FER and Outage capacity analysis of Space-Time Trellis Coding using Modulation Techniques

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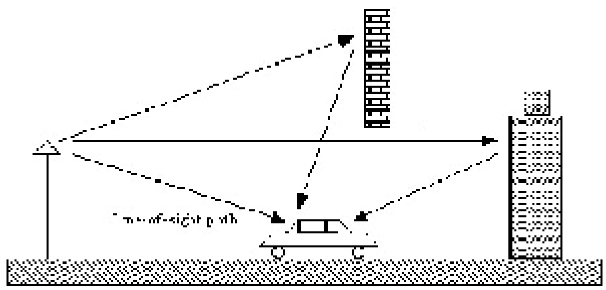
Abstract : In this paper, we analyze the performance of space-time codes.Here we derive FER and outage capacity for space-time trellis coded modulations over Rayleigh fading channels. This thesis is concerned with the 'FER and Outage Capacity Analysis of Space-Time Trellis Coding (STTC) using Modulation Techniques'. The analysis of channel codes for improving the data rate and the reliability of communications over fading channels using multiple transmit antennas has been considered. Data is encoded by a convolutional encoder and the en- coded data is split into streams that are simultaneously transmitted using n transmit antennas. The received signal at each receive antenna is a linear superposition of the n transmitted signals with noise. Performance criteria for designing such codes, under the assumption that the fading is slow and frequency nonselective, is also analysed.

I.INTRODUCTION

High rate of data transmission is limited in wireless communication due to factors like limited bandwidth, propagation loss,noise.
Radio waves propagate from a transmitting antenna, and travel through free space un-dergoing absorption, reflection, refraction, diffraction, and scattering. They are greatly affected by the ground terrain, the atmosphere, and the objects in their path, like buildings, bridges, hills, trees, etc. These multiple physical phenomena are responsible for most of the characteristic features of the received signal. In most of the mobile or cellular systems, the height of the mobile antenna may be smaller than the surrounding structures. Thus, the existence of a direct or line-of-sight path between the transmitter and the receiver is highly unlikely.



At the receiver, these multipath waves with randomly distributed amplitudes and phases combine (constructively and destructively) to give a resultant signal that fluctuates in time and space. Therefore, a receiver at one location may have a signal that is much different from the signal at another location, only a short distance away, because of the change in the phase relationship among the incoming radio waves. This causes significant fluctuations in the signal amplitude. This phenomenon of random fluctuations in the received signal level is termed as fading. Space time (ST) codes have recently attracted significant attention since they provide an effective way to fully exploit both transmit diversity and receive diversity to overcome the impairments of wireless fading channels.

II Space Time Coding

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:

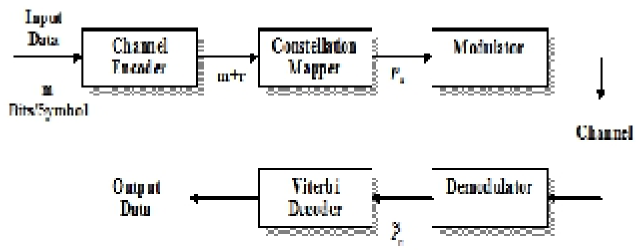
- Space–time trellis codes (STTCs) distribute a trellis code over multiple antennas and multiple time-slots and provide both coding gain and diversity gain.
- Space–time block codes (STBCs) act on a block of data at once (similarly to block codes) and provide only diversity gain, but are much less complex in implementation terms than STTCs.

Space-time coding has been introduced as an effective means to achieve high data rates in such wireless communication environment. This technique integrates channel coding, modulation, and multiple transmit antennas at the base station, with optional receive diversity incorporated at the mobile station.

III 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').

Space-time trellis codes encode the input symbol stream into an output vector symbol stream. Unlike space-time block codes, space-time trellis codes map one input symbol at a time to an $M_t \times 1$ vector output. Since the encoder has memory, these vector codewords are correlated in time. Decoding is performed via maximum likelihood [5]-[7] sequence estimation.



