Design of MIMO Space-Time Code for High Data Rate Wireless Communication

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ABSTRACT

Multiple-input and multiple-output, or MIMO, is the use of multiple antennas at both the transmitter and receiver to improve communication performance. MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or transmit power. In this paper, multiple-input–multiple-output (MIMO) systems with reduced complexity is considered. The *space–time block coding*, for communication over Rayleigh fading channels using multiple transmit antennas is considered. Also the Alamouti code is tested for the performance. Data is encoded using a space–time block code and the encoded data is split into *n* streams which are simultaneously transmitted using *n* transmit antennas. The received signal at each receive antenna is a linear superposition of the *n* transmitted signals perturbed by noise. In current research, high data rate wireless communications, transmission rates, is of major interest. The idea behind MIMO is that the signals on the transmit (Tx) antennas at one end and the receive (Rx) antennas at the other end are "combined" in such a way that the quality (bit-error rate or BER) or the data rate (bits/sec) of the communication for each MIMO user will be improved.

Index Terms - MIMO systems. Space- time codes, Alamouti code, Multiple Antennas, Wireless Communication.

INTRODUCTION

MIMO technology has attracted attention in wireless communications, since it offers significant increases in data throughput and link range without additional bandwidth or transmit power. It achieves this by higher spectral efficiency and link reliability or diversity (reduced fading). Because of these properties, MIMO is a current theme of international wireless research. Recently, there has been growing interest in providing a broad range of services including wire-line voice quality and wireless data rates of about 64–128 kb/s (ISDN) using the cellular (850-MHz). Rapid growth in mobile computing is inspiring many proposals for even higher speed data services. The requirement to provide reliable high data rate communication over the wireless channel has led to the development of efficient modulation and coding schemes. A wireless channel suffers from time-varying impairments like multipath fading, interference and noise. Diversity is an effective method to combat the fading of the wireless channel [1]. Thus, link reliability is improved. Diversity may be of various types like time/frequency/space/polarization/angle diversity. Out of these, the time and frequency diversity lead to loss in bandwidth efficiency. But, by employing multiple antennas at the transmitter and/or at the receiver, spatial diversity mitigates fading without sacrificing resource. Because of this reason, this concept is gaining popularity. Receive diversity technique-wherein multiple receiver antennas along with suitable combining are used –have already been implemented to improve the performance in the uplink. But, it is difficult to implement receive diversity in the downlink because of the size/power limitations on the portable/mobile terminal. This has motivated the use of transmit diversity schemes wherein multiple antennas are used at the transmitter for the downlink transmission from the base station to the portable terminals. For the case at hand, the slope, and therefore, the diversity order is two, a result that confirms what we already know: the Alamouti code users two transmit antennas, and the MRC uses two receive antennas. In order to enable high data rate transmission over wireless fading channels, recently different transmit diversity techniques have been introduced to benefit from antenna diversity also in the downlink while putting the diversity burden on the base station [2,3]. In [2] authors introduced space–time trellis-coded modulation (STTCM) proposing a joint design of coding, modulation and transmit diversity for flat Rayleigh fading channels. By avoiding destructive superposition after combination of the signals transmitted simultaneously from different antennas STTCM achieves the same, theoretically optimal, diversity advantage as receive diversity. Deploying multiple transmit and receive antennas broadens this data pipe. Information theory [4], [5] provides measures of capacity, and the standard approach to increasing data flow is linear processing at the receiver [6], [7]. We will show that there is a substantial benefit in merging signal processing at the receiver with coding technique appropriate to multiple transmits antennas. Space–time coded modulation has been shown to efficiently use transmit diversity to increase spectral efficiency [8]. Authors have proposed a new trellis codes found through systematic code search. These codes achieve the theoretically maximal diversity gain and improved coding gain compared to known codes.

MIMO SYSTEMS PRINCIPLES

In this paper the multi-antenna system is considered. A digital source in the form of a binary data stream is fed to a simplified transmitting block encompassing the functions of error control coding and mapping to complex modulation symbols such as BPSK, QPSK, M-QAM. The latter produces several separate symbol streams which range from independent to partially redundant to fully redundant. Each is then mapped onto one of the multiple transmitting antennas. Mapping may include linear spatial weighting of the antenna elements or linear antenna space–time coding. After upward frequency conversion, filtering and amplification, the signals are launched into the wireless channel. At the receiver, the signals are captured by possibly multiple antennas and demodulation and demapping operations are performed to recover the message. This determines the class and performance of the multi-antenna solution that is implemented.

