NEW TRANSMISSION SCHEME FOR MIMO-OFDM SYSTEM

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ABSTRACT

This contribution introduces a new transmission scheme for multiple-input multiple-output (MIMO) orthogonal frequency division multiplexing (OFDM) systems. The new scheme is efficient and suitable especially for symmetric channels such as the link between two base stations or between two antennas on radio beam transmission. The principle is based on the estimation of channel parameters of a pilot data send by the receiver to the transmitter. Then, the transmitter codes the transmitted signal using the estimated channel parameters to adapt the signal to the channel variations. Conducted Monte-Carlo simulation results show that the proposed scheme has better performance, in terms of bandwidth efficiency and complexity, compared to the conventional MIMO-OFDM scheme methods in the case of a symmetric channel.

KEYWORDS

LTE, Channel Coding, MIMO, OFDM, Symmetric channel.

1. INTRODUCTION

In recent years, orthogonal frequency division multiplexing (OFDM) technique has attracted a lot of attention in the standardization of broadband wireless systems. OFDM technique is a multicarrier modulation technique with a rather simple implementation performed using FFT/IFFT algorithms, and robust against frequency-selective fading channels which is obtained by converting the channel into flat fading subchannels [1]. OFDM has been adopted for various of transmission systems such as Wireless Fidelity (WIFI), Worldwide Interoperability for Microwave Access (WIMAX), Digital Video Broadcasting (DVB), Long Term Evolution (LTE) [2].

Combining OFDM with multiple input multiple output (MIMO) technique increases spectral efficiency to attain throughput of 1 Gbit/sec and beyond, and improves link reliability [3]. MIMO concept can be implemented in various ways, if we need to use the advantage of MIMO diversity to overcome the fading then we need to send the same signals through the different MIMO antennae, and at the receiver end, the different antennae will receive the same signals traveled through diverse paths. If we want to use MIMO concept for increasing capacity then we need to send different set of data at the same time through the different MIMO antennae without the automatic-repeat request of the transmission.

Theoretically, MIMO technique to be efficient the antenna spacing needs to be at least half the wavelength of the transmitted signal, even though, in some recent research this theoretical bound has been conquered and recently some broadband mobile phones support more than one antenna [3]&[4]. Efficient implementation of MIMO-OFDM system is based on the Fast Fourier Transform (FFT) algorithm and MIMO encoding, such as Alamouti Space Time Block coding (STBC), the Vertical Bell-Labs layered Space Time Block code VBLASTSTBC, and Golden Space-Time Trellis Code (Golden STTC).

DOI : 10.5121/ijngn.2011.3102

In this paper, a new transmission scheme for MIMOOFDM systems is proposed. The new transmission approach reduces significantly the complexity of the conventional MIMO-OFDM systems for the symmetric channel. The principal of the proposed scheme is based on channel coding which make use of the estimated channel parameters extracted from a pilot signal transmitted by the destination receiver. Thus, the transmitted signal is very much adapted to the channel impairments and variations.

The paper is organized 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 performances of the proposed transmission scheme are analyzed via simulations, and a comparative study with the conventional MIMO-OFDM system using Alamouti encoder is also conducted. Finally, conclusions are drawn in section V. Although formatting instructions may often appear daunting, the simplest approach is to use this template and insert headings and text into it as appropriate.

2. CONVENTIONAL MIMO-OFDM SYSTEM

The general structure of MIMO-OFDM system is shown in figure 1. The proposed system consists of 2 transmit and 2 receive antennae. The OFDM signal for each antenna is obtained by applying the inverse Fast Fourier transform (IFFT) and can be detected using Fast Fourier transform (FFT) [5]. A pilot sequence is inserted and used for the channel estimation. Also, 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. The main function of the 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 [Ref]. The MIMO coding can use several encoders such as STBC, VBLAST and Golden coding. In this paper, the conventional MIMO-OFDM system is implemented using Alamouti STBC with two transmits and two receive antennas.