The input data bits coming at the rate of m bits/symbol are encoded by a channel (convolutional) encoder, to produce m + r bits which are mapped with the help of a constellation mapper to give on of the possible states of the encoder. This is then further modulated using techniques like PSK, FSK, QAM etc. and transmitted through N_t transmit antennas to the channel, where the signal gets corrupted by noise. At the receiving end, N_r receive antennas are used to receive the transmitted signal which is then demodulated and the resultant noise affected signal is feed to a Viterbi Decoder. It is a maximum likelihood (ML) decoder that gets back the original signal by construction a trellis structure. The decoder is designed such as to minimize the error due to noise or any other factors.

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below.

Code Rate: It is defined as the ratio of the input bits to the encoder to the output bits produced per unit time.

Constraint Length: It is the number of shifts over which a single message bit can influence the encoder output. In an encoder with M -stage shift register, the memory of the encoder equals M message bits, and K = M + 1 shifts are required to enter the shift register and finally come out. Hence the constraint length of the encoder is K.

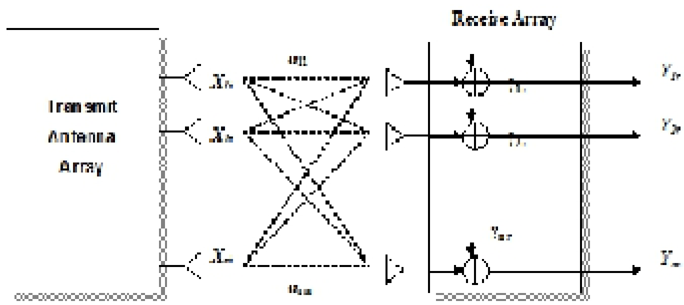
Generator Polynomial: Each path connecting the output to the input of a convolutional encoder may be characterized in terms of its impulse response, defined as the response of that path to a symbol 1 applied to its input, with each flip-flop in the encoder set initially in the zero state. Equivalently each path can be characterized in terms of a generator polynomial, defined as the unit-delay transform of the impulse-response. To be specific, let the generator sequence ($g^{0i)}$, $g^{1i)}$, $g^{2i)}$, · · · · · · , $g^{Mi)}$) denote the impulse-response of the i^{th} path, where the coefficients $g^{0i)}$, $g^{1i)}$, $g^{2i)}$, · · · · · · , $g^{Mi)}$ equal 0 or 1. Correspondingly, the generator polynomial of the i^{th} path is defined by

$$g^{(i)}(D) = g^{0i)} + g^{1i)}D + g^{2i)}D^2 + \cdots + g^{Mi)}D^M$$

IV System Model: STTC

Consider a mobile communication system where the base-station is equipped with antennas and the mobile is equipped with antennas. Data is encoded by the channel encoder, the encoded data goes through a serial-to-parallel converter, and is divided into n streams of data. Each stream of data is used as the input to a pulse shaper. The output of each shaper is then modulated. At each time slot t, the output of modulator i is a signal c^t that is transmitted using transmit antenna (Tx antenna) i for $1 \le i \le n$.

We emphasize that the n signals are transmitted simultaneously each from a different transmit antenna and that all these signals have the same transmission period T . The signal at each receive antenna is a noisy superposition of the n transmitted signals corrupted by Rayleigh fading. It is assumed that the elements of the signal constellation are contracted by a factor ofE_s chosen so that the average energy of the constellation is 1.



Important parameters:

- **Frame error rate**

In this case $E\alpha_{i,j} = 0$ and $K_{i,j}$ for all i and j. Then the inequality obtained above can be written as

$$P(c \to e) \le \left[\frac{1}{\prod_{i=1}^{n}(1-\lambda_i E_s/4N_0)}\right]^m$$

Let r denote the rank of matrix A, then the kernel of A has dimension n − r and exactly n−r eigen values of A are zero. Say the nonzero eigen values of A are $\lambda_1, \lambda_2, \cdots, \lambda_r$, then it follows from inequality above that

$$P(c \rightarrow e) \leq \left[\prod_{i=1}^{r} \lambda_i\right]^{-m} (E_s/N_0)^{-rm}$$

This is the expression for the Frame Error Rate (FER).