If one estimates the response of each antenna element to a given desired signal, and possibly to interference signal(s), one can optimally combine the elements with weights selected as a function of each element response. One can then maximize the average desired signal level or minimize the level of other components whether noise or co-channel interference. When combined together, leverages of antennas are shown to improve the coverage range versus quality tradeoff offered to the wireless user.

This makes multiple antenna elements transceivers a possibility at both sides of the link, even though pushing much of the processing and cost to the network's side still makes engineering sense. In fact, the advantages of MIMO are far more fundamental. While coding and signal processing are key elements to successful implementation of a MIMO system, the propagation channel and antenna design represent major parameters that ultimately impact system performance.

CODE DESIGN

Space–Time Codes

This scheme transmits the same information from both antennas simultaneously but with a delay of one symbol interval. We can view this as a special case of the arrangement in Fig. 1, where the information is encoded by a channel code. In order to provide improved performance while maintaining the same transmission rate it has been proposed a new method of codes for this application referred to as the *Space– Time Codes*. The restriction imposed by the delay element in the transmitter is first removed. Then performance criteria are established for code design assuming that the fading from each transmit antenna to each receive antenna is Rayleigh.

Space–time trellis coding is a recent proposal that combines signal processing at the receiver with coding techniques appropriate to multiple transmit antennas. Specific space–time trellis codes designed for two transmitting and receiving antennas perform extremely well in slow-fading environments, typically of indoor transmission. However, when the number of transmit antennas is fixed, the decoding complexity of space–time trellis codes increases exponentially with transmission rate.

When the receiver has multiple antennas, the transmit beamforming cannot simultaneously maximize the signal level at all of the receive antennas, and precoding with multiple streams is used.

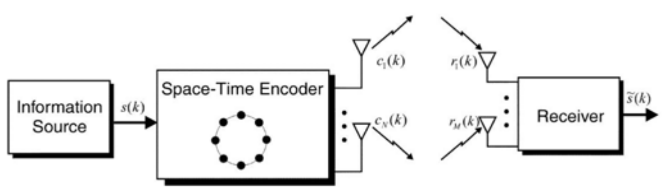

Fig. 1. 2X2 Antenna Communication System

The Alamouti Code: An efficient space-time block code

The encoder for Alamouti schemes can be seen in figure. This scheme with two transmit antennas and two receive antenna is interpreted here. In general case, we may use M receive antennas. In Alamouti encoding scheme, during any given transmission period two signals are transmitted simultaneously from two transmit antennas.

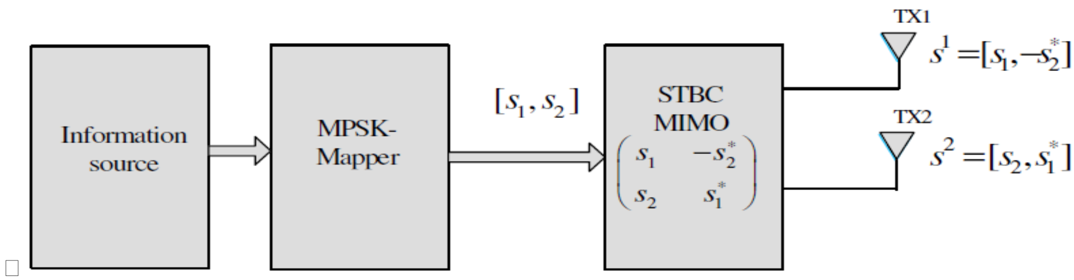

Fig. 2. Encoder for Alamouti schemes

The two-by-two space-time block code is formally written in matrix form as

$$TIME\begin{bmatrix} \tilde{s}_1 & \tilde{s}_0 \\ -\tilde{s}_0{}^* & \tilde{s}_1{}^* \end{bmatrix}$$

