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BER & SNR Performance of MIMO OFDM with Space-Time Block Coding

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Abstract

Multi-Input and Multi output-OFDM system which is the merging of two systems, MIMO and OFDM, have more data transmission rate with huge diversity. STBC with MIMO-OFDM has a better performance against the multipath interference including destructive interference which causes fading with less Bit Error rate, coding complexity and more SNR ratio. Created and analyzed a digital prototype of a physical model for estimating the performance of the MIMO-OFDM system with STBC. The analysis carried out here shows that the MIMO-OFDM system along with STBC has better Signal to Noise Power Ratio with less BER than the Non-STBC MIMO-OFDM system.

Keywords: Bit Error Rate (BER), MIMO-OFDM, Signal to Noise Ratio (SNR), Space Time Block Code(STBC).

INTRODUCTION

With a lot of engineering research being pursued in wireless mobile communication systems, two significant areas need to be examined, namely Multi-Path fading and the Frequency Spectrum usage, they impact the signals over the path lengths. The impact of multipath fading can be limited by changing the frequency selective fading channel into flat fading channel. Orthogonal frequency division multiplexing that simplifies technology and produces independent parallel channels in space. The system's transmission rate can be effectively expanded by transmitting numerous data streams in the meantime. MIMO-OFDM systems which consolidate the MIMO and OFDM advances have the two favourable circumstances over them. The fundamentals of MIMO and OFDM are discussed in this paper along with space-time block coding scheme for MIMO- OFDM and analyses the system under AWGN Channel OFDM Technology.

This Technology is a strategy for Digital Communication that breaks a huge transmission capacity into little subcarriers utilizing the Inverse Fast Fourier Transform (IFFT).When the subcarrier signals fulfill the orthogonality condition, spectrum overlaps and improves its spectral efficiency as shown in figure 1. This technique is known as orthogonal FDM or OFDM.The OFDM system block diagram is shown in Figure 2. In the transmitter, modulated signal S_n is changed into N parallel sequence of bits by series-parallel conversion, which corresponding to N different sub-carrier. What's more, a while later it uses modulation to map the constellation points of the channel. Next, it can get a message from transmitted information of OFDM symbols and after IFFT module, parallel to serial converter and embed cyclic prefix (CP). At last, the signal is sent into the channel after a digital to analog conversion.

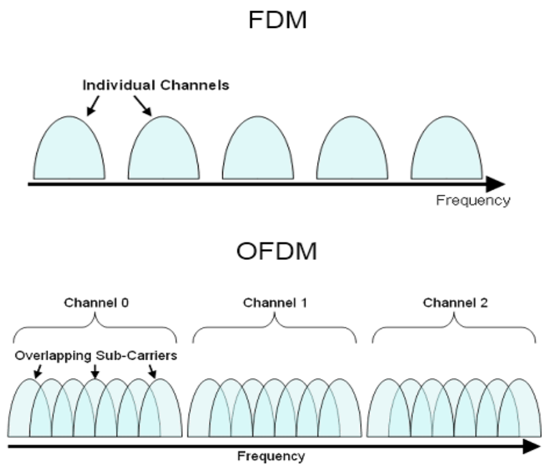

Figure 1. Spectrum of OFDM

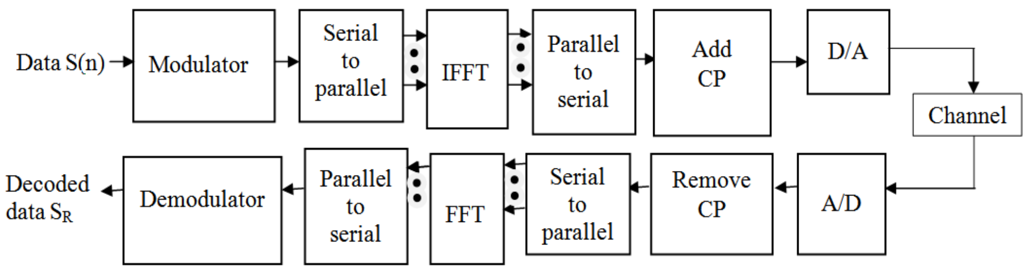

Figure 2. Block Diagram of OFDM

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At Receiver, the analog signal is received from receive antenna will be converted into Digital by analog to digital conversion. Then the message is sent to the following module one by one: removal CP (Cyclic Prefix), series-parallel conversion, FFT process and receives the signal of each sub-carrier. Finally, the sequence of bits of each sub-carrier will be obtained after mapping the constellation points and then passing through series-parallel conversion.

