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TECHMIND RESEARCH
OPEN ACCESS PUBLISHER
International Journal of Management Excellence
Volume 1 No.1 April 2013

4x4 Time-Domain MIMO encoder with OFDM Scheme in WIMAX Context

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Abstract- *The Standard Worldwide Interoperability for Microwave Access (WiMAX) offers the opportunity to develop applications that require more bandwidth and increased communication up to 50 km. Through literature reviews, the coding block is done in the frequency domain of the OFDM chain in a wireless communication system. This solution offers outstanding performance within the meaning of binary error rate and throughput. We propose to design a Simulink model of 4x4 OFDM transmission chain for WIMAX context and using a coding block in the temporal domain to test system performance and compare it to the one used in the frequency domain .We use the IEEE 802.16 standard [1] for the construction of the OFDM symbol, the generation of the preamble and the choice of the cyclic prefix length. Our choice is situated to test the performances of the system when the coding block is in the temporal domain. Our simulated chain offers a slightly better performance than the chain where the MIMO encoder is located in the frequency domain. This approach provides the ability to expand the number of transmitting antennas without revising all of the calculations.*

Keywords-*MIMO Encoder; WIMA; ODFM; BER; SNR (Eb/No); IFFT/FFT; performance*

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1. INTRODUCTION

Through studies of literature [2], we found that the coding STBC block is located in the frequency domain of the chain [3]. i.e. the output of the constellation is reconstructed through block coding sequences as N such that N is the number of transmit antennas. Each sequence contains samples and replicas join other samples in other sequences. Each sequence is the amount of information in the OFDM symbol. This context provides a good performance in the wireless communication system. Our goal is to achieve an OFDM chain in the context WiMAX and the block coding is located in the temporal part to compare it with the chain where the coding block in the frequency domain. Then we propose to send and receive the same OFDM symbol through four antennas.The IEEE 802.16 standard introduces the multi-carrier modulation OFDM. OFDM is based on the simultaneous transmission of multiple orthogonal frequencies narrow, often called OFDM sub-carriers. The number of sub-carriers is often noted N frequencies that are orthogonal to each other [4]. This orthogonality substantially eliminates interference between channels and greatly reduces inter-symbol interference (ISI) by avoiding multiple frequencies for selecting channels. Each frequency is modulated with a possibly different digital modulation. If the transmitted performances of the proposed transmission scheme are analyzed via simulations. A comparative study with the OFDM transmission scheme where the MIMO encoder is signal is attenuated over a sub-carrier, we can get to another.The frequency associated with each of these channels is then much smaller than if the total bandwidth is occupied by a single modulated. This is known as a single carrier. With OFDM, the communication system provides a smaller frequency bandwidth for each channel is equivalent to greater time periods and then better resistance multipath propagation. To transmit each K symbol on separate frequencies, we are in a position to add an encoder with a rate $\left({}^{k}/_{n}\right)$ followed by an interleaved before the series-parallel converter. The introduction of redundancy and frequency diversity overcomes much of the signal degradation due to fading. The drawback of such an encoding is that it reduces the flow rate by a factor of $\left({}^{n}/_{k}\right)$. In this article, we developed a Simulink model of an OFDM system in the context of IEEE 802.16 and using a MIMO channel with four transmit and reception antennas. In this model, calculations of bit error rate and throughput depending on the signal to noise ratio for different modulation schemes BPSK, QPSK, 16-QAM are performed. The calculated results are in the form of curves that describe the performance of the system studied.The paper is organized as follows. In section II, the OFDM transceiver is described. In section III, we present a spatial-temporal technique in time domain. In section IV, the performed behind pilot insertion. Finally, the conclusion is drawn in section V.

2. THEORITICAL ANALYSIS

2.1 Brief description of the OFDM transceiver chain

The simulated chain consists of two main parts: the OFDM transceiver chain and the multi-antenna MIMO channel in WIMAX context.

