International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 7, September - 2012

A Study on Space Time/Frequency Block Codes for MIMO OFDM System

Parul Gupta,Prof. Rajiv Chechi,JyotiWadhwa

Haryana College of Technology and Management, Kaithal(Haryana),136027
Kurukshetra University, Kurukshetra
INDIA

Abstract— **Now a days, wireless communication is used worldwide. For larger capacity and higher data rate there is a need of multiple antenna at the transmitter and the receiver. So we use MIMO system. As the data rate is increasing in transmission system there occur some problems also with wireless communication. These are inter-carrier interference, multipath fading. To combat these problems we use OFDM. OFDM is an Orthogonal Frequency Division Multiplexing technique having great intensity to enhance the performance of wireless communication system.**

***Keywords*—OFDM, STBC, SFBC, STFBC**

I. Introduction

As the advancement in wireless communication is going on peak, the demand of high data rate with high efficiency is soaring. One favourable solution of this is to combine the two, MIMO and OFDM as MIMO-OFDM [1].MIMO is basically the multiple inputs and multiple output system which increases the data rate rather using a single input single output system. OFDM is a multiplexing technique which uses the orthogonality principle to convert the frequency selective channel into narrow flat fading channels.It employs multicarrier to transmit information in parallel over the channel which improves the data rate as well as bandwidth efficiency.For MIMO-OFDM spatial diversity can be achieved by using multiple antennas and space time coding [1]OFDM modulation is implemented using IFFT.
In this paper we are studying the performance of STFBC-OFDM over STBC-OFDM and SFBC-OFDM. We will see that how STFBC-OFDM is better than the other two. STBC-OFDM is a multi antenna system which provides special as well as frequency diversity gains.

This paper is organized as follow. In section II, STBC-OFDM technique will be discussed and mathematical equations are given. In section III SFBC-OFDM technique and its equations are discussed for 2x1 antenna system. In section IV coding and decoding technique for STFBC is discussed. Finally section V will present the conclusion for the entire paper.

II. MIMO-OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is a transmission scheme that is having enough potential for attaining high transmission rate overfrequency selective channels during the transmission of multicarrier signal. OFDM generally uses the process of removal of inter-symbol interference due to multipath fading by insertingguard interval. By inserting the guard interval transmitting symbols never interfere with each other and signal remains undistorted.This scheme has been proposed topreserve the orthogonality. This also provideequalization at the receiver side. OFDM uses a frequency-domain equalizer that consists of a single tap per sub-carrier for compensating channel distortion occurred due to each sub-carrier. MIMO system refers to the transmission systemtat is formed bymultiple antennas at both the transmitter and receiver. The main advantage of employingmultiple antennas is to obtain more high data rate and accurate performance through *diversity* and *spatial multiplexing* [2]. This conceptis briefly discussedusing figure below.
Thus by combining the two MIMO and OFDM (MIMO-OFDM) schemes provides high-rate. In OFDM the frequency selective channels are subdivided in to narrowband channels and IFFT is done. Then by adding a guard interval(G.I) signals are transmitted. Then DFT is applied to receive the signals at all receiving antennas[9].

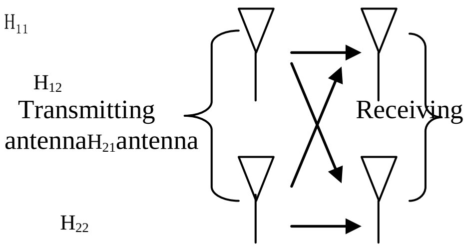

Fig.1. OFDM in MIMO SYSTEM for 2x2 antenna

III. SPACE TIME/FREQUENCY CODES FOR MIMO OFDM

To enhance the data rate we use multiple antennas. These multiple antennas are arranged by some form of diversity. Diversity is a technique in which same data is transmitted through multiple antenna to get the highest diversity gain. Basically, it used to mitigate degradation because of error performance due to multipath fading. There are various forms of diversity. These are space diversity, time diversity, frequency diversity, Angle diversity. Here the use of three diversity techniques space, time and frequency is used. Now we will study Space Time Block Coded-OFDM and Space Frequency Block Coded- OFDM and space time-frequency block coded OFDM.

