A REVIEW ON SPACE TIME CODING

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Abstract— **The invention of the radio telegraph by Marconi more than hundred years ago was the begining of wireless communications. In the last few decades, the rapid progress in radio technology has activated a communications revolution. Wireless systems have undergone through the world to help people and machines to communicate with each other independent of their location.This is a review paper on space time coding. We have done the study analysis of different space time code, its mathematical analysis with the help of equations.We have discusse here two new stbc which are respectively OSTBC and Qo-STBC.**

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1. INTRODUCTION

Space-Time Codes (STCs) have been utilized in mobile communications as well as in wireless local area networks. Space time coding has been used in both spatial and temporal domain introducing redundancy between signals transmitted from various antennas at various time periods, attaining transmit diversity and antenna gain over spatially un-coded systems without sacrificing bandwidth. The research on STC focuses on improving the system performance by employing extra transmits antennas. In general, the designs of STC amounts to finding transmit matrices that satisfy certain optimality criteria. Constructing STC, researchers have to trade-off between three goals: simple decoding, reducing the error probability on one hand and maximizing the information rate on the other. The essential question is: How the transmitted date rate can be maximized using a simple coding and decoding algorithm at the same time as the bit error probability is minimized? Here we will be giving a review work on this topic.

2. BASIC PRINCIPLE

Fig. 2.1 shows the Basic Principle of Space Time Coding. In this STC, multiple antennas are used at transmitter side only and at receiver side, only single antenna is used. This means that transmit diversity is used for Space Time Coding. First, the information bit sequence is encoded with the help of Space Time Encoder. After this, the same redundant signal is transmitted using M transmitter antennas. Using Space Time Decoder, the transmitted bit sequences is estimated in receiver side.

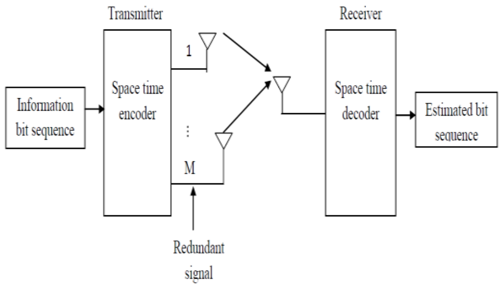

Fig. 2.1: Basic Principle of Space Time Coding

Now the underlying phenomena for MIMO systems employing space-time coding system have been studied. To support greatly enhanced performance, more detailed exploration of space time coding is given. First, the relationship between different types of codes, as well as the codes within each class is explained. A system level overview of space-time transmission through generic transmitter and receiver models is given.

2.1 Transmitter and Receiver System Models

To formalize the main ideas behind space-time coding and express them in a clear mathematical framework, begin by presenting generic system models for the space-time transmitter (Fig. 2.2) and receiver (Fig. 2.3). These diagrams encapsulate many of the structures and ideas that are mentioned in the space-time coding review. More importantly, they provide us with a starting point for studying the similarities and differences between existing approaches, and also lay the groundwork for further discussion and analysis.

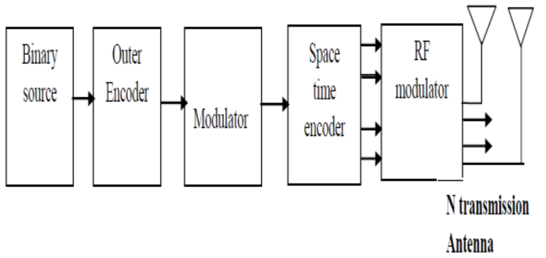

Fig. 2.2: System model of generic Space-Time Transmitter

A space-time transmission starts from the source, which generates k bit data vectors by considering BQ/V vectors at a time. The outer encoder represents a traditional error correcting code of rate K/V. Therefore it produces from this input [BQ/V] V-bit codewords. Work of the modulator is to map bits into that outputs Q symbols from finite and generally complex alphabet, where the modulation order is B = log2 |X|.

