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Implementation of Transmit Diversity Schemes

Shaik Parvez, D. Gowri Sankar Reddy

PG Student, Dept. of ECE, Sri Venkateswara University College of Engineering, Tirupati, India

Assistant Professor, Dept. of ECE, Sri Venkateswara University College of Engineering, Tirupati, India

ABSTRACT: LTE has been developed for low latencies, high data rates and greater spectral efficiency. In downlink space diversity is used to provide better quality of service to the user. In space diversity schemes transmit diversity is preferred over the receiver diversity schemes. In this paper data is generated and transmitted by employing both transmit diversity and receiver diversity and the performance is examined with respect to the data received.

KEYWORDS: transmit diversity, receiver diversity, maximal ratio combining, space frequency block coding, space–time coding.

I. INTRODUCTION

Adopting superior technologies like Orthogonal Frequency Division Multiplexing (OFDM) systems and Multiple-Input, and Multiple-Output (MIMO) to the existing wireless technology to handle the growing traffic and quality of service to be provided has revolutionized the wireless era and resulted into a new technology known as Long Term Evolution (LTE) and it has become the promise for the best future wireless communication systems to be built.

The radio propagation effects on the transmitted data should be estimated to recover the transmitted data accurately. Therefore channel estimation plays a vital role in the receiver designs of LTE. MIMO can improve LTE system performance by spatial multiplexing and transmit diversity, in which the Space Frequency Block Codes (SFBC) are used to obtain diversity gain. SFBC uses alamouti coding in the frequency domain. In SFBC multiple flat fading channels can be obtained by performing orthogonal frequency division multiplexing (OFDM) on frequency selective fading channels. In wireless communication systems fading is the major drawback for failure of quality oriented services hence to counter attack it the channel should be properly analysed. The operation of SFBC is carried out on pair of complex valued modulation symbols. Hence, each pair of modulation symbols are mapped directly to OFDM subcarriers of first antenna while for the second antenna each pair of symbols of the corresponding subcarriers are mapped by reversely ordering, complex conjugating and reversing the sign.

In Section II, diversiy schemes are exclusively explained with mathematical interpretation both the transmit diversity and the receiver diversity. In section III the simulations results are presented and evaluated on comparing both the schemes and the bit-error performance is presented. In Section V overall summary is discussed with practical limitations.

II. DIVERSITY SCHEMES

In wireless communications channel is a path between transmitter and receiver for the information exchange. In a wireless communication channel data propagation is a function of the E.M wave propagation effect such as reflection, diffraction, scattering in an environment. These propagation effects causes the attenuation due to multipath which is known as fading of radio waves. This attenuation varies with respect to time and the mobile user mobility. Fading effect can be overcome effectively by without using high power or increasing bandwidth is par difficult prior to invention of Alamouti coding but after its invention fading can be effectively mitigated. Fading can be reduced by employing either of receiver diversity at the receiver end or the transmit diversity at the transmitter end. By employing receiver diversity more number of receiver antennas has to be considered but it increases the device cost and size which is practically unacceptable to all. Hence transmit diversity is employed at the transmitter by considering more number of transmitter antennas and thus the transmit diversity scheme is employed in a specific base station's coverage area to improve the reception quality of all the remote

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units. Let us consider the receiver diversity initially and tally out the results with that of the transmit diversity results to evaluate the performances.

RECEIVER DIVERITY SCHEME

Maximal Ratio Receiver Combining Scheme

Let us look at the third technique which is also the more which is the maximal ratio combining method is a popular technique where all the co-phased signals combine in a weighted manner so as to have the highest achievable SNR at the receiver at all times. MRRC is a combining method which is used in a noise limited communication systems to improve performance where the fading and the AWGN are independent among the diversity branches. The mean SNR is obtained as M times gamma which is for one branch. As the number of branches increases, average SNR increases.

Consider 'S_0' is a signal transmitted from the transmitter through a channel to the receivers(r_0, r_1)at a specific instance of time 't'. Consider 'h_0' be the channel which acts as medium of interface between the antenna Tx1 at the transmitter and the receiving antenna 'r_0' and 'h_1'between the antenna Tx2 at the transmitter and the receive antenna 'r_1'where

$$h_0 = \alpha_0 e^{j\theta_0} \ and \ h_1 = \alpha_1 e^{j\theta_1}$$

Where α_0, α_1 are the attenuation factors and θ_1, θ_2 represents the complex distortion in the channel due to the obstacles.

