# Performance Analysis of STBC- OFDM System under Multipath Fading Channel

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*Abstract: In current 4G systems growing demand of multimedia services and the growth of Internet related contents lead to increasing interest to high speed communications. Recently, space time block codes (STBC) have gained much attention as an effective transmit diversity technique to provide reliable transmission with high peak data rates to increase the capacity of wireless communication systems. In this paper, performance of STBC-OFDM is analyzed under different constraints in Rayleigh fading channels. We have studied the effect of modulation order, antenna selection techniques, slow and fast fading conditions and power conditions on the performance of STBC-OFDM.*

*Index Terms: MIMO, OFDM, STBC, Multipath, fading*

## I. INTRODUCTION

High spectral efficiency and high transmission rate are the challenging requirements of future wireless broadband communications. In a multipath wireless channel environment, the deployment of Multiple Input Multiple Output (MIMO) systems leads to the achievement of high data rate transmission without increasing the total transmission power or bandwidth. Multiple-Input Multiple-Output antenna systems are a form of spatial diversity. An effective and practical way to approaching the capacity of MIMO wireless channels is to employ space-time block coding in which data is coded through space and time to improve the reliability of the transmission, as redundant copies of the original data are sent over independent fading channels. Then all the signal copies are combined at the receiver in an optimal way to extract as much information from each of them as possible. In practice, wireless communications channels are time varying or frequency selective especially for broadband and mobile applications. To address these challenges, a promising combination has been exploited, namely, MIMO with Orthogonal Frequency Division Multiplexing (OFDM), MIMO-OFDM, which has already been adopted for present and future broadband communication standards such as LTE or WiMax.

OFDM can reduce the effect of frequency selective channel. This is because OFDM is a multi carrier transmission technique, which divides the available spectrum into many carriers, each one being modulated by a low-rate data stream. One popular combination of MIMO and OFDM is the STBC-OFDM.In this STBC coding is applied across multiple OFDM blocks to enhance the system Performance inherent in MIMO-OFDM system. The coding distributes symbols along different transmit antennas and time slots. In this context, the STBC-OFDM system is one of most promising system configurations that is adopted for 4th generation mobile systems. Its advantages are the simple linear decoding and low complexity receiver which have made them a popular choice for future wireless communications. The paper is outlined as follow: In section 2, system model of STBC-OFDM is described. In section 3, the effect of various factors like modulation order, antenna selection techniques, slow and fast fading conditions and power conditions is analyzed on the performance of STBC-OFDM is analyzed in different conditions. Then the paper ends with the Conclusion.

## II. SYSTEM MODEL

We consider a multiple antenna wireless communication system which is equipped with 2 transmits and 2 receive antennas .The binary input data stream is first modulated and mapped to a sequence of modulation symbols. The modulated sequence is then passed through a serial-to-parallel converter.

The Alamouti scheme is then applied across two consecutive OFDM symbols within each subcarrier in STBC encoder. According to this coding scheme the signal copy is not only transmitted from another antenna but also at another time. At a given symbol period, two signals are simultaneously transmitted from the two antennas. The signal transmitted from antenna zero is denoted by $s_0$ and from antenna one by $s_1$.

**Table I Alamouti STBC Scheme**

|          | antenna 0 | antenna 1 |
|----------|-----------|-----------|
| time t   | $s_0$     | $s_1$     |
| time t +T | $-s_1^*$  | $s_1^*$   |

