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Analysis of MIMO system using MMSE-SIC, MMSE & ZF receiver with spatial multiplexing

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Abstract

Multiple-antenna techniques constitute a key technology for modern wireless communications, MIMO wireless technology has grown in the last few years. The principal goal of MIMO technology is to improve the BER or the data rate of the communication system. SM is an entirely new modulation concept that exploits the uniqueness and randomness properties of the wireless channel for communication. Paper analyzes to improve the BER performance by trying out SIC and compares the performance with ZF Equalization, MMSE Equalization & extending the concept of SIC to the MMSE Equalization.

Keywords: *Multiple Input Multiple Output (MIMO), Spatial Modulation (SM), Successive Interference Cancellation (SIC), Zero Forcing (ZF), Minimum Mean Square Error (MMSE).*

1. Introduction

In a 2x2 MIMO channel probable usage of the available 2 transmit antennas can be as follows: consider that we have a transmission sequence for example $\{x_1\, x_2\, x_3 \ldots\ldots x_n\}$. In normal transmission we will be sending x_1 in the first time slot, x_2 in the second time slot, x_3 and so on. Now we have two transmit antennas, we may group the symbols into two groups. In the first time slot, send x_1 and x_2 from the first and second antenna. In the second time slot send x_3 and x_4 from the first and second antenna, and so on. The channel experienced between each transmit to the receive antenna is independent and randomly varying in time. In classical SIC, the receiver arbitrarily takes one of the estimated symbols and subtract its effect from the received symbol. Once the effect is removed, the new channel becomes a one transmit antenna, 2 receive antenna case and can be optimally equalized by Maximal Ratio Combining (MRC).

2. MIMO SCHEMES

MIMO, uses multiple antennas at the same time in the transmitter and receiver of the communication system, and it can increase the transmission rates. The diversity gain is obtained by exploiting multiple uncorrelated paths of MIMO channel, reducing the probability of deep fading. On the other side spatial multiplexing (SM) sends parallel data streams from different transmitting antennas allowing an increased spectral efficiency. Alamouti code, with two transmitting antennas and a single receiving antenna, provides a diversity gain of two, with no spatial gain. The advantage of MIMO communication can be divided into three main categories: spatial multiplexing for enhancing the data transmission rate, transmit diversity using space time coding for enhancing the robustness of the transmission and beam forming for improving other users. Because of the enormous capacity increase MIMO systems gained a lot of interest in mobile communication research. One essential problem of the wireless channel is fading, which occurs as the signal follows multiple paths between the transmit and the receive antennas.

2.1 Non-Linear MIMO Receiver

V-BLAST (Vertical-Bell Labs Layered Space Time Architecture) employs a unique method of reception known as Successive interference cancellation (SIC), it is non-linear in nature. SIC means impact of each estimated symbol is cancelled. ‘Diversity Order’ progressively increases as we proceed through the scheme. However, adopting a MIMO system increases the system complexity and the cost of implementation. MIMO makes antenna work smarter by enabling them to combine data streams arriving from different paths and at different times to effectively increase receive signal-capturing power. Smart antennas use spatial diversity technology, which puts surplus antennas to good use. When there are more antennas than spatial streams, the antennas can add receiver diversity and increase range.

2.2 Alamouti Scheme

The diversity scheme without the knowledge of Channel State Information (CSI) is the Alamouti Code. In this the coding is done across the space and time. Alamouti belongs to special class of codes called Space Time Block codes (STBC). It transmits a net of two symbols x_1, x_2 in two time instants. Hence it effectively transmits 1 symbol per time instant. Therefore it is also termed as a rate R=1

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code or full rate code. In the scenario of multiple transmitting antennas, Space time codes (STC) are utilized to improve the reliability of the communication channel. The STC works on the principle of transmitting redundant bits from multiple antennas to ensure that few of them will be received at the receiver end. Diversity gain at the transmitter end can be improved by using the STC so that at the receiver end it is easy to decode the message. Alamouti code is the example of STBC and can be applied in case of multiple transmit antennas.