A. SPACE TIME BLOCK CODED OFDM:-

Space time block coding is a technique used in wireless communications to transmit multiple copies of a data stream across a number of antennas[7]. Space-time coding combines all the copies of the received signal in asubsequent way to extract as much information from each of them as possible.

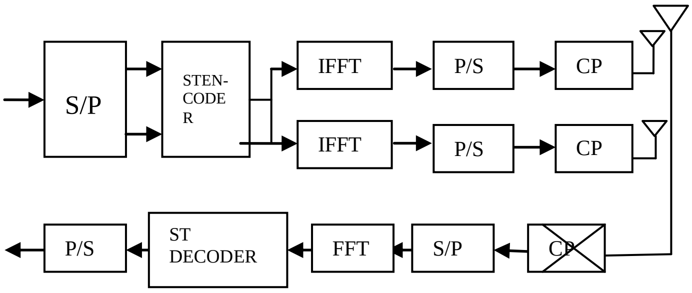

Fig.1Block diagram of STBC in MIMO-OFDM system

Here we are considering a MIMO system having 2 transmitter and 1 receiver antenna.The Diversity order or diversity gain of a MIMO system is defined as the number of independent receptions of the same signal. In [5] it is proposed that a AMIMO system with N_t transmit antennas and N_r receive antenna has maximum diversity gain=N_tN_r

STBC is usually represented by a matrix. Each row shows a different time instant and the column shows transmission symbol by each antenna.

$$X = \begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix} \quad (1)$$

where * denotes complex conjugate.

Here the first column corresponds to the symbols transmitted from the first antenna and the second column corresponds to the symbols transmitted from second antenna while the first row represents the first transmission period t and the second row represents the second transmission period t+1.

During first symbol period t, the first antenna transmit s_1 and the second antenna transmits s_2.During the second symbol period t+1, the first antenna transmits $-s_2^*$ and the second antenna transmits s_1^* i.e. the complex conjugate of s_1.

For this STBC OFDM system the outputs are four $N_t\times 1$ vectors shown as:-

$X_1[t] = [s_1\, s_3 \ldots.. s_{2N_a-1}]^T$, (2)

$X_2[t] = [s_2\, s_4 \ldots.. s_{2N_a}]^T$,(3)

$X_1[t+1] = [-s_2^* - s_4^* \ldots.. -s_{2N_a}^*]^T = -X_2[t]^*$, (4)

$X_2[t+1] = [s_1^* - s_3^* \ldots.. -s_{2N_a-1}^*]^T = X_2[t]^*$,(5)

where t is the symbol duration. The consecutive received signals, $\mathbf{Y}[t]$ and $\mathbf{Y}[t+1]$, are used for decoding of transmitted symbols in the STBC-OFDM systems. If we will take the received signals on k-th subcarrier, the vectors for received signal during two time periods are:

$$\tilde{Y} = \tilde{\nabla}\mathrm{H}\tilde{X} + \tilde{N}, \qquad (6)$$

Where

$$\tilde{Y} = [Y(k\,;t) \quad Y(k\,;t+1)^*\,]^T,$$

$$\tilde{H} = \begin{bmatrix} \mathrm{H}_1[t]_{k,k} & \mathrm{H}_2[t]_{k,k} \\ \mathrm{H}_2[t+1]_{k,k}^* & -\mathrm{H}_1[t+1]_{k,k}^* \end{bmatrix},$$

$$\tilde{N} = [n_{k,t} n_{k,(t+1)}^*]^T$$

b_{st} is zero as $\tilde{\mathrm{H}}$ turns to an orthogonal matrix. SDS introduced in [3] is present at receiver to separate the transmitted symbols. When orthogonality gets lose, there occurs a problem of ISI. Due to this ISI the performance of STBC-OFDM degrades in fast fading environment.

