which are available at the receiver. V. Tarokh [2] proposed various space-time coding techniques so that they can be decoded and demodulated without channel estimates at the receiver and these STBCs are based on orthogonal design. At the receiver, the performance is worse by 3 dB when compared with ideal channel state information. . B. L. Hughes [3] proposed a new approach to differential modulation for MIMO transmitting and receiving antennas. These schemes are estimated with or without channels and then demodulates. The performance gets degrades by 3 dB when estimates are not available.

This paper presents the improvement of Frame Error Rate in differential space-time block codes. This approach is applied to transmitting and receiving antennas using various Doppler spectra. By implementing the concept of Doppler spectra, the Frame Error Rate can be improved and the performance is noticed when channel estimates are not present. The structure of the paper is as follows: introduction is dealt in Section 1 and section 2 describes about Objectives & Methodology, section 3 deals about DSTBC section 4 with performance evaluation of DSTBC. Results and conclusions are discussed in section 5 and 6.

II. OBJECTIVES & METHODOLOGY

Objectives:

The modulation and coding techniques have been proposed in MIMO wireless communication systems. A MIMO system uses the concept of spatial diversity which is very successful and promising technique.

When a coherent transmission system is considered, the estimation of radio channel impulse response is done precisely. In MIMO systems, the radio channel is estimated among every transmitting and receiving antennas such that the complexity can be increased. For this reason, in MIMO systems differential modulation schemes are estimated. As the channel estimates are not required in DSTBC, it is useful in the Raleigh fading.

Methodology:

Space-time coding with MIMO antennas at transmitting and receiving reduces the consequences of fading in multiple paths and therefore the performance of digital transmission throughout wireless radio channel can be improved. Therefore it was assumed that the ideal CSI is available to the receiver and a coherent detection is used. Improvement of Frame Error Rate (FER) for differential space-time block code using various Doppler spectra.

III. DIFFERENTIAL SPACE-TIME BLOCK CODE

A. Differential STBC Encoding:

Based on orthogonal design, the block diagram of the differential space-time block encoder is shown in the Fig 1. The transmission is done by sending reference modulated signals a_1 and a_2. For two transmitting antennas, two modulated reference signals are transmitted. According to the Alamouti scheme, the transmitter sends signals a_1 and a_2 in one time period from two transmitters to transmit simultaneously and signals $-a_2^*$ and a_1^* at second time interval from the transmitting antenna. The transmitter doesn't carry any data information. It sends the data sequence differentially.

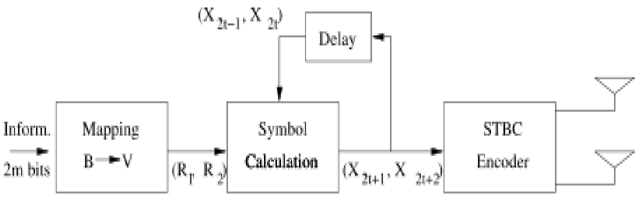

Fig.1: Block Diagram of Differential Space-Time Encoder

Suppose that a_{2t-1} and a_{2t} are transmitted from first and second transmitting antennas in 2t-1 time and at time 2t, the signals are transmitted $-a_{2t}^*$ and a_{2t-1}^* from first and second transmit antennas. At a time of 2t + 1, a block of 2 bits of information indicating c2t + 1 reaches the encoder. Two complex parameters R1 and R2 are chosen by the message block based on the previously transmitted signals and the complex parameters. The modulated symbols for the next two transmissions is computed from encoder as

$$(a_{2t+1}, a_{2t+2}) = R_1(a_{2t-1}, a_{2t}) + R_2(-a_{2t}^*, a_{2t-1}^*) \quad (1)$$

At time 2t+1, the transmitter transmits corresponding signals a_{2t+1} and a_{2t+2} from first and second antennas. At time 2t+2, the transmitter transmits $-a_{2t+1}^*$ and a_{2t+1}^* from first & second antennas. This process is iterated till the end of the data frame. The encryption system is called as differential time block code for two transmit antennas and also known as differential encoding rule.

