EFFECT OF MIMO AND CHANNEL MODELING WITH
THE PERFORMANCE OF THE OFDM SCHEME IN THE
WIMAX CONTEXT

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Abstract - All radio systems regardless of the mobile telephone systems or wireless radio networks must provide high data rates. To do this, we must find the minimum order i.e. the minimum number of antennas to the communication system provides the desired flow rate. Through literature reviews, we noticed that the block coding is done in the frequency domain of the Orthogonal Frequency Division Multiplexing (OFDM) chain in a wireless communication system. This solution offers outstanding performance within the meaning of binary error rate (BER), throughput and channel capacity. We propose to design an OFDM-MIMO chain (with four antennas) with RAYLEIGH and RICIAN fading channel model to provide the opportunity to develop applications that require more than one antenna and more precision. This article provides in the first time a transceiver system using a time domain Multiple Input-Multiple Output (MIMO) encoder with four antennas to better invest bandwidth and meet the demands of the changing wireless applications. At the second time we propose to establish two channel models such as the RAYLEIGH fading channel model and the RICIAN fading channel model to extract the system performance for NLOS and LOS propagation.

Keywords – MIMO, OFDM, Wimax

I INTRODUCTION

An adaptive array with four antennas can provide the higher antenna gain and higher throughput, and the multipath diversity gain for improved reliability, more the system can eliminate the interference and can ensure the highest link capacity through the use of a MIMO encoder with spatial multiplexing. When communicating through a wireless channel, transmitted signals undergo attenuation and fading due to multipath in the channel, making it difficult for the receiver to identify these signals. A diversity technique takes advantage of the characteristics of multipath propagation to improve reception sensitivity. The MIMO encoder is characterized by the use of multiple antennas at both transmitter and receiver. The main advantages of MIMO encoder than the traditional Single Input-Single Output (SISO) channels are the gain of the network, the diversity gain and multiplexing gain. The network gain and the diversity gain are not mutually exclusive and MIMO encoder also exists in the Single Input-Multiple Output (SIMO) and Multiple Input-Single Output (MISO) encoder. The diversity gain has improved link reliability obtained by receiving replicas of the information signal through links independently to fainting, branches or dimensions.

The three main forms of diversity in wireless communication systems are time diversity, frequency and spatial diversity. The transmit diversity is more difficult to operate than receive diversity as a special modulation and coding are required. The multi-antenna technology allows inter alia increasing the gain and the antenna directivity using the spatial diversity. In this paper, we propose to design an OFDM-MIMO chain (with four antennas) with RAYLEIGH and RICIAN fading channel model in a Worldwide Interoperability for Microwave Access (WIMAX) context. Our goal is to better improve bit error rate, throughput and channel capacity. Our work is divided into two main parts. First, is to develop the matrix code word MIMO channel modeling the issue and we believe the symbols sent on receipt. Second, we derive the system performance for RAYLEIGH fading channel model when there is no dominant propagation along a line of sight between the transmitter and
receiver and where we have a line of sight between the transmitter and the receiver, we will be forced to use the RICIAN fading channel model.

II DIVERSITY IN MIMO CHANNEL

A. Spatial multiplexing

Multiplexing MIMO increases data transmission rates (through multiplexing gain). Each message is divided into sequences. Different sequences in each of the transmit antennas simultaneously transmit. The signals received at the reception antenna are combined to reconstitute the entire original message. Multiplexing MIMO can increase throughput and channel capacity (through multiplexing gain).

In [1], diversity at the receiver is a well-known promising avenue for improving mean signal strength and reducing signal level fluctuations in fading channels, where the multiple received copies can be combined intelligently to provide a higher average received signal-to-noise ratio (SNR). In [2], the combination of OFDM and diversity has been becoming popular in a wireless communications system. At the same time, multiple data streams transmitted in a single channel. In the next instant, the correlated data streams will be sent by antennas other than those of the previous issue.

