Performance Study of Space Time Trellis Code with Multiple bit Feedback

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***Abstract*—In this paper, 1-bit, 2-bit and 3-bit feedback performances of Space Time Trellis Code in Rayleigh channel are studied. The open loop performance shows better result whereas due to complexity of trellis the performance degrades with feedback. But still with increasing the number of bits, the error rate performance improves again. In case of error rates, 3-bit feedback system has the lowest value. 2-bit feedback system needs lowest time for simulation and 1-bit feedback offers highest channel capacity.**

***Index Terms*— STTC, Rayleigh Channel, 1-bit, 2-bit, 3-bit Feedback.**

I. Introduction

The supreme challenge for future wireless communication systems is to supply broadband mobile data access with a high quality of service (QoS). The most desired speed in communication can be achieved through various multiple access (MA) methods. SDMA is accessed through the use of multiple antennas. It is now possible to achieve a major increase in spectral efficiency (bps/Hz) with a simultaneous increase[1] in failure safety of connections through the use of MIMO technique. MIMO transmit diversity is achieved by STBC/ SFBC (Space Time/ Frequency Block Coding) is a proficient technique that doesn't require any channel state information at the transmitter providing complete code rate and diversity. There are another coding technique is STTC, although it has more complexity but it offers coding gain in addition with diversity gain.

STTC is addressed by Tarokh et al [2]. STTC is designed for block fading channel to use the rank and determinant [3]. But in Additive White Gaussian Noisy channel it shows degraded performance. In practice, a single scheme is needed for all fading channels. This paper addresses this problem for Rayleigh fading. The problem is addressed by both open loop and with feedback system for power division method. Another rotation method has also been introduced. These methods precode the space time trellis coded transmit signal in a predetermined manner. The power applied on the transmitted signal or the precoding angle of rotation is obtained by optimizing the free distance (d_{free}) of the STTC used. The above method improves the error rate in AWGN and Rician channels [4]. In block fading, power division method performs lower. This is overcome using 1-bit feedback method [5] for the same bandwidth, power and trellis complexity. Earlier works on partial feedback are discussed in [6-8]. 1-bit feedback angle with STBC/ SFBC for 4 antenna system is proposed in [9].

In this paper, the work has been expanded with 2-bit and 3-bit feedback methods and the performance is compared with the open loop system. The MIMO channel capacity is also measured for all feedback conditions.

II. Transmit Diversity in MIMO

This paper focuses on Transmit Diversity. It averages out the channel variation for delay sensitive services. It works very efficient for both low and high UE speeds. Transmit diversity can be further sub-divided into Block-codes-based, Cyclic delay diversity, Frequency shift transmit diversity and Time shift transmit diversity [10].

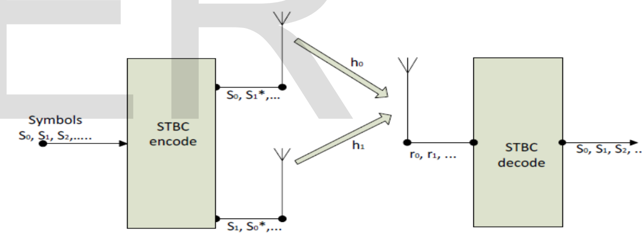

Fig. 1 Simplified Transmit Diversity Scheme.

A. *Space Time Trellis Code*

Space-Time Trellis Codes (STTCs) is the extension of conventional convolution codes. The encoder output is a function of the input bits and the state of the encoder, the later depends upon the previous input bits. This memory can provide the extra coding gain relating to space-time block coding.

Fig. 2 describes the encoder strategies and discusses the performance of several popular STTCs as functions of the design criterion, the number of receive antennas and the complexity [11].

STTC are based on definite trellis structures and Viterbi decoding are used to decode the receive signal. STTC modulations proposed a join design of coding, modulation, and transmit diversity for flat Rayleigh fading channels.