Consider 'n_0 ', 'n_1', be the noises with Gaussian distribution present along with received signal at the receiver and the resulting received signals are:

$$r_0 = h_0 s_0 + n_0 \ \ldots.. (1)$$
$$r_1 = h_1 s_1 + n_1 \ \ldots.. (2)$$

Where n_0 and n_1 noises are due to natural and manmade noises or interference, at the receiver. To choose signal s_i maximum likelihood decision rule is applied if and only iff

$$d^2(r_0, h_0 s_i) + d^2(r_1, h_1 s_i) \leq d^2(r_0, h_0 s_k) + d^2(r_1, h_1 s_k) \qquad \textbf{where } i \neq k \qquad \textbf{(3)}$$

where $d^2(x,y)$ is the squared Euclidean distance between signals and calculated by the following expression:

$$d^2(x,y) = (x-y)(x^*-y^*) \qquad \textbf{(4)}$$

The receiver combining scheme for two-branch MRRC is as follows:

$$\widetilde{s_0} = h_0^* r_0 + h_1^* r_1 \qquad (5)$$
$$= h_0^*(h_0 s_0 + n_0) + h_1^*(h_1 s_1 + n_1)$$
$$= (h_0^2 + h_1^2) s_0 + h_0^* n_0 + h_1^* n_1$$

On expanding equation (3) we get

$$(h_0^2 + h_1^2)|s_i|^2 - \widetilde{s_0} s_i^* - \widetilde{s_0^*} s_i \leq (h_0^2 + h_1^2)|s_k|^2 - \widetilde{s_0} s_k^* - \widetilde{s_0^*} s_k \quad \textbf{where } i \neq k \textbf{(6)}$$

The above equation can be rewritten as:

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$$\left(h_0^2+h_1^2-1\right)|s_i|^2+d^2(\widetilde{s_0},s_i)\leq\left(h_0^2+h_1^2-1\right)|s_k|^2+d^2(\widetilde{s_0},s_k) \quad (7)$$

For PSK signals

$$|s_k|^2=|s_i|^2=E_s \dots\dots(8)$$

Where E_s represents signal energy. Hence, for PSK signals, the decision rule in (7) is reduced to choose $\mathbf{s_i}$ iff

$$d^2(\widetilde{s_0},s_i)\leq d^2(\widetilde{s_0},s_k) \quad \text{where } i\neq k \qquad (9)$$

The maximal-ratio combiner construct the signal $\widetilde{s_0}$ through detector which produce $\widehat{s_0}$(maximum likelihood estimate of s_0).

TRANSMIT DIVERSITY SCHEME

Space Frequency Block Coding

Space frequency block coding is *a* transmitter diversity scheme over frequency selective fading channels for wireless communication. Consider two transmitter antennas at the transmitter and a receiver antenna at the receiver and it is pictorially represented in fig:3. The encoding of data take place as follows:

Table 3.1 represents data encoding scheme in SFBC 1x2 and 2x2

subcarriers	**Antenna 0**	**Antenna 1**
f_1	s_0	s_1
f_2	$-s_1^*$	s_0^*

After converting frequency selective channel to frequency flat channel by using OFDM technique and the data is transmitted through the respective antennas to the receiver. At the receiver end the data is retrieved after performing inverse of FFT and the decoding techniques. Presently here Quadrature amplitude modulation is employed.

- OFDM Modulation

Consider a simple OFDM modulation scheme by considering only one data vector. In polyphase notation the data vector $S(n)$ expressed as:

$$S(n)=[S_0(n)\ S_1(n)\dots\dots\dots S_{N-2}(n)\ S_{N-1}(n)]^T$$

OFDM symbols are obtained by performing IDFT on the encoded data stream and to avoid intersymbol interference a cyclic prefix is used. The guard interval should be maintained such that it overcomes ISI and the guard interval acts as the cyclic prefix. The guard interval value 'G' is selected such that it is greater than the delay spread of the channel i.e., G ≥L. At the receiver, the guard interval is first removed from the received signal vector **.**As per 3GPP standards the cyclic prefix in downlink are tabulated as below:

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Table 3.2: Resource block allocation and cyclic prefix in downlink as per 3GPP standards