Focusing for simplicity on 4x4 antenna configurations [3], two limiting transmission schemes are as follows. One could transmit the same samples, say x, from the four transmit antennas. In this case, the signal crosses sixteen propagation paths, and, if these are affected by independent fading, the diversity achieved is 16.

MIMO encoder involves Space Time Transmit Diversity shown in Fig.1 i.e. the same data is coded and transmitted through different antennas, which effectively doubles the power in the channel. This improves SNR for cell edge performance.

![Figure 1. Space Time Transmit Diversity](image)

On the other hand, since only one signal is transmitted per channel use, one has no multiplexing gain with respect to single-antenna transmission. If two independent signals are transmitted simultaneously, then each one of them crosses four independent paths, thus achieving diversity 4, but every channel use transmits four signals, thus achieving a foothold multiplexing gain.

We consider a MIMO system with an equal number of receive and transmit antennas ($N_t = N_r = 4$) which shown in Fig.2, where we denote by $\{x_1, x_2, x_3, x_4\}$ the transmitted sequence, and by $h_{ij}$ the fading gain along the propagation path joining transmit antenna $j$ to receive antenna $i$. These fading gains are organized in a square matrix.

$$H = \begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} \\ h_{21} & h_{22} & h_{23} & h_{24} \\ h_{31} & h_{32} & h_{33} & h_{34} \\ h_{41} & h_{42} & h_{43} & h_{44} \end{bmatrix}$$
In the time domain we have:

\[ y(t) = h(t) \cdot x(t) + n(t) \]  \hspace{1cm} (1)

Then, in the frequency domain we have the following equation:

\[ Y = H \cdot X + N \]  \hspace{1cm} (2)

where

- \( X \in \mathbb{C}^{4 \times 4} \) is the input sequence to the RAYLEIGH fading channel,
- \( Y \in \mathbb{C}^{4 \times 4} \) is the output sequence of the RAYLEIGH fading channel,
- \( H \in \mathbb{C}^{4 \times 4} \) represents the transfer function of the RAYLEIGH fading channel,
- \( N \in \mathbb{C}^{4 \times 4} \) is an additive white Gaussian noise.

The matrix of codeword’s on the MIMO encoder with four antennas (rate = \( \frac{3}{4} \)) is as follows:

\[
X = \begin{bmatrix}
    x_1 & x_2 & x_3 & 0 \\
    -x_2^* & x_1^* & 0 & x_3^* \\
x_3^* & 0 & -x_1^* & x_2 \\
0 & x_3^* & -x_2^* & -x_1^*
\end{bmatrix}_{Space}
\]

At time \( t_0 \): the samples \( x_1, x_2 \) and \( x_3 \) are sent through the antenna number 1, 2 and 3 respectively. 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 [4]:

<table>
<thead>
<tr>
<th>Time</th>
<th>Antenna 1</th>
<th>Antenna 2</th>
<th>Antenna 3</th>
<th>Antenna 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_0 )</td>
<td>( x_1 )</td>
<td>( x_2 )</td>
<td>( x_3 )</td>
<td>0</td>
</tr>
<tr>
<td>( t_0 + T )</td>
<td>( -x_2^* )</td>
<td>( x_1^* )</td>
<td>0</td>
<td>( x_3^* )</td>
</tr>
<tr>
<td>( t_0 + 2T )</td>
<td>( x_3^* )</td>
<td>0</td>
<td>( -x_1^* )</td>
<td>( x_2 )</td>
</tr>
<tr>
<td>( t_0 + 3T )</td>
<td>0</td>
<td>( x_3^* )</td>
<td>( -x_2^* )</td>
<td>( -x_1^* )</td>
</tr>
</tbody>
</table>

B. Channel Modeling
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B.1 RAYLEIGH Fading Channel

In wireless telecommunications, multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. Causes of multipath include atmospheric Ducting, ionosphere reflection and refraction, and reflection from water bodies and terrestrial objects such as mountains and buildings.

The effects of multipath include constructive and destructive interference, and phase shifting of the signal. This causes RAYLEIGH fading. The standard statistical model of this gives a distribution known as the RAYLEIGH distribution.