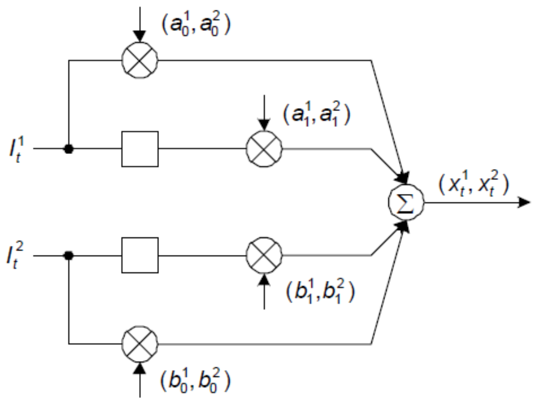

Fig 2. 4 state, 4PSK Encoder Structure

The final output can be described as

$$X_t^k = \left[\sum_{\rho=0}^{v_1} l_{t-p}^1 . a_p^k + \sum_{q=0}^{v2} l_{t-q}^2 . b_q^k\right] mod4, k = 1,2$$

X_t^1 and X_t^2 are transmitted simultaneously on the 1st and 2nd antenna, respectively[12].

The trellis code used in simulation is shown in Table 1.

Table 1: Coefficient Pairs for 4PSK 4-State STTC code.

v	(a_0^1, a_0^2)	(a_1^1, a_1^2)	(b_0^1, b_0^2)	(b_1^1, b_1^2)
2	(0,2)	(2,0)	(0,1)	(1,0)

The generator matrix for the 4PSK case is

$$G = \begin{vmatrix} 0 & 2 \\ 0 & 1 \\ 2 & 0 \\ 1 & 0 \end{vmatrix}$$

where the elements are taken from the MPSK constellation. Each G matrix has the dimensions of (i+s) × n, where I = $\log_2 M$ represents the number of information bits transmitted, s and n represent the number of shift registers in the encoder, and the number of transmit antennas, respectively. The elements of this matrix define the coefficient pairs described earlier in the encoder structure. The code presented here provides the best tradeoff between data rate, diversity advantage, and trellis complexity [2].

III. 1–Bit feedback System

The closed-loop power division (CLPD) based on a 1-bit feedback is prepared in two steps:

1) Step one: The optimal power is obtained as in OLPD as follows:

a) Consider any STTC proposed for a 2 × 1 system in the literature.

b) The two antennas transmit symbols drawn from any constellation with unequal powers p and $(1 - p)$.

c) Find the optimal p by an exhaustive search based on the criteria for AWGN channels.

2) Step two: Due to the fact that in OLPD higher power is sent on one of the two antennas even when statistically, about half the time, this transmitter would encounter a poorer channel resulting in degradation in performance. A 1-bit feedback ensures that higher power is sent on the better channel, and this will obtain some array gain as follows:

a) Estimate the channel gains h_0 and h_1 at the receiver.

b) Determine the better channel by comparing $|h_0|$ and $|h_1|$.

c) If $|h_0| > |h_1|$, then channel one is better and bit 0 is feedback.

d) Else, if $|h_0| \leq |h_1|$, then channel two is better and bit 1 is feedback.

e) Now, if the feedback bit is 0, then the transmitter one is provided with the higher power, and therefore in (2), $a_0 = \sqrt{1 - p}$ and $a_1 = \sqrt{p}$.

f) Else if the feedback bit is 1, then the transmitter 2 is provided with the higher power, and therefore, in (2) $a_0 = \sqrt{p}$ and $a_1 = \sqrt{1 - p}$. The receiver must know the power division applied at the transmitters. The decoding rule in [4] is modified appropriately to include the power division, and decoding is performed using Viterbi algorithm.

IV. Simulation And Results

A. *Diversity System Model*

In this paper, the communication system having two transmit antennas and one receive antenna (2×1) has been considered. At every time instant t, the space-time coded symbols x_t and y_t are transmitted through the two antennas simultaneously. The received signal r_t is given by

$$r_t = \begin{bmatrix} h_0 & h_1 \end{bmatrix} W \begin{bmatrix} x_t \\ y_t \end{bmatrix} + n_t \qquad (1)$$

where W is a weighting matrix and $\{h_i\}$, n_t are channel gains and noise, respectively, with mean and variance as 0.5, $1/2\gamma$, respectively, for both real and imaginary parts. The channel gains $\{h_i\}$ remain constant and independent in a frame. We assume the total energy of the signals at the transmitter is unity, so that γ is the signal-to-noise ratio (SNR).