From equation (1), the signals transmitted at different times are represented at different times in terms of their linear groups. Therefore the coefficient vector (R_1, R_2) of the linear coefficient is determined by the data transmitted. The process to generate the DSTBC is to calculate a set of the parameter vectors (R_1, R_2) and allot a set of 2m information bits to the coefficient vector set which represents the data to be transmitted.

Assume an M-PSK modulation with the constellation signal set

$$A = \{e^{j2\Pi kj/M}/\sqrt{2}\} \text{ where k is given as } 0, 1, 2\ldots. M-1 \quad (2)$$

The total power transmitted for the base band signals from two transmitting antennas is equal to 1 and the signal amplitude is divided by$\sqrt{2}$. The complex reference vectors are orthogonal to each other (a_{2t-1}, a_{2t}) and $(-a_{2t}^*, a_{2t-1}^*)$ having unit length. The coefficients of the representation are given as

$$R_1 = a_{2t+1}\, a_{2t-1}^* + a_{2t+2}\, a_{2t}^*$$
$$R_2 = -a_{2t+1}\, a_{2t} + a_{2t+2}\, a_{2t-1} \quad (3)$$

There are $M^2 = 2^{2m}$ distinct coefficient vectors (R_1, R_2) for a given constellation A and reference vector (a_{2t-1}, a_{2t}). Let V be the set of coefficient vectors (R_1, R_2). There is correspondence between a set of 2m information bits to the coefficient vector of V.

Consider few properties of the DSTBC where all the elements of the coefficient vector set have equal length of one. Given a vector (a_{2t-1}, a_{2t}) mapping from (R_1, R_2) to (a_{2t+1}, a_{2t+2}), this maintains the distance between 2D complex spaces. Assume that (R_1, R_2) and $(\hat{R}_1, \hat{R}_2)$ are two distinct elements in set V and (a_{2t+1}, a_{2t+2}) & $(\hat{a}_{2t+1}, \hat{a}_{2t+2})$ are their constellation signal vectors. Then, a_{2t+1} ^

$$\|(R_1, R_2) - (\hat{R}_1, \hat{R}_2)\| = \|(a_{2t+1}, a_{2t+2}) - (\hat{a}_{2t+1}, \hat{a}_{2t+2})\|$$
(4)

The squared Euclidean distance is equal to the squared Euclidean distance between (a_{2t+1}, a_{2t+2}) and $(\hat{a}_{2t+1}, \hat{a}_{2t+2})$ mapping can be considered as changing the orthonormal basis from standard vectors.

B. Differential STBC Decoding:

Suppose a single receiving antenna is used. At time interval t let b_t be the received signal, by n_t the noise sample at time t and h_1 & h_2 are the fading coefficients from transmitting antennas first and second of the receiving antenna. The received signals are represented 2t-1, 2t, 2t+1 times as

$$b_{2t-1} = h_1\, a_{2t-1} + h_2\, a_{2t} + n_{2t-1}$$
$$b_{2t} = -h_1\, a_{2t}^* + h_2\, a_{2t-1}^* + n_{2t}$$
$$b_{2t+1} = h_1\, a_{2t+1} + h_2\, a_{2t+2} + n_{2t+1}$$
$$b_{2t+2} = -h_1\, a^*_{2t+2} + h_2\, a^*_{2t+1} + n_{2t+2} \quad (5)$$

Let $$H = \begin{bmatrix} h_1 & h_2^* \\ h_2 & -h_1^* \end{bmatrix}$$

(6)

$$N_{2t-1} = (n_{2t-1}, n^*_{2t})$$
$$N_{2t} = (n_{2t}, -n^*_{2t-1})$$

The received signals in the vector form are given by

$$(b_{2t-1}, b^*_{2t}) = (a_{2t-1}, a_{2t})\, H + N_{2t-1} \quad (7)$$
$$(b_{2t+1}, b^*_{2t+2}) = (a_{2t+1}, a_{2t+2})\, H + N_{2t+1} \quad (8)$$
$$(b_{2t}, -b^*_{2t-1}) = (-a^*_{2t}, a^*_{2t-1})\, H + N_{2t} \quad (9)$$

