An Analytical study of Space Time Block coding techniques for Wireless Networks

Praveen Kumar Kaithal
M.Tech Scholar
LNCT Bhopal
praveenkaithal@yahoo.com

Vivek Richhariya
Asst. Professor
LNCT Bhopal
vivekrich@gmail.com

Vineet Richhariya
Asst. Professor (HOD)
LNCT Bhopal
vineet_rich@yahoo.com

Abstract:

In next generation wireless communication, with increase of internet and multimedia applications, the demand of high data rates services is rapidly growing. Space-time wireless technology with uses multiple antennas and with appropriate signaling and receiving techniques offers a high performance powerful tool . The use of multiple antennas in most future wireless communication systems seems to be inevitable. We are trying to provide solutions to some of the challenges in wireless communication by using multiple antennas .By using appropriate Space Time Coding techniques on multiple antennas we can achieve high performance gains in multipath fading wireless links. This paper covers all works done in area of Space Time Block Coding.

Keywords: Space-Time Coding (STC), Multiple Input Multiple Output (MIMO), fading, diversity.

Introduction:

There are many systems in which wireless communication is applicable. While various applications have different specifications and use different wireless technologies, most of them face similar challenges. Some of the challenges in wireless communications are:

- a need for high data rates
- quality of service
- mobility
- portability
- connectivity in wireless networks
- interference from other users
- privacy/security

Space-time block coding is a simple yet ingenious transmit diversity technique in MIMO technology. We shall first examine the Alamouti code [1], which started it all. Basically Alamouti proposed a simple scheme for a 2x2 system that achieves a full diversity gain with a simple maximum likelihood decoding algorithm. We shall then examine higher-order diversity systems involving a large number of antennas, but whose basic approach is derived from the method proposed by Alamouti [1]. The premise in all of these approaches has been that we have perfect knowledge of the channel at the receiver and that the data streams are independent. In reality, however, this is not true. Therefore, we shall then go on to examine the behavior of these space-time codes in the presence of imperfect channel estimates and correlated slow Rayleigh fading channels.

The Alamouti scheme brought in a revolution of sorts in multiantenna systems by providing full diversity of two without channel state information (CSI) at the transmitter and a very simple maximum likelihood decoding system at the receiver. Maximum likelihood decoders provide full diversity gain of M_R(reciveing antennas) at the receiver.M_T as (transmitter antennas). Hence, such a system provides a guaranteed overall diversity gain of $2M_R$, without CSI at the transmitter. This is achieved by the key feature of orthogonality between the sequences generated by the two transmit antennas. Due to these reasons, the scheme was generalized to an arbitrary number of transmit antennas by applying the theory of orthogonal Space-Time Block Codes designs. The generalized schemes are referred to as space-time block codes (STBCs) [2]. These codes can achieve the full transmit diversity of M_T M_R , while allowing a very simple maximum likelihood decoding algorithm, based only on linear processing of received signals [3].

MIMO Multiple Input Multiple Output channel:

One of the distinguishing characteristics of wireless channels is the fact that there are many different paths between the transmitter and the receiver. The existence of various paths results in receiving different versions of the transmitted signal at the receiver. We consider a communication system, where N signals are transmitted from N transmitters simultaneously. For example, in a wireless communication system, at each time slot t, signals $C_{t,n}$, n = 1 , 2 , . . . , N are transmitted simultaneously from N transmit antennas. The signals are the inputs of a multiple-input multiple-output (MIMO) channel with M output [4]. Each transmitted signal goes through the wireless channel to arrive at each of the M receivers. In a wireless communication system with M receive antennas; each output of the channel is a linear superposition of the faded versions of the inputs perturbed by noise. Each pair of transmit and receive antennas provides a signal path from the transmitter to the receiver. The coefficient $\alpha_{n,m}$ is the path gain from transmit antenna n to receive antenna m. Figure 2 depicts a baseband discrete-time model for a flat fading MIMO channel. Based on this model, the signal $r_{t,m}$, which is received at time t at antenna m, is given by

$$r_{t,m} = \sum_{n=1}^{N} \alpha_{n,m} C_{t,n} + \eta_{t,m}$$

where $\eta_{t,m}$ is the noise sample of the receive antenna m at time t Based on (2.1), a replica of the transmitted signal from each transmit antenna is added to the signal of each receive antenna. Although the faded versions of different signals are mixed at each receive antenna, the existence of the M copies of the transmitted signals at the receiver creates an opportunity to provide diversity gain.

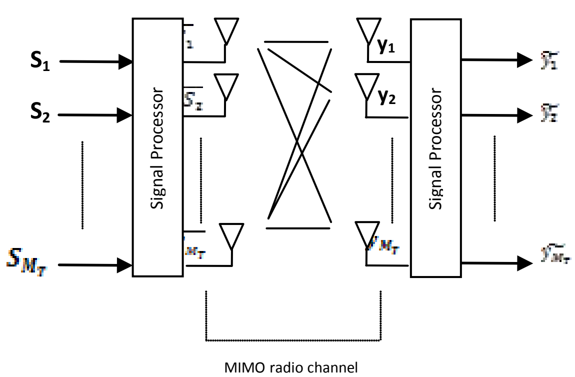

Fig 1: A MIMO Channel

Alamouti scheme:

The encoder for Alamouti schemes can be seen in figure. This scheme [5] 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.

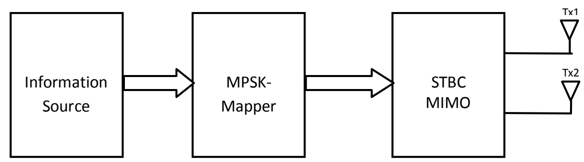

Fig 2 Encoder for Alamouti schemes

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

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

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.

Related Works on STBC

The investigation of the concatenation of 4D-8-PSK-TCM scheme [6] in conjunction with space-time block codes. At first,evaluation of the performance of the presented scheme which achieves better coding gains over quasi static fading channel than uncoded system with perfect CSI knowledge. A novel technique of codes called the Space–Time codes for transmission using multiple transmit antennas over Rayleigh or Rician wireless channels is discussed in [7]. The performance of these codes was shown to be excellent, and the decoding complexity comparable to codes used in practice on Gaussian channels. The novel Extended Balanced Space-Time Block Codes (EBSTBC) is proposed in [7].A modified shaping criterion in the design of STBCs that enabled us to propose two STBCs[8], one each for 4 and 6 transmit antennas, that have the best known normalized minimum determinants in their class. This shaping criterion can be employed to see if better STBCs, in terms of coding gain, can be obtained for arbitrary number of transmit antennas. In [8] The performance of space-time codes for wireless multiple-antenna systems with channel state information (CSI) at the transmitter has been also studied. Alamouti code is the only OSTBC that provides full diversity at full data rate (1 symbol/time slot) for two transmit antennas [9].

Conclusion:

Space Time Block Coding

This paper gives a basic study of the MIMO technology and basic introduction to Space-Time Coding with presenting Alamouti's scheme. Also give an idea of related works around Space Time Block Coding.

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