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BER Performance of MIMO-OFDM System using STTC

K.Vidhya [*], K.R.Shankarkumar [**]

[*] AP/ECE, Sri Ramakrishna Engineering College, Coimbatore-22, Email:vidhyasrec@gmail.com
[**] Professor/ECE, Sri Ramakrishna Engineering College, Coimbatore-22, Email:shanwire@gmail.com

Abstract- This paper provides the channel parameter estimation and bit error rate performance for multiple-input multiple-output (MIMO) orthogonal frequency division multiplexing (OFDM) system in new transmission scheme. Channel estimation parameter and bit error rate calculation for 2 x 2 MIMO OFDM system is performed. This new transmission scheme is used in symmetric channels such as the link between two transmit antennas and two receive antennas in the system. Channel parameters are estimated with the help of pilot data. These are send by the receiver to the transmitter. The proposed 2 x 2 MIMO channel model provides good performance compared to conventional MIMO OFDM system model. Mat lab software is used to simulate the results in this paper.

I. INTRODUCTION

High data rate wireless communication links with transmission rates nearing 1 Gigabit/second , in which channel capacity is achieved[1]. MIMO OFDM system model provides high speed links that offer good quality of service , this will minimize the probability of error. Real life issues are minimize complexity and cost of implementation of proposed system, minimize the transmission power required and bandwidth used. MIMO is known to boost channel capacity[2]. OFDM system is band width efficient, robust to multipath fading , easy to implement by using IFFT /FFT algorithm and flexible in resource allocation. It converts a frequency selective channel into a parallel collection of frequency flat sub channels[3]. It improves multipath fading issues. It reduces the effect of inter symbol interference.

In OFDM system, transmitter side initially the high serial data rate input with sampling time T_s is modulated using any digital modulation techniques to give digital symbols. Next the modulated serial data is converted to low rate parallel data stream using serial to parallel converter. Due to this parallel conversion, the effective symbol duration is increased to $T= MT_s$. To mitigate the effect of ISI , cyclic prefix is used.

In Channel the transmitted signal x(t) travels though wireless channel through multipath in various types of environments (indoor, outdoor , static and mobile)thus the signal y(t) undergo distortion, scattering, reflection and addition of noise. These phenomenon ultimately characterizes the channel mathematically in terms of delay spread and fading coefficients of the channel which are treated as random variables.

In receiver side cyclic prefix is carried out from the received signal first. After CP removal the signal is demodulated using FFT, which converts the time domain signal to frequency domain signal. MIMO encoding, such as Alamouti Space Time Block coding (STBC), the Vertical Bell-Labs layered Space Time Block code (VBLASTSTBC), and Space-Time Trellis Code (STTC)[4]

In this paper, channel parameter estimation and bit error rate performance of MIMO OFDM systems is proposed. The no of receiving antennas increases, bit error rate will be reduces significantly for the symmetric channel. The principal of this paper is based on channel coding which make use of the estimated channel parameters extracted from a pilot signal transmitted by the destination receiver.

The paper is described as follows. In section II, the conventional MIMO-OFDM system is described. In section III, the new transmission model is presented. In section IV, the channel matrix and bit error rate performances of the proposed transmission scheme are analyzed via simulations, and a comparative study with the conventional MIMO-OFDM system using space time trellis code (STTC) encoder is also described. Finally, conclusions are drawn in section V.

II. CONVENTIONAL MIMO-OFDM SYSTEM

The conventional MIMO-OFDM system is shown in figure 1. The proposed system consists of 2 transmit and 2 receive antennas. In transmitter side initially maps the sequence of bits in each spatial stream to constellation points. Then it is encoded in to digital form. A pilot sequence is inserted and used for the channel estimation. Then, a cyclic prefix is inserted in front of the OFDM symbol at the last step of OFDM modulation block. The time length of the cyclic prefix should be greater than the maximum delay spread of the channel[5]. The purpose of adding cyclic prefix is to guard the OFDM symbol against Inter Symbol Interference (ISI), hence, this cyclic prefix is called the guard interval of the OFDM symbols. The MIMO coding can use several encoders such as STBC, STTC coding. In this paper, the conventional MIMO-OFDM system is implemented using STTC with two transmit and two receive antennas[6].