MIMO Technology

Multiple antenna elements are kept at both in transmitter and receiver of MIMO system. It utilizes different antennas to rise the spatial dimension based on the equivalent time dimension, each antenna is autonomous of others. Examination on the capacity of MIMO system in AWGN channel demonstrates that MIMO could build the capacity of wireless communication system considerably compared with SIMO. Let us consider a Single Input-Single Output(SIMO) system with one transmitter antenna, and two receive antenna as shown in figure 3 and suppose that a complex symbol “s” is transmitted in a flat fading condition, at that point two received samples can be written as follows:

$$y_1 = h_1 s + n_1 \quad (1)$$

$$y_2 = h_2 s + n_2 \quad (2)$$

Where the channel gain between the transmitting and the receiving antenna is given by h_1 and h_2 and n_1 and n_2 are the uncorrelated noise.

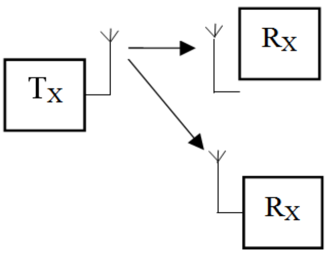

Figure 3. SIMO System

Now let us consider a Multiple Input-Single Output (MISO) system shown in figure 4 with two transmitter antenna and one receiving antenna as shown in the picture. At any given moment of time, the symbol “s” is transmitted by pre-weighted with w1 and w2 and then the received sample will be

$$y=h_1 w_1 s+h_2 w_2 s+n \quad (3)$$

Where h_1 and h_2 indicates channel gain between transmitting, receiving antenna and ‘n’ is the noise sample.

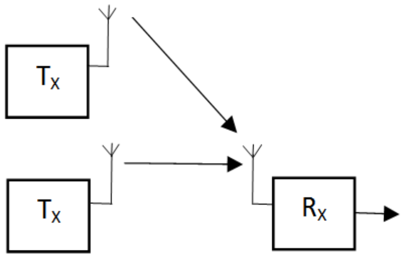

Figure 4. MISO System

Suppose MIMO system has two transmit antennas and two receive antenna as shown in figure 5. We will obtain 2-times of channel capacity, in case, transmission characteristics of the channel are known in the receiver.

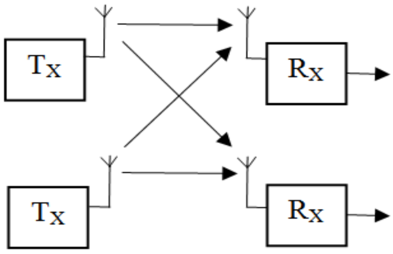

Figure 5. 2x2 MIMO System

Supposed that the MIMO system has N-transmit antennas and N-receive antennas. We will be obtained N times of channel capacity in case of the transmission characteristics of the channel have been known in the receiver with following model shown in figure 6.

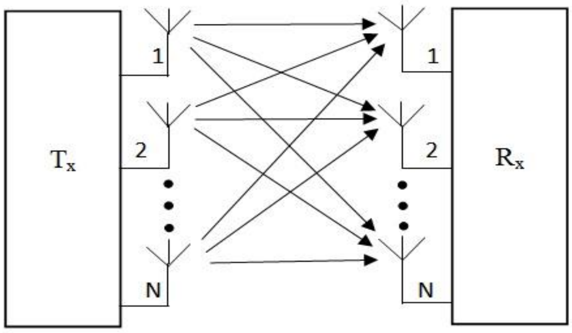

Figure 6. NxN MIMO System

The three specialized points of interest of MIMO are Beamforming , Spatial Diversity and spatial multiplexing. Space-time coding is used to achieve high diversity gain in MIMO system with reduced the probability of symbol error created by channel fading and noise generated due to coding of the data stream, which increases the redundancy of signal and spatial diversity in the receiver with enhanced diversity gain to improve the quality of links . Further, we can develop data transfer rate and spectral efficiency by using higher order modulation under the same security of connections shown in Figure 7.