		Blocks	(l)	Prefix
1.	Normal CP $\Delta f = 15kHz$	12	7	160 for l=0 144 for l=1 to 6
2.	Extended CP			512 for l=0 to 5
2.i	$\Delta f = 15kHz$	12	6	
2.ii	$\Delta f = 7.5kHz$	24	3	

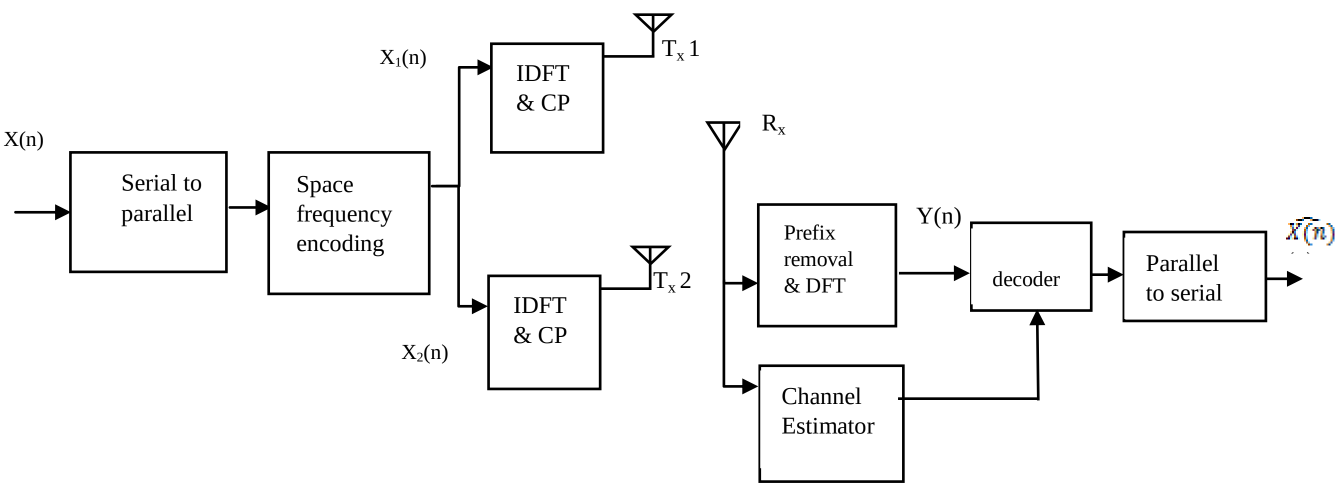

Fig 3: Block diagram of a two branch Space frequency Block

After encoding with SFBC by the space-frequency encoder block, the data symbol vector at the transmitter end $\boldsymbol{S(n)}$ is split into $\boldsymbol{S_1(n)}$ and $\boldsymbol{S_2(n)}$ vectors after and they are represented as below:

$$\boldsymbol{S_1(n) = [S_0(n)\ -S_1^*(n) \ldots \ldots \ldots S_{N-2}(n)\ -S_{N-1}^*(n)]^T}$$

$$\boldsymbol{S_2(n) = [S_1(n)\, S_0^*(n) \ldots \ldots \ldots S_{N-1}(n)\ -S_{N-2}^*(n)]^T} \qquad \textbf{(1)}$$

Through the transmitter antenna Tx_1 the data vector $\boldsymbol{S_1(n)}$ is transmitted, while through the transmitter antenna Tx_2 the data vector $\boldsymbol{S_2(n)}$ is transmitted simultaneously during the block instant $\boldsymbol{n}$. Encoded data vectors can also be explained in terms of even and odd poly-phase component vectors and the decoded data vectors can also be well explained in terms of

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even and odd poly-phase component vectors. Let $S_e(n)$ *and* $S_o(n)$ be indicating the even and odd component vectors of $S(n)$, of length ***N/2*** vectors i.e.,

$$S_e(n) = [S_0(n)\, S_2(n) \ldots \ldots \ldots . S_{N-4}(n)\, S_{N-2}(n)]$$

$$S_o(n) = [S_1(n)\, S_3(n) \ldots \ldots \ldots . S_{N-3}(n)\, S_{N-1}(n)] \quad (2)$$