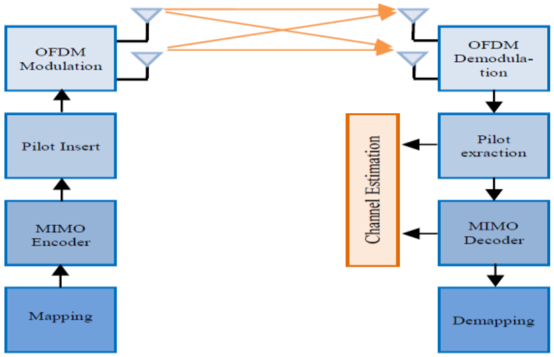

Figure 1.Conventional MIMO-OFDM system model

III. New Transmission Model

The new transmission model is suitable for symmetric channels, such as the transmission between two transmit antennas and two receive antennas. The proposed MIMO-OFDM model is shown in the following figure 2.

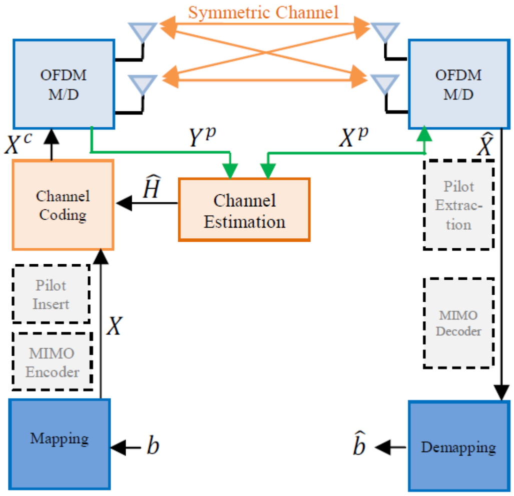

Figure 2. Proposed MIMO-OFDM system model for symmetric channel.

In this new MIMO-OFDM model, the channel parameters are estimated from a pilot data transmitted by the receiver side[7]. These estimated parameters are used by a special channel coding block to adapt the transmitter signal to the diverse channel impairments and variations[8]. To reduce the system complexity we have removed the pilot insert, the pilot extraction, the MIMO encoder and the MIMO decoder from the conventional MIMO-OFDM scheme[9]. The channel coding is based on the channel parameters , this channel in our case is between two transmit antennas and two receive antennas, and it can be modeled as shown in the figure 2. First, the receiver send a pilot signal to the transmitter, which can expressed as follows :

$$\begin{cases} Y_1^p = H_{11}.X_1^p + H_{21}.X_2^p + N_1^p \\ Y_2^p = H_{12}.X_1^p + H_{22}.X_2^p + N_2^p \end{cases} \qquad (1)$$

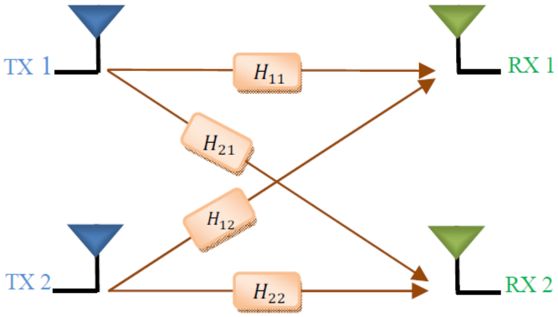

Figure 3. 2 x 2 channel model

Where:

X_1^p and X_2^p are the orthogonal transmitted pilot signals from the transmit antenna TX1 and TX2 respectively.

Y_1^p and Y_2^p are the received pilot signals on the receive antenna RX1 and RX2 respectively.

Y_1^2 and Y_2^2 are the received information at time slot 2 on receive antenna RX1 and RX2 respectively.

H_{ij} is the channel from j^{th} transmit antenna *TXj* to i^{th} receive antenna *RXi* with *i* and *j* ε {1,2}.

N_1^p and N_2^p are the noise components on receive antenna RX1 and RX2 respectively.

N_1^2 and N_2^2 are the noise at time slot 2 on the receive antenna RX1 and RX2 respectively.

