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Implementation of Space Time Trellis Code Using Rayleigh Fading Scenario

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Abstract: In this paper we implement space time trellis code using relay fading scenario. We present here the design of the 4psk with 2 transmit antennas and 1,2 receiver antennas at 4,8,16& 32 state. In this paper we constructed 4-psk sttc code using rank, determinant and euclidean distance criterion over rayleigh fading scenario.

Keywords: space-time trellis code; multiple transmit antenna, multiple receiver antenna; diversity; wireless communication; fading; s\n ratio;

I. INTRODUCTION

All A typical S'ITC based wireless system has an encoder, pulse shaper, modulator and multiple transmit antennas at the transmitter, and the receiver has one or more receive antennas, demodulator, channel estimator and STTC decoder. We consider a mobile communication system with n_t transmit antennas and n_r receive antennas as shown in Figures 1 (a) and (b). The space-time trellis encoder encodes the data $s(t)$ coming from the information source and the encoded data is divided into n_t streams of data $c_t^1 \quad c_t^2 \quad \ldots\ldots \quad c_t^{n_t}$. Each of these streams of data passes through a pulse shaper before being modulated. The output of modulator i at time slot t is the signal c_t^i, which transmitted through is transmit antenna i. Here $n_t \; 1 \le i \le n_t$.

The transmitted symbols have energy E_t. We assume that the n_t signals are transmitted simultaneously from the antennas. The signals have transmission period T. In the receiver, each antenna receives a superposition of n_t transmitted signals corrupted by noise and multipath fading. Let the complex channel coefficient between transmit antenna i and receive antenna j have a value of $h_{i,j}(t)$ at time t, where $1 \le i \le n_r$.

The received signal at antenna $j, \; j = 1, 2, \ldots\ldots, n_r$ G.L. Stuber [1] is then

$$r_t = \sqrt{E_s} \sum_{i=1}^{n} h_{i,j}(t) c_t^i(t) + \eta_t^j \qquad (1.1)$$

Where η_t^j is additive white Gaussian noise (AWGN) at receive antenna j, which has zero mean and power spectral density N_0 and $h_{i,j}(t)$ channel coefficient between transmit and receive antennas J. Yuan, Chen and B. Vucetic [11].

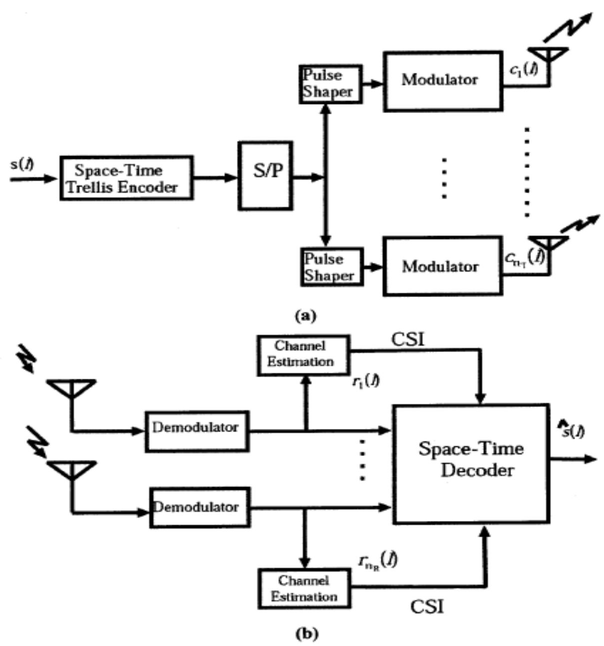


Figure1

II. CODE CONSTRUCTION OF 4-PSK STTC

A signal constellation diagram for 4-PSK is shown in Figure 2. With PSK information is contained in the signal phase. For 4-PSK, the phase takes one of four equally spaced values, such as $0, \frac{2\pi}{4}, \frac{4\pi}{4}$, and $\frac{6\pi}{4}$. These are typically represented by a Gray code S. Haykin [10] and B. Sklar [9], as shown on the right side of Figure 2. These signal points are also labeled as 0, 1, 2 and 3. We can also express these in complex notation

The encoder structure of a 4-state 4-PSK STTC is shown in Figure 3 (a), with bits input to the upper and lower branches. The memory orders of the upper and lower branches are υ_1 and υ_2 respectively. These are basically shift registers. The main purpose of the shift registers in the encoder is to store the previous transmitted bits. The length of the shift register is the memory of the encoder. The branch coefficients are arranged alternatively in the generator matrix, with a_i representing the most significant bit (MSB).