At the receiver a decision statistics signal is represented as $\tilde{R}_1$, the product of the two received signal vectors (7) and (8)

$$\tilde{R}_1 = (b_{2t+1}, b^*_{2t+2})\,(b_{2t-1}, b^*_{2t})$$
$$= b_{2t+1}\, b^*_{2t} - b^*_{2t+2}\, b_{2t-1}$$
(15)

The product can be computed as

$$\tilde{R}_2 = (a_{2t+1}, a_{2t+2})\, HH^H (-a^*_{2t}, a^*_{2t-1})^H + (a_{2t+1}, a_{2t+2})\, HN^H_{2t} + N_{2t+1}H^H (-a^*_{2t}, a^*_{2t-1})^H + N_{2t+1} \quad N^H_{2t} \qquad (16)$$

Substituting (6) in (16), we get

$$\tilde{R}_2 = (|h_1|^2 + |h_2|^2)\,(-a_{2t+1}\, a_{2t} + a_{2t+2}\, a_{2t-1}) + (a_{2t+1}, a_{2t+2})\, HN^H_{2t} + N_{2t}H^H (-a^*_{2t}, a^*_{2t-1})^H + N_{2t+1} \quad N^H_{2t} \qquad (17)$$

Let $\tilde{N}_2 = (a_{2t+1}, a_{2t+2})\, HN^H_{2t} + N_{2t+1}H^H (-a^*_{2t}, a^*_{2t-1})^H + N_{2t+1}N^H_{2t}$ (18)

Equation (17) is rewritten as

$$\tilde{R}_2 = (|h_1|^2 + |h_2|^2)\, R_2 + \tilde{N}_2 \qquad (19)$$

The statistics are written in a vector form as

$$(\tilde{R}_1, \tilde{R}_2) = (|h_1|^2 + |h_2|^2)\,(R_1, R_2) + (\tilde{N}_1, \tilde{N}_2) \qquad (20)$$

The decision statistics signals $\tilde{R}_1$ and $\tilde{R}_2$ are function of different coefficients R_1 and R_2 to achieve a specific channel h_1 and h_2. Since all the vectors have equal lengths, the receiver now chooses the closest vector from V to the resolution statistics signal vector ($\tilde{R}_1, \tilde{R}_2$) as the detector output. The inverse mapping is applied to decode the transmitted block of bits. The block diagram of DSTBC decoder is shown in Fig 2

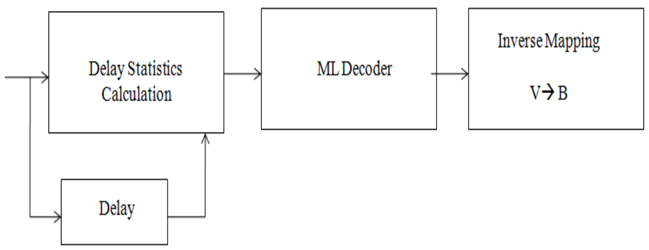

Fig 2: DSTBC Decoder

IV. PERFORMANCE EVALUATION

The performance of the differential pattern with MIMO antennas is evaluated by simulations on Rayleigh fading channel. DSTBC simulation results using different Doppler spectra are shown in figures. Over a frame of 100 symbols, the fading is assumed to be independent of tires. The differential schemes also achieves full transmit diversity due to orthogonal designs. However, neither the sender nor receiver requires the CSI. The differential schemes are 3 dB worse than the respective STBC with coherent detection.

V. SIMULATION RESULTS

By using different types of Doppler spectra, FER is optimized for DSTBC by looking at MIMO antennas in the transmitter and receiver. A Frame Error Rate (FER) with SNR is computed in dB and the following figures show the simulation results.