- **Outage Capacity**

It is defined in terms of mutual information between input and output, I(input, output). When the output is composed of independent additive noise, and multiple of the transmitted signals, then I(input, output) = ε(output) − ε(noise). Here ε() represents entropy. Since ε(output) and ε(noise) are each expressed as the sum of N_T conditional entropies.

$$I(input, output) = \frac{1}{N_T}\sum_{i=1}^{N_T}\left[\varepsilon(output \mid i^{th} outcome) - \varepsilon(noise \mid i^{th} outcome)\right]$$

V RESULTS

The plot of outage capacity and frame error rate (FER) is drawn for different number of transmit and receive antenna.

Case 1:

N =2 ,M =1 ,Frame length = 100

Frames = 20 ,Initial SNR = 1 dB

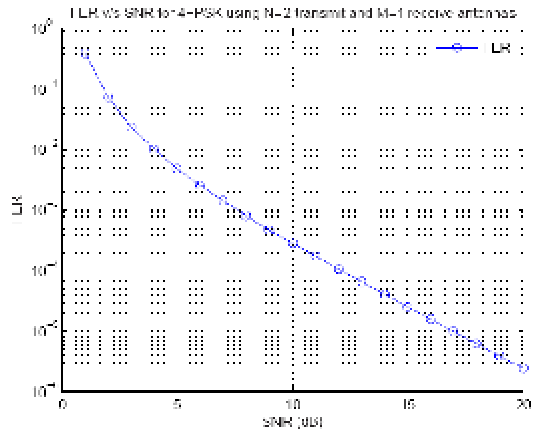


Fig1.FER v/s SNR for 4-PSK using N=2 transmit and M=1 receive antennas

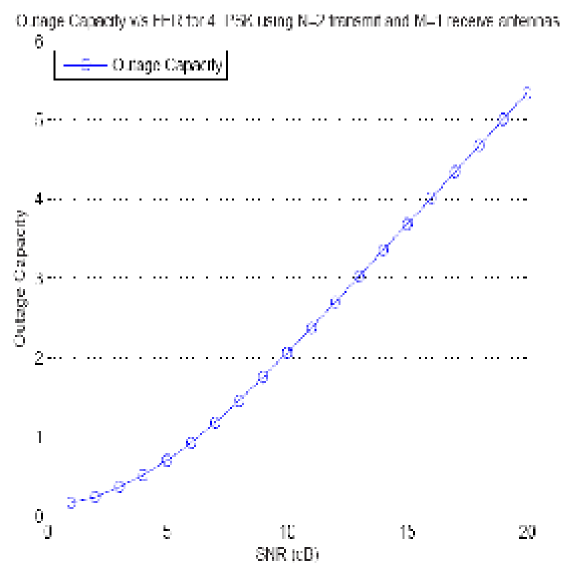


Fig 2.Outage capacity v/s FER for 4-PSK usingN=2 transmit and M=1 receive antennas

Case 2:

