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Adaptive Modulation for MIMO OFDM Systems over Rayleigh Fading Channel

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Abstract

This paper presents the design and performance analysis of MIMO antennas for wireless communication systems. The 2x2 MIMO system process applies an adaptive approach in order to reduce the impact of wireless channel impairments such as multipath fading. The MIMO system was applied in AWGN and single Rayleigh fading channel that uses modulation schemes to simulate the BER performance in MIMO system and finally compares BER results with fixed and adaptive modulation schemes.This adaptive modulation technique gives a better trade off between the BER and SNR conditions. Performance have been evaluated under fading effects. Matlab has been used to simulate this wireless system under wimax standards

Keywords: MIMO OFDM

Introduction

Multiple Input and Multiple Output (MIMO) and adaptive modulation and coding (AMC) have received considerable attention in recent years by telatar [1] and foschini [2].Attractive features of why we choosing MIMO and Adaptive Modulation is higher spectral efficiency by adapting transmit parameters such as constellation size ,transmit power and coding rate that results maximum throughput, minimum average power and minimum average BER according to the channel state information (CSI) fed back from the receiver to the transmitter over single input and single output (SISO).At high signal to noise ratio (SNR) ,the spectral efficiency of a MIMO system increases by m bits/s/Hz for every 3 Db increase in SNR, where m is the minimum number of transmit and receive antennas. In contrast Single Input and Single Output (SISO) is only 1 bits/s/Hz. Various attempts have been made to utilize this multiplexing gain in a practical systems .Adaptive modulation and coding (AMC) a proven technique for approaching the channel capacity in SISO systems has been applied to singular value decomposition (SVD) based MIMO systems and the resultant AMC MIMO system is shown to achieve a good spectral efficiency performance assuming that the both transmitter and receiver have the perfect channel state information (CSI)

Adaptive Modulation and coding , a proven technique for approaching the channel capacity in SISO systems [3],[4], has been applied to singular

value decomposition(SVD) based MIMO systems and the resultant AMC MIMO system is shown to achieve a good spectral efficiency performance assuming that both the transmitter and receiver have the perfect channel state information (CSI)[5].However the perfect CSI assumption is not always practical, due to channel estimation errors , feedback channel delay and noise . Assume that perfect Channel State Information (CSI) is available at both the transmitter and receiver side. A MIMO channel is splinted in to the several parallel eigen sub- channels by Singular Value Decomposition (SVD). According to the instantaneous values and /or statistics of the sub channel gains under an average transmit power and instantaneous bit error rate constraint the transmit power and spectral efficiency at each eigen sub-channel are varied. Two Categories of AM systems ,the continuous rate and discrete rate systems , where the rate is used interchangeably with the spectral efficiency .The continuous rate adaptive modulation system is more analytically tractable due to rate continuity whereas discrete rate adaptive modulation system is more practical for implementation.

In discrete rate system the power and rate adaption policy are derived for VRVP, VR , VP . Already shown that the discrete rate variable rate system obtained a very close bound expression for the average spectral efficiency and it has 2 db SNR power penalty compared to the continuous rate counterpart. However it has some advantages like simpler adaption

rule, reduced bit error rate performance and a increased spectral efficiency. VR MIMO system under an imperfect CSI we have to derive a closed form expression for the average spectral efficiency and bit error rate performance.

In this paper , we propose a design of adaptive modulation MIMO system under AWGN noise and single Rayleigh fading channel .The multiplexing gain and the Bit error rate are the main focuses of the system design against the feedback channel delay and spectral efficiency .To achieve a reduced Bit error Rate and increased spectral efficiency performance against the CSI delay , we incorporate the STBC in to the AMC MIMO system and hence proposed the Adaptive STBC MIMO system.