B. SPACE FREQUENCY BLOCK CODED OFDM:-

The problem that occurs in STBC-OFDM system is of flat time variations with respect to time which is known as FAST FADING. To remove that problem we use SFBC-OFDM technique in which orthogonal symbols are transmitted on the neighbouring sub-carriers of the same OFDM [2]. The block diagram shows the SFBC-OFDM system for 2x1 antenna. Serial to parallel converter is to convert the data into two parallel streams.

$$X = \begin{matrix} f_k \\ f_{k+1} \end{matrix}\begin{bmatrix} s_k & s_{k+1} \\ -s_{k+1}^* & s_k^* \end{bmatrix}$$ is a transmitted signal

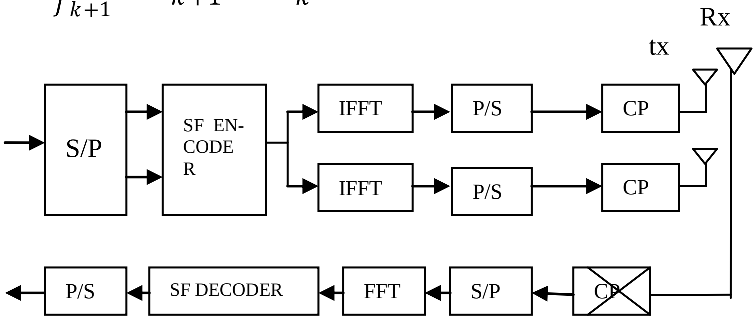

Fig. 2Block diagram of SFBC in MIMO-OFDM system

The vectors generated by SFBC-OFDM encoder are,

$X_1[t] = [s_1 - s_2^* s_3 \quad - s_4^* \ldots . s_{N_a-1} - s_{N_a}^*]^T$,

$X_2[t] = [s_2\, s_1^* s_4 \quad s_3^* \ldots . s_{N_a} s_{N_a-1}^*]^T$, (7)

As here we are altering the frequencies for transmission of data, so received signal on kth and (k+1)th are used to decode transmitted signal. The received signal vector is

$\tilde{Y} = \tilde{H}\tilde{X} + \tilde{N}$

Where

$\tilde{Y} = [Y(k\,;\,t) \quad Y(k+1\,;\,t)^*]^T$,

$$\tilde{H} = \begin{bmatrix} H_1[t]_{k,k} & H_2[t]_{k,k} \\ H_2[t]_{k+1,k+1}^* & -H_1[t]_{k+1,k+1}^* \end{bmatrix},$$

$$\tilde{X} = \begin{bmatrix} X_1[k;t] \\ X_2[k;t] \end{bmatrix} = \begin{bmatrix} X_2[k+1;t]^* \\ -X_1[k+1;t]^* \end{bmatrix},$$

$$\tilde{N} = \left[n_{k,t} n_{(k+1),t}^*\right]^T$$

The STBC-OFDM systems suffers from the problems of fast fadingenvironments, SFBC-OFDM systems faces the problem of frequency-selectivity of channels due to loss of orthogonality. As to maintain the orthogonality in a channel , the frequency channelresponse must be constant over neighboring subcarriersin SFBC-OFDM.If the channel response is not constant then the orthogonality will be lost. And there will be degradation in performance.

C. SPACE TIME- FREQUENCY BLOCK CODED OFDM:-

As we have already discussed that space time block codes are having problem of fast fading and space-frequency block codes faces a problem of frequency-selectivity.

Therefore, in this method we will transmit the sub-carriers of the orthogonal design in both time and frequency to remove the problems that occurs in space time block codes and space frequency block codes. The signal is transmitted in separate time as well as at separate frequency simultaneously.

In Space Time-Frequency block coding the OFDM symbol S is divided into two vectors S = (s_1,s_2). The Space Time Frequency Block coding (STFBC) scheme is used to enhance the performance of system by taking together the three diversity techniques space, time and frequency in MIMO-OFDM system[8]. The table figure shows that how the transmission of symbol is going on in this STFBC-OFDM [12].