Space-time encoder transforms the Q symbols xq into N vectors of complex signals to be transmitted from the N antennas. Each is of length L, which is the number of symbol periods that it takes to complete the transmission. These vectors form the rows of space-time signal matrix. The overall rate of the code is therefore BQ/ L , where the first term arises from theouter code, the second from the modulation order, and the third from the inner space-time code.

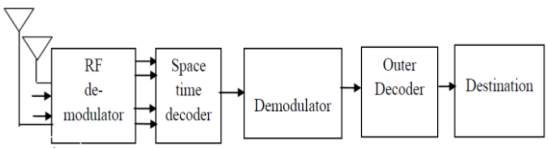

Fig. 2.3: System model of generic Space-Time Receiver

Fig. 2.3 depicts the system model of a space-time receiver. As is typical in transmission systems, the receiver blocks perform the inverse operations of their transmitter-side counterparts.

3. SPACE TIME CODED SYSTEMS

Let us consider a space-time coded communication system with n_t transmit antennas and n_r receive antennas. The transmitted data are encoded by a space-time encoder. At each time slot, a block of $m.n_t$ binary information symbols

$$c_t = [c_t^1, c_t^2, c_t^3, \dots \dots \dots c_t^{m.n_t}]^T \qquad (3.1)$$

is fed into the space-time encoder. The encoder maps the block of M binary data into n_t modulation symbols from a signal set of constellation $M = 2^m$ points. After serial-to-parallel (SP) conversion, the n_t symbols

$$s_t = [s_t^1, s_t^2, s_t^3, \dots \dots \dots s_t^{n_t}]^T \; 1 \le t \le N \qquad (3.2)$$

are transmitted simultaneously during the slot t from n_t transmit antennas. Symbol $s_t^i, 1 \le i \le n_t$, is transmitted from antenna i and all transmitted symbols have the same duration of T sec. The vector in (3.2) is called a space-time symboland by arranging the transmitted sequence in an array, a $n_t \times N$Space-time codeword matrix can be defined.

$$S = [s_1 s_2 \dots \dots \dots s_N] = \begin{bmatrix} s_1^1 & s_2^1 & \cdots & s_N^1 \\ s_1^2 & s_2^2 & \dots & s_N^2 \\ \vdots & \vdots & \ddots & \vdots \\ s_1^{n_t} & s_2^{n_t} & \cdots & s_N^{n_t} \end{bmatrix} \qquad (3.3)$$

The $i-\text{th}$ row $s^i = [s_1^i, s_2^i, \dots \dots s_N^i]$ is the data sequence transmitted form the $i-\text{th}$ transmit antenna and the $j-\text{th}$ column $s_j = [s_j^1, s_j^2, \dots \dots s_j^{n_t}]$ is the space-time symbol transmitted at time j, $1 \le j \le N$.

The received signal vector can be calculated as: $Y = HS + N$ (3.4)

The MIMO channel matrix H corresponding to n_t transmit antennas and n_r receive antennas can be represented by an$n_t \times n_r$ matrix:

$$H = \begin{bmatrix} h_{1,1}^t & h_{1,2}^t & \cdots & h_{1,n_t}^t \\ h_{2,1}^t & h_{2,1}^t & \dots & h_{2,n_t}^t \\ \vdots & \vdots & \ddots & \vdots \\ h_{n_r,1}^t & h_{n_r,2}^t & \cdots & h_{n_r,n_t}^t \end{bmatrix} \qquad (3.5)$$

where the $ji-\text{th}$ element, denoted by $h_{j,i}^t$, is the fading gain coefficient for the path from transmit antenna i to receive antenna j. Perfect channel knowledge is assumed at the receiver side and also assumed that the transmitter has no information about the channel available at the transmitter side. At the receiver, the decision metric is computed based on the squared Euclidian distance between all hypothesized receive sequences and the actual received sequence:

$$d_H^2 = \sum_t \sum_j^{n_r} \left| y_t^j - \sum_{i=1}^{n_t} h_{j,i}^t s_t^i \right|^2 \qquad (3.6)$$

Given the receive matrix Y the ML-detector decides for the transmit matrix S with smallest Euclidian distance d_H^2.