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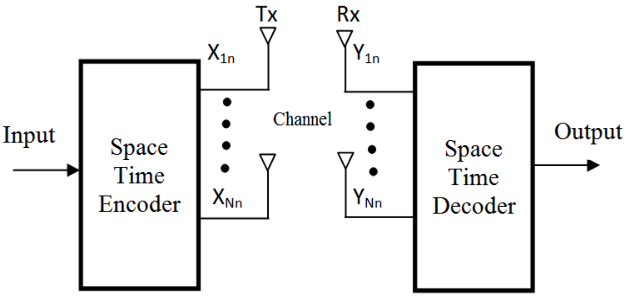


Figure 7. Principles of spatial diversity in MIMO

MIMO-OFDM Technology

MIMO system can make use of multipath components to a considerable extent. Also, it can be anti-multipath fading system. Recently, there are two schemes to solve the problem of frequency selective fading namely Equalization, and OFDM. Although OFDM is critical for the B30&40 broadband wireless communications, its ability to improve the spectrum utilization is limited. Contrarily, MIMO-OFDM provides higher data transfer rate by the developing space resources in OFDM. Because of low bit rate and insertion of the guard interval, OFDM has a large capacity for anti-multi path interference. The system is free from (ISI) inter-symbol interference, as the delay of Multipath is less than the guard interval. So that allows single frequency networks to be used for broadband OFDM systems, which rely on multiple antennas. The MIMO-OFDM scheme is shown in Figure 8.

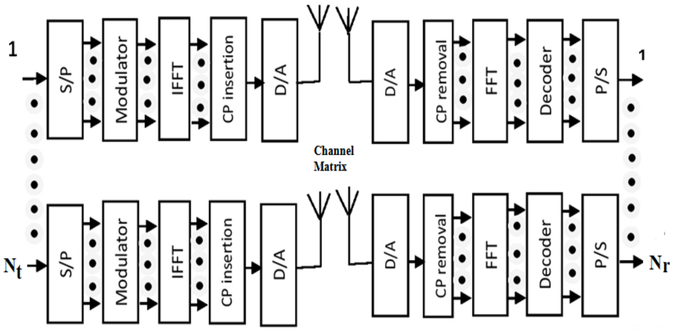
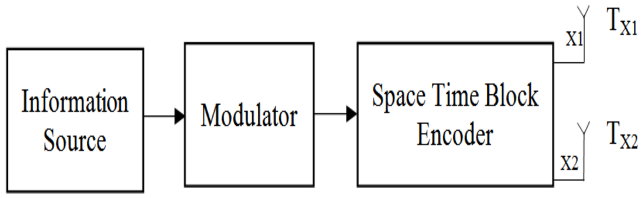


Figure 8. MIMO-OFDM scheme

From Figure 8, we know that MIMO-OFDM system has N_t transmitted antennas and N_r received antennas. Multiple antennas in transmitter and receiver can provide space diversity effect and can reduce the impact of frequency fading. Fading does not occur in all channels of various antennas at the same time. Data input can change into various branches through serial to parallel transform. And each branch will be modulated through OFDM processing, which includes coding, interleaving, QAM mapping, pilot signal inserting, IFFT, cyclic prefix insertion and so on. Then the message will be sent to the wireless channel by the antenna. Ultimately with inverse signal processing as the transmitter, the original data is obtained at receiver



STBC IN MIMO-OFDM SYSTEMS

Space diversity of multiple antennas has good performance against fading in the transmitter and receiver. Transmit diversity, receive diversity and transmit-receive diversity are three kinds of diversities. A system with transmit diversity has multiple sets of antennas in the transmitter, and it will gain spatial heterogeneity by coding different antennas. The input symbols of STBC encoder are isolated into two groups {s_1, S_2} of each team will be transmitted simultaneously in given time period T. S_1 is transmitted from antenna-1 and S_2 is transmitted from antenna-2. $-S_2$* will be sent from antenna-1 and $-S_1$* is transmitted from antenna-2. It is shown as

$$\begin{bmatrix} s_1 & s_2 \end{bmatrix} \rightarrow \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix} \qquad (4)$$

And the STBC Encoder Block diagram is Shown in figure 9.

