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Abstract: Performance evaluation of super orthogonal space-time trellis codes for non-frequency selective fading channels & frequency selective fading channels. The analysis is done in presence of fast fading, block fading and quasi-static fading in Rayleigh, and Nakhagami fast fading channels along with comparison. While providing full diversity and full rate, the structure of our new codes allows an increase in the coding gain. Not only does our new SOSTTC outperform the space-time trellis codes in the literature, but it also provides a systematic method for designing space time trellis codes at different rates and for different trellises. Since we have used orthogonal designs as the building blocks in our new SOSTTCs, the complexity of the decoding remains low while full diversity is guaranteed. Codes operating at different rates, up to the highest theoretically possible rate, for different number of states, can be designed by using our optimal set partitioning. In general, new SOSTTCs can provide a tradeoff between rate and coding gain while achieving full diversity.

Index Terms—*Orthogonal designs, set partitioning, space–time codes, super-orthogonal codes, and transmitter diversity, trellis codes*

1. INTRODUCTION

Space time trellis codes provide the improved error performance for wireless systems using multiple transmit antennas. Such codes can provide full diversity gain as well as additional signal-to-noise ratio (SNR) advantage that they call the coding gain. Code design rules for achieving full diversity are also provided. Using these design rules, some of codes with full diversity as well as some coding gain were constructed that are not necessarily optimal. Since there is no general rule for designing codes that provide diversity as well as coding gain, it is unclear how to design new codes for different number of states or different rates. To achieve additional coding gain, one should concatenate an outer code such as a trellis code with an inner space–time block code. In space time block coding is combined with a trellis code to provide more coding gains. The same scheme is used for Rayleigh-fading channels with large space–time correlations and simulation results are provided. The shortcoming of the scheme is the fact that it does not provide the highest possible rate. The idea of concatenating a space time block code with an outer trellis code is also exploited. We combine space time block codes with a trellis code to come up with a new structure that guarantees the full diversity with increased rate. Also, to design the trellis codes to maximize the coding gain. The result is a systematic method to design space time trellis codes for any given rate and number of states.[1] In 2003 Jafarkhani proposed an idea of combining the principal advantages of these two coding schemes. He called it Super-Orthogonal Space Time Trellis Codes (SOSTTCs). The SOSTTCs are simply concatenation of outer trellis code with STBCs. Here we may add that each codeword generated by a STBC represents a point of MIMO constellation. In STTCs a point of MIMO constellation is represented by a vector of space time symbols whereas in SOSTTCs a point of MIMO constellation is represented by codeword matrix generated by STBCs The role of outer trellis code is to select one signal point from MIMO constellation points based on the current state and the input bits. [2]It is shown that for slow fading channels, the trellis code should be based on the set partitioning concepts of Ungerboeck. The main idea behind SOSTTCs is to consider STBCs as modulation scheme for the trellis. In following section we discuss in detail SOSTTCs, their construction and performances at different rates. [3]

2. BLOCK DIAGRAM OF SOSTTC ENCODER

Encoder is intended for use with a transmitter having N transmission elements. Encoder comprises a buffer or shift register, a lookup table, and a transmission module. Encoder encodes input data bits using the enhanced codes. Input data bits are shifted into shift registers. These data bits are then provided to lookup table as an input. Look-up table uses the input data bits to determine at least N variables. [4]

