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Weighted Space Time Trellis Code for Student-T Distribution Channel

Engineering

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ABSTRACT

In this paper we present the concept of weighted space-time trellis codes. These codes are a grouping of space-time codes and ideal beam forming. It has been revealed that if perfect CSI is available at transmitter, the performance of STTC can be further enhanced through weighting the transmitted signals. In this thesis, we weight up the performance of STTC combined with ideal beam forming over slow fading channels.

In this paper we present the theory of weighted space-time trellis codes. These codes are a combination of space-time codes and ideal beam forming. In this paper, we weight up the performance of space-time trellis codes combined with ideal beam forming over slow fading channels using 4-QAM and 4-PSK modulation schemes in which we have used two transmit and four receive antennas. Simulation results demonstrate that the projected scheme extensively outperforms the predictable space-time trellis without weighting.

1. INTRODUCTION

To get better efficiency for the transmission of reliable data Tarokh invented the Space Time Coding Techniques, in which the signal does not fluctuates due to fading. In these techniques the alternative paths are provided to the channel for the transmission of signal from transmitter to receiver these are called as diversity schemes.

A. Diversity

It is a scheme that occur from Space Time Coding. It is a method which is used to improve the reliability of a signal by using more than two communication channels which should different in characteristics. It can be categorized into following parts:

a. Temporal diversity: in which the signal is sent in different time slots.
b. Frequency Diversity: in which the signal is sent at different frequencies.
c. Spatial Diversity: in which more than one transmission or receiving antennas are used.

These are the main diversity schemes that we have used in this paper.

B. MIMO

Multiple-input and multiple-output, or MIMO, uses multiple antennas at both the transmitter and receiver to improve communication performance. MIMO modulation schemes with receive-only channel knowledge are mainly of two types, diversity systems and spatial multiplexing systems. Diversity modulation, or space-time coding, uses codewords designed to maximize the diversity advantage of the transmitted information. Such codes tend to maximize diversity gain at the expense of some loss in available capacity. This paper was followed by Tarokh and Alamouti's paper, which led to the development of what are now known STTCs which can concurrently provide substantial coding gain, spectral efficiency and diversity improvement. But with the increase in number of antennas and the size of the modulation there is increase in decoding complexity set is a major drawback. So, basically we can't use them for larger constellations. This paper carries the technique WSTTC which is discussed next.

2. PROPOSED TECHNIQUE

Weighted Space Time Trellis Coding Techniques (WSTTC) using Student-t fading channel.

Weighted student-t fading channel means beam forming on student-t fading channel. When we had used the methods for reliable data transmission with better efficiency rates some of the information has to be sacrificed. Therefore with the help of these proposed schemes i.e. transmission scheme over student-t fading channel, WSTTC is used. In this scheme data in transmitted without any sacrifice of information. And as a result we get for about efficiency of 2bits/sec/hz.

Appropriate beamforming technique will be devised to work on MIMO system using Student-T fading channel. In this research we have used WSTTC using student-t fading channel comparing the results with WSTTC using Rayleigh fading channel. For the transmission of data we have used from one to two transmit antennas and different receiving antennas in four state QAM and four state PSK modulation schemes.

2.1 SYSTEM MODEL

We consider a WSTTC system as shown in Fig. 1, with trans-mit antennas n_T and receive antennas n_R. The symbol transmitted at time t by the i_{th} transmit antenna is denoted by x^i_t, $1 \leq i \leq n_T$ is less than or equal to i which is less than or equal to n_T. We assume that the channel exhibits a quasi-static frequency flat Student-T fading over the frame duration. Thus, it is constant over one frame and varies independently between frames. We assume perfect CSI is available at the receiver and the transmitter both.