Let us also define the pilot received signal Y^p the matrix channel H the pilot transmitted signal X^p and the noise vector N^p as follows respectively.

$$Y^p = \begin{bmatrix} Y_1^p \\ Y_2^p \end{bmatrix} \qquad \mathrm{H} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix}$$

$$X^p = \begin{bmatrix} X_1^p \\ X_2^p \end{bmatrix} \text{ and } \mathrm{N}^p = \begin{bmatrix} N_1^p \\ N_2^p \end{bmatrix}$$

By using the above notations, equation (1) can be rewritten as

$$Y^p = H'.X^p + N^p \qquad (2)$$

Using the transmitted pilot signal X^p and the received pilot signal Y^p, the channel parameters are estimated as following

$$\hat{H}_{11} = \left(Y_1^p.X_1^p\right) / \left(X_1^p\right)^2$$

$$= \left(H_{11}.X_1^p.X_1^p + H_{21}.X_2^p.X_1^p\right) + N_1^p.X_1^p / \left(X_1^p\right)^2$$

$$= \mathrm{H}_{11} + \frac{\mathrm{N}_1^p}{X_1^p} \tag{3}$$

The term $X_2^p.X_1^p = 0$ because the pilots X_2^p and X_1^p are chosen to be orthogonal signals.

In addition, if the pilot signal power is $\left\|X_1^p\right\|^2 >> 1$ then

$$\hat{\mathrm{H}}_{11} \approx \mathrm{H}_{11} \tag{4}$$

Similarly, all channel parameters H_{ij} can be easily deducted

$$\begin{aligned}
\hat{H}_{21} &= \left(Y_1^p.X_2^p\right)/\left(X_2^p\right)^2 \\
&= \left(H_{11}.X_1^p.X_2^p + H_{21}.X_2^p.X_2^p\right) + N_2^p.X_2^p/\left(X_2^p\right)^2 \\
&= \mathrm{H}_{21} + \frac{\mathrm{N}_2^p}{X_2^p} \\
\hat{\mathrm{H}}_{21} &\approx \mathrm{H}_{21}, \qquad \left(if\ \left\|X_2^p\right\|^2 >> 1\right)
\end{aligned} \tag{5}$$

$$\begin{aligned}
\hat{H}_{12} &= \left(Y_2^p.X_1^p\right)/\left(X_1^p\right)^2 \\
&= \left(H_{12}.X_1^p.X_2^p + H_{22}.X_2^p.X_1^p\right) + N_2^p.X_1^p/\left(X_2^p\right)^2 \\
&= \mathrm{H}_{12} + \frac{\mathrm{N}_1^p}{X_1^p} \\
\hat{\mathrm{H}}_{12} &\approx \mathrm{H}_{12} \qquad \left(if\ \left\|X_1^p\right\|^2 >> 1\right)
\end{aligned} \tag{6}$$

$$\begin{aligned}
\hat{H}_{22} &= \left(Y_2^p.X_2^p\right)/\left(X_2^p\right)^2 \\
&= \left(H_{12}.X_1^p.X_2^p + H_{22}.X_2^p.X_2^p\right) + N_2^p.X_2^p/\left(X_2^p\right)^2 \\
&= \mathrm{H}_{22} + \frac{\mathrm{N}_2^p}{X_2^p} \\
\hat{\mathrm{H}}_{22} &\approx \mathrm{H}_{22} \qquad \left(if\ \left\|X_2^p\right\|^2 >> 1\right)
\end{aligned} \tag{7}$$

By combining results obtained from equations (3), (5), (6) and (7), a more compact expression can be easily written

$$\begin{bmatrix} \hat{H}_{11} & \hat{H}_{21} \\ \hat{H}_{12} & \hat{H}_{22} \end{bmatrix} = \left(\begin{bmatrix} Y_1^p \\ Y_2^p \end{bmatrix}.[X_1^p\ X_2^p]\right).\begin{bmatrix} 1/\left(X_1^p\right)^2 & 0 \\ 0 & 1/\left(X_2^p\right)^2 \end{bmatrix} \tag{8}$$

$$\begin{bmatrix} \hat{H}_{11} & \hat{H}_{21} \\ \hat{H}_{12} & \hat{H}_{22} \end{bmatrix} = \hat{H} = \begin{bmatrix} H_{11} + \frac{N_1^p}{X_1^p} & H_{21} + \frac{N_2^p}{X_2^p} \\ H_{12} + \frac{N_1^p}{X_1^p} & H_{22} + \frac{N_2^p}{X_2^p} \end{bmatrix} \tag{9}$$