The weighting matrix W in (1) is given by

$$W = \begin{bmatrix} a_0 & 0 \\ 0 & a_1 \end{bmatrix} \qquad (2)$$

where $a_0 = \sqrt{p}$, and $a_1 = \sqrt{1 - p}$ in general for the considered schemes except ideal closed loop transmit beamforming (CLBF) and closed loop power division (CLPD) which is defined later. $|a_i|2$, $i = 0, 1$ is the power applied to the ith antenna. The diagonal nature of W allows control of power in each antenna separately In uncoded selection gain transmission (SGT) with a one-bit feedback, when $|h_0| > |h_1|$, $p = 1$ results in $a_0 = 1$ and $a_1 = 0$, and otherwise $p = 0$ resulting in $a_0 = 0$ and $a_1 = 1$. Computer simulation generates 1000 frames each with 24 symbols. A frame is in error when one/more symbols in that frame are error. For illustration we consider 4 state STTCs using QPSK modulation in Rayleigh channel. Here we consider 1-bit, 2-bit and 3-bit feedback system. For different feedback bits the channel parameters is modified.

$$R = \frac{H^H H}{trace(H^H H)} = A + iB \qquad (3)$$

For 1-bit feedback

For ith antenna and jth antenna,
if A1(i,j)<0.5,then A1(1,1)=A1(2,2)=0.25, otherwise A1(1,1)=A1(2,2)=0.75,
Or,
If A1(i,j)<0, then A1(i,j)= -0.25, otherwise A1(i,j)=0.25,
And,
If B1(i,j)<0, then B1(i,j)= -0.25, otherwise B1(i,j)=0.25,

For 2-bit feedback,

For i=j,
If A2(i,j)<0.25, then A2(i,j)=1/8, otherwise
If A2(i,j)<0.5, then A2(i,j)=3/8, otherwise
If A2(i,j)<0.75, then A2(i,j)=5/8, otherwise
A2(i,j)=7/8.
When i≠j,
If A2(i,j)< -1/4, then A2(i,j)= -3/8, otherwise
If A2(i,j)<0, then A2(i,j)= -1/8, otherwise
A2(i,j)=3/8,
And
If B2(i,j)< -1/4, then B2(i,j)= -3/8, otherwise
If B2(i,j)< 0, then B2(i,j)= -1/8, otherwise
If B2(i,j)<1/4, then B2(i,j)= 1/8, otherwise
B2(i,j)=3/8

For 3-bit feedback,

For i=j,
If A3(i,j)<1/8, then A3(i,j)=1/16, otherwise
If A3(i,j)<0.25, then A3(i,j)=3/16, otherwise
If A3(i,j)<3/8, then A3(i,j)=5/16, otherwise
If A3(i,j)<0.5, then A3(i,j)=7/16, otherwise
If A3(i,j)<5/8, then A3(i,j)=9/16, otherwise
If A3(i,j)<6/8, then A3(i,j)=11/16, otherwise
If A3(i,j)<7/8, then A3(i,j)=13/16,otherwise
A3(i,j)=15/16.
Or,
For i≠j,
If A3(i,j)<-3/8, then A3(i,j)=-7/16, otherwise
If A3(i,j)<-2/8, then A3(i,j)=-5/16, otherwise
If A3(i,j)<-1/8, then A3(i,j)=-3/16, otherwise
If A3(i,j)<0, then A3(i,j)=-1/16, otherwise
If A3(i,j)<1/8, then A3(i,j)=1/16, otherwise
If A3(i,j)<2/8, then A3(i,j)=3/16, otherwise
If A3(i,j)<3/8, then A3(i,j)=5/16,otherwise
A3(i,j)=7/16.
If B3(i,j)<-3/8, then B3(i,j)=-7/16, otherwise
If B3(i,j)<-2/8, then B3(i,j)=-5/16, otherwise
If B3(i,j)<-1/8, then B3(i,j)=-3/16, otherwise
If B3(i,j)<0, then B3(i,j)=-1/16, otherwise
If B3(i,j)<1/8, then B3(i,j)=1/16, otherwise
If B3(i,j)<2/8, then B3(i,j)=3/16, otherwise
If B3(i,j)<3/8, then B3(i,j)=5/16,otherwise
B3(i,j)=7/16.