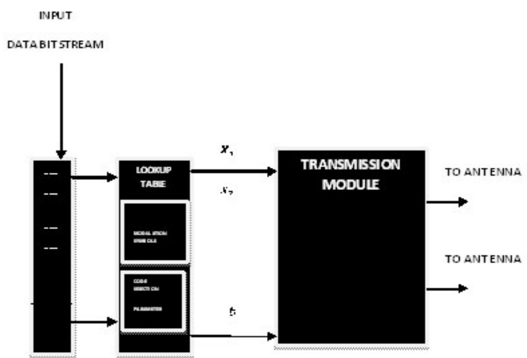

Figure 1.SOSTTC Encoder with Transmission module

In an embodiment encoder comprises buffer or shift register, a look up table and a transmission module. Encoder encodes input data bits using SOSTTC code. During the operation encoder two or more bits from input data stream are temporarily stored in shift register at a time T_0 .These bits are divided into two groups. The first group is referred to as a state bit $B_{A.}$ The second group is referred to as modulation bits $B_{B.}$ The location of these bits in shift register is unimportant. thus any group of bits in shift register can be used as the state bits B_A .similarly any group of bits in shift register can be used as the modulation bits B_A . the look up table contains both modulation symbols (X_1, X_2) and code selection parameter (θ), [4]Both the state bits are modulation bits stored in shift register are provided to look up table as inputs. the modulation bits are used to select modulation symbols X_1 andX_2 and state bits are used to select the code selection parameter (θ),these symbols (X_1, X_2, θ) are referred as transmission variables. The transmission variables output are provided to transmission module. The transmission module operates on transmission variables to form four signals $X_1 e^{J\theta}, X_2, X_2^* e^{J\theta}, X_1^*$.The transmission module output signal $X_1 e^{J\theta}$ to a first transmission element A_1 and signal X_2 to a second transmission element A_2 at a time T_1.The transmission module output signal X_2^* to a first transmission element A_1 and signal X_1^* to a second transmission element A_2 at a time T_2.

3. MATRIX REPRESENTATION OF NEW SOSTTC CODE

To improve the performance of SOSTTCs in addition to θ another rotation parameter $\emptyset$ is used by designing the following class of orthogonal designs.[5]

$$C(x_1, x_2, \emptyset, \theta) = \begin{bmatrix} x_1 e^{j\emptyset} e^{j\theta} & x_2 e^{j\emptyset} \\ -x_2^* e^{-j\emptyset} e^{j\theta} & x_1^* e^{-j\emptyset} \end{bmatrix} \quad (1)$$

Where $\emptyset$ can be any real number between θ and 2π? This is equivalent to rotating the constellation by $\emptyset$. Since the number of paramenters has been increased, more codes are available and a better error performance may be achieved if the parameter is chosen appropriately. The optimal value of the rotation parameters θ and $\emptyset$ have been determined analytically for some QPSK and BPSK codes .However 8PSK codes have not been considered so far it is not known if any performance improvement can achieved. We will implement this new SOSTTC on Rayleigh as well as on Nakagami fading models.[6]

The code can be represented by a simple generator matrix, allowing for a systematic and exhaustive computer search of all possibilities. This matrix representation is similar to that used for the search of space-time trellis codes. Maximizing the determinant and trace produced by a SOSTTC has proven effective in the design of optimal codes with a small number of states. However, as the number of states in the code increases, the complexity involved in the design of these codes increases proportionally and it becomes more difficult to produce optimal codes. In general, the generator matrix G of a full-rate SOSTTC for n_T transmit antennas is of the form r rows by n_T columns, where r is determined by the sum of the number of input bits m at each trellis level and the number of bits s needed to represent each state. Note that in this example each trellis level corresponds to a transmission matrix and hence, a trellis level corresponds to two time slots. s is given by[7]

$$s = log_2 N \quad (2)$$

Where N is the number of states, for an M -PSK or M -QAM constellation with the highest possible rate, m is given by

$$m = 2log_2 M \quad (3)$$

As an example, an 8-state code requires three bits to represent each state. For QPSK with a rate of 2 bits/s/Hz and 2 transmit antennas, four bits are input at each trellis level. Hence, the generator matrix has 7 rows and 2 columns, as shown below

$$G = \begin{pmatrix} a_1 & a_2 \\ a_3 & a_4 \\ \vdots & \vdots \\ a_{13} & a_{14} \end{pmatrix} \quad (4)$$

where a_i = 0, 1, 2 or 3, and i = 1, 2, ..., 14. For an M -PSK modulation, a_i = 0, 1, ..., $M - 1$.

