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Design and Analysis of Performance Evaluation for Spatial Modulation

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ABSTRACT

A novel multiple-input multiple-output (MIMO) transmission scheme called space time trellis coded spatial modulation is proposed. It combines spatial modulation(SM) and space time trellis coding(STTC) to take advantage of both. The transmitted information symbols are expanded not only to space and time domain but also to spatial(antenna) domain which corresponds to the on/off status of the transmit antenna available at the space domain, and therefore both core STTC and antenna indices carry information. Besides the high spectral efficiency advantage provided by antenna domain the proposed scheme is also optimized by deriving its diversity gain. Transmit diversity schemes for the coherent multiple-antenna flat-fading channel range from space-time block codes (STBC) to space-time trellis codes (STTC). In this project we compare the performance of STBC and STTC by means of frame error rate. Our result holds for small numbers of receive antennas and trellis states, and may extend to greater numbers of antennas and states.

INTRODUCTION

The basic idea is to map a block of information bits to two information carrying units symbol from constellation diagram and unique transmit antenna. The use of transmit antenna index as an information bearing unit increases the overall spectral efficiency by base-2 logarithm. A space–time code (STC) is a method employed to improve the reliability of data transmission in wireless communication systems using multiple transmit antennas. STCs rely on transmitting multiple, redundant copies of a data stream to the receiver in the hope that at least some of them may survive the physical path between transmission and reception in a good enough state to allow reliable decoding. Space time codes may be split into two main types:

1) Space–time trellis codes (STTCs) distribute a trellis code over multiple antennas and multiple time-slots and provide both coding gain and diversity gain.

2) Space–time block codes (STBCs) act on a block of data at once (similarly to block codes) and provide only diversity gain, but are much less complex in implementation terms than STTCs.

STC may be further subdivided according to whether the receiver knows the channel impairments. In coherent STC, the receiver knows the channel impairments through training or some other form of estimation. Space–time trellis codes (STTCs) are a type of space–time code used in multiple-antenna wireless communications. This scheme transmits multiple, redundant copies of a trellis (or convolutional) code distributed over time and a number of antennas ('space'). These multiple, 'diverse' copies of the data are used by the receiver to attempt to reconstruct the actual transmitted data.

II Existing System:

A) V-Blast (Vertical-Bell Lab Layered Space-Time):

The increase demand for high data rate and the spectral efficiency has led to development of Spatial Multiplexing systems such has V-BLAST. In V-BLAST high level of Inter Channel Interference occurs, since

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all antenna transmit their own data at the same instant. This further increases the complexity of optimal decoder exponentially, while complexity sub optimum linear decoders such as minimum mean square error(MMSE) degrade the error performance of the system significantly.

B) Stbc-Sm (Space Time Block Code-Spatial Modulation):

STBCs offer an excellent way to exploit the potential of MIMO systems because of their implementation simplicity as well as their low decoding complexity (Telatar, E., 1999; Wolniansky, P., *et al.*, 1998). A special class of STBCs, called orthogonal STBCs (OSTBCs), have attracted attention due to their single-symbol maximum likelihood (ML) receivers with linear decoding complexity. However it has been shown that the symbol rate of an OSTBC is upper bounded by ¾ symbols per channel use (pcu) for more than two transmit antennas (Alamouti, S.M., 1998). Several high rate STBCs have been proposed in the past decade (Tarokh, V., *et al.*, 1999; Liang, X.-B., 2003; Biglieri, E., *et al.*, 2009), but their ML decoding complexity grows exponentially with the constellation size, which makes their implementation difficult and expensive for future wireless communication systems

III. Proposed System:

A) The proposed work combines the spatial modulation with STTC. (Space Time Trellis codes)

B) The system functionalities are evaluated with BER and FER, metrics under various possible fading Environments.

IV Space–Time Trellis Code:

For an STC to be used, there must necessarily be multiple transmit antennas, but only a single receive antennas is required; They are able to provide both coding gain and diversity gain and have a better bit-error rate performance. However, being based on trellis codes, they are more complex than STBCs to encode and decode; they rely on a Viterbi decoder at the receiver where STBCs need only linear processing. STTCs were discovered by VAHID TAROKH