The simulated chain is as follows:

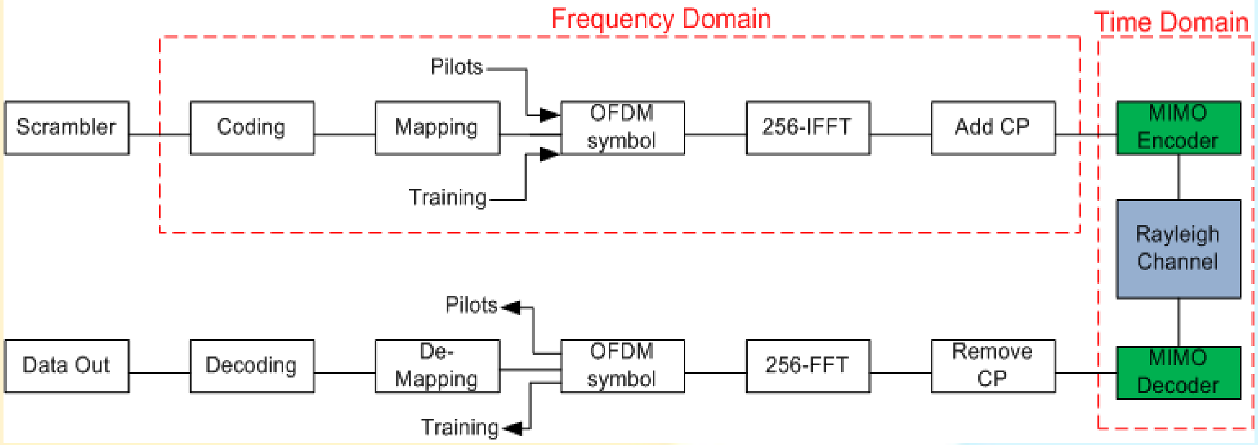

Figure 1- OFDM-MIMO Scheme in Time Domain Case

The encoded data will be punctured to adjust the rate of transfer in WIMAX from rate $(^{1}/_{2})$ produced by the convolutional encoder. The transmitting bits will be reordered so that they are transmitted at different frequencies and phases, and then the noise will be distributed over multiple data packets. Our chain offers multiple choices of modulation namely BPSK$(^{1}/_{2})$, QPSK$(^{1}/_{2})$, QPSK$(^{3}/_{4})$,16QAM (1/2), 16-QAM$(^{3}/_{4})$. After data modulation, the binary values are converted to complex symbols. This channel uses the OFDM multi-carrier modulation with 256 sub-carriers$\{-128 \ \ldots \ 127\}$. Each OFDM symbol is composed of 192 data sub-carrier, one zero sub-carriers called DC, 8 pilot sub-carriers $\{-88 \ \ -63 \ \ -38 \ \ -13 \ \ 13 \ \ 38 \ \ 63 \ \ 88\}$ and 55 guard sub-carriers $\{-128 \ \ldots \ -101 \ \ldots \ 127\}$. Therefore, an assembly process of the DC sub-carrier and pilot data required to construct the symbols. We assume that, even in the Doppler Effect, the data sub-carriers close to each other can be considered to be transmitted over a constant channel. Therefore, each of the data sub-carriers will be associated with a single pilot sub-carrier. Depending on the number of pilot sub-carriers and data mentioned above, it was determined that each pilot sub-carrier cover 24 data sub-carriers. Each group of data is decoded with channel estimation parameters using the corresponding pilot signal. Therefore, if the estimation was not done properly because of interference or noise, only a portion of the OFDM block is not properly recovered. Further comprising the preambles of the training sequences are inserted at the beginning of each data burst. These training sequences are designed to make an estimate of the channel coefficients at the receiver.

2.2 MIMO encoder technique

a. Transmitter

The structure of space time block coding for this case is as follows:

Each OFDM symbol contains 256 complex samples.