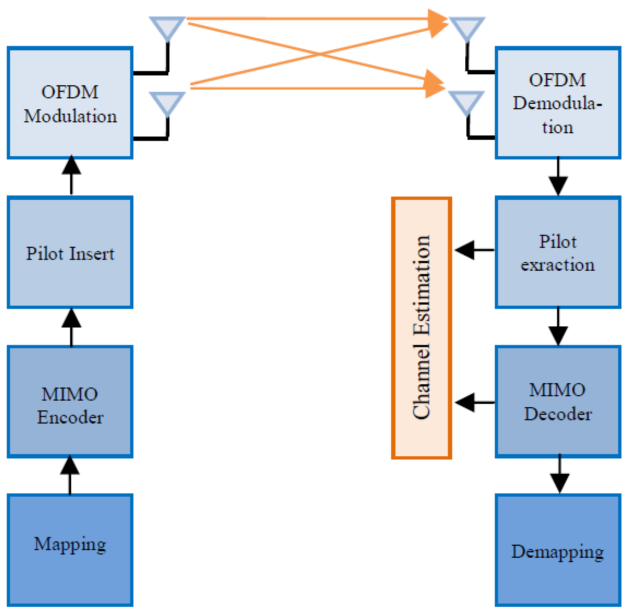

Figure 1. MIMO-OFDM system model.

3. NEW TRANSMISSION MODEL

The new transmission model is suitable for symmetric channels, such as the transmission between two base stations, microwave links, or radio beam transmission. The proposed MIMO-OFDM model is shown in the following figure 2.

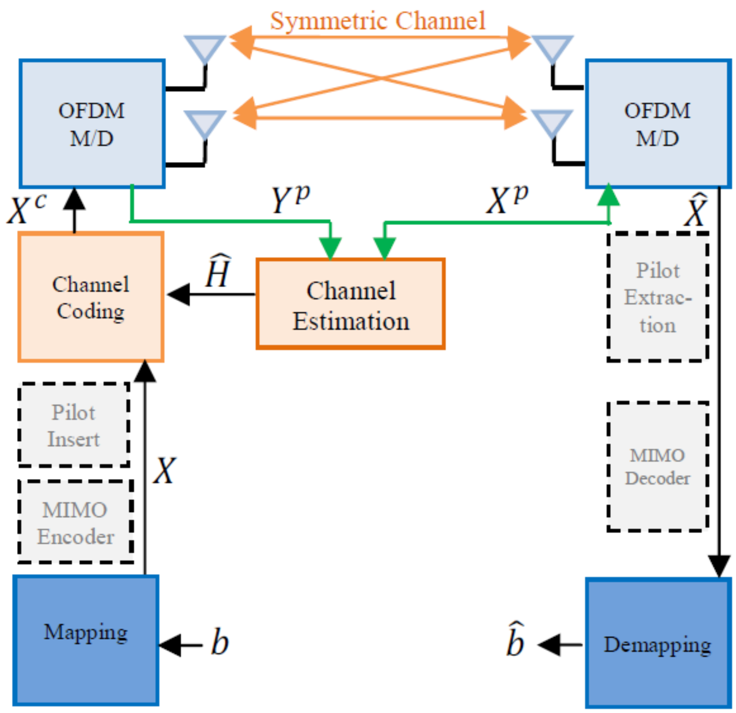

Figure 2. Proposed MIMO-OFDM system model for symmetric channel.

In this new MIMO-OFDM model, the channel parameters are estimated from a pilot data transmitted by the receiver end. These estimated parameters are used by a special channel coding block to adapt the transmitter signal to the diverse channel impairments and variations. 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. The channel coding is based on the channel variations, this channel in our case is between two transmit antennae and two receive antennae, and it can be modelled as shown in the figure 2. First, the receiver send a pilot signal to the transmitter, which can expressed as follows :

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

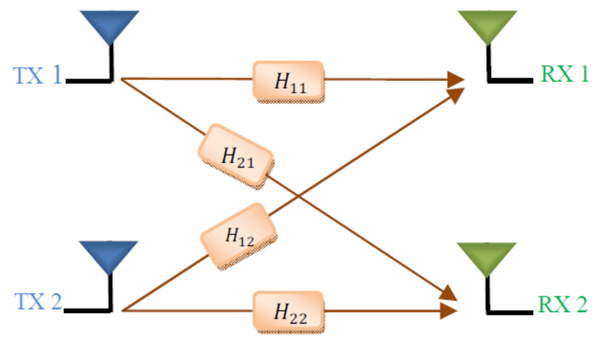

Figure 3. MIMO channel model.