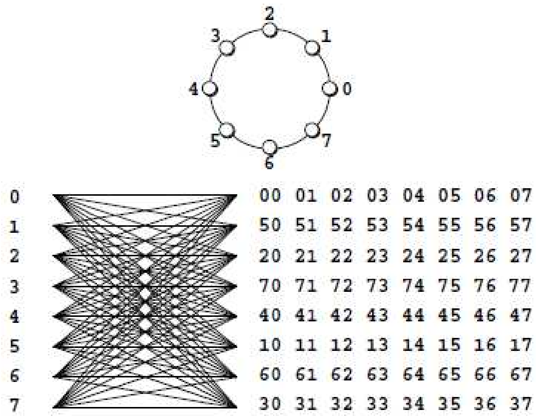

Fig. 1: Trellis code state diagram

A) STTC Encoder:

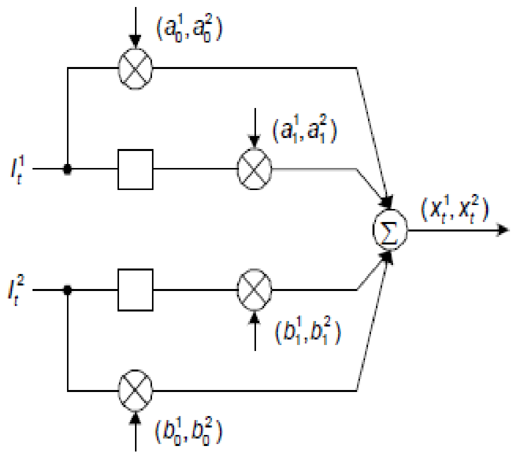

Fig. 2: Encoder

The space-time encoder maps the raw information bits into space-time symbols based on the trellis diagram. The encoder takes L = 130 symbols (one frame) from the MPSK signal constellation and encodes them into an (L x n) matrix of complex symbols where n is the number of transmit antennas. This mapping procedure is accomplished through the encoder structure. At the beginning and end of each frame, the encoder is required to be in state 0. The encoding algorithm then loops through each pair of input symbols and determines the output for each antenna based on those current inputs and the current state. Then the next state is determined based on the current input.

B) Sttc Decoder:

The decoding procedure is based on the well-known Viterbi algorithm. However, for space-time codes the Viterbi decoder is modified from the conventional convolutional decoder so that the branch metric is computed from the complex inputs and the CSI. The Viterbi decoder is then used to calculate the path through the trellis diagram with the lowest accumulated metric. Assuming that j t r is the received signal at receiver antenna j at time t, the branch metric is determined by

$$\text{Branch Metric} = \sum_{j=1}^{m} \left| r_t^j - \sum_{i=1}^{n} h_{ij} \cdot x_t^i \right|^2$$

where I t x is the transmitted signal. In these simulations, at every time unit of the trellis, a survivor is determined for each state from the minimum partial metric. The state from which the minimum partial metric originated is saved into a state predecessor (or state history) table. Once the end of the trellis is reached, the decoder can begin to determine the sequence of bits that were input into the space-time encoder. First, beginning at the end of the trellis, select the state with the smallest total metric and save that state into a state sequence table (if we assume that the trellis begins and ends in state 0, then this initial chosen state would be state 0).

The decoder iteratively performs the following trace back procedure until the beginning of the trellis is reached: using the state predecessor table, for the selected state, determine a new state which is the predecessor to that state. Save the state number of that selected state onto the state sequence table. Once the trellis is exhausted, the completed state sequence table will show the state transitions taken by the final survivor.

C) Statistical Models for Fading Channels:

In wireless communications, signal fading is caused by multi-path effect. Multi-path effect means that a signal transmitted from a transmitter may have multiple copies traversing different paths to reach a receiver. Thus, at the receiver, the received signal should be the sum of all these multi-path signals. Because the paths traversed by these signals are different; some are longer and some are shorter. The one at the direction of light of signal (LOS) should be the shortest. These signals interact with each other. If signals are in phase, they would intensify the resultant signal; otherwise, the resultant signal is weakened due to out of phase. This phenomenon is called channel fading. In general, there are two criteria to measure channel fading, including (1) Doppler spread, and (2) delay spread.

1) Doppler spread:

Due to Doppler effect, if a transmitter is moving away from a receiver, the frequency of the received signal is lower than the one sent out from the transmitter; otherwise, the frequency is increased. In wireless communications, there are many factors that can cause relative movement between a transmitter and a receiver. It can be the movement of a mobile such as a cell phone; it can be the movement of some background objectives, which causes the change of path length between the transmitter and the receiver. The lengths of signal path are often different, which correspond to different movement speeds of transmitter signals, and in turn different frequency shifts on the signal paths. As a result, a frequency spread is caused in the signal spectrum. Corresponding to Doppler spectrum spread, there is a concept called coherence time, which is related to the reciprocal of the maximum Doppler shit. Coherence time is used to measure a time interval, in which a smaller amount of fading is occurred. Specifically, if the baseband signal varies faster than the coherence time, the distortion from Doppler spread fading is negligible. Such a situation is called slow fading. Otherwise, if the baseband signal varies more slowly than the coherence time, the distortion from Doppler spread fading may be significant. This situation is called fast fading.