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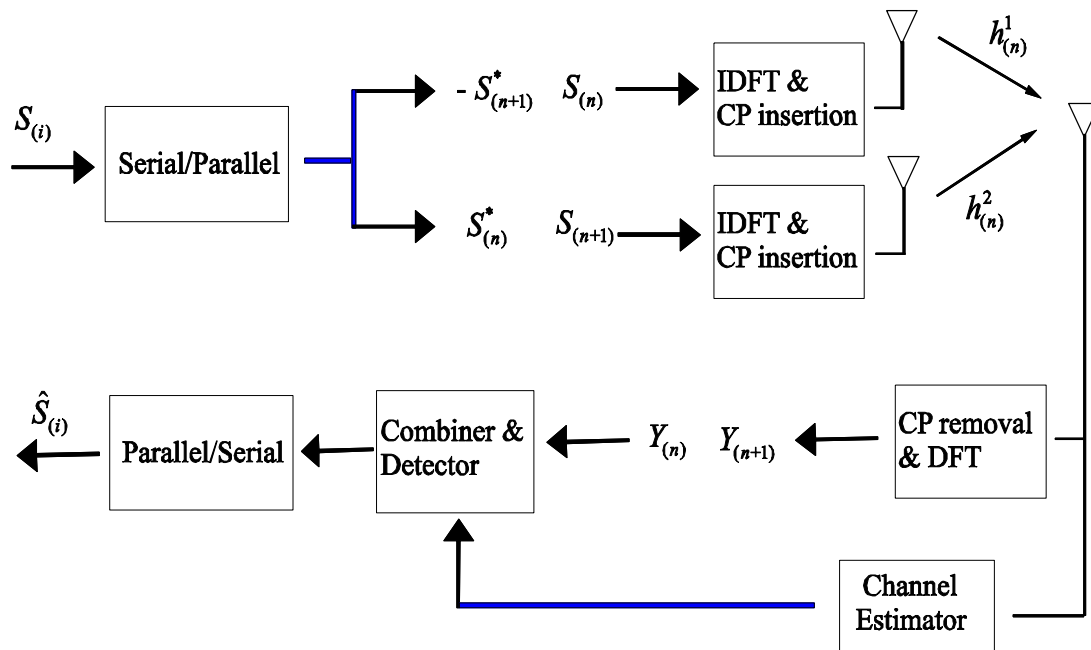
**Fig 1: STBC-OFDM Block Diagram**

During the next symbol period signal $(-s_1^*)$ is transmitted from antenna zero, and signal $s_0^*$ is transmitted from antenna one where (*) is the complex conjugate operation as shown in table 1. So for two transmit antenna, vectors $S_1(n)$ and $S_1(n+1)$ are transmitted alternatively form antenna 1. Simultaneously, $S_2(n)$ and $S_2(n+1)$ are similarly transmitted from antenna 2. Channel is constant during transmission for two time slots An Inverse Discrete Fourier Transform (IDFT) is performed on each serial data stream. To find the corresponding time waveform an inverse Fourier transform is used. After the IFFT operation the received symbols are given as:

$$R_j(n) = \sum_{j=1}^{N_r} H_{1,j}(n)S_1(n) + H_{2,j}(n)S_2(n) + N_j(n) \quad \text{(1 a)}$$

$$R_j(n+1) = \sum_{j=1}^{N_r} H_{1,j}(n+1)S_1(n+1)$$
$$+ H_{2,j}(n+1)S_2(n+1) + N_j(n+1)$$
$$= \sum_{j=1}^{N_r} -H_{1,j}(n)S_2^*(n) + H_{2,j}(n)S_1^*(n) + N_j(n+1)$$
(1b)

where $R_j(n)$ ,$S_i(n)$ and $N_j(n)$ are the received symbols, transmitted vector symbols and the Gaussian noise sample respectively; n refers to the nth OFDM symbol and j to the jth receive antenna.