4. SPACE TIME BLOCK CODES

In a general form, an STBC can be seen as a mapping of$n_N$complex symbols $\{s_1, s_2, s_3, \dots \dots \dots s_N\}$ onto a matrix Sof dimension $n_t \times N$:

$$\{s_1, s_2, s_3, \dots \dots \dots s_N\} \rightarrow S$$

An STBC code matrix S taking on the following form:

$$S = \sum_{n=1}^{n_N} (\bar{s}_n A_n + j\tilde{s}_n B_n) \quad (4.1)$$

where$\{s_1, s_2, s_3, \dots \dots \dots s_N\}$is a set of symbols to be transmitted with $\bar{s}_n = \mathrm{Re}\ \{s_N\}$ and $\tilde{s}_n = \mathrm{Im}\{s_N\}$, and with fixed code matrices $\{A_n, B_n\}$ of dimension $n_t \times N$ are called linear STBCs. The following STBCs can be regarded as special cases of these codes.

4.1 Alamouti Code

Historically, the Alamouti code is the first STBC that provides full diversity at full data rate for two transmit antennas. A block diagram of the Alamouti space-time encoder is shown in fig 4.1:

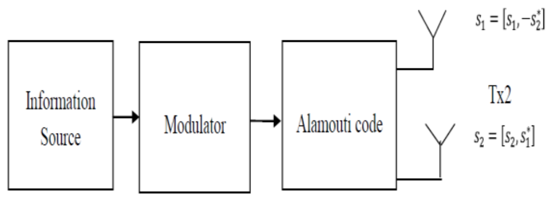

Fig. 3.4: ALAMOUTI code

4.2 Orthogonal Space Time Block Codes (OSTBCs)

The pioneering work of Alamouti has been a basis to create OSTBCs for more than two transmits antennas. First of all, Tarokhstudied the error performance associated with unitary signal matrices. Orthogonal STBCs are an important subclass of linear STBCs that guarantee that the ML detection of different symbols $\{s_n\}$is decoupled and at the same time the transmission scheme achieves a diversity order equal to $n_t n_r$. The main disadvantage of OSTBCs is the fact that for more than two transmits antennas and complex valued signals, OSTBCs only exist for code rates smaller than one symbol An OSTBC is a linear space-time block code S that has the following unitary property:

$$S^H S = \sum_{n=1}^{N} |s_n|^2\, I \quad (4.2)$$

The i-th row of S corresponds to the symbols transmitted from the i-th transmit antenna in N transmission periods, while the j-th column of S represents the symbols transmitted simultaneously through n_t transmit antennas at time j.According to equation the columns of the transmission matrix S are orthogonal to each other. That means that in each block, the signal sequences from any two transmit antennas are orthogonal. The orthogonality enables us to achieve full transmit diversity and at the same time, it allows the receiver by means of simple MRC to decouple the signals transmitted from different antennas and consequently, it allows a simple ML decoding.

4.3 Quasi Orthogonal Space Time Block Codes (QO-STBC)

The main characteristic of the code design methods explained in previous sections is the orthogonality of the codes. The codes are designed using such orthogonal designs using transmission matrices with orthogonal columns. It has been shown how simple decoding which can separately recover transmit symbols, is possible using an orthogonal design. These codes achieve full data rate at the expense of a slightly reduced diversity. In the proposed quasi-orthogonal code designs, the columns of the transmission matrix are divided into groups. While the columns within each group are not orthogonal to each other, different groups are orthogonal to each other. Using quasi-orthogonal design, pairs of transmitted symbols can be decoded independently and the loss of diversity in QO-STBC is due to some coupling term between the estimated symbols.

5. CONCLUSION

This ia a review work of space-time codes and their performance. Performance and design criteria of the STCs have been discussed. A substantial part of this paper was dedicated to orthogonal STBCs. General Principles of space time coding will be focused. The simple Alamouti code and its performance were discussed. Then a short introduction into QO-STBCs has been given.

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