For no feedback the channel information is not changed.
The capacity equation for MIMO is,

$$C = \log_2 \det(IM + \frac{\frac{E_b}{N_0}}{N_{tx}} HH^H)$$

The graph for BER, SER, FER, PEP and channel capacity of STTC MIMO in case of 1-bit, 2-bit, 3-bit feedback and no feedback system are plotted.

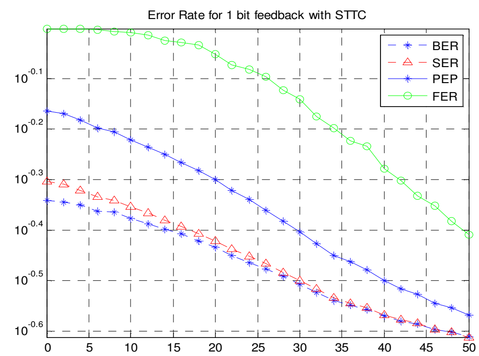

Fig 3: Error rate for 1-bit feedback with STTC

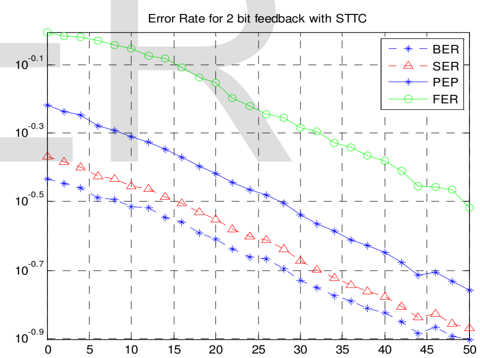

Fig 4: Error rate for 2-bit feedback with STTC

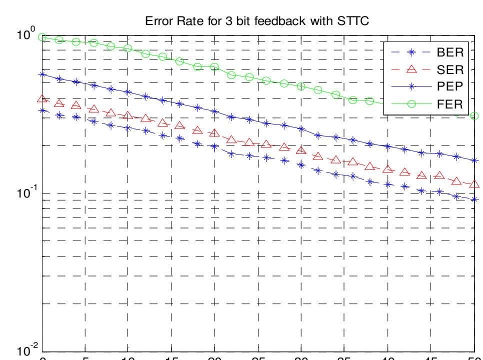

Fig 5: Error rate for 3-bit feedback with STTC

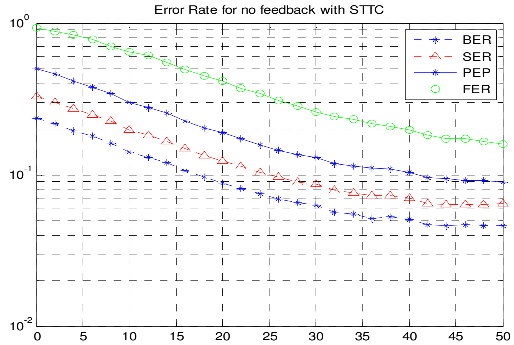

Fig 6: Error rate for No feedback with STTC

From Fig. 3-6 it is seen that with increasing in SNR value, all the error rates are logarithmically decreasing. In case of 3-bit feedback the BER value is lowest and the value is $10^{-1.1}$. In case of SER, again with 3-bit feedback the lowest value of $10^{-0.9}$ for 50 db SNR is obtained. It is also obtained for the value of PER 3 bit feedback shows lowest value of $10^{-0.8}$. At last the value of FER of $10^{-0.51}$ is obtained as lowest value for 2-bit feedback. All those values for no feedback override the rest of values. The performance of feedback degrades due to Trellis complexity.