The signal is converted to the time domain by means of the inverse fast Fourier transform (IFFT) algorithm. After that, a cyclic prefix (CP) with the aim of preventing inter-symbol interference is added and the resulting signal has a length of $N = 384$ samples. The signal is fragmented into $K = 128$ blocks of length Ns=3 as: $= K \times N_s$. Then the input signal to the Time-Domain MIMO encoder (four antennas) has the form of vector with dimension N and the output has the form of a matrix with$(\frac{4}{3}N \times 4)$.The OSTBC encoder codes each 3 consecutive complex samples in a spatiotemporal matrix as:

$$S = \begin{bmatrix} s_1 & s_2 & s_3 & 0 \\ -s_2^* & s_1^* & 0 & s_3^* \\ s_3^* & 0 & -s_1^* & s_2 \\ 0 & s_3^* & -s_2^* & -s_1 \end{bmatrix}$$

At time t0: the samples s1, s2 and s3 are respectively sent through the antenna number 1, 2 and 3. For four consecutive times, the Time-Domain MIMO encoder finishes sending the three samples and so on until the entire OFDM symbol. The following table describes the sending structure of these samples:

Table 1- Distribution of samples on the antennas during the time

Time	Antenna n°			
	1	**2**	**3**	**4**
t_0	s_1	s_2	s_3	0
t_0+T	$-s_2^*$	s_1^*	0	s_3^*
t_0+2T	s_3^*	0	$-s_1^*$	s_2
t_0+3T	0	s_3^*	$-s_2^*$	$-s_1$

Our transmission system is modeled by the following equation:

$$Y = H.X + W \qquad (1)$$

$X \in \mathbb{C}^{\frac{4}{3}N\times 4}$ is the input sequence to the Rayleigh channel

$Y \in \mathbb{C}^{\frac{4}{3}N\times 4}$ is the output sequence of the Rayleigh channel

$H \in \mathbb{C}^{\frac{4}{3}N\times 4\times 4}$ represents the transfer function of the Rayleigh channel

$W \in \mathbb{C}^{\frac{4}{3}N\times 4}$ is an additive white Gaussian noise

b. Receiver

At the reception, we need the channel estimation to properly detect the transmitted data. We must solve (1) at the end to extract the samples sent$\hat{X}$, we get the following equation:

$$\mathrm{Y} = \mathrm{H}.\hat{\mathrm{X}} + \mathrm{W} \qquad (2)$$

$$\mathrm{H}^{\mathrm{H}}\mathrm{Y} = \mathrm{H}^{\mathrm{H}}.\mathrm{H}.\hat{\mathrm{X}} + \mathrm{H}^{\mathrm{H}}.\mathrm{W} \qquad (3)$$

For each recipient antenna $n°i$ and during the time when the channel is constant:

The channel coefficients are:

$$\mathrm{h} = [\mathrm{h}_{1,\mathrm{i}} \quad \mathrm{h}_{2,\mathrm{i}} \quad \mathrm{h}_{3,\mathrm{i}} \quad \mathrm{h}_{4,\mathrm{i}}] = [\mathrm{h}_1 \quad \mathrm{h}_2 \quad \mathrm{h}_3 \quad \mathrm{h}_4]$$

Where $H^H = \bar{H}^t$ and $H^H.H = \|H\| = \sum_1^4 |h_i|^2$.

Then (4) is as follows:

$$\mathrm{H}^{\mathrm{H}}\mathrm{Y} = (\textstyle\sum_1^4 |\mathrm{h}_\mathrm{i}|^2).\hat{\mathrm{X}} + \mathrm{H}^{\mathrm{H}}.\mathrm{W} \qquad (4)$$

The input data for the MIMO decoder is:

$$\mathrm{y} = [\mathrm{y}_{1,\mathrm{i}} \quad \mathrm{y}_{2,\mathrm{i}} \quad \mathrm{y}_{3,\mathrm{i}} \quad \mathrm{y}_{4,\mathrm{i}}]^\mathrm{T} = [\mathrm{y}_1 \quad \mathrm{y}_2 \quad \mathrm{y}_3 \quad \mathrm{y}_4]^\mathrm{T}$$

