Space Time Block Coding for High Data Rate Wireless Communication

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Abstract: Wireless communication using multiple-input multiple-output (MIMO) systems enables increased spectral efficiency for a given total transmit power. MIMO stand for multiple inputs and multiple outputs. It is a system that uses several antennas at the transmitter and receiver links. Multiple-input–multiple-output (MIMO) systems with reduced complexity is considered. The transmit diversity scheme becomes more popular to solve multi-path fading problem which use multiple antenna at transmitter to improve reliable data transmission. This scheme called combination of spatial (antenna) and temporal processing known as space time block coding (STBC). Alamouti’s STBC scheme is the most famous and popular one since the only STBC which can achieve both full diversity and full code rate. In current research, high data rate wireless communications, transmission rate 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.

Key words: MIMO systems • Space-time codes • Alamouti code • Multiple Antennas • Wireless Communication

INTRODUCTION

Multiple-input multiple-output (MIMO) systems are a natural extension of developments in antenna array communication. While the advantages of multiple receive antennas, such as gain and spatial diversity, have been known and exploited for some time the use of transmit diversity has only been investigated recently [1]. The advantages of MIMO communication, which exploits the physical channel between many transmit and receive antennas are currently receiving significant attention. While the channel can be so nonstationary that it cannot be estimated in any useful sense, in this article we assume the channel is quasi-stationary [2]. MIMO systems provide anumber of advantages over single-antenna-to-single-antenna communication. Sensitivity to fading is reduced by the spatial diversity provided by multiple spatial paths. Generally, a MIMO system consists of \( n \) transmit (Tx) and \( m \) receive (Rx) antennas. It is called a MIMO \((n,m)\) system. All the Tx antennas can send their signals simultaneously in the same band width of a radio channel. Each Rx antenna receives the superposition of all the transmit signals disturbed by the noise in the radio channel. If more than \( \min(n,m) \) independent signals are transmitted, they can be correctly decoded at the receiver. Receiver diversity is a form of space diversity, where there are multiple antennas at the receiver. The presence of receiver diversity poses an interesting problem – how do we use ‘effectively’ the information from all the antennas to demodulate the data. We use multiple antennas at receiver to improve the signal quality. It is costly and difficult to implement in hand held mobile devices like cell phone. A good example for this is MRRC (maximum Ratio combining) diversity. This method uses multiple antennas at receiver to improve the signal quality [3-8].

Transmitter Diversity: This scheme needs complete channel knowledge at the transmitter. However the new simple transmit diversity technique like Alamouti’s scheme they do not need channel information. In transmit diversity using different kind of modulation and
coding technique we can achieve with almost zero probability error whereas in receiver diversity we can achieve it by increasing SNR which is improved by increasing the number of antenna element receiver side. Space time block codes. This scheme transmits the same information from both antennas simultaneously but with a delay of one symbol interval. 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.

Existing System

**Maximum Ratio Combining:** This approach practically applied only to base station to improve their reception quality because of the cost, size and power of remote units [9]. The channel is modelled by complex multiplicative distortion. For two receive antenna. channel between the transmitter antenna and the receive antenna one is $h_1 = \beta e^{j\phi}$ and the channel between the transmitter and receive antenna two is $h_2 = \beta e^{j\phi}$. Noise would be add at two receiver so that the two received base band signal would be

$$y_1 = h_1 x + n_1$$
$$y_2 = h_2 x + n_2$$

where the signal sent from transmitter, $n_1$ and $n_2$ represent complex noise which is assumed to be Gaussian distributed with zero mean.

**MRRC with two receive antenna**

![Fig. 1 MRRC with two receive antenna](image1)

The two-branch MRRC receiver will combine the receive signals as follows:

$$x = h_1 y_1 + h_2 y_2$$
$$= h_1^* (h_1 x + n_1) + (h_2 x + n_2)$$
$$= h_1^* h_1 x + h_1^* n_1 + h_2^* n_2$$

Proposed System

Alamouti STBC 2x1: Alamouti scheme is a simple transmit diversity scheme suitable for two transmit antennas. Before coding the base band signal would be modulated at each antenna using a B-PSK modulated scheme. Then the modulated signal is encoded by space time block code technique. We assume here the transmitter does not have channel knowledge but the receiver have full knowledge about the channel [10]. We will first see, two transmit antenna and one receive scheme then two transmit and two receive scheme.