RAYLEIGH fading is a term used when there is no direct component, and all signals reaching the receiver are reflected.

Mathematically, the multipath RAYLEIGH fading wireless channels modeled by the channel impulse response (CIR).

$$h(t) = \sum_{l=0}^{L-1} a_l \delta(t - \tau_l)$$  \hspace{1cm} (3)

Where, \(L\) is the number of channel paths, \(a_l\) and \(\tau_l\) are the complex value and delay of path \(l\), respectively. The paths are assumed to be statistically independent, with normalized average power. The channel is a time variant due to the motion of the mobile terminal, but we will assume that the CIR is constant during one OFDM symbol. In our case, we begin to use the RAYLEIGH distribution as a basic model to characterize the fading through the transmission channel. The bit error rate (BER) performance of OFDM chain communicates over RAYLEIGH fading channels has been frequently studied in literature reviews [8].

RAYLEIGH fading channel model [1] is viewed as a reasonable model for the troposphere and ionosphere signal propagation as well as the effect of heavily built-up urban environments on radio signals. RAYLEIGH fading is mostly used when there is no dominant propagation along a line of sight between the transmitter and receiver.

The RAYLEIGH distribution is basically the magnitude of the sum of two equal independent orthogonal Gaussian random variables and the probability density function (pdf) given by:

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}}$$  \hspace{1cm} (4)

Where \(0 \leq r \leq \infty\) and \(\sigma^2\) is the time-average power of the receive signal [5], [6].

B.2 RICIAN Fading Channel

If we have a line of sight between the transmitter and the receiver, we will be forced to use the RICIAN fading channel model.

A RICIAN model is obtained in a system with Line of sight (LOS) propagation and scattering. The model is characterized by the RICIAN factor, denoted by \(k\) and defined as the ratio of the line of sight and the scatter power components.

The probability density function for a RICIAN random variable \(x\) is given by:

$$p(x) = 2x(1 + k)e^{-k(1+k)x^2} I_0(2x\sqrt{k(k+1)}) \quad \text{with} \quad x \geq 0$$  \hspace{1cm} (5)

Where \(\frac{\sigma^2}{2\alpha^2}, D^2\) and \(2\sigma^2\) are the powers of the LOS and scattered components, respectively.
The powers are normalized such that $D^2 + 2\sigma^2 = 1$. The channel matrix for a Rician fading channel model can be decomposed as:

$$H = D_H + \sqrt{2}\sigma H_{RAY}$$  \hspace{1cm} (6)

Where, $H_{LOS}$ is the channel matrix for the LOS propagation with no scattering and $H_{RAY}$ is the channel matrix in the case with scattered only.

### III Simulation results

In this section SISO and MIMO BER, Throughput and Capacity results are presented using the Fixed WiMAX simulator. The Simulation model was implemented in Matlab® 7. The physical level parameters used in the simulation are given in the following table.

<table>
<thead>
<tr>
<th>Table 2. Simulation Parameters considered for simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation Parameters</td>
</tr>
<tr>
<td><strong>Simulation Parameters</strong></td>
</tr>
<tr>
<td>Standard</td>
</tr>
<tr>
<td>Channel Bandwidth</td>
</tr>
<tr>
<td>Source Coding</td>
</tr>
<tr>
<td>Time Domain MIMO Encoder</td>
</tr>
<tr>
<td>Cyclic Prefix Length</td>
</tr>
<tr>
<td>Constellation</td>
</tr>
<tr>
<td>Useful symbol period Tb</td>
</tr>
<tr>
<td>Gard Time $T_g=Tb/G(μs)$</td>
</tr>
<tr>
<td>Sub-carrier spacing (KHz)</td>
</tr>
<tr>
<td>IFFT Length</td>
</tr>
<tr>
<td>Data Sub-carrier Used</td>
</tr>
<tr>
<td>Number of pilot Sub-carrier</td>
</tr>
<tr>
<td>Upper guard</td>
</tr>
<tr>
<td>Lower guard</td>
</tr>
<tr>
<td>NDC</td>
</tr>
<tr>
<td>Maximum Number of Antennas</td>
</tr>
</tbody>
</table>
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The link throughput is calculated from the BER as given by equation (7). The system model has been tested for BPSK, QPSK, 16QAM and 64QAM modulations with a RAYLEIGH fading channel. In this simulation, there are 4 transmitter antennas and the number of the receiving antennas is the same. The simulation result of Fig. 4 shows the BER comparison for BPSK modulation with a RAYLEIGH fading channel of the proposed technique for SISO, 2x1 MISO, 2x2 MIMO, 3x3 MIMO and 4x4 MIMO configurations. The simulation result of Fig. 5 shows the Throughput comparison for BPSK modulation with a RAYLEIGH and RICIAN (k=1, k=5) fading channels for 4x4 MIMO configuration.