MIMO System

MIMO is effectively a radio antenna technology as it uses multiple antennas at the transmitter and receiver side. It enables a variety of signal paths to carry the data, choosing separate paths for each antenna to enable multiple signal paths to be used. One of the important method behind MIMO system space time signal processing in which time is combined with the spatial dimension inherent in the use of multiple spatially distributed antennas, I.e the use of multiple antennas located at different points. MIMO wireless system is a logical extension of smart antennas. Multiple path has been found between transmitter and receiver these multiple path between source and destination create interference but by using Multiple Input Multiple output these multipath channel is used effectively.
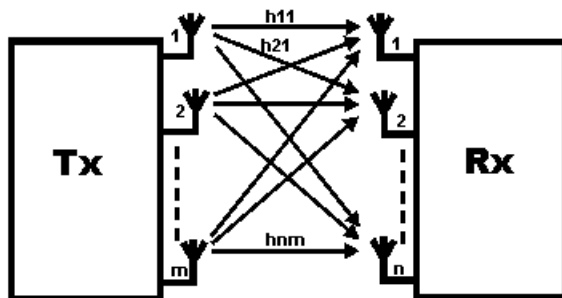

Figure 1: MIMO system model

In wireless communication the propagation channel is characterized by multipath propagation due to scattering on different obstacle. The multipath problem is a typical issue in communication system with time variations and time spread. For time variations the channel is fading and caused SNR

variations. For time spread, it becomes important for suitable frequency selectivity.

In an urban environment, these signals will bounce off trees, buildings, etc. and continue on their way to their destination (the receiver) but in different directions. With MIMO, the receiving end uses an algorithm or special signal processing to sort out the multiple signals to produce one signal that has the originally transmitted data. In recent years MIMO technology has significant consideration in wireless communication because it uses multiple antenna at the transmitter side as well as in the receiver side which increases the data throughput without additional power and bandwidth for the system .MIMO plays major role in WIMAX, WiFi, 4G, 3GPP long term evolution .whereas in conventional wireless system it as single input and single output which has no diversity and no additional processing required,it doesnt require diversity technique which induces multipath fading and interferrence due to scattering,reflection and refraction , later on it has two methods like multiple input and single output (MISO) and single input multiple output (SIMO) .In MISO multiple antenna at the transmitter side and single antenna in the receiver side,which transmit multiple copies of the same data in different transmitter in belief some of the data will reach the receiver by using diversity technique will reduce the impact of interference and fading in the conventional systems which is also reffered as transmitter diveristy There are two forms of SIMO that can be used:

- *Switched diversity SIMO:* In switched diversity it looks for the strongest signal and switches to that antenna among the weakest antenna .
- *Maximum ratio combining SIMO:* In maximum ratio combining it takes both signals from the antenna and sums them to give a combination. In this way, the signals from both antennas contribute to the overall signal.

MIMO exploits the space dimension to improve wireless systems capacity, range and reliability. It offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. MIMO achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency (more bits per second per hertz of bandwidth) or to achieve a diversity gain that improves the link reliability (reduced fading).

As the number of antenna element increasing, the channel capacity is increased too. Instead of logarithmic-increasing of channel capacity in SIMO

and MISO system, the MIMO system owned linear-increasing of channel capacity as antenna increased. The improving of MIMO from SIMO and MISO is shown below:
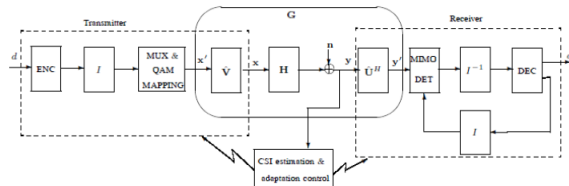

Figure2: Adaptive MIMO systems

As a result of the use multiple antennas, MIMO wireless technology is able to considerably increase the capacity of a given channel while still obeying Shannon's law. By increasing the number of receive and transmit antennas it is possible to linearly increase the throughput of the channel with every pair of antennas added to the system. This makes MIMO wireless technology one of the most important wireless techniques to be employed in recent years. As spectral bandwidth is becoming an ever more valuable commodity for radio communications systems, techniques are needed to use the available bandwidth more effectively.
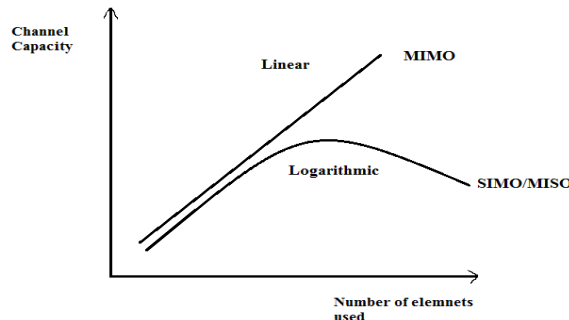