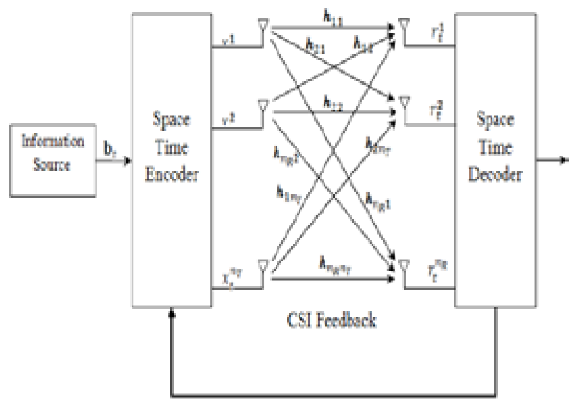

Fig 1: General structure of a WSTTC system

The received signal at time t, at the jth receive antenna is a noisy superposition of separately Student-T faded versions of the n_T transmitted signals and is denoted by r_t^j, $1 \leq j \leq n_R$. The discrete complex baseband output of the j_{th} receive antenna at time t is given by, $r_t^j = \sum_{i=1}^{n_T} h_{j,i}^t x_t^i + \eta_t^j$

Where, $h_{j,i}^t$ is the path gain between the i_{th} transmit and j_{th} receive antennas and η_t^j is the noise associated with the j_{th} receive antenna at time t. The path gains, $h_{j,i}^t$, are modeled as samples of independent complex Gaussian rando variables with zero mean and variance of $1/2$ per dimension. The noise quantities are samples of independent complex Gaussian random variables with zero mean and variance of $\frac{N_0}{2}$ per dimension.

In matrix form, (4.1) can be represented as,

$$\begin{bmatrix} r_t^1 \\ r_t^2 \\ \vdots \\ r_t^{n_R} \end{bmatrix} = \begin{bmatrix} \boldsymbol{h}_{1,1}^t & \boldsymbol{h}_{1,2}^t & \cdots & \boldsymbol{h}_{1,n_T}^t \\ \boldsymbol{h}_{2,1}^t & \boldsymbol{h}_{2,2}^t & \cdots & \boldsymbol{h}_{2,n_T}^t \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{h}_{n_R,1}^t & \boldsymbol{h}_{n_R,2}^t & \cdots & \boldsymbol{h}_{n_R,n_T}^t \end{bmatrix} \begin{bmatrix} x_t^1 \\ x_t^2 \\ \vdots \\ x_t^{n_T} \end{bmatrix} + \begin{bmatrix} \eta_t^1 \\ \eta_t^2 \\ \vdots \\ \eta_t^{n_R} \end{bmatrix}$$

or, in compact form as $\mathbf{r_t} = \mathbf{H}_t \mathbf{x}_t + \boldsymbol{\eta}_t$

where, $\mathbf{r_t} = \left(r_t^1, r_t^2, r_t^3, \ldots, r_t^{n_R}\right)^{\mathbf{T}}$,

$\mathbf{x_t} = \left(x_t^1, x_t^2, \ldots, x_t^{n_T}\right)^{\mathbf{T}}$, $\boldsymbol{\eta}_t = \left(\eta_t^1, \eta_t^2, \ldots, \eta_t^{n_R}\right)^{\mathbf{T}}$

and $\mathbf{H_t}$ is the $n_R \times n_T$ channel matrix

whose j, i_{th} entry is represented by $\boldsymbol{h}_{j,i}^t$.

2.3 WSTTC Encoder

WSTTC encoder employs the STTC encoder, followed by weighting as shown in Fig. 1. The information bits encoded by the STTC encoder are weighted by the weighting matrix based on the CSI feedback from the receiver.