The output of the IDFT block is time-domain samples, corresponding to an OFDM frame. To avoid the effects of inter symbol-interference, a cyclic prefix (CP) of length *is* added to output samples. After that the symbols are converted back to serial time waveform. After the serial to parallel operation at transmit antennas 1 and 2 respectively, we get signals $S_1(n)$ and $S_2(n)$ for the OFDM symbol n and n+1 by the following equations:

$$S_1(n) = [S_0, S_2, \ldots, S_{2k}, \ldots S_{2N_{s-4}}, S_{2N_{s-2}}] \quad \text{(2 a)}$$
$$S_2(n) = [S_1, S_3, \ldots, S_{2k+1}, \ldots S_{2N_{s-3}}, S_{2N_{s-1}}] \quad \text{(2 b)}$$

$$S_1(n+1) =$$
$$[-S_1^*, -S_3^* \ldots, -S_{2k+1}^*, \ldots. -S_{2N_{s-3}}^*, -S_{2N_{s-1}}^*]^\mathrm{T} = -S_2^*(n)$$
(2 c)
$$S_2(n+1) = [S_0^*, S_2^*, \ldots \ldots, S_{2k}^* \ldots, S_{2N_{s-4}}^*, S_{2N_{s-2}}^*]^\mathrm{T}$$
$$= S_1^*(n) \text{ (2 d)}$$

This is then the base band signal. The symbols are transmitted from the multiple transmitting antennas simultaneously during every OFDM symbol period. At the receiver basically the reverse operation to the transmitter is performed. The signal is received by two receiving antennas. At the receiver, first the cyclic prefix is removed. Then the signal is demodulated by an FFT demodulator and data is recovered by the space time decoder.

$$\overline{S_{1,k}}(n) = \sum_{j=1}^{N_r}(H_{1,j,k}(n)R_{j,k}(n) + H_{2,j,k}(n+1)R_{j,k}(n+1)) \text{ (3 a)}$$

$$\overline{S_{2,k}}(n) = \sum_{j=1}^{N_r}(H_{2,j,k}^*(n)R_{j,k}(n)$$
$$+ H_{1,j,k}(n+1)R_{j,k+1}^*(n+1))$$
(3 b)

with k=1, 2, ...,Ns, representing the symbol number, j represent the j-th receive antenna .$\overline{S_{1,k}}(n)$, $\overline{S_{2,k}}(n)$ are the decoded symbols.

### III Performance Analysis of STBC-OFDM

In this paper performance of STBC-OFDM is analyzed. Simulations are done in MATLAB using the Rayleigh fading channel model. For each sample, blocks of 1000 symbols are simulated. The system to be examined have, 2 transmit and 2 receive antennas, maximum Doppler frequency (f = 50 Hz). We have used channel conditions, which have two independent paths with path delays in seconds and average path gains = [0 -18]

dB. The performance is analyzed under following constraints.

1) Effect of Modulation order

The modulation order specifies the number of the different symbols that can be transmitted by a digital communication system. Simulations have been performed using Matlab. In the proposed results, two transmit antennas and two receive antennas with different modulation orders have been used.
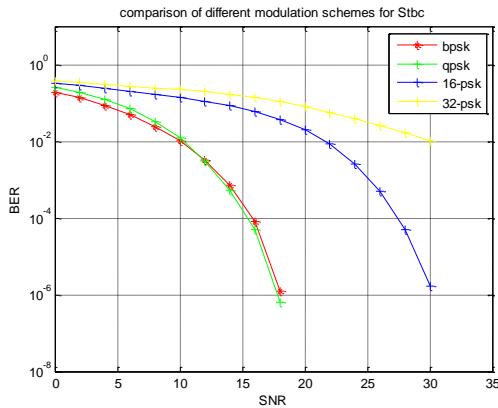


**Fig 2: Performance comparison of 2*2 STBC-OFDM with M-PSK Modulation**

**TABLE 2 For BER= 10^-2**

| Modulation order | BPSK | QPSK | 16-PSK | 32-PSK |
|---|---|---|---|---|
| SNR | 10db | 10db | 21db | 30db |

The simulation results in figure 2 show that increasing the order of modulation will result in a significant SNR loss. Therefore, it can be said that for higher order of modulation order, the system will have higher BER.