If $\left(\left\|X_1^p\right\|^2 and \left\|X_2^p\right\|^2 >> 1\right)$ then

$$\hat{\mathrm{H}} \approx \mathrm{H} \tag{10}$$

Moreover, equation (9) can be further simplified and rewritten as follows.

$$\hat{\mathrm{H}} = \left((\mathrm{Y}^{\mathrm{P}}.(X^{\mathrm{P}})).A\right) \tag{11}$$

Where,

$$A = .\begin{bmatrix} 1/\left(X_1^p\right)^2 & 0 \\ 0 & 1/\left(X_2^p\right)^2 \end{bmatrix} \tag{12}$$

Finally, the channel can be easily estimated using the following expression

$$\hat{\mathrm{H}} = A'.\left(Y^p.(X^p)'\right)' \tag{13}$$

$$\Leftrightarrow \hat{\mathrm{H}} = A'.\left(X^p.(Y^p)'\right) \tag{14}$$

$$\Leftrightarrow \hat{\mathrm{H}} = A.\left(X^p.(Y^p)'\right) \tag{15}$$

Consequently, the channel coding principal can be easily implemented by just multiplying the original transmitted signal with the inverse of the estimated channel to extract the coded signal X^c given by

$$X^c = \hat{H}^{-1}.\ \mathrm{X} \approx H^{-1}.X \tag{16}$$

The received signal of the second time slot is given by the following equation (17)

$$\begin{cases} Y_1^2 = H_{11}.X_1^c + H_{12}.X_2^c + N_1^2 \\ Y_2^2 = H_{22}.X_1^c + H_{22}.X_2^c + N_2^2 \end{cases} \tag{17}$$

$$\Leftrightarrow \begin{bmatrix} Y_1^2 \\ Y_2^2 \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix}.\begin{bmatrix} X_1^c \\ X_2^c \end{bmatrix} + \begin{bmatrix} N_1^2 \\ N_2^2 \end{bmatrix} \tag{18}$$

$$\Leftrightarrow \mathrm{Y} = H.X^c + \mathrm{N} \tag{19}$$

The advantage of this channel coding is that there is no need to perform the channel estimation and MIMO encoding at the receiver, because going through the channel the received signal becomes

$$Y = H.X^{c} + N = H.\hat{H}^{-1}.X + N$$

$$\Leftrightarrow Y = \hat{X} \approx X + N \qquad (20)$$

So we can directly demodulate the received signal to find the estimation of the original transmitted symbol .

IV. SIMULATION RESULTS

The new transmission MIMO-OFDM system is simulated using parameters shown in Table 1. These parameters are based on transmission between two transmit and two receive antennas.

Table 1. Simulation Parameters

Parameters	**Specifications**
System	2x2 MIMO-OFDM
No of Subcarrier	64
Modulation	QAM
Delay Spread	15
Size of DFT/IDFT	64
MIMO encoder	STTC (2Tx 2Rx)

In this paper we are interested in comparing the proposed scheme with the conventional MIMO- OFDM system in the case of symmetric channel based on STTC coding [10]. This simulation considers the transmission between two transmit and receive antennas . The channel parameters are used for the channel coding in the new transmission scheme[11].

Figure 4 shows the variation of BER as a function of SNR. This system has better performances than the conventional MIMO-OFDM system. Besides the performance of this scheme, its complexity is low and there are no needs of complicate MIMO encoder or channel estimation at the receiver side. In addition, to the simplification of the conventional MIMO-OFDM system, bandwidth efficiency can be highly increased.

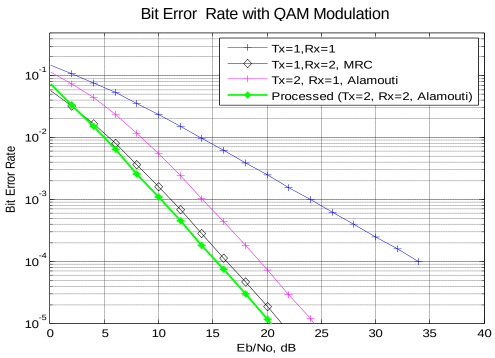

Figure 4. Bit Error R ate as function of Signal to Noise Ratio

Table 2 shows the values of BER corresponding SNR The proposed scheme has better performances than the conventional MIMO-OFDM system when the number of antennas increases.