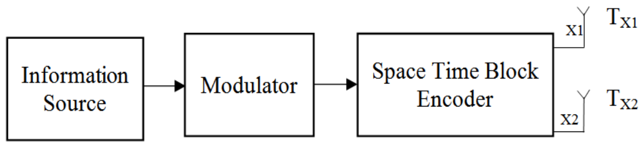


Figure 9. STBC Encoder Block diagram

In 1998 Alamouti proposed STBC with two antennas. Its structure is shown in Figure 10. It is the only pure STBC which can achieve full Gain. S_1 and S_2 are transmitted from both the antennas independently. At any given timeslot t. $-S_2$* will be transmitted from antenna-1 and S_1* is transmitted from antenna-2 at t+T. In the receiver, r_1 is received at timeslot 1, and r2 is received at timeslot 2. At the same time, n_1 and n_2 noise occur in r_1 and r_2 in the receiver.

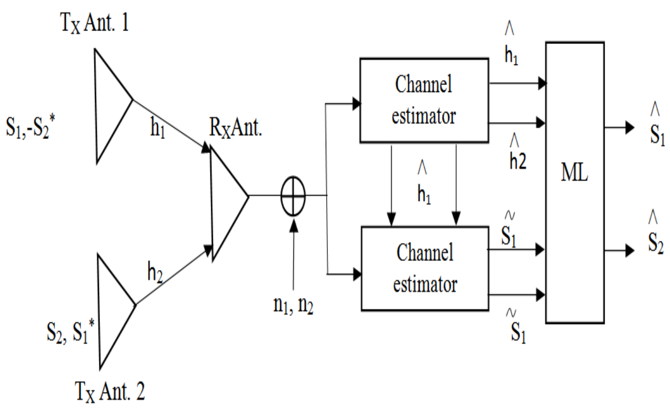


Figure 10. Alamouti's STBC

That is shown as

$$r_1 = h_1 s_1 + h_2 s_2 + n_1 \quad (5)$$

$$r_2 = -h_1 s_2^* + h_2 s_1^* + n_2 \quad (6)$$

$$s_1 = h_1^* r_1 + h_2 r_2^* = (|h_1|^2 + |h_2|^2) s_1 + h_1^* n_1 + h_2 n_2 \quad (7)$$

$$s_2 = h_2 r_1^* + h_1 r_2^* = (|h_1|^2 + |h_2|^2) s_2 + h_2^* n_1 + h_1 n_2 \quad (8)$$

Where h_1, h_2 is the channel fading factor it obeys the Rayleigh distribution. From Eq.(4) and Eq. (5), we can conclude that STBC with two antennas has 2nd order diversity gain with code rate is equal to 1.While full rate is maintained, there is no loss of frequency utilization. Extending to N-STBC receiver, we can obtain 2xN-orders diversity gain. Assume that the received signal of the system can be expressed as

$$r = hs + n \quad (9)$$

Where s is the sending vector, r is the received vector; and then we can get S^, that is an estimate of transmitted signal s, after a simple linear processing in the receiver. There are lots of MIMO detection algorithms. The performance of an algorithm is mainly based on the probability of P_e, which makes S^≠s. The smaller P_e, the better performance of the algorithm. Maximum likelihood criterion (ML) is a conventional MIMO detection algorithm. Although the performance of this algorithm is better than others, the computational complexity will be an exponential growth of the number of antennas and modulation orders [6] [7]. The posterior probability should be maximal to limit the decision error probability. We can write posterior probability as

$$P(s_j \mid r) = \frac{P(r \mid s_j) P(s_j)}{P(r)} \quad (10)$$

So $P(S_j |r)$ should be maximal. In calculating the easily, We chose its likelihood number. So Eq.(7) can be expressed as

$$P(r \mid s_j) = \frac{1}{(\pi N_0)^{\frac{N}{2}}} \exp[-\sum_{k=1}^{N} \frac{(r_k - s_{jk})^2}{N_0}] \quad (11)$$

After logarithmic transformation, $P(s_j|r)$ can be written as

$$\ln P(r \mid s_j) = -\frac{1}{2} N \ln(\pi N_0) - \sum_{K=1}^{N} \frac{(r_k - s_{jk})^2}{N_0} \quad (12)$$

The distance D(r, SJ) should be minimal to maximize likelihood number. D(r, S_j) is written as

$$D(r, s_j) = \sum_{k=1}^{N} (r_k - s_{jk})^2 = \| r - s_j \|^2 \quad (13)$$

Therefore, we can get the maximum likelihood decision rule for the receiver as the following equation.

$$\hat{s} = \arg\min(\| r - hs_j \|^2) \quad (14)$$

Because of full diversity gain and lower decoding complexity, STBC has become the preferred scheme for the wireless systems.