2) Effect of Power conditions

We have compared the performance of equal power distributed and unequal power distributed TX antenna. In equal power condition both the Tx are getting same power but in unequal first antenna is getting more power than second one.
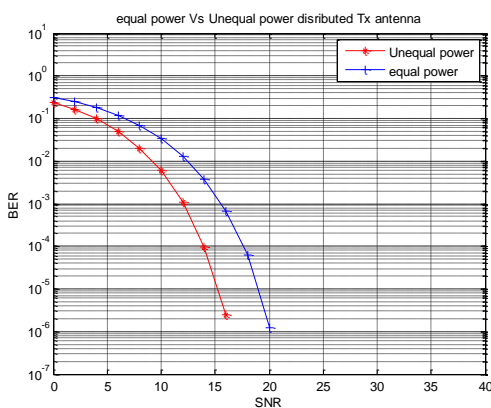


**Fig 3: Performance comparison of 2*2 STBC-OFDM with equal and unequal power distributions**

**TABLE 3 For BER= 10^-5**

| Power Conditions | Unequal power | Equal power |
|---|---|---|
| SNR | 15 db | 18 db |

From the fig. 3, it can be noticed that equal power system gives a 3dB penalty when compared with unequal power system.

3) Effect of Antenna selection technique

Then comparison is carried out with and without antenna selection technique. The antenna selection criterion is based on fading coefficients at all frequency components. The channel coefficients are arranged in descending order for each frequency component. Then best fading coefficient is chosen at each frequency for both of the antennas and then data is sent on antenna with the best fading coefficient at that particular frequency.

a) F1: if H2 [n,1]>H3 [n,1]>H1[n,1], Antenna 2 and 3 are selected.

b) F2:F1:if H1[n,1]>H3[n,1]=H2[n,1], Antenna 1 and either of antennas 2 and 3 can be selected.

c) Fn :if H1[n,1]=H2[n,1]>H3[n,1], Antenna 1 and antenna 2 are selected.



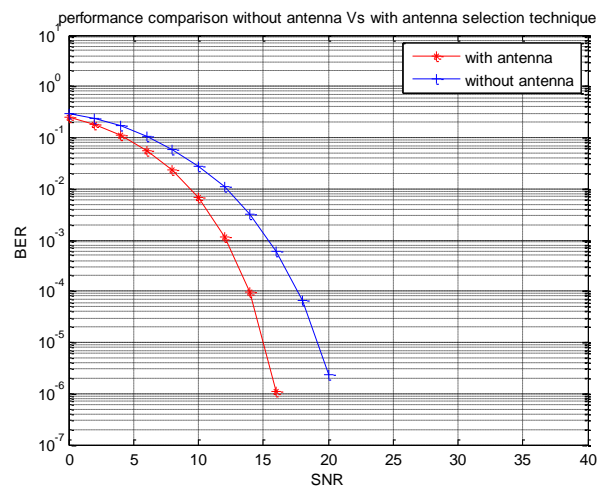**Fig 4: Performance comparison of 2*2 STBC-OFDM with and without antenna selection**

**TABLE 4 For BER= 10^-5**

| Antenna selection technique | With antenna selection | Without antenna selection |
|---|---|---|
| SNR | 15db | 19db |

The simulation results show that STBC-OFDM performs better with the antenna selection technique.

### 4) Slow fading and fast fading:

Fading is deviation of the attenuation that a carrier-modulated telecommunication signal experiences over certain propagation media. The terms slow and fast fading refer to the rate at which the magnitude and phase change imposed by the channel on the signal changes. The coherence time is defined as the time over which the time correlation function is above 0.5 and given as

$$T_c = \frac{9}{16\pi f_d}$$

where $f_d$ is the maximum Doppler shift. Slow fading arises when the coherence time of the channel is large relative to the delay constraint of the channel. Fast fading occurs when the coherence time of the channel is small relative to the delay constraint of the channel.