where, the explanation is :
At time t, antenna 1 transmits s_1 , and simultaneously, antenna 2 transmits s_0 . At time t + T, where T is the symbol duration, signal transmission is switched, with $-s_0$ * transmitted by antenna 1 and s_1 * simultaneously. transmitted by antenna 2.
The receiver model as the receiving signal *r* can be designed with taking a random value of *h* as follows :

$$\tilde{s}_1 = h_1^* r_0 - h_0 r_1^* + h_3^* r_2 - h_2 r_3^*$$
$$\tilde{s}_0 = h_0^* r_0 + h_1 r_1^* + h_2^* r_2 - h_3 r_3^*$$

$$r_0 = h_0 s_0 + h_1 s_1 + n_0$$

$$r_1 = -h_0 s_1^* + h_1 s_0^* + n_1$$

$$r_2 = h_2 s_0 + h_3 s_1 + n_2$$

$$r_3 = -h_2 s_1^* + h_3 s_0^* + n_3$$

where, *n* values represent the noise components for respective receivers.

Time to move on to a transmit diversity scheme where the information is spread across multiple antennas at the transmitter. For our discussion, it has been assumed that the channel is a flat fading Rayleigh multipath channel and the modulation is BPSK.

RESULT

Simulation results demonstrated that the estimator at the receiver is capable of providing dual branch diversity. The BER comparison shows the efficacy of the 2X2 antenna MIMO system.

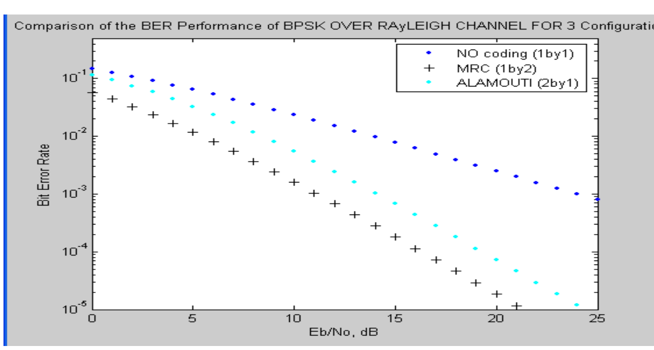

Fig. 3. Comparison of BER for BPSK modulation with 2X1 Antenna with Alamouti Code

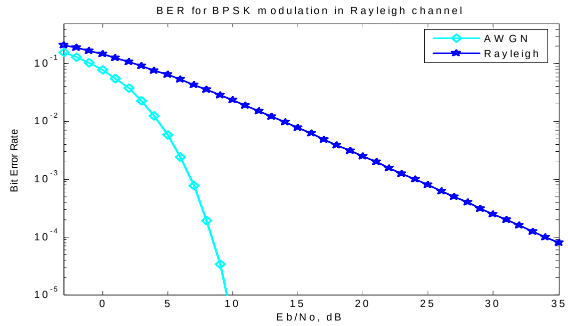

Fig. 4. BER for BPSK modulation in Raleigh Channel

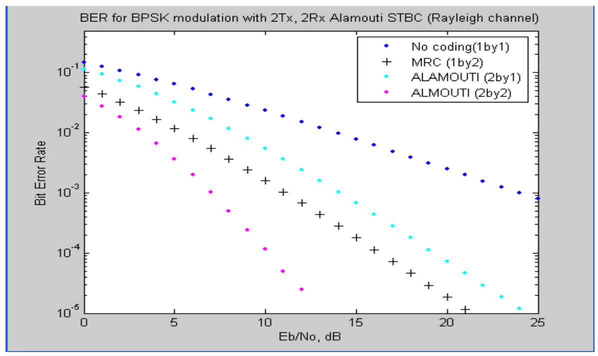

Fig. 5. Comparison of BER for BPSK modulation with 2X2 Antenna with Alamouti Code

CONCLUSION

In addressing the issue of decoding complexity, Alamouti has a remarkable scheme for transmission using two transmits antennas. This scheme is much less complex than space–time trellis coding for two transmit antennas but there is a loss in performance compared to space–time trellis codes. Despite this performance penalty, Alamouti's scheme is still appealing in terms of simplicity and performance and it motivates a search for similar schemes using more than two transmit antennas. It is a starting point for the studies in this paper, where we apply the *theory of orthogonal designs* to create analogs of Alamouti's scheme, namely, *space–time block codes*, for more than two transmit antennas.

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