Where:
X_1^p and X_2^p are the orthogonal transmitted pilot signals from the transmit antenna RX1 and RX2, respectively.
Y_1^p and Y_2^p are the received pilot signals on the receive antenna TX1 and TX2, 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 $i\ and\ j \in \{1,2\}$.
N_1^p and N_2^p are the noise components on receive antenna TX1 and TX2, respectively.
N_1^2 and N_2^2 are the noise at time slot 2 on the receive antenna TX1 and TX2 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.

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

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

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

$$Y^p = H'.X^p + N^p \tag{2}$$

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

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

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

$$= H_{11} + \frac{N_1^p}{X_1^p} \tag{3}$$

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 $\|X_1^p\|^2 \gg 1$ then

$$\widehat{H}_{11} \approx H_{11} \tag{4}$$

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

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

$$\begin{aligned}\widehat{H}_{12} &= \left(Y_2^p.X_1^p\right) / \left(X_1^p\right)^2 \\ &= \left(H_{12}.X_1^p.X_1^p + H_{22}.X_2^p.X_1^p + N_2^p.X_1^p\right) / \left(X_2^p\right)^2 \\ &= H_{12} + \frac{N_1^p}{X_1^p} \approx H_{12}, \left(if\ \left\|X_1^p\right\|^2 \gg 1\right)\end{aligned} \tag{6}$$

$$\begin{aligned}\widehat{H}_{22} &= \left(Y_2^p.X_2^p\right) / \left(X_2^p\right)^2 \\ &= \left(H_{12}.X_1^p.X_2^p + H_{22}.X_2^p.X_2^p + N_2^p.X_2^p\right) / \left(X_2^p\right)^2 \\ &= H_{22} + \frac{N_2^p}{X_2^p} \approx H_{22}, \left(if\ \left\|X_2^p\right\|^2 \gg 1\right).\end{aligned} \tag{7}$$

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

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

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

if $\left(\left\|X_1^p\right\|^2 and \ \left\|X_2^p\right\|^2 \gg 1 \right)$ then

$$\widehat{H}' \approx H' \tag{10}$$

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

$$\widehat{H} = \left(\left(Y^p.(X^p)'\right).A \right)' \tag{11}$$

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

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

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

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

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

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

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

$$\begin{cases} Y_1^2 = H_{11}.X_1^c + H_{12}.X_1^c + N_1^2 \\ Y_2^2 = H_{21}.X_1^c + H_{22}.X_2^c + N_2^2 \end{cases} \tag{17}$$

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

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

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

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

$$\Leftrightarrow Y = \hat{X} \approx X + N \tag{20}$$

So we can directly demodulate the received signal Y to find the estimation of the original transmitted symbol b (see in figure 2).

4. SIMULATION RESULTS

The proposed MIMO-OFDM transceiver system is simulated using parameters shown in Table 3. These parameters are based on transmission between two base stations in LTE system.

Table 1. Simulation Parameters [6], [7], [8] and [9].

Parameters	**Specifications**
System	MIMO-OFDM
Constellation	16-QAM
T_s (μs)	72
f_c (GHz)	2.15
δf (KHz)	15
B (MHz)	5
Size of DFT/IDFT	512
MIMO encoder	Alamouti STBC (2Tx 2Rx)

In this part we are interested in comparing the proposed scheme with the conventional MIMO-OFDM system in the case of symmetric channel based on Alamouti STBC coding [10]. Figure 4 presents the variations in time and in frequency of the channel frequency response. The scenario of this simulation considers the transmission between two base stations in LTE system. The channel parameters are used for the channel coding in the new proposed scheme.