2) Delay spread:

The different signal paths between a transmitter and a receiver correspond to different transmission times. For an identical signal pulse from the transmitter, multiple copies of signals are received at the receiver at different moments. The signals on shorter paths reach the receiver earlier than those on longer paths. The direct effect of these unsimultaneous arrivals of signal causes the spread of the original signal in time domain. This spread is called delay spread. The delay spread puts a constraint on the maximum transmission capacity on the wireless channel. Specifically, if the period of baseband data pulse is larger than that of delay spread, inter-symbol interference (ISI) will be generated at the receiver. That is, the data signals on two neighbouring pulse periods are received at the same time, which causes the receiver not to be able to distinguish them. Corresponding to the concept of delay spread, there is a term called coherence bandwidth used to measure the up-limit bandwidth that can be transmitted for a channel to be free of ISI. Coherence bandwidth is defined as 10% of the reciprocal of root mean square (rms) delay delay spread. If the bandwidth of a transmitter signal is less than the channel coherence bandwidth, the channel shows flat fading to be free of ISI. Otherwise, the channel shows frequency selective fading, and may surfer from ISI.

D) How to Get Rid of Fading?:

Fading effect is a physical phenomenon, which can never be eliminated from the communication system channel. But through some techniques we may try to reduce the effects of fading. In wireless mobile communications, diversity techniques are widely used to reduce the effects of multipath fading and improve the reliability of transmission without increasing the transmitted power or sacrificing the bandwidth. Because of the randomness in the channel behavior, the deeply faded signals results in worst maximum bit error rate.

So the basic principle in the diversity technique is that, multiple replicas of the transmitted signals at the receiver are created, all carrying the same information but with small correlation in fading statistics. The basic idea of diversity is that, if two or more independent samples of a signal are taken, these samples will fade in an uncorrelated manner, e.g., some samples are severely faded while others are less attenuated. This means that the probability of all the samples being simultaneously below a given level is much lower than the probability of any individual sample being below that level.

V Transmitter Design:

A) Antenna:

An antenna (or aerial) is an electrical device which converts electric currents into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter applies an oscillating radio frequency electric current to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals, that is applied to a receiver to be amplified. An antenna can be used for both transmitting and receiving.

B) Omni-Directional Antenna:

Antennas can be designed to transmit or receive radio waves in all directions equally (omnidirectional antennas), or transmit them in a beam in a particular direction, and receive from that one direction only (directional or high gain antennas).

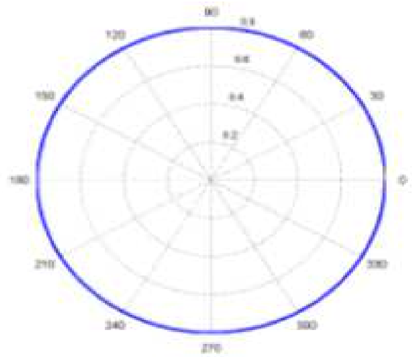

Fig. 3: Radiation Pattern

C) Algorithm:

1) Given the total number of transmit antennas nT , calculate the number of possible antenna combinations for the transmission of TC, i.e., the total number of TC-SM code words from

$$c = \left\lfloor \binom{n_T}{2} \right\rfloor_{2^p}$$

2) Calculate the number of code words in each codebook χi, i = 1, 2, . . ., $n - 1$ from $a = \lfloor nT/2 \rfloor$ and the total number of codebooks from $n = \lceil c/a \rceil$. Note that the last codebook χn does not need to have ' ‘code words, i.e, its cardinality is $a' = c - (n - 1)$.