The output of the MIMO decoder $\tilde{x} = [\tilde{x}_1 \quad \tilde{x}_2 \quad \tilde{x}_3]^T$ is as follow in this equation system:

$$\begin{cases} h_1^* y_1 + h_2 y_2^* - h_3 y_3^* - h_4^* y_4 = (\sum_1^4 |h_i|^2).\tilde{x}_1 \\ h_2^* y_1 - h_1 y_2^* - h_3 y_4^* + h_4^* y_3 = (\sum_1^4 |h_i|^2).\tilde{x}_2 \\ h_3^* y_1 + h_1 y_3^* + h_2 y_4^* + h_4^* y_2 = (\sum_1^4 |h_i|^2).\tilde{x}_3 \end{cases} \qquad (5)$$

$$\Rightarrow \begin{cases} \tilde{x}_1 = (h_1^* y_1 + h_2 y_2^* - h_3 y_3^* - h_4^* y_4)/\sum_1^4 |h_i|^2 \\ \tilde{x}_2 = (h_2^* y_1 - h_1 y_2^* - h_3 y_4^* + h_4^* y_3)/\sum_1^4 |h_i|^2 \\ \tilde{x}_3 = (h_3^* y_1 + h_1 y_3^* + h_2 y_4^* + h_4^* y_2)/\sum_1^4 |h_i|^2 \end{cases} \qquad (6)$$

The duration of transmission the sequence which contains a modulated OFDM symbol and the cyclic prefix through the Rayleigh Channel can be equal to $T_s = K \times 4T$.

3. SIMULATION RESULTS

The OFDM signal is transmitted over the Rayleigh channel for various values of the signal to noise ratio (SNR). To evaluate the performance of each value of SNR, the received signal is demodulated and the data received will be compared to the original information. The simulation result is in the form of curves of the bit error rate and throughput over many signals to noise ratios (SNR). In this part we are interested in comparing the MIMO-OFDM scheme in the case where the MIMO encoder is situated in the frequency domain with the OFDM-MIMO scheme where the MIMO encoder is located in time domain (after IFFT modulation).

Table 2- Simulation Parameters [1] and [5]

Simulation Parameters	
Standard	IEEE 802.16 (Fixed WIMAX)
Channel Bandwidth	5 Mhz
Source Coding	Convolutif (1/2)
Time Domain MIMO Encoder	OSTBC (4Tx-4Rx)
Cyclic Prefix Length	1/4
Constellation	BPSK, QPSK, 16-QAM, 64-QAM
Useful symbol period Tb	44,44 (µs)
Gard Time Tg=Tb/G(µs)	11,11 (µs)
Sub-carrier spacing (KHz)	11.2
IFFT Length	256
Data Sub-carrier Used	200
Number of pilot Sub-carrier	8
Upper guard	28
Lower guard	27
NDC	1(prefix 128)
Maximum Number of Antennas	4
Channel model	Rayleigh

Based on the parameters in Table 2, the MIMO-OFDM transmission scheme is simulated in Matlab-Simulink software. Figure 2 presents the variation of Bit Error Rate (BER) as a function of signal to noise ratio (E_s/N_0) if the constellation is BPSK and for different number of transmitting and received antenna. Figure 3 presents the variation of Bit Error Rate (BER) as a function of signal to noise ratio (E_s/N_0) where MIMO 4x4 and for different constellation. Our simulated chain offers a slightly better performance than the chain where the MIMO encoder is located in the frequency domain. In addition, our chain using the time domain MIMO-encode wins in terms of computing power and occupied bandwidth. In the frequency domain, to send a complex sequence generated by the constellation, we should code this sequence in four blocks and form four OFDM symbol. The four symbols are sent through the Rayleigh channel four by four samples (each belongs to a different symbol) which reduce the speed of calculation and complicate it at the reception. Whereas in the temporal case where the MIMO encoder is located in the time domain, each modulated OFDM symbol is transmitted through an antenna system with four antennas. The table as follows describes the values of BER and SNR for different MIMO systems.