![Figure 4. BER with MIMO RAYLEIGH 1x1, 2x1, 2x2, 3x3, 4x4](image)

Fig. 4 shows that the BER is decreased exponentially with the increase in the number of antennas used.

![Figure 5. The throughput of each MIMO configuration](image)
The simulation result of Fig.5 shows the throughput comparison for BPSK modulation with a RAYLEIGH fading channels of the proposed technique for SISO, 2x1 MISO, 2x2 MIMO, 3x3 MIMO and 4x4 MIMO configurations where the throughput is measured in Mbps. 4x4 MIMO and 3x3 MIMO configurations have the highest throughput performance.

The link throughput for each user is calculated from the BER as follows:

\[ R = (1 - BER)C \]  \hspace{1cm} (7)

where \( C \) represents the Capacity of channel.

![Figure 6. Comparative Study of Rayleigh and Rician in 4x4 MIMO](image)

![Figure 7. Ergodic Capacity in RAYLEIGH and RICIAN model](image)

Fig.6 shows that the RICIAN fading channel model is more efficient for small values of SNR. System performance increases for large values of SNR and with RICIAN fading channel model for large values of k factor.

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The maximum error-free data rate that a channel can support is called the channel capacity; otherwise, the channel capacity is the maximum amount of information that can pass through the channel per time unit.
Effect of MIMO and Channel Modeling with the Performance of the OFDM Scheme in the WIMAX Context

For fixed linear $N_t \times N_r$ matrix channel when the transmitted signal vector is composed of statistically independent equal power components each with a Gaussian distribution and the receiver knows the channel, its capacity is [7]:

$$C = \log_2 \det \left( I + \frac{\rho}{N_t} HH^H \right) \text{ Bits/s/Hz} \quad (8)$$

where $N_t = N_r = 4$ is the number of transmit or receive antennas; $\rho$ is the average SNR where $\rho = \frac{P}{\sigma^2}$ ($P$ is the average power at the output of each receive antennas and $\sigma^2$ is the variance of the additive Gaussian noise); $I$ is $4 \times 4$ identity matrix; $H$ is the normalized channel matrix, which is considered to be frequency independent over the signal bandwidth; and $(H^H)$ means a transpose conjugate.

Fig. 7 shows the performance comparison of ergodic capacity for 4x4 MIMO configurations with a RAYLEIGH fading channel model, 4x4 RICIAN fading channel model with $K = 1$, and 4x4 RICIAN fading channel with $K = 5$. As the value of $K$ increases, the ergodic capacity decreases.

IV CONCLUSION

From the simulation results, the Bit Error Ratio of a digital communication system is an important figure of merit used to quantify the integrity of data transmitted through the system. By implementing the different modulation techniques, the criterion is a comparison of the variation of BER for different SNR. For RICIAN fading channel it is found that the BER is less than RAYLEIGH fading channel for different value of $k$ factor. System performance is inversely proportional with the $k$ factor. The ergodic capacity to RAYLEIGH fading channel is more than our configuration of the RICIAN fading channel (for different value of $k$ factor).

REFERENCE