The input bit streams I_t^1 and I_t^2 are fed into the branches of the encoder with I_t^1 being the MSB. The output of the encoder is Z. Chen, J. Yuan, B. Vucetic[19], V. Tarokh, N. Seshadri, A. R. Calderbank [6]

$$x_t^k = \left(\sum_{p=0}^{v1} I_{t-p}^1 . a_p^k + \sum_{q=0}^{v2} I_{t-q}^2 . b_{t-q}^k \right) \bmod 4 \quad k = 1, 2, \tag{1.2}$$

where $v_1 + v_2 = v$ and the number of states is 2^v. v_i is calculated as

$$v_i = \left\lfloor \frac{v+i-1}{2} \right\rfloor, \quad i = 1, 2 \tag{1.3}$$

Here $\lfloor x \rfloor$ denotes the largest integer smaller than or equal to x. For each branch, the output is the sum of the current input scaled by a coefficient and the previous input scaled by another coefficient. The two streams of input bits are passed through their respective shift register branches and multiplied by the coefficient pairs (a_p^1, a_p^2) and (b_q^1, b_q^2). Here,

$$a_p^k, b_q^k \in \{0,1,2,3\}, k = 1,2, p = 0,1,....,v_1, q = 0,1,....,v_2.$$

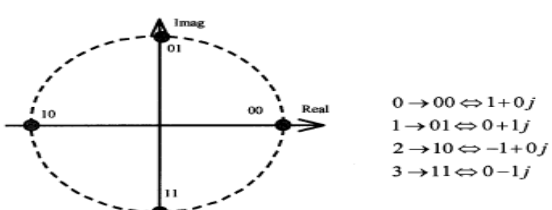
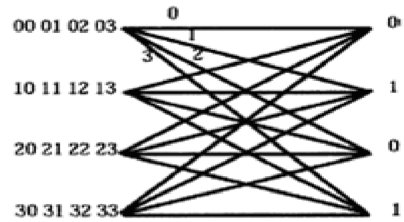
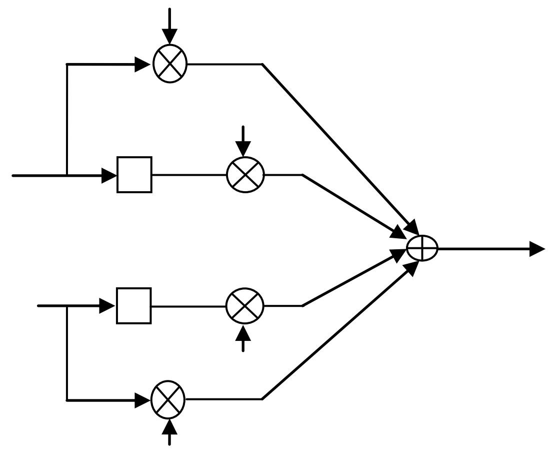


Figure 2. 4-PSK signal constellation diagram



(a)



(b)

Figure 3 4 PSK 4 state STTC (a) Trellis Diagram (b) Encoder Structure

Then x_t^1 and x_t^2 are transmitted simultaneous through the first and second transmit antennas, respectively. Figures 4 (a) and (b) shows 8 state and 16 state trellis diagrams respectively, for a rate of 2 b/s/Hz N. Seshadri, V. Tarokh, A.R. Calderbank [3].