Figure 2: MIMO vs SIMO/MISO

System Model

We assume a flat fading MIMO channel with n_T and n_R receive antennas represented by an n_R x n_T matrix H.The values of H matrix are independent to each other and $H_{j,I} \sim CN(0,1)$. The input input into the channel is denoted by an n_T x 1 vector X,while the additive white Gaussian noise (AWGN) and the channel output are represented by n_R x 1 column vector **n** and **y.** The entries of **n** are also assumed to be independent and $n_j \sim CN(0, \sigma^2)$. For convenience we define

$$m \triangleq \min(nT, nR), n \triangleq \max(nT, nR),$$
$$d \triangleq n - m.$$

The channel capacity input/output equation can be written as

$$Y = Hx + n.$$

By applying singular value decomposition (SVD) to H,we can express it as

$$H = UDV^H$$

Where D is an n_R x n_T non negative and diagonal matrix with the singular values of H.

Channel Capacity

Assuming that the transmit power is subject to an instantaneous constraint

$$\sum_{i=1}^{m} Pi = P$$

Where P_i is the transmit power at subchannel i and P is the total transmit power

The transmit power for each subchannel, allocated according to the waterfilling rule is given by

$$P_i = (\mu - \sigma^2 / \lambda i)^{+,}$$

Our aim is to approach the capacity in Adaptive modulation .The whole system is illustrated in figure 3. The channel estimation module estimates the channel matrix H and extracts (U,V, λ) by doing an SVD , or alternatively ,it can estimate (U,V, λ) directly without estimating H[10].V and U are used at the transmitter and receiver side ,respectively ,to decompose the MIMO channel into parallel subchannels. λ is used at both sides to adapt the transmit parameters to maximize the ASE under constraint ,such as transmit parameters and BER restriction. From now on ,we will use P_i , k_i ,and BER_i to denote instantaneous transmit power,spectral efficiency and BER for subchannel i ,respectively

Multiplexing gain analysis

In [5], we have shown that AM MIMO systems using uncoded QAMs as the component modes achieve full multiplexing gains. In this section, we analyze the multiplexing gain of the generic AM MIMO system presented in (11). The key to AM is to maintain the minimum Euclidean distance of the signal constellation constant in all fading circumstances [3], [6]. If the CSI is perfect, the _m_ eigen-subchannels can be seen as _m_ SISO AWGN channels within one fading block. received SNR at the SNR thresholds of the component modes [9]. For an uncoded M-QAM with minimum Euclidean distance (d0) and where is a constant, it spectral efficiency k=log₂M the symbol power P_s can be expressed as P_s

$$Ps = \frac{d2}{6}(M-1) = \frac{d2}{6}(2k-1)$$

Thus for a fixed d
K= log2(1+6Ps/d2)

In a high SNR range

k ≈ log2(6γsσ2d20)= log2 γs + log2(6σ2d20)
Clearly shows a 1 bit/s/Hz per 3 dB SNR relation.

Adaptive Stbc Mimo Systems

With the main objective to maximize the spectral efficiency, many approaches of adaptive modulation have been proposed in literature. An early work includes in Chapter 13 of [5], where W.T. Webb and L. Hanzo introduce variable rate QAM. The transmitter varies the signal constellation size from 1bit/symbol corresponding to BPSK to 6bits/symbol star 64-QAM. In a good quality channel, the constellation size is increased, and as the channel quality become worst, i.e. as the receiver enters a deep fade, the constellation size is decreased to a value, which provides an acceptable BER. Two choices of implementation can be applied where to keep constant of one parameter and varying the other parameter. Specifying a required BER value leads to varying data throughput and vise versa. The chapter also highlights two different types of switching criteria to control the modulation modes, Received Signal Strength Indicator (RSSI) system and error detector switching system. RSSI system use SNR values corresponding to the BER of interest as the switching thresholds while the later system use the channel coder to monitor the channel quality. Simulation results showed the performance improvement over fixed modulation and comparisons of the two switching systems. It is observed that RSSI typically offering a slightly higher number of bits/sym at low SNRs for some BERs. This is due to the RSSI switching system's ability to select a lower number of levels before any errors occurred. RSSI is also more attractive in term of implementation complexity because no additional BCH codec is needed.