The Simulation results for different Doppler frequency ($f_d$) 50, 200, 300, 500 are presented.

From the performance result in Figure 4, it can be seen that the performances of STBC-OFDM degrades in fast fading conditions.

## IV CONCLUSION

The paper analyses the performance of STBC-OFDM under different constraints in Rayleigh fading channels. The simulation results are performed in terms of BER & SNR. It is found that the BER performance of the system decreases on increase in modulation order. Performance of STBC-OFDM get improves with unequal power conditions and with antenna selection technique. The system performs well in slow fading (even very slow fading). If fading is somewhat rapid, it does not achieve good performance.
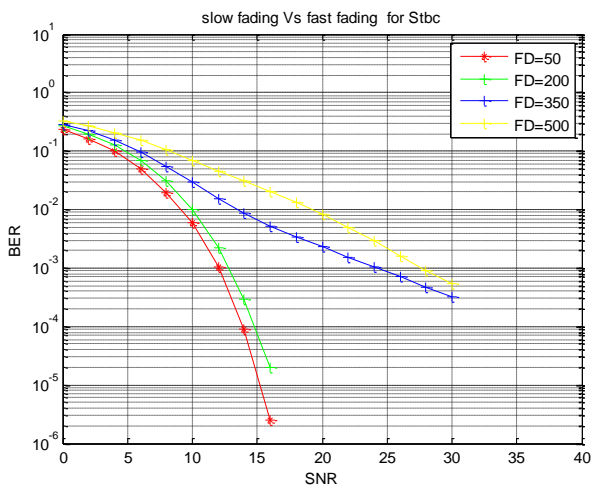


**Fig 5: Performance comparison of 2*2 STBC-OFDM with fd=50, fd=200, fd=350, fd=500**

## REFERENCES

1. [1] S. M. Alamouti, "A simple transmitter diversity scheme for wireless communications," IEEE J. Select. Areas Commun., vol. 16, pp. 1451–1458, Oct. 1998.
2. [2] B. Lu and X. Wang, "Space-time code design in OFDM systems," in *IEEE Conference on Global Telecommunications*, vol.2, pp. 1000-1004*, 2000.*
3. [3Z. Wei, X. Xia and K. Ben Letaief, "Space-Time/Frequency Coding for MIMO-OFDM in Next Generation Broadband Wireless Systems," *IEEE Wireless Communications,* vol. 14, pp.32-43, 2007.
4. [4] 3GPP TR 25.996 V6.1.0, "Spatial Channel Model for Multiple Input Multiple Output (MIMO) Simulations."
5. [5] S. M. Alamouti, "A Simple Transmit Diversity technique for Wireless Communications," *IEEE JSAC*, vol. 16, no. 8, Oct. 1998, pp. 1451–58.
6. [6] W. Huiming, X. Xiang-Gen, Y. Qinye and L. Bin, "A family of space-time block codes achieving full diversity with linear receivers," *IEEE Transactions on Communications,* vol. 57, pp. 3607-3617, 2009.
7. [7] A. Slaney and Y. Sun, "Space-time coding for wireless communications: an overview," *IEE Proceedings in Communications,* vol. 153, pp. 509-518, 2006.
8. [8] S. N. Diggavi, N. Al-Dhahir, A. Stamoulis and A. R. Calderbank, "Great expectations: the value of spatial diversity in wireless networks," *Proceedings of the IEEE,* vol. 92, pp. 219-270, 2004.
9. [9] D. Agrawal, V. Tarokh, A. Naguib and N. Seshadri, "Space-time coded OFDM for high data-rate wireless communication over wideband channels," in *IEEE Conference on Vehicular Technology*, vol.3, pp. 2232-2236*, 1998.*
10. [10] D. Torrieri and M. C. Valenti, "Efficiently decoded full-rate space-time block codes," *IEEE Transactions on Communications,* vol. 58, pp. 480-488, 2010.