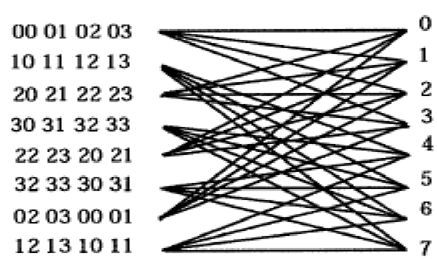


Figure 4 (a)Trellis Diagram of 4-PSK 8 State STTC

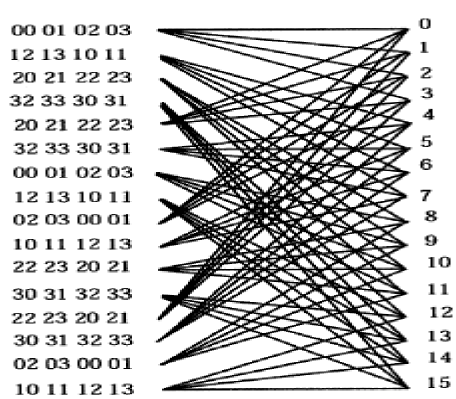


Figure 4 (b)Trellis Diagram of 4-PSK 16 State STTC

III. PERFORMANCE CRITERIA

We assume that the STTC codeword is given by

$c = (c_1^1 c_1^2 \dots c_1^{n_t} c_2^1 c_2^2 \dots c_2^{n_t} \dots c_l^1 c_l^2 \dots c_l^{n_t})$

Where l is the frame length. We consider a maximum likelihood receiver, which may possibly decide on an erroneous code word e , given by

$e = (e_1^1 e_1^2 \dots e_1^{n_t} e_2^1 e_2^2 \dots e_2^{n_t} \dots e_l^1 e_l^2 \dots e_l^{n_t})$

We can write the difference code matrix, the difference between the erroneous codeword and the transmitted codeword as follows –

$$B(c,e) = \begin{pmatrix} e_1^1 - c_1^1 & e_2^1 - c_2^1 & \dots\dots & e_l^1 - c_l^1 \\ e_1^2 - c_1^2 & e_2^2 - c_2^2 & \dots\dots & e_l^2 - c_l^2 \\ e_1^3 - c_1^3 & e_2^3 - c_2^3 & \dots\dots & e_l^3 - c_l^3 \\ . & . & \dots\dots & . \\ . & . & \dots\dots & . \\ . & . & \dots\dots & . \\ e_1^{n_t} - c_1^{n_t} & e_2^{n_t} - c_2^{n_t} & \dots\dots & e_l^{n_t} - c_l^{n_t} \end{pmatrix} \quad (1.4)$$

The difference matrix $B(c,e)$ has dimension $n_t \times l$. From N. Seshadri, V. Tarokh, A.R. Calderbank [9] we know that to achieve the maximum diversity order $n_{r,}\ n_t$ ($n_{r,}$ receive antennas, n_t transmit antennas) matrix $B(c,e)$ must have full rank for all possible codewords c and e . If $B(c,e)$ has minimum rank r over the set of pairs of distinct codewords then the diversity will be $r.n_r$ N. Seshadri, V. Tarokh, A.R. Calderbank [3].

IV. DESIGN CRITERIA FOR STTC OVER RAYLEIGH FADING

A. Rank Criterion:

The rank criterion optimizes the spatial diversity gain achieved by a STTC. Assume B(c,e) has minimum rank r over the set of pairs of distinct codewords so a diversity of $r.n_r$ is acheved V. Tarokh, N. Seshadri, A. R. Calderbank [6], Z. Chen, J. Yuan, B. Vucetic [8]. To illustrate this criterion N. Yuen [5], consider a CPSK system where the transmitted codeword is c = 220313, and the erroneous codeword the receiver decides upon is e = 330122. Figure 2 gives the 4PSK signal constellation. In this example, n_t = 2 and the message length is L = 3. The 2×3 difference matrix is

$$B(c,e) = \begin{vmatrix} -j-(-1) & 1-1 & -1-j \\ -j-(-1) & j-(-j) & -1-(-j) \end{vmatrix}$$

The rank of B(c,e) is 2, as is the rank of A(c,e) . For this system with n_t = 2 transmit antennas and n_r = 1 receive antenna, the diversity gain is 2.