Figure 5 shows the variation of BER as a function of Es/N0. The proposed scheme has better performances than the standard 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 reception. In addition, to the simplification of the conventional MIMO-OFDM transceiver structure, bandwidth efficiency (also frame efficiency) can be highly increased.

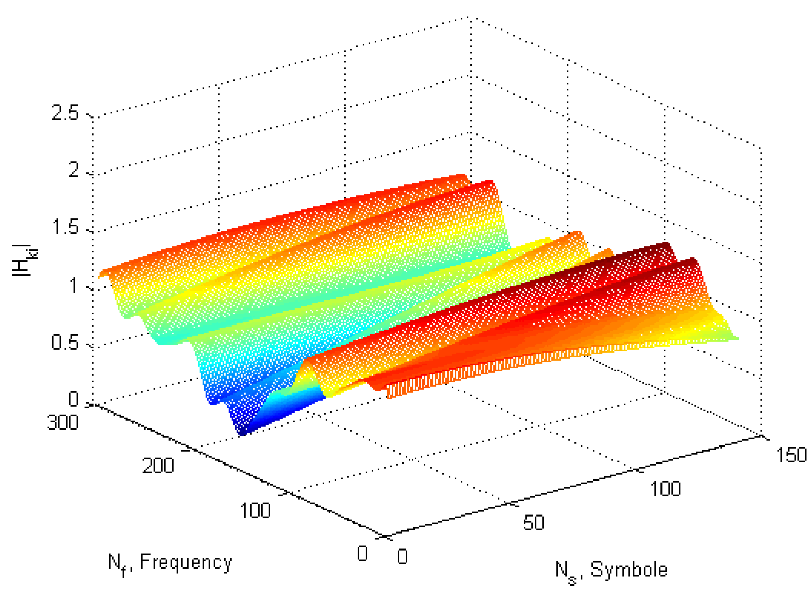

Figure 4. Channel Frequency response variation in time and in frequency.

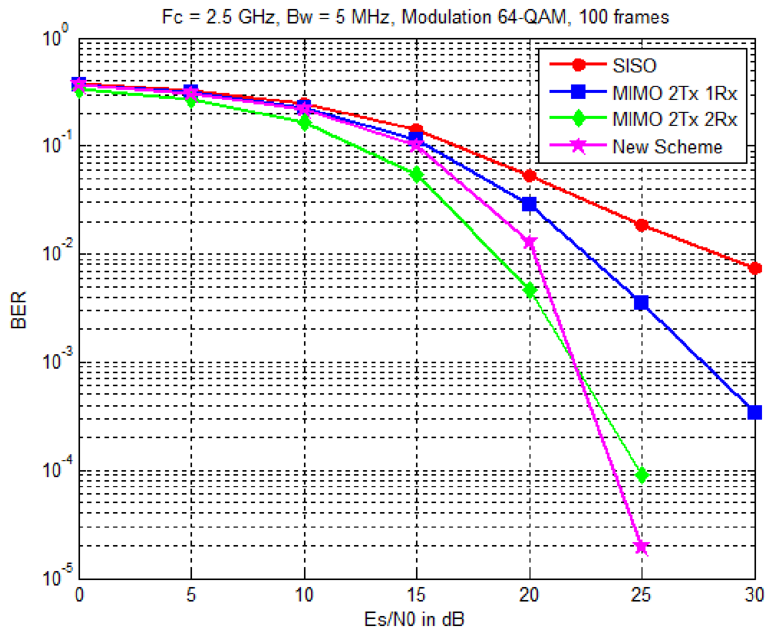

Figure 5. Bit Error Rate as a function of Signal to Noise Ratio.

3. CONCLUSIONS

This contribution introduces a new transmission scheme for multiple-input multiple-output (MIMO) orthogonal frequency division multiplexing (OFDM) systems. This scheme is based on channel coding using estimated channel parameters from a transmitted pilot data at the receiver end. Consequently, the prior information used by the coding scheme, will help the transmitted signal to adapt to the channel impairments and be more resilient to noise and interference. Simulation results confirm the high performance and the low complexity of the proposed scheme when compared to the conventional MIMOOFDM system using Alamouti STBC Coding.

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