3. Math for Extracting the Two Symbols

3.1 System Model

In the first time slot the received signal on the first receive antenna is,

$y_1 = h_{1,1}\, x_1 + h_{1,2} x_2 + n_1$

The received signal on the second receive antenna is,

$y_2 = h_{2,1}\, x_1 + h_{2,2} x_2 + n_2$

Where,

y_1, y_2 are the received symbols on the first and second antenna respectively,

$h_{1,1}$ is the channel from 1st transmit antenna to 1st receive antenna,

$h_{1,2}$ is the channel from 2nd transmit antenna to 1st receive antenna,

$h_{2,1}$ is the channel from 1st transmit antenna to 2nd receive antenna,

$h_{2,2}$ is the channel from 2nd transmit antenna to 2nd receive antenna,

x_1 and x_2 are the transmitted symbols and

n_1 and n_2 is the noise on 1st,2nd receive antennas.

Therefore, $y = H\, x + n$

To solve for x, The Zero Forcing (ZF) linear detector for meeting this constraint is, estimate of x

$(H^T H)^{-1} H^T y$

The Linear MMSE estimator for MIMO system is:

$P_d(HH^H + \sigma_n^2 I)^{-1} H^H y$

Where,

H is the channel matrix,

σ_n^2 is the noise power at the receiver,

P_d is the transmitted data power.

Successive Interference Cancellation (SIC) for successively cancelling the interference by decoding the symbols:

$y_1 = x_1 + n$, employed to decode x_1,

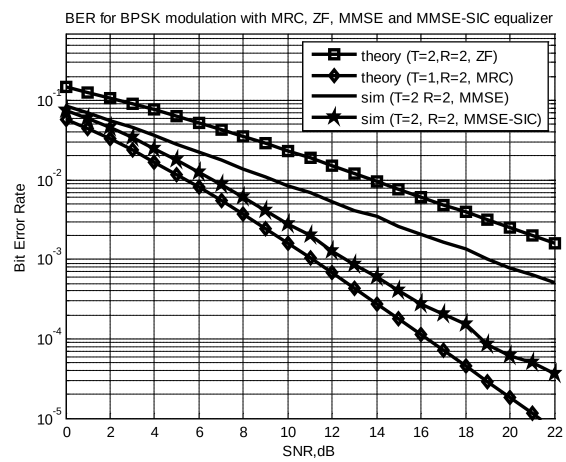
$y_2 = y - h_1\, x_1$ (Remove the effect of having decoded x_1)

$y_2 = (h_1\, x_1 + h_2\, x_2 + \ldots\ldots.. + h_t\, x_t) + n - h_1 x_1$

$y_2 = h_2 x_2 + h_3 x_3 + \ldots\ldots\ldots + h_t x_t) + n$

By cancelling x_1, we effectively reduce this to an [r x (t-1)] MIMO system. Now repeat the process by decoding x_2 and so on.

3.2 Performance Evaluation & Simulation Results



Compared to Minimum Mean Square Estimation with Successive Interference Cancellation Case, it results in improvement of BER (Bit Error Rate). Capacity increases linearly as we increase the number of receive antennas for same transmit power. As the number of receive antenna is increasing, the BER decreases at a much faster rate. Probability of deep fade decreases significantly with more receive antennas.

4. Conclusion

In this paper, performance of MRC, ZF, MMSE & MMSE-SIC is evaluated using Binary Phase Shift Keying (BPSK) modulation Scheme. It is observed that in MMSE-SIC case that BER reduces than that of MMSE and ZF equalization. Once the effect of one of the transmitted symbol is removed, the new channel becomes a1 transmit antenna, 2 receive antenna case and can be equalized by Maximal Ratio Combining (MRC). The capacity of the system increases but along with this the complexity of the overall transceiver increases. To increase the capacity further we make use of Channel State Information (CSI) that can be made available by using any estimation technique.

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