The weighted signal transmitted at time t, denoted by $\mathbf{C_t}$, can be written as

$$\mathbf{c_t} = \left(c_t^1, c_t^2, \ldots, c_t^{n_T}\right)^{\mathbf{T}} = \left(w_t^1 x_t^1, w_t^2 x_t^2, \ldots, w_t^{n_T} x_t^{n_T}\right)^{\mathbf{T}}$$

where, T means the transpose of a matrix, x_t^i, $1 \leq i \leq n_T$, is signal coded by the space-time trellis encoder at the stream i at time t, w_t^i is the weighting coefficient of signal c_t^i, $c_t^i = w_t^i x_t^i$ denotes the weighted signal transmitted through antenna i at time t. Based on our assumption of perfect CSI available at the transmitter the beamforming coefficients are given by;

$$w_t^i = \sum_{j=1}^{n_R} \left(\frac{\left(\boldsymbol{h}_{j,i}^t\right)^*}{\sqrt{2 * \sum_{k=1}^{n_T} \left|\boldsymbol{h}_{j,k}^t\right|^2}} \right)$$

Where (.)* represents the complex conjugate operator.

2.4 Detection/Decoding

Decoder is used to decode the received data, encoded by WSTTC, as shown in Fig. 4.1. The decoder starts by decoding the output of the first component code. The estimated values of $\mathbf{x}_t(1)$, $\bar{\mathbf{x}}_t(1)$ are then passed to the next decoding stage and are used to decode the values of $\mathbf{x}_t(L-1)$ and so forth. The final stage of the decoder uses the estimates obtained from levels 1 1 to $L-1$ $L-1$, namely $\bar{\mathbf{x}}_t(1), \bar{\mathbf{x}}_t(2), \ldots, \bar{\mathbf{x}}_t(L-1)$ to obtain $\bar{\mathbf{x}}_t(L)$. The received signal at the j_{th} receive antenna at time t is given by,

$$r_t^j = \sum_{i=1}^{n_T} \boldsymbol{h}_{j,i}^t w_t^i x^i + \eta_t^j$$

STTC Decoder works on the same principle as explained in section 3.2. It uses Viterbi algorithm to perform maximum likelihood decoding. It is assumed that perfect CSI is available at the receiver and none at the transmitter. For a branch labeled by the symbol x_t, the branch metric is computed as the squared Euclidean distance between the hypothesized received symbols and the actual received signals as,

$$\sum_{j=1}^{n_R} \left| r_t^j - \sum_{i=1}^{n_T} \boldsymbol{h}_{j,i}^t x_t^i \right|^2$$

The Viterbi algorithm is then used to decode the path with the lowest accumulated metric.

3. RESULTS

We calculate the WSTTC system and its performance for Student-T channel via examples based on an underlying 4-QAM and 4-PSK constellation and using 2 transmit and 4 receive antennas.

In this section, we study WSTTC systems designed for an underlying 4-QAM constellation with 2 transmit and 4 receive antennas for Student-T fading channel. We use STTCs as component codes. We assume a Student-T fading channel model which is constant over a frame and varies independently between frames. We take a frame size of 130 symbols. Detection/Decoding of the received symbols is done via Viterbi Decoder described in chapter 4. We evaluate system performance and discuss the effects transmit and receive diversity. For performance comparison, we consider STTC system which has similar specifications as described above for the WSTTC system.

We show that weighting scheme introduced for STTCs for Student-T Channel significantly outperforms the conventional STTCs without weighting and without losing the capability of simultaneously providing diversity improvement, bandwidth efficiency and coding gain with reduced decoding complexity.

In this section we take an example WSTTC system with n_T transmit and n_R receive antennas, designed for 4-QAM and 4-PSK using two component code levels as shown in Fig. 5.1. The setup is based on the WSTTC system model described in Section 4.2.

4. Receive Diversity

Here we consider the effect of receive diversity on the error performance of the code. Performance is evaluated using 2 transmit antennas and different number of receive antennas. We also considered it for QAM & PSK both modulation schemes for Student-T fading channel. The Frame Error Rate (FER) performance of a STTC system for Student-T fading channel is shown. The spectral efficiency is 2 bits/sec/Hz and the underlying constellation is 4-QAM& 4-PSK. 4-state STTCs based on trace criterion are used as component codes. We use component codes designed for 2 transmit antennas. The result shows that increasing the number of receive antennas yield a significant performance gain.