Space-time block codes are used for MIMO systems to enable the transmission of multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data-transfer. Space-time coding combines all the copies of the received signal in an optimal way to extract as much information from each of them as possible.

Space time block coding uses both spatial and temporal diversity and in this way enables significant gains to be made. Space-time coding involves the transmission of multiple copies of the data. This helps to compensate for the channel problems such as fading and thermal noise. Although there is redundancy in the data some copies may arrive less corrupted at the receiver. When using space-time block coding, the data stream is encoded in blocks prior to transmission. These data blocks are then distributed among the multiple antennas (which are spaced apart to decorrelate the transmission paths) and the data is also spaced across time. A space time block code is usually represented by a matrix. Each row is at having represents a time slot and each column represents one antenna's transmissions over time.

A particularly elegant scheme for MIMO coding was developed by Alamouti. The associated codes are often called MIMO Alamouti codes or just Alamouti codes. The MIMO Alamouti scheme is an ingenious transmit diversity scheme for two transmit antennas that does not require transmit channel knowledge.

In this section, we incorporate STBC into the AMC MIMO system in a straightforward way to, calling it an adaptive STBC MIMO system.

System Architecture

The block diagram of an adaptive STBC MIMO system is shown in Fig. 2. The information bits are first encoded by a convolutional encoder (ENC); the codeword symbols are interleaved by a bit-interleaver (I) the interleaved symbols are demultiplexed and composed into m streams of QAM symbols according to the adaptation algorithm; after passing through the steering matrix $\hat{V}$, the QAM symbol streams are transmitted from nT antennas. At the receiver, the received vector **y** is first multiplied by the orthonormalization matrix $\hat{v}H$ and then processed iteratively between the inner MIMO detector (MIMO DET) and the outer channel decoder (DEC). Note that all the components at both the transmitter and receiver are controlled by the CSI estimation and adaptation control module, where the CSI is estimated, the optimal coding and modulation parameters are determined and all necessary coordination signals are generated. The soft-input soft-output channel decoder is somewhat standardized. We use the APP algorithm presented in [11], which can calculate the *a posteriori probability* (APP) for both the information bits and coded symbols.

Results and Discussion

In this paper the information symbols are space time block coded ,before that the blockcodes are interleaved by a bit intereaver ,the interleaved symbols are demultiplexed and composed into m streams of QAM symbols according to the adaption algorithm after passing through the steering matrix ,the QAM symbol streams are transmitted from n_T antennas.At

the receiver the received vector y is first multiplied by thr ortho normalization matrix UH and then proposed iterartively between the inner MIMO detector (MIMO DET) and the outer channel decoder (DEC).In addition to that channel is assumed Rician channel.Monte carlo simulations are performed for about 500 times for each transmission and BER is evaluated.The performance shown in the form of BER even at worse signal conditions.(-5db and lesser).all the components at both the transmitter and receiver are controlled by the CSI estimation and adaption control module,where the CSI is estimated,the optimal coding and modulation parameters like transmit power are determined and all necessary coordintion signals are generated.compared to the traditional trellis codes and fixed rate modulation,the new scheme shown more than 20 dB power savings