SIMULATION RESULTS

Simulation parameters considered here are shown below table 1

Table 1. The parameters considered for simulation

Parameters	
Channel Type	Rayleigh Fading
No. Of Sub-Carriers(N)	64
Channel Attenuation(dB)	Ideal (1)
Diversity Scheme	2 or 4 or 6 Tx, 1Rx
Antenna Transmitting Power	Equality
Modulation Type	16QAM

SIMULATION RESULT ANALYSIS

The simulation was carried out under different diversity cases by taking the parameters as shown in Table 1.Simulation Results are summarized in Table 2. The performance of the OFDM systems for different diversity schemes with & without STBC are shown below in Figure 11,12 &13.

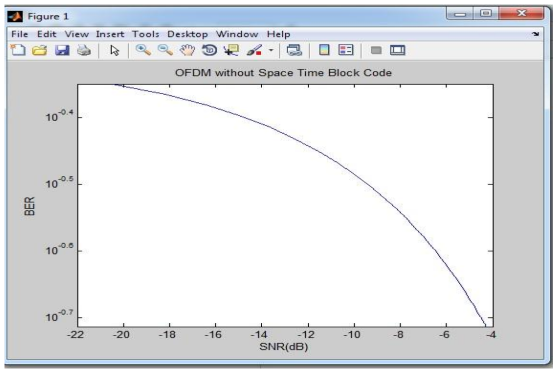


Figure 11. OFDM without STBC

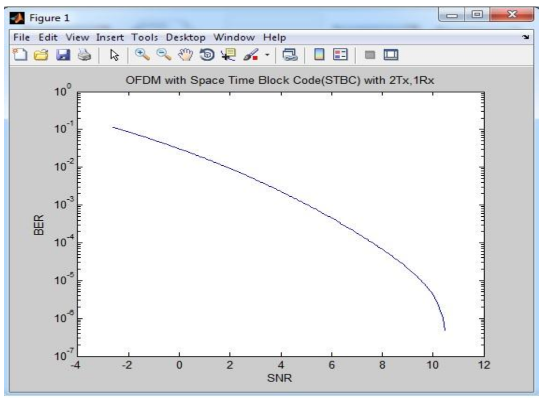


Figure 12. OFDM with STBC with 2Tx, 1Rx

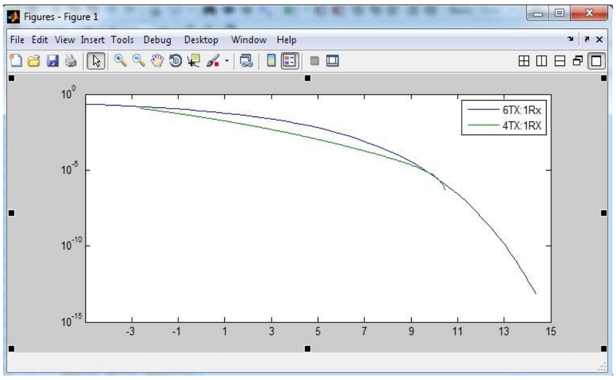


Figure 13. OFDM with STBC with 4Tx, 6Tx,1Rx

The simulation results are summarized in the following Table 2.

Table 2. Simulation Results summery

OFDM without STBC		OFDM with STBC		
BER	SNR(dB)	Diversity type	BER	SNR(dB)
0.79	-4	2Tx,1Rx	0.15	10.98
		4Tx,1Rx	0.11	11.01
		6Tx,1Rx	0.09	14.90

Simulation Results shows that the diversity Scheme with 6Tx,1Rx has better SNR and low BER value due to STBC Coding.

CONCLUSION

Simulation results show that MIMO-OFDM with STBC has an outstanding impact against Multi-path effects and frequency selective fading. And it can satisfies reliable high data transmission rate through diversity what's more its BER and coding complexity are low with increased SNR This paper provides an effective theoretical basis for evaluating the performance of Practical MIMO-OFDM systems with STBC.

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