A. Improvement of FER for DSTBC system employing Bell Doppler Spectrum:

Fig 3 shows improvement of FER for DSTBC & STBC system employing Bell Doppler Spectrum with different SNR values

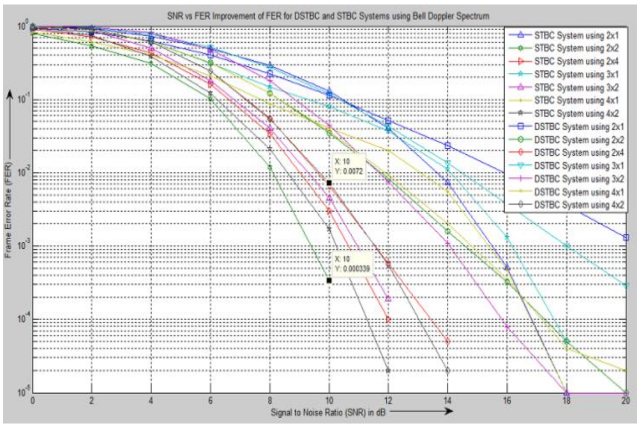

Fig. 3: Improvement of FER for DSTBC & STBC system employing Bell Doppler Spectrum

From Fig. 3, it is observed that without considering channel estimates the FER at the SNR value of 10 dB is 0.0072 for a DSTBC system with two transmitting antennas and four receiving antennas when compared to other multiple transmitting and multiple receiving antennas and when channel estimates are considered the STBC system is having FER value 0.000339 using the Doppler Bell spectrum.

B. Improvement of FER for DSTBC system employing Jakes Doppler Spectrum:

Fig 4 shows improvement of FER for DSTBC & STBC system employing Jakes Doppler Spectrum with different SNR values.

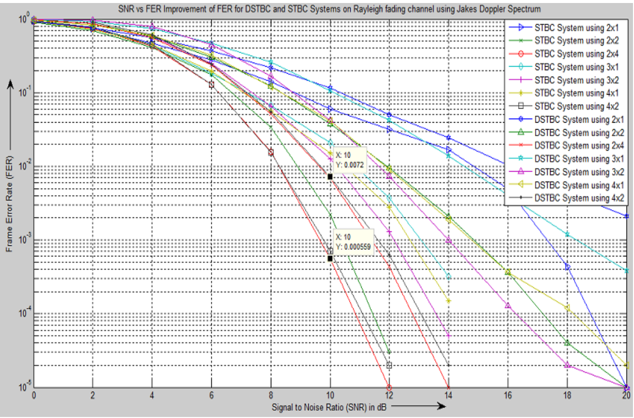

Fig. 4: Improvement of FER for DSTBC & STBC system employing Jakes Doppler Spectrum

From Fig. 4, it is observed that without considering channel estimates the FER at SNR value of 10 dB is 0.0071 for a DSTBC system with two transmitting antennas and four receiving antennas when compared to other multiple transmitting and multiple receiving antennas and when channel estimates are considered the STBC system is having FER value of 0.0005599 with two transmitting antennas and two receiving antennas using Jakes Doppler spectrum.

C. Improvement of FER for DSTBC system employing Rounded Doppler Spectrum:

Fig 5 shows improvement of FER for DSTBC & STBC system employing rounded Doppler Spectrum with different SNR values.

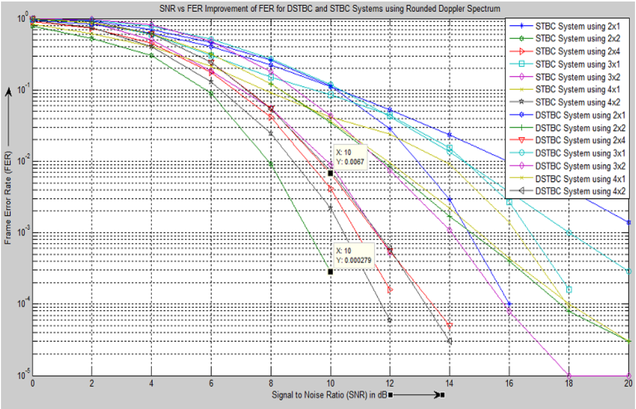

Fig. 5: Improvement of FER for DSTBC & STBC system employing Rounded Doppler Spectrum

From Fig. 5, it is observed that without considering channel estimates the FER at SNR with a value of 10 dB is 0.0067 for a DSTBC system with two transmitting antennas and four receiving antennas when compared to other multiple transmitting and multiple receiving antennas and for a STBC system it is 0.000279 with two transmitting antennas and two receiving antennas considering channel estimates using a rounded Doppler spectrum. The differential scheme is worse by about 3 dB relative to the coherent scheme.