**Two transmitter and one receiver scheme**

![Fig. 2 Two transmitter and one receiver scheme](image2)
Two symbols are considered at a time, say \( x_1 \) and \( x_2 \), they are transmitted in two consecutive time slots. In first time slot, \( x_1 \) is transmitted from antenna one and \( x_2 \) is transmitted from antenna two. In the second time slot, \( -x_2^* \) is transmitted from antenna one and \( x_1^* \) is transmitted from antenna two [11].

The fading coefficient from antenna one and two are denoted by \( h_1(t) \) and \( h_2(t) \) respectively at time \( t \). By assuming these coefficients are constant across two consecutive symbols,

\[
h_1(t) = h_1(t+T) = h_1 = \beta_1 e^{i\theta_1}
\]

\[
h_2(t) = h_2(t+T) = h_2 = \beta_2 e^{i\theta_2}
\]

The received signal at time \( t \) and \( t+T \) in matrix form expressed as

\[
\begin{pmatrix}
y_1 \\
y_2
\end{pmatrix} =
\begin{pmatrix}
x_1 & x_2 \\
-x_2^* & x_1^*
\end{pmatrix}
\begin{pmatrix}
h_1 \\
h_2
\end{pmatrix} +
\begin{pmatrix}
n_1 \\
n_2
\end{pmatrix}
\]

where \( y_1 \) and \( y_2 \) the received signal at time \( t \) and \( t+T \) and are independent zero mean additive white Gaussian noise. The combiner combines the received signal as

\[
x_1 = h_1^* y_1 + h_2^* y_2^*
\]

\[
x_2 = h_1^* y_2 + h_2^* y_1^*
\]

Finally similar to MRRC, the maximum likelihood decision rule is used at receiver to choose which symbol was actually transmitted for each of the signals \( x_1 \) and \( x_2 \).

We can conclude that 2x1 Alamouti scheme gives the same diversity order with that of 1x2 MRRC.

**Alamouti Stbc 2x2:** Let us consider the channel model for two consecutive channel uses at time \( t \) and \( t+T \)

\[
Y(t) = Hc(t) + n(t)
\]

\[
Y(t+T) = Hc(t+T) + n(t+T)
\]

**Alamouti scheme with two transmit and two receive antenna**

![Diagram](attachment:image.png)

Fig. 3: Alamouti scheme with two transmit and two receive antenna
Finally the maximum likelihood decision rule is used at receiver to choose which symbol was actually transmitted for each of the signals $x_1$ and $x_2$. Alamouti’s 2x2 schemes give the same diversity order with 1x4 MRRC. Generally we can conclude that Alamouti scheme with two transmit and M receive antennas is equivalent to MRRc with one transmit antenna and 2M receive antenna.

**Advantages:**
- lowcost
- full diversity can be achieved
- increased data rate
- ease of implementation
- less complex

**Simulation Results**

**BER vs SNR for Maximum Ratio Combining:**

![Figure 4: BER vs SNR for Maximum Ratio Combining](image)

**BER for Bpsk modulation with 2Tx,2rxalamouti STBC(Rayleigh channel)**

![Figure 5: BER for Bpsk modulation with 2Tx,2rxalamouti STBC(Rayleigh channel)](image)

**Comparison of SNR for 2x1 and 2x2 Alamouti**

![Figure 6: Comparison of SNR for 2x1 and 2x2 Alamouti](image)

**CONCLUSION**

In addressing the issue of decoding complexity, Alamouti has a remarkable scheme for transmission using two transmit 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 and mrrc. Despite this performance penalty, Alamouti’s scheme is still appealing in terms of simplicity and performance and it motivates a search for similarschemes using more than two transmit antennas.

- The Alamouti’s channel capacity is very close to Shannon capacity channel that means Alamouti’s code is good code.
- Alamouti’s coding technique we get better error probability performance than SISO. However MRRC with the same diversity order with transmit diversity gives the same error performance if there is no power limitation.
- In transmit diversity using different kind of modulation and coding technique we can achieve with almost zero probability error whereas in receiver diversity we can achieve it by increasing SNR which can be improved by increasing the number of antenna element at receiver side [12].

**Future Work:** This project is limited only on simple space time block code (Alamouti’s coding) which is focus only to enhance diversity. However, further works could be done in the scheme in order to enhance both the capacity of channel and diversity. A detailed study and analysis has to be done on the trade off between the diversity gain and the multiplexing gain [13-18]).

**REFERENCES**