TRANSMISSION OF SYMBOLS THROUGH 1ST AND 2ND ANTENNA

	T_1	T_2
Frequencyi	S_1	S_2
Frequencyj	S_2	S_1

	T_1	T_2
Frequency i	$-S_2^*$	S_1^*
Frequencyj	S_1^*	$-S_2^*$

At the receiver, the received samples on ith frequency are given by:

$$y_i^1 = H_i^1 s_1 - H_i^2 s_2^* + n_i^1$$
$$y_i^2 = H_i^1 s_2 - H_i^2 s_1^* + n_i^2$$

And the received samples on jth frequency are given by:

$$y_j^1 = H_j^1 s_1 - H_j^2 s_2^* + n_j^1$$
$$y_j^2 = H_j^1 s_2 - H_j^2 s_1^* + n_j^2$$

.Firstly in STFBC-OFDMsystem the input data is encoded and interleaving is performed by a block interleaver.After that the symbol is mapped by themodulator, thenthe signals enters the Space Time-Frequency encoder andthen are applied to OFDM section of theseparate antennas.

Each antenna system consists of N number of subcarriers. The Nsignals from antennas are passedthrough IFFT.This IFFT section contains a cyclicprefix which is added to each ofthe signal components. This cyclic prefix is used to avoid the inter-symbol interference and converts a frequency selective channel in to many parallel independent frequency non selective channels.This prefix has a guard interval.That guard interval is chosen longer than the delay spread in channel. The signalreceived isof desired transmission frequency andtransmitted through the channel. The coderate of the STFBC encoder is r/n, where the encodertakes r sequences of N tones and outputs of nsequences ofN tones.

IV. CONCLUSION

In this paper we have studied the three techniques of block coding with OFDM. By investigating the three techniques we can judge that STFBC-OFDM is a better technique to transmit the signal over OFDM..As there is a problem of time and frequency selectivity in STBC-OFDM and SFBC-OFDM systems which generates the Inter-symbol Interference(ISI), due to which performance degrades witha negative effect greatly. To remove this type of problem which concerned with both STBC-OFDM and SFBC-OFDM, we have studied a technique STFBC-OFDMin which both spatial and frequency diversity areused, by the advantage of the OFDM modulation foradditional diversity which removes the problem of ISI. And also preserve the orthogonality.

V. REFERENCE

[2] H.Bolcskei, A.J.Paulraj, Space-frequency coded broadband OFDM*systems*,IEEE WCNC2000.

[3] Z. Liu, G.B. Giannakis, S.Zhou, B. Muquet, *Space-time coding*for broadband wireless communications, Wirel.Commun. Mob.Comput. 2001:1:35-53.

[4] S.K.S. Yusof, and A.I.A. Zamani, "Intercarrier interference self cancellation for space-time-frequency MIMO-OFDM system, " in *IEEE international RF and microwave conference,* 2008, p 520-523

[5] Xiaoli Ma and G.B. Giannakis, Space-time-multipath coding usingdigital phase sweeping, Globecom2002.

[6] Keonkook Lee, Hoojin Lee*†*, Namseok Chang, and Joonhyuk Kang,Design of Novel Orthogonal Space-Time-FrequencyBlock Codes for OFDM Systems over FadingChannel Environments.

[7] G. Bauch, "Space-time block codes versus space-frequency block Codes",*Proc. IEEE VTC'03*, pp. 567-571, 2003.

[8] A. Molisch, M. Win, and J. Winters, "Space-time-frequency (STF) coding for MIMO-OFDM systems," *IEEE Communications Letters*, vol. 6, pp. 370–372, September 2002

[9] Wei Zhang, ,Space-Time/Frequency Coding for MIMO-OFDM in Next Generation Broadband Wireless Systems *IEEE,* Xiang-Gen Xia, *Senior Member, IEEE,* andKhaled Ben Letaief,*Fellow, IEEE*

[10] T. Rappaport, *Wireless Communications*. Upper Saddle River: Prentice Hall, second ed., 2002.

[11] K.Thenmozhi, VamsiKrishnaKonakalla, S PraneethVabbilisetty RengarajanAmirtharajan, "Space Time Frequency Coded (STF) OFDM for Broadbandcommunication systems".

[12] IlhemOuachani, Karine Gosse, Pierre Duhamel, "Trading Rate versus Diversity in Space-Time-Frequency Block Coding schemes".

[1] V. Tarokh, N. Seshadri, and A. Calderbank, "Space-time codes for high data rate wireless communication: Performance criterion and code construction," *IEEE Transactions on Information Theory*, vol. 44, pp.744–765, March 1998.