Again $S_1(n)$ and $S_2(n)$ is subdivided into even and odd terms as follows $\mathrm{S}_{1,e}(n)$, $\mathrm{S}_{2,e}(n)$, $\mathrm{S}_{1,o}(n)$ *and* $\mathrm{S}_{2,o}(n)$. The above encoded vector is represented in the matrix form as below:

$$\begin{pmatrix} \mathrm{Se} & \mathrm{So} \\ -\mathrm{S}_o^* & \mathrm{Se}^* \end{pmatrix} = \begin{pmatrix} \mathrm{S}_{1,e} & \mathrm{S}_{2,e} \\ \mathrm{S}_{1,o} & \mathrm{S}_{2,o} \end{pmatrix} \quad (3)$$

Let $\mathbf{D_1}(n)$ and $\mathbf{D_2}(n)$ be two diagonal matrices of discrete fourier transformed channel impulse responses $\mathbf{h_1}(n)$ and $\mathbf{h_2}(n)$ respectively. The demodulated signal at the receiver is given by

$$\mathrm{Y_e(n)} = \mathrm{D}_{1,e}(n) S_{1,e}(n) + \mathrm{D}_{2,e}(n) S_{2,e}(n) + Z_e(n)$$

$$\mathrm{Y_o(n)} = \mathrm{D}_{1,o}(n) S_{1,o}(n) + \mathrm{D}_{2,o}(n) S_{2,o}(n) + Z_o(n) \quad \mathbf{(4)}$$

Or

$$\mathrm{Y_e(n)} = \mathrm{D}_{1,e}(n) S_e(n) + \mathrm{D}_{2,e}(n) S_o(n) + Z_e(n)$$

$$\mathrm{Y_o(n)} = -\mathrm{D}_{1,o}(n) S_o^*(n) + \mathrm{D}_{2,o}(n) S_e^*(n) + Z_o(n) \quad \mathbf{(5)}$$

The decision estimate vector $\hat{X}(n)$ which can be built by the space frequency decoder as:

$$\widetilde{S_e} = \mathrm{D}_{1,e}^*(n)\mathrm{Y_e(n)} + \mathrm{D}_{2,o}(n)\mathrm{Y_o^*(n)}$$

$$\widetilde{S_o} = \mathrm{D}_{2,e}^*(n)\mathrm{Y_e(n)} - \mathrm{D}_{1,o}(n)\mathrm{Y_o^*(n)} \quad \mathbf{(6)}$$

Assuming that the complex channel gain between adjacent subcarriers is approximately constant, i.e., $\mathrm{D}_{1,e}(n) = \mathrm{D}_{1,o}(n)$ and $\mathrm{D}_{2,e}(n) = \mathrm{D}_{2,o}(n)$ then substituting (5) into (6) results in

$$\widetilde{S_e} = \mathrm{D}_{1,e}^*(n)\mathrm{Y_e(n)} + \mathrm{D}_{2,o}(n)\mathrm{Y_o^*(n)}$$

$$= \left(\mathrm{D}_{1,e}^2(n) + \mathrm{D}_{2,o}^2(n)\right) S_e(n) + \mathrm{D}_{1,e}^* Z_e(n) + \mathrm{D}_{2,o}(n) Z_o^*(n) \ldots (7)$$

$$\widetilde{S_o} = \mathrm{D}_{2,e}^*(n)\mathrm{Y_e(n)} - \mathrm{D}_{1,o}(n)\mathrm{Y_o^*(n)}$$

$$= \left(\mathrm{D}_{2,e}^2(n) + \mathrm{D}_{1,o}^2(n)\right) S_o(n) + \mathrm{D}_{2,e}^*(n) Z_e(n) - \mathrm{D}_{1,o}(n) Z_o^* \ldots \mathbf{(7)}$$

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The decision variable equation (7) is similar to that of the optimal two branch maximal ratio combining (MRC) receiver diversity system as that of ST-OFDM

III. SIMULATION RESULTS

The bit error rate (BER) performance SF-OFDM transmitter diversity system for 2x1, 2x2 are verified by simulation. The simulation system used OFDM with cyclic prefix length set in accord with 3GPP standards where the cyclic prefix length varies with respect to the DFT size chosen and 4-QAM on each subcarrier. In this simulation six tapped channel used throughout the simulations, and assumed that perfect channel estimation available at the receiver. It is assumed that the fading amplitude is Rayleigh distributed and mutually uncorrelated. Channel is assumed to be constant between two adjacent subcarriers and the receiver is assumed to have perfect knowledge of the channel. These assumptions seems to be unrealistic but they provide reference for practical available techniques. Simulation results are as follows