D. Improvement of FER for DSTBC system employing Flat Doppler Spectrum:

Fig 6 shows improvement of FER for DSTBC & STBC system employing flat Doppler Spectrum with different SNR values.

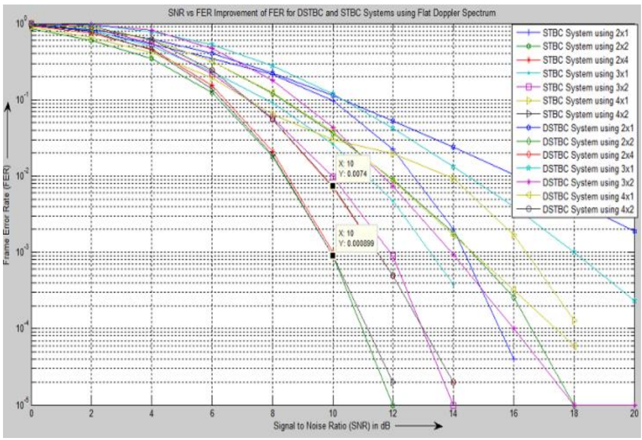

Fig. 6: Improvement of FER for DSTBC & STBC system employing Flat Doppler Spectrum

From Fig. 6, it is observed that without considering channel estimates the FER at SNR of 10 dB has a value of 0.0074 for a DSTBC system with two transmitting antennas and four receiving antennas when compared to other multiple transmitting and multiple receiving antennas and for a STBC system FER value is 0.000899 with two transmitting antennas and two receiving antennas when channel estimates are considered using a flat Doppler spectrum.

E. Improvement of FER for DST BC system employing Asymmetric Jakes Doppler Spectrum:

Fig 7 shows improvement of FER for DSTBC & STBC system employing asymmetric Jakes Doppler Spectrum with different SNR values.

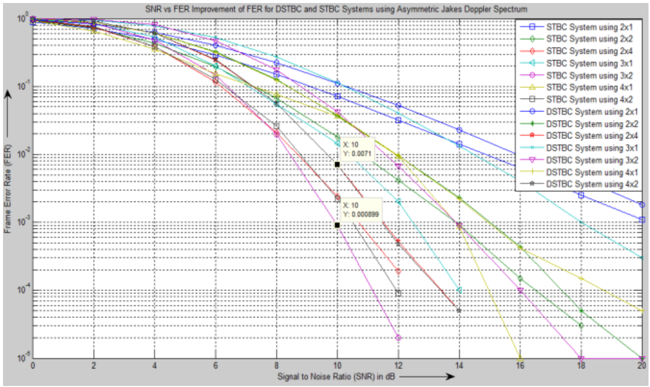

Fig. 7: Improvement of FER for DSTBC & STBC system employing Asymmetric Jakes Doppler Spectrum

From Fig. 7, it was observed that without considering channel estimates the FER at SNR with a value of 10 dB has a value of 0.0071 for a DSTBC system with two transmitting antennas and four receiving antennas when compared to other multiple transmitting and multiple receiving antennas and 0.000899 for a STBC system with three transmitting antennas and two receiving antennas considering channel estimates using asymmetric Jakes Doppler spectrum.

VI. CONCLUSION

In this paper, improvement of Frame Error Rate (FER) for DSTBC system is evaluated using various Doppler Spectra. It has been observed that for different SNR values ranging from 0 dB to 20 dB, the FER value for DSTBC system observed under different Doppler spectra at maximum Doppler shift as follows:

Sl. no	Doppler Spectrum	DSTBC System
1	Jakes Doppler Spectrum	0.0071
2	Rounded Doppler Spectrum	0.0067
3	Asymmetric Jakes Doppler Spectra	0.0071
4	Flat Doppler Spectra	0.0074
5	Bell Doppler Spectra	0.0072

When channel estimates are not available, it is noticed that the DSTBC system has an FER of 0.0067 for rounded Doppler spectrum and when channel estimates are considered the STBC system has 0.000279 for rounded Doppler spectrum with two transmitting and two receiving antennas. From the above information it is concluded that Rounded Doppler spectra achieved a lower Frame Error Rate when channel estimates are not considered and when compared with other multiple transmitting and multiple receiving antennas.

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