B. Determinant Criterion:

The determinant criterion optimizes the coding gain. Recall that r is the rank of $A(c,e)$. Coding gain corresponds to the minimum r th roots of the sum of the determinants of all $r\times r$ principal cofactors of $A(c,e) = B(c,e)B^*(c,e)$ taken over all pairs of distinct codewords c and e V. Tarokh, N. Seshadri, A. R. Calderbank [6]. Now $(\lambda_1\lambda_2\lambda_3\dots\dots\lambda_r)$ is the absolute value of the sum of the determinants of all principal $r\times r$ cofactors of A. Thus if a diversity advantage of $n_r r$ is achieved, the coding gain is $(\lambda_1\lambda_2\lambda_3\dots\dots\lambda_r)^{1/r}$. So if maximum diversity of $n_r n_t$ is the design target then we have to maximize the minimum determinant of $A(c,e)$. From the example, for the rank criterion the eigenvalues of the matrix A are

$$\lambda_1 = -2.2679 - 3j$$
$$\lambda_2 = -5.7321 - 3j$$

For r = 2, the coding gain for the codeword given in the example is 4.9327 N. Yuen [31].

C. Euclidean distance Criterion:

When the diversity gain is large (with two or more receive antennas), Chen, B. Vucetic, J. Yuan and Lo. Ka. Leong [2] proposes another design criterion, namely the Euclidean Distance Criteria (EDC). According to Chen, B. Vucetic, J. Yuan and Lo. Ka. Leong [2], the Rank and Determinant criteria (RDC) applies to the systems with a single receive antenna and a small number of transmit antennas. This shows that with diversity gain $rn_r \geq 4$ S. M. Alamouti [12] shows that the error probability is upper bounded by

$$P_e(c \to e) \leq \frac{1}{4}\exp\left(-n_r \frac{E_s}{4N_0} \sum_{i=1}^{n_t}\sum_{j=1}^{l}\left|e_j^i - c_j^i\right|\right) \quad (3.13)$$

When $rn_r \geq 4$, Which indicates that we should maximize the minimum squared Euclidean distance between any two different codewords Chen, B. Vucetic, J. Yuan and Lo. Ka. Leong [2] .

V. SIMULATION SYSTEM MODEL

The simulation is carried out in MATLAB. The simulation system model is illustrated in Figure 5.

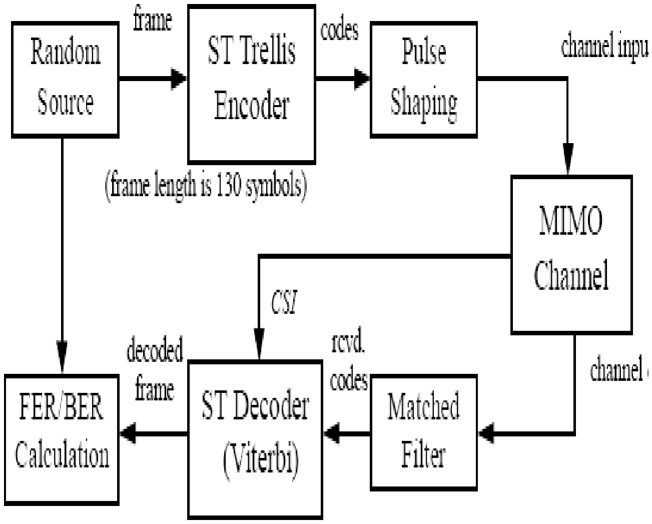


Figure 5. Simulation system model

Random M-PSK symbols are grouped into frames, which consists of 130 symbols each. The space-time encoder takes the frame as input and generates codeword pairs for each input symbol simultaneously for all the transmit antennas. Pulse shaping and matched filter are used for simulation over frequency selective fading channels.