Table 2 . SNR Vs BER values for MIMO OFDM System

Eb/No	BER			
	1Tx 1Rx	1Tx 2Rx	2Tx 1Rx	2Tx 2Rx
0	0.1464	0.0581	0.1151	0.0759
2	0.1085	0.0328	0.0748	0.0348
4	0.0771	0.0169	0.0442	0.0146
6	0.0530	0.0081	0.0239	0.0064
8	0.0355	0.0037	0.0119	0.0028
10	0.0233	0.0016	0.0055	0.0011
12	0.0151	$6.74e^{-4}$	0.0024	$4.3799\ e^{-4}$
14	0.0097	$2.7843e^{-4}$	0.0010	$1.8634e^{-4}$
16	0.0062	$1.1351e^{-4}$	$4.3606e^{-4}$	$7.5599e^{-5}$
18	0.0039	$4.587e^{-5}$	$1.7884e^{-4}$	$2.936e^{-5}$
20	0.0025	$1.8442e^{-5}$	$7.2564e^{-5}$	$1.1225e^{-5}$
22	0.0016	$7.3867e^{-6}$	$2.924e^{-5}$	$4.7282e^{-6}$
24	$9.9231e^{-4}$	$2.9521e^{-6}$	$1.1731e^{-5}$	$1.8987e^{-6}$
26	$6.2679e^{-4}$	$1.1781e^{-6}$	$4.6928e^{-6}$	$7.4031e^{-7}$
28	$3.9575e^{-4}$	$4.6974e^{-7}$	$1.874e^{-6}$	$2.953e^{-7}$
30	$2.4981e^{-4}$	$1.8719e^{-7}$	$7.4757e^{-7}$	$1.1871e^{-7}$
32	$1.5766e^{-4}$	$7.4567e^{-8}$	$2.9795e^{-7}$	$4.9188e^{-8}$
34	$9.9497e^{-5}$	$2.9697e^{-8}$	$1.1871e^{-7}$	$1.9007e^{-8}$

Table 3 shows the channel parameter values for 2x2 channel model for only five subcarriers.

Table 3 . Channel Matrix of 2 x 2 Channel Model

H_{11}	H_{12}	H_{21}	H_{22}
2.0195+0.0 ….	2.0195+0.0….	2.0195+0.0….	2.0195+0.0 ….
1.9617+0.2 ….	1.9617+0.2….	1.9617+0.2….	1.9617+0.2 ….
1.8093+0.5 ….	1.8093+0.5….	1.8093+0.5….	1.8093+0.5 ….
1.6111+0.6 ….	1.6111+0.6….	1.6111+0.6….	1.6111+0.6 ….
1.4134+0.7 ….	1.4134+0.7….	1.4134+0.7….	1.4134+0.7 ….

V. CONCLUSION

This paper provides channel parameter estimation and bit error rate performance for multiple-input multiple-output (MIMO) orthogonal frequency division multiplexing (OFDM) systems in new transmission scheme. This system is based on channel coding using estimated channel parameters from a transmitted pilot data at the receiver end. Simulation results confirm the high performance and the low complexity of the proposed transmission scheme when compared to the conventional MIMO OFDM system using STTC Coding.

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AUTHORS

First Author – K.Vidhya obtained her Bachelor’s degree in Electronics and Communication Engineering from University of Madras. Then she obtained her Master’s degree in Communication Systems from Anna University Chennai and pursuing PhD in wireless communication in Anna University, Chennai. She is a Assistant Professor at the Faculty of Electronics and Communication Engineering, Sri Ramakrishna Engineering College, Coimbatore. Her specializations include Wireless Communication, Wireless networks. Her current research interests are channel estimation on OFDM Systems. She is a member of ISTE, IETE.

Second Author – Dr.K.R.Shankar Kumar received the B.E. degree in Electronics and Communication Engineering from the Coimbatore Institute of Technology, Coimbatore in 1997, M.E. degree in Electronics from the Madras Institute of Technology, Chennai , in 1999, and the Ph.D. degree in CDMA Systems from the Indian Institute of Science, Bangalore in 2004. He is currently Professor in the Department of Electronics and Communication Engineering at Sri Ramakrishna Engineering College, Coimbatore . His specializations are Mathematics and Wireless Communication. His current research interests are MIMO systems, Transceiver Design. He is a member of IEEE, ISTE, IETE.