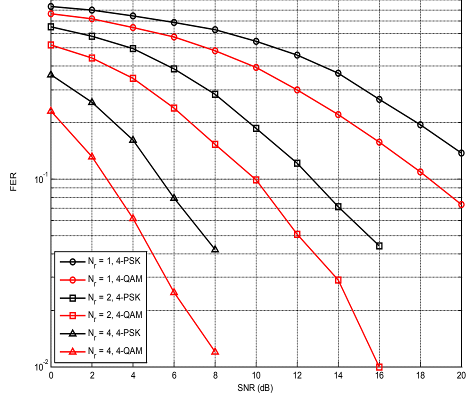

Fig 2 : FER performance of 4-QAM& 4-PSK,STTC for two transmit and different number of receive antennas.

5. Comparison with STTCs

Here we compare the error performance of a WSTTC system for Student-T fading channel. For comparison purposes, we have used a STTC system with same specifications as the above WSTTC system but without weighting. The spectral efficiency is 2 bits/sec/Hz and the basic constellation is 4-QAM for both STTC and WSTTC systems. 4-state STTCs based on trace criterion are used as component codes for both the systems. Performance is calculated using 4 transmit antennas; so, we use component codes designed for 4 transmit antennas, trellis structures of which are shown in Fig. 4.1 (section 4). We assumed perfect CSI at the receiver and the transmitter both.

It can be seen that WSTTC is superior to STTC by about 2.4dB at FER of 10^{-1}.

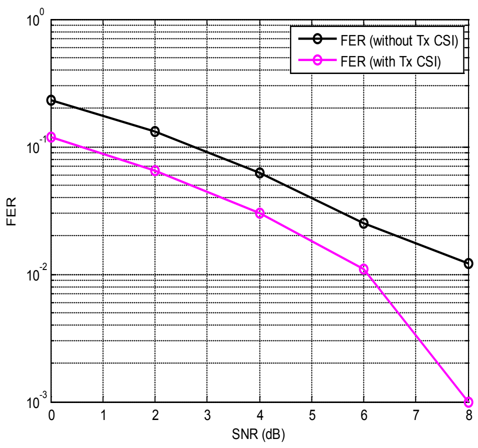

Fig 3 : Error performance of 4-QAM, WSTTC vs. STTC for two transmits and four receive antenna.

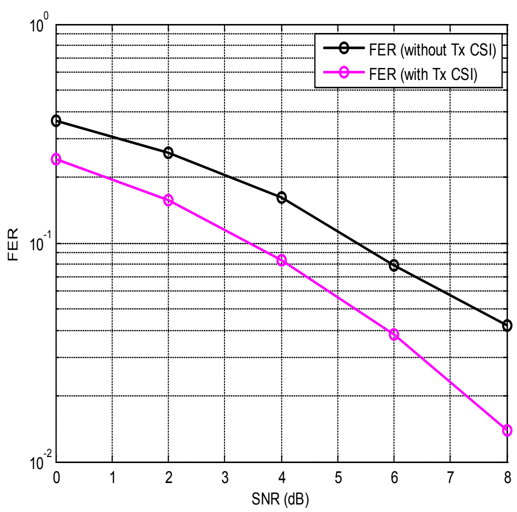

Fig 4 : Error performance of 4-PSK, WSTTC vs. STTC for two transmits and four receive antenna It can be seen that WSTTC is superior to STTC by about 2dB at the FER of 10^{-1}

6. CONCLUSION

In this paper, a new transmission weighting scheme for Student-T fading channel, WSTTCs has been presented, as an extension for the STTC scheme, without sacrificing the capability of concurrently providing bandwidth efficiency, coding gain and diversity improvement with reduced decoding complexity. Hence it has been concluded from simulation results that the proposed weighting scheme for STT Cover Student-T fading channel extensively outperforms the conventional STTCs. weighting scheme for STT Cover Student-T fading channel enhances the bandwidth efficiency, coding gain and diversity improvement with reduced decoding complexity.

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