N =2 ,M =2 ,Frame length = 100

Frames = 20 Initial SNR = 1 dB

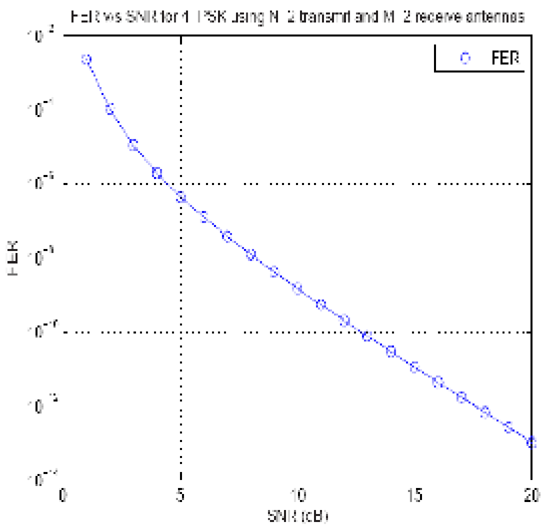


Fig 3: FER v/s SNR for 4-PSK using N=2 transmit and M=2 receive antennas

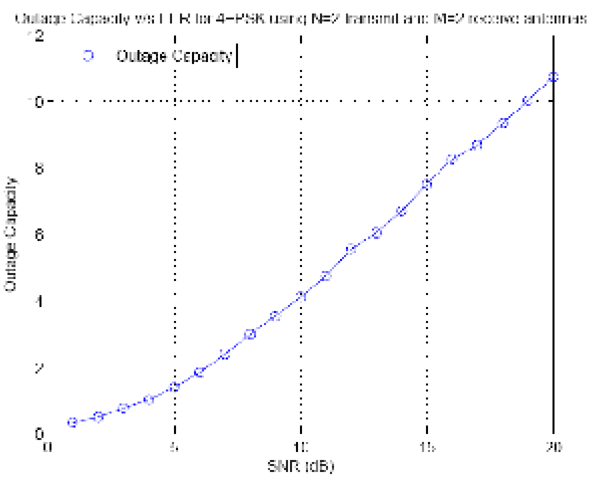


Fig 4. Outage capacity v/s FER for 4-PSK using N=2 transmit and M=2 receive antennas

Case 3: 8-PSK N=2 transmit and M=1 receive antennas

N =2,M =1

Frame length = 99 Frames = 20

Initial SN R = 1 dB

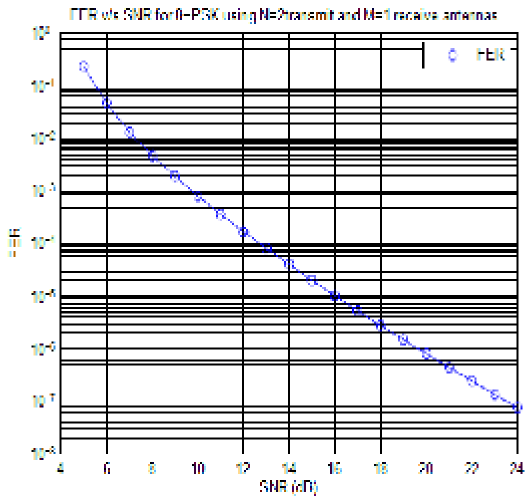


Fig 5 : FER v/s SNR for 8-PSK using N=2 transmit and M=1 receive antennas

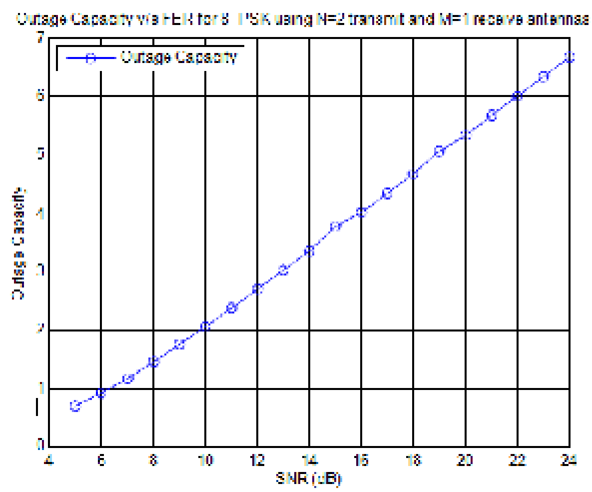


Fig 6: Outage capacity v/s FER for 8-PSK using N=2 transmit and M=1 receive antennas

VI CONCLUSION

This paper defined the analysis and evaluation of Space-Time Trellis Coding (STTC) using PSK modulation in digital communication. We provided examples of spacetime trellis codes for transmission using multiple transmit antennas. we compare the performance of STTC in terms of frame error rate keeping the transmit power, spectral efficiency and number of trellis states fixed. We discover that a simple concatenation of space time block codes with traditional AWGN (additive white Gaussian noise) trellis codes outperforms some of the best known space-time trellis codes at SNRs of interest. Our result holds for a small number of trellis states with one or two receive antennas, and is useful for the design and implementation of multiple-antenna wireless systems. But for higher number of receiver space time trellis code are used. In this simulations have been conducted to study the Frame Error Rate (FER) performance and outage capacity in wireless communication for different number of transmit (N=2) and receive antennas (M=1,2,5) with 4-PSK and 8-PSK modulation Scheme.

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