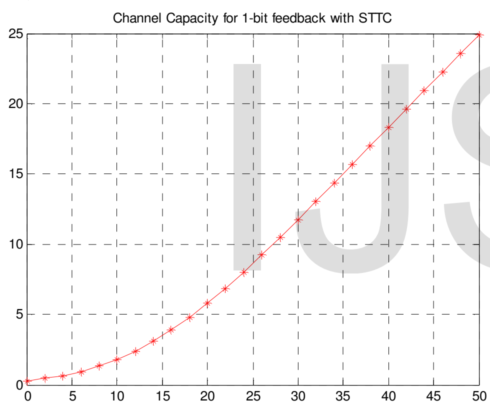

Fig 7: Channel capacity for 1-bit feedback with STTC

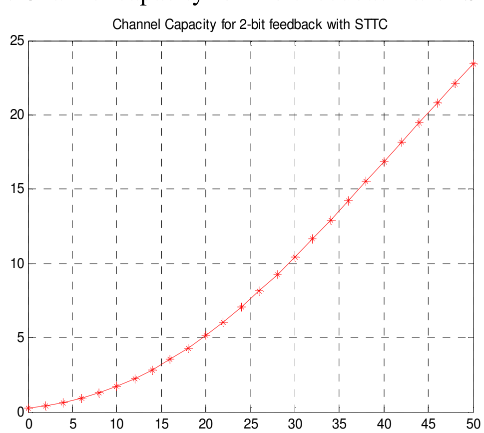

Fig 8: Channel capacity for 2-bit feedback with STTC

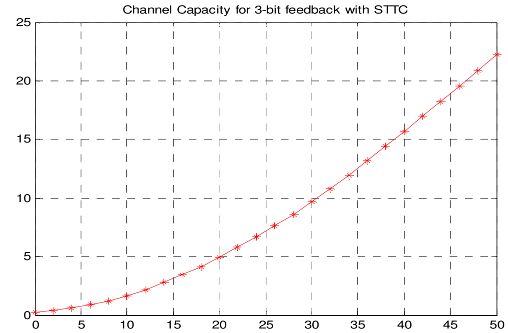

Fig 9: Channel capacity for 3-bit feedback with STTC

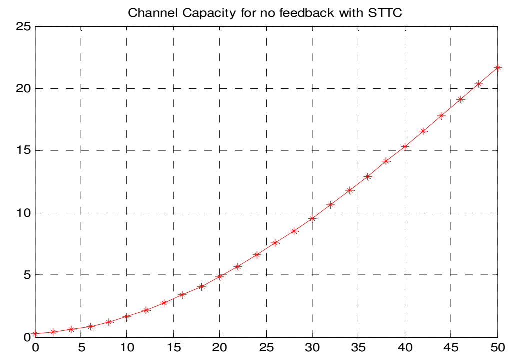

Fig 10: Channel capacity for No feedback with STTC

From Fig 7, Fig 8, Fig 9 and Fig 10 the MIMO channel capacity for 1-bit, 2-bit, 3-bit are 25, 24, 23 and no feedback is 22 for 50db SNR. The channel capacity is highest for 1-bit feedback system.

Table 2: Program Running Time for Different Feedback of STTC

No. of Feedback	1-Bit	2-Bit	3-Bit	No feedback
Elapsed time	313.24 sec	154.27 sec	157.98 sec	322.51 sec

The Elapsed time is for lowest for 2-bit feedback.

IV. Conclusion

The performance of Space Time Trellis Code with 1-bit, 2-bit, 3-bit power division feedback method in Rayleigh channel is studied. Due to complexity of STTC the performance is degraded then open loop method. Perhaps when the number of feedback bits is increased then the performance is improved. From the simulation it can be shown that the BER, SER, PER, FER performance are better in case of three bit feedback system. But the channel capacity is the highest for the 1-bit feedback. Due to complexity it takes more time to run the simulation. But still it takes less time for 2-bit feedback system. In future work it can compare the results with higher order of antennas, higher order of modulations and also higher states of STTC code.

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