Table 3- BER values vs. SNR for different MIMO systems

SNR/MIMO	2×1	2×2	3×3	4×4
2	0,1	0,1	0,003	0,0085
4	0,1	0,04	0,002	0,0002
6	0,04	0,02	0,0002	0,00004
8	0.01	0.005	0.00004	0.00002

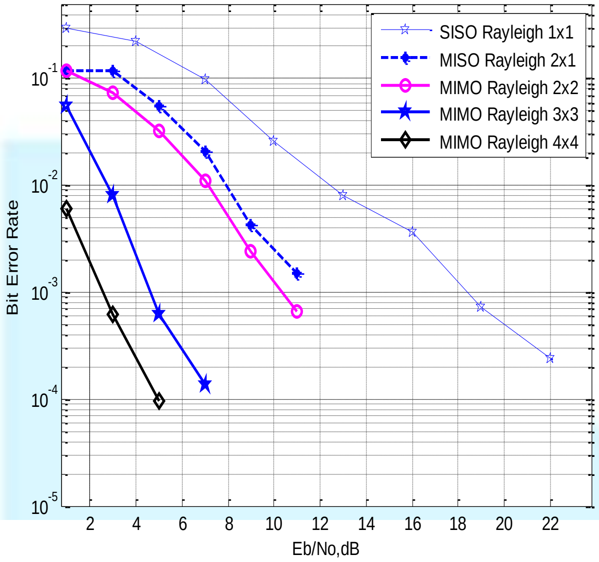

Figure 2. Bit Error Rate as a function of signal to noise ratio for different antenna system

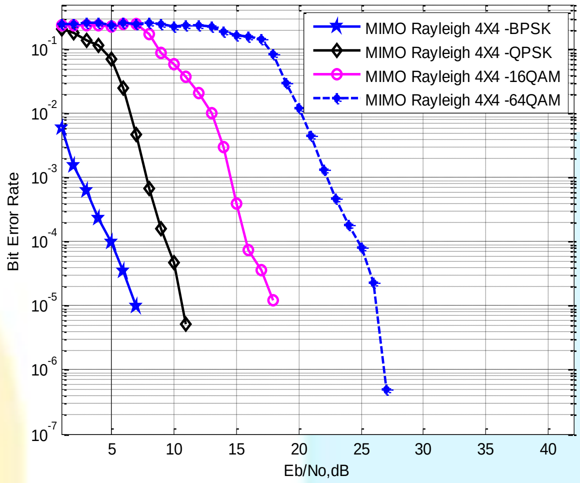

Figure 3- Bit Error Rate as a function of signal to noise ratio for different constellation

In MIMO channel, when we increase the number of transmission and/or reception antenna, dramatically increase the performance. In figure 2, the bit error rate is equal to 0.1 for 2X1 MIMO system and decreases to 0.0085 for 4x4 MIMO systems to a value of signal to noise ratio that is equal to 4. Increasing the value of the signal to noise ratio, we notice a significant decrease in bit error rate. For the same value of the signal to noise ratio, we show that the value of the bit error rate for 4x4 MIMO systems is the lowest. In figure 3, we extract the bit error rate for 4x4 MIMO systems at different modulation. Performance is better for the BPSK modulation for low values of signal to noise ratio. With a gradual increase in the signal to noise ratio, we find that the big order modulations would be better. Comparing with the performance of MIMO-OFDM system in the frequency domain, we derive the bit error rate is somewhat low.

3. CONCLUSION

This contribution introduces a Time Domain MIMO encoder where the bloc of MIMO encoder is situated in the time domain. Our study prepares us to simulate a MIMO-OFDM-MIMO scheme that encodes both in the frequency and time domains. This solution permits designer to adjust multiple 4x4 MIMO blocks to perform higher order MIMO systems. For example, if we want to design an OFDM chain with 16 antennas, we can insert two blocks MIMO encoder with 4 antennas. This solution provides us the ability to expand the number of transmitting antennas without revising all of the calculations.

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