These complex signals are transmitted through the MIMO channel. The signals and channels are modeled in base-band, thus modulation/demodulation operations are not carried out. Channels used in this project include flat Rayleigh fading channels and two-ray model frequency selective fading channel.

We assume that perfect channel state information (CSI) is available at the receiver. At the receiver, a maximum likelihood sequence detector is used to decode the received signal. A modified vector Viterbi decoder is employed. Error probability calculation is carried out after decoding each frame.

VI. SIMULATION RESULT

Table: 1 Type Styles

states	a_0^1, a_0^2	a_1^1, a_1^2	a_2^1, a_2^2	a_3^1, a_3^2	b_0^1, b_0^2	b_1^1, b_1^2	b_2^1, b_2^2	b_3^1, b_3^2
4	(2,2)	(1,0)	-	-	(0,2)	(3,1)	-	-
8	(2,2)	(2,0)	-	-	(0,1)	(1,0)	(2,2)	-
16	(0,2)	(2,0)	(0,2)	-	(2,1)	(1,2)	(2,0)	-
32	(0,2)	(2,3)	(1,2)	-	(2,2)	(1,2)	(2,3)	(2,0)

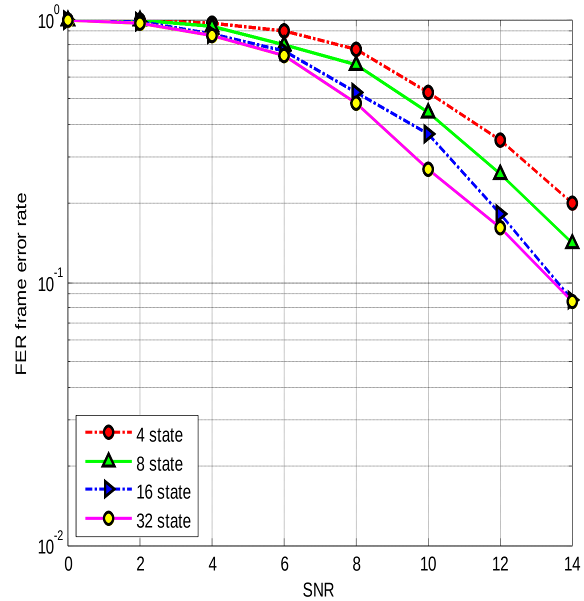


Figure 6. 4psk, 2 transmitter, 1 receiver

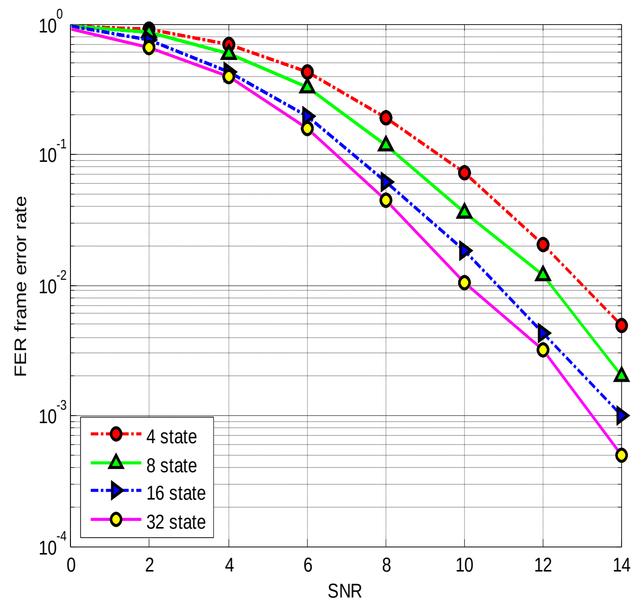


Figure 7. 4psk, 2 transmitters, 2 receiver

VII. CONCLUSION

In this paper ,an efficient method to design the best 4-psk STTCs with two transmit antennas and 1,2 receiver antennas has been presented.we find that when we increase the receiver antennas .we get more coding gain .it increase 4to32states.we find higher coding gain at 2 receiver antennas at 32 state. We also get less s\n ratio.

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