Table 1 : Simulation Parameters

| PARAMETERS	TYPE
Modulation	4-QAM, 8-QAM, 16-QAM,32-QAM
MIMO Antenna configuration	2x2
Signal to Noise Ratio	0:3:15
Average transmit power	1 dB
	Flat fading channel
Bandwidth	5 MHz
Link Adaption Resolution	1
Number of frames	50
Sampling Rate	1.08
Number of Subcarriers	512
Symbols per Frame	6
Delay Spread	0
Channel knowledge	Channel State Information at the transmitter
SNR threshold	1.22
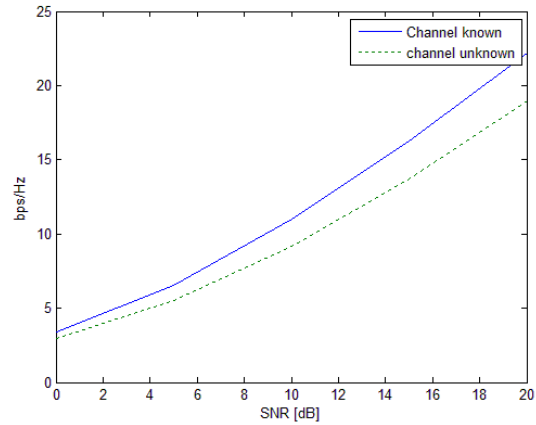
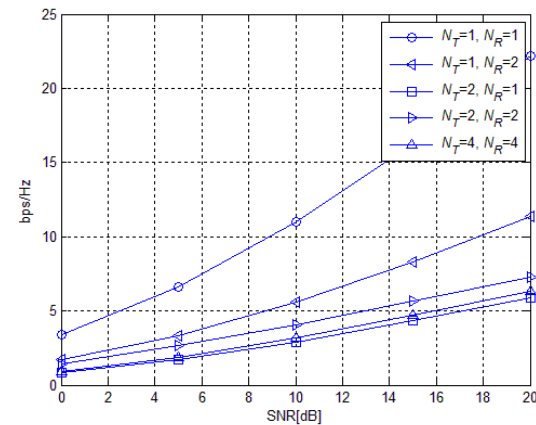**Figure 4: Spectral Efficincy for known and unknown channel**

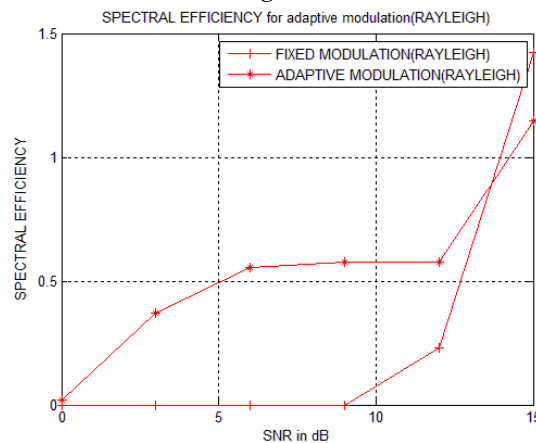**Figure 5 : Channel capacity for various antenna configuration**

Figure 6 : Spectral Efficiency for fixed and adaptive modulation
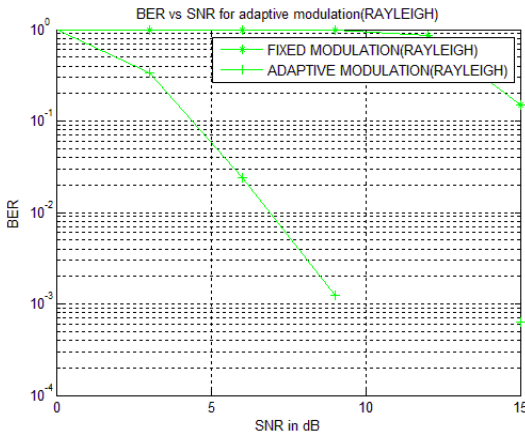
Figure 7 : Bit error rate for fixed and adaptive modulation.

Conclusion

This project presented the design and performance analysis of MIMO antennas for wireless communication systems. The 2x2 MIMO system process applies an adaptive approach in order to reduce the impact of wireless channel impairments such as multipath fading. The MIMO system was applied in AWGN and single Rayleigh fading channel that uses QAM modulation schemes to simulate the BER performance for QPSK in MIMO system and finally compares BER results with SISO and MISO systems. In addition to the 64 QAM modulation, 16 and 4 QAMs are performed based on channel conditions. For fixed modulation 64 QAM modulation is used whereas for adaptive modulation 64,32,16,8 QAM modulation schemes are used.This adaptive modulation technique gives a better trade off between the BER and SNR conditions.

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