Let the n-bit information sequence to be transmitted be $u = (u_1, \dots\dots, u_n)$, Where $u_i = 0\, or\, 1$. The number of bits influencing the transmission matrix (1) of a given trellis level is equal to the number of rows of G or (m + s). The m bits come from the information sequence u and the s bits represent the current state. Let these (m + s) bits be represented by a vector u^l , where l is the trellis level. When u^l is multiplied (modulo 4 or in the general case, modulo M) by G, we obtain two symbols x_1 and x_2 which are then mapped to a transmission matrix using the mapping scheme .The rotation θ depends on the current state and is determined in advance. As an example, if two rotations are used, all transitions originating from an odd state are assigned θ = 0, and those from an even state, θ = π. Hence, all possible outputs or transmission matrices of the SOSTTC can be obtained from $u^l G$. There is no need to list all possible outputs from each state, making the implementation of the encoder and decoder much easier. If the number of transmit antennas exceeds two and the code is not full-rate the number of columns of G is no longer equal to n_T but to the number of symbols used in the transmission matrix. For the rate-3/4 SOSTTC, three symbols x_1, x_2 and x_3 are used and hence, G have three columns. The generator matrix for the code is represented by.[8]

$$G^T = \begin{pmatrix} 1 & 1 & 2 & 2 & 3 & 2 & 3 \\ 2 & 3 & 0 & 2 & 3 & 0 & 2 \end{pmatrix} \quad (5)$$

In this example of an 8-state code with two parallel branches, the bits of $\mathbf{u}^l$ can be considered as follows

$$u^l = \begin{bmatrix} \overbrace{u_7 u_6 u_5}^{Next\ state} & \overbrace{u_4}^{Parallel\ branch} & \overbrace{u_3 u_2 u_1}^{current\ state} \end{bmatrix}$$

upon moving to the next transition, four new input bits are shifted into the u^l vector. The next state is determined from the current state and the input bits by using a lookup table. Note that in the previous example only the bits $u_7u_6u_5$, labeled 'Next State' are required to determine the next state. Bit u_4 specifies the parallel branch and the next state do not depend on its value. At the next trellis level, four new input bits are shifted into $u^l$and the three bits representing the next state that have been obtained from the lookup table become the current state bits of u^l . In general, these three bits are not equal to $u_7u_6u_5$ except in the special case where there is a possible transition from a state .The description of the bits of u^l given is different when the number of parallel branches changes[9]

4. PERFORMANCE ANALYSIS OF SOSTTC

In this system, performance is measured by the frame error rate (FER) for a frame consisting of 130 symbols. We also assumed ideal channel state information (CSI) is available at the receiver. We carried out the simulation by MATLAB. Random M-PSK symbols are set in frames as a group, which consists of 130 symbols each. [10]

The simulation results for our new SOSTTCs using two transmit antennas and one receive antenna. We compare our results with those of the existing space-time trellis codes in the literature when a comparable code exists. In all simulations, similar to the results in, a frame consists of 130 transmissions out of each transmit antenna. [11]To illustrate the simulation results of SOSTTCs with two transmit antennas and one receive antenna. A slow Rayleigh fading channel has been taken into account. Therefore, the channel coefficients are independent complex Gaussian random variables and fixed during the transmission of one frame. In analyzing the performances of such codes, simulations are driven for the Frame Error Rate (FER) as a function of received SNR. The space-time encoder takes the frame as input and generates codeword pairs of each input symbol simultaneously for all the transmit antennas. Pulse shaping and matched filter are used. These complex signals are transmitted through the MIMO channel. We modeled the signals and channels in base-band. So modulation/demodulation operations are not carried out. We used Monte Carlo simulation to carry out the FER evaluation of the space-time coded system.[12] The FER is given by