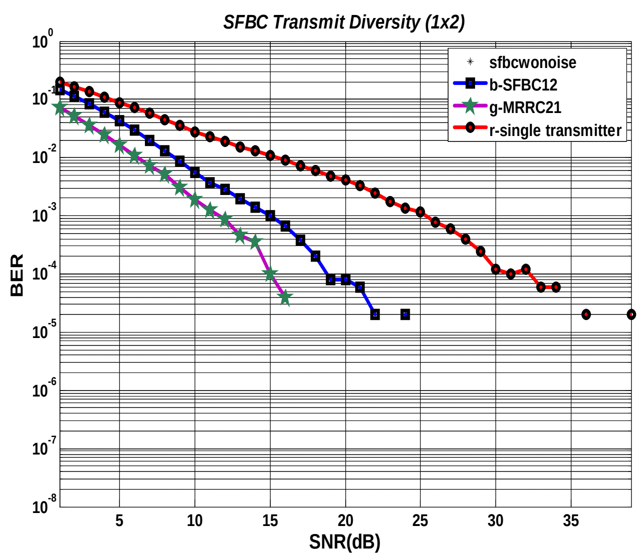

Fig 4.1: Represents SFBC 1x2 diversity simulation result

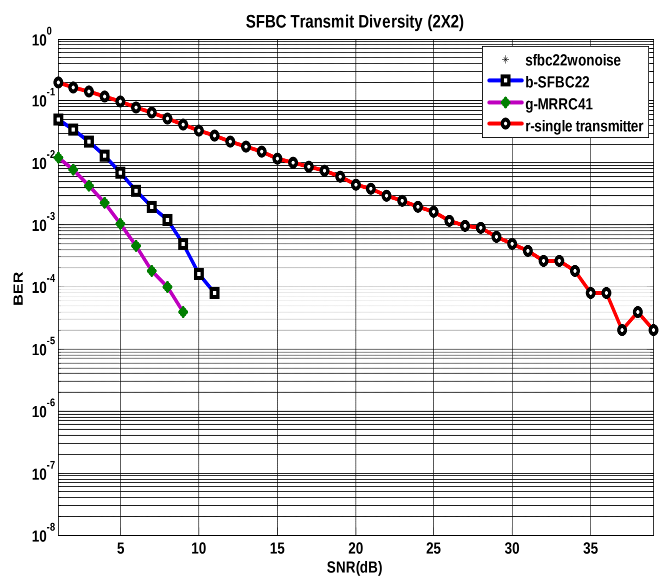

Fig 4.2: Represents SFBC 2x2 diversity simulation result

SFBC simulation results indicate at a bit error rate (BER) of 10^{-2} with diversity gain of about 5 dB and about 15 dB of gain at a BER of 10^{-4}. SFBC performance curve gives an error floor due to the characteristic of OFDM system in a Doppler spread channel at higher SNR values**.** In OFDM systems, BER is a function of the normalized Doppler frequency i.e., as the Doppler spread increases, the BER error floor degrades. The variations in the complex channel gain between adjacent subcarriers causes errors in the decoding process which results into degradation of BER performance of the SFBC diversity scheme. In non-dispersive or flat channels only the constant channel gain between adjacent subcarriers exists. Hence the frequency selective channel is converted to frequency flat fading channel by using OFDM technique. Here in simulations we have considered a channel order of 6. In the simulation results 2x2 transmit diversity scheme outperforms when compared to 1x2. When we go for higher order systems from second order system the data rate/ throughput falls due to the error floor arises due to lose of the unity code rate. At this code rate the data rate can be improved by increasing the bandwidth and employing some error correcting codes. Here for the simulation study of symbol rate and channel characteristics a block size of 2048 is considered. It can also be observed by considering a moderate block size of 512.

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IV. CONCLUSION

SFBC transmitter diversity technique over frequency selective fading channels is performed and it is observed from the simulations results that SFBC is efficient and effective transmitter diversity technique when normalized Doppler frequency is large. SFBC performance is intact with that of the MRC with a little degradation and hence the portable user equipment is realizable. Here we have considered the lower ordered system because of unity code rate as we go for higher order complex orthogonal block codes unity code rate degrades and becomes less than unity which hampers the data throughput. By applying certain error correcting codes the data throughput may be improved and hence it has become a topic of future scope for further research.

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