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3) Start with the construction of $\chi 1$ which contains a which is non interfering code words as given below:

$$\chi_1 = \{ (\mathbf{X} \ \mathbf{0}_{2\times(n_T-2)}) \\ (\mathbf{0}_{2\times 2} \ \mathbf{X} \ \mathbf{0}_{2\times(n_T-4)}) \\ (\mathbf{0}_{2\times 4} \ \mathbf{X} \ \mathbf{0}_{2\times(n_T-6)}) \\ \vdots \\ (\mathbf{0}_{2\times 2(a-1)} \ \mathbf{X} \ \mathbf{0}_{2\times(n_T-2a)}) \}$$

4) Using a similar approach, construct for $2 \leq i \leq n$ by considering the following two important facts:

a)Every codebook must contain non-interfering code words chosen from pair wise combinations of nT available transmit antennas.

b)Each codebook must be composed of code words with antenna combinations that were never used in the construction of a previous codebook.

5) Determine the rotation angles θi for each χi, $2 \leq i \leq n$, that maximize δmin (χ) in (5) for a given signal constellation and antenna configuration; that is

$\boldsymbol{\theta}_{op}$ = argmax $\delta_{\min}(\chi)$,

where **$\boldsymbol{\theta} = (\theta 2, \theta 3, \ldots, \theta n)$.**

Then spectral efficiency of the system calculated is as follows

$$m = \frac{1}{2}\log_2 c + \log_2 M \ \text{[bits/s/Hz]}.$$

Then, Interfering codewords are chosen as

$$\mathbf{X}_{1k} = (\mathbf{x}_1 \ \mathbf{x}_2 \ \mathbf{0}_{2\times(n_T-2)}) \\ \mathbf{X}_{2l} = (\mathbf{0}_{2\times 1} \ \hat{\mathbf{x}}_1 \ \hat{\mathbf{x}}_2 \ \mathbf{0}_{2\times(n_T-3)}) \, e^{j\theta}$$

Minimum CGD is calculated using the formula given

$$\delta_{\min}(\mathbf{X}_{1k}, \hat{\mathbf{X}}_{1k}) \\ = \min_{\mathbf{X}_{1k}, \hat{\mathbf{X}}_{1k}} \det \begin{pmatrix} x_1 & x_2 - e^{j\theta}\hat{x}_1 & -e^{j\theta}\hat{x}_2 & \mathbf{0}_{1\times(n_T-3)} \\ -x_2^* & x_1^* + e^{j\theta}\hat{x}_2^* & -e^{j\theta}\hat{x}_1^* & \mathbf{0}_{1\times(n_T-3)} \end{pmatrix} \\ \times \begin{pmatrix} x_1^* & -x_2 \\ x_2^* - e^{-j\theta}\hat{x}_1^* & x_1 + e^{-j\theta}\hat{x}_2 \\ -e^{-j\theta}\hat{x}_2^* & -e^{-j\theta}\hat{x}_1 \\ \mathbf{0}_{(n_T-3)\times 1} & \mathbf{0}_{(n_T-3)\times 1} \end{pmatrix}$$

Signal constellation angles are calculated as follows

$$\theta_k = \begin{cases} \frac{(k-1)\pi}{n}, & \textbf{for BPSK} \\ \frac{(k-1)\pi}{2n}, & \textbf{for QPSK} \end{cases}$$

The following formula will maximize the CGD

$$\max \delta_{\min}(\chi) = \max \min_{i,j,i\neq j} \delta_{\min}(\chi_i, \chi_j) \\ = \max \min_{i,j,i\neq j} f_M(\theta_j - \theta_i)$$

D) Block Diagram Of Transmitter:

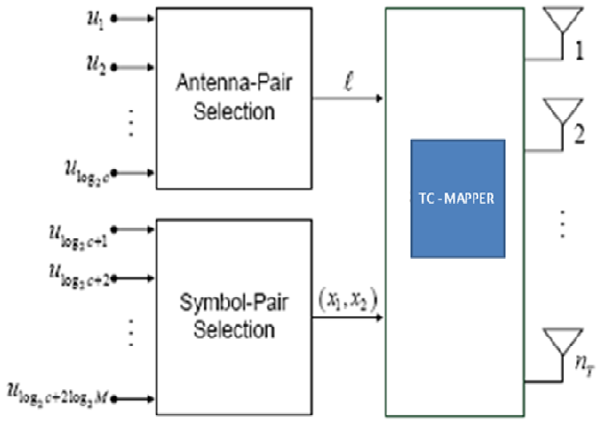

Fig. 4: Block diagram

Conclusion:

In this paper, as an alternative to existing techniques such as SM and VBLAST. The proposed new transmission scheme employs both APM techniques and antenna indices to convey information and exploits the transmit diversity potential of MIMO channels. Thus by this technique the spectral efficiency can be improved by increasing the coding gain of STTC.

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