$$p_e = \lim_{F\to\infty} \frac{F_e}{F} \qquad (7)$$

Where F is the total number of transmitted frames and Fe is the total number of erroneous frames received at the receiver. It is impossible to run the simulation for an infinite length of time, so we take F as a very large number. The maximum number of iterations used was 50,000 for a FER above 10^{-2}.Influencing the transmission matrix of a given trellis level is equal to the number of rows of G or (m + s). The m bits come from the information sequence u and the s bits represent the current state. Let these (m + s) bits be represented by a vector u^l , where l is the trellis level. When u^l is multiplied (modulo 4 or in the general case, modulo M) by G, we obtain two symbols x_1 and x_2 which are then mapped to a transmission matrix using the mapping scheme .The rotation θ depends on the current state and is determined in advance. As an example, if two rotations are used, all transitions originating from an odd state are assigned $\theta = 0$, and those from an even state, $\theta = \pi$. Hence, all possible outputs or transmission matrices of the SOSTTC can be obtained from u^lG. There is no need to list all possible outputs from each state, making the implementation of the encoder and decoder much easier. If the number of transmit antennas exceeds two and the code is not full-rate the number of columns of G is no longer equal to n_T but to the number of symbols used in the transmission matrix. As an example, for the rate-3/4 SOSTTC, three symbols x_1, x_2 and x_3 are used and hence, G have three columns.[13] The generator matrix for the code is

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Where F is the total number of transmitted frames and Fe is the total number of erroneous frames received at the receiver. It is impossible to run the simulation for an infinite length of time, so we take F as a very large number. [16] The maximum number of iterations used was 50,000 for a FER above 10^{-2}.

5. SOSTTC PERFORMANCE OVER NAKHAGAMI CHANNELS

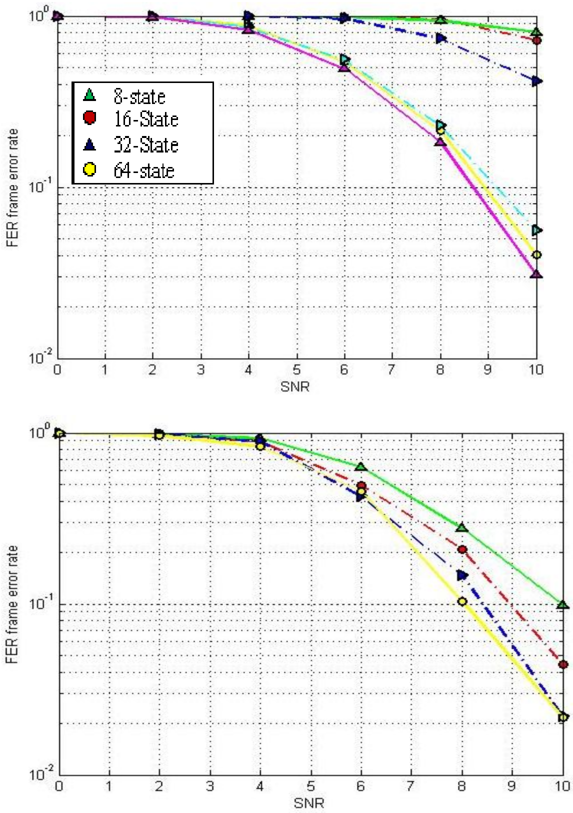

Figure 2. (a) SOSTTC QPSK with two transmit antenna and four receive antenna over Nakagami fading model. (b)SOSTTC 8PSK two transmit antenna four receive antenna over Nakagami fading model

Figures 2 give the performance of the 8-state SOSTTCs, respectively for a system with n_r = 1,2 and n_t = 2. If we compare the results in these figures, we see that the performance of the 8 state codes in for m =1 (Rayleigh fading channel) and n_r =1. For m =2 and n_r =2.

6 CONCLUSIONS

The performances analyses for different space time codes. The performance of SOSTTC over Nakagami fading channel is investigated. Simulation results with various fading parameter shows that the SOSTTCs designed for Rayleigh fading channels based on the rank, minimum determinant and trace criterion, are also suitable for Nakagami fading channels. It can be seen that new 8 state code out performs the code approximately 0.15 dB .As the number of states increases code out performs that only known code by almost 1.5 dB at the cost of additional complexity. The new SOSTTC for 8PSK outperforms the previous 8 state code .the error performance of SOSTTCs for QPSK bur not for 8PSK. New code for nakhagami fading model gives more gain then Rayleigh fading channel.

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