CHANNEL ESTIMATION AND PERFORMANCE EVALUATION OF STBC WITH CHANNEL CODING

Bhawna Ahlawat,
Research Scholar, Lingayas University,
Faridabad, Haryana (INDIA).

R.K. Reddy,
Associate Professor, Lingayas University,
Faridabad, Haryana (INDIA).

ABSTRACT

Nowadays as we can see that wireless systems are gaining importance in day to day life. These networks have become an essential part of common man's life. The most widely used wireless networks are wireless LAN's, cell phone networks, and other data transfer applications. The main limitations of these wireless devices are the range and data rate. A lot of research has been done to overcome these limitations. One of the technologies is to use Multiple Input Multiple Output (MIMO) system. MIMO along with diversity coding i.e. Space Time Coding concatenated with channel coding and channel estimation at the receiver can be used to increase the data rate or increase the transmit range without sacrificing the bandwidth or increasing the transmitter power. This paper presents a detailed study of diversity coding for MIMO systems concatenated with channel coding and channel estimation at the receiver side. Alamouti's Space Time Block Coding schemes for two transmit antennas and two receive antennas are explored. Orthogonal STBC for 3 and 4 transmit antennas are also analyzed.

These STBC techniques along with channel coding and channel estimation are implemented in Matlab and analysed for performance according to their Bit error rates using BPSK, QPSK, 16 QAM modulation schemes.

KEYWORDS
STBC SPACE TIME BLOCK CODE; OSTBC ORTHOGONAL SPACE TIME BLOCK CODES; MIMO MULTIPLE INPUT MULTIPLE OUTPUT SYSTEM.

1.1 INTRODUCTION

The transmission of information using a wireless medium with the help of electromagnetic waves was demonstrated by Tesla using Hertz and Maxwell work on the transmission of electromagnetic waves. Future wireless Broadband Communication requires high spectral efficiency and high transmission speed. The MIMO system enhances the channel capacity so that we can achieve a high data rate transmission without making any increase in the total transmission power or bandwidth. With the introduction of Alamouti Space Time Block codes in which the data is coded through Space & Time, the MIMO systems have got a higher consideration. The Space Time Block Codes provide redundant copies of the original data by coding the data through time and space and these redundant copies are sent over independent fading channels. There has been intensive research on STBC over the past few years. MIMO and STBC have been adopted in IEEE802.11n for a more reliable data transfer than the traditional single antenna system. It is well known that channels which used in broadband and mobile wireless application are time varying or frequency selective.

Multipath wireless environment introduces severe attenuation in the transmitted signal and it becomes extremely difficult for the receiver to calculate the transmitted signal unless there is some form of diversity provided to the receiver. Using diversity at the receiver we are providing some less attenuated copy of the transmitted signal to the receiver.

Diversity could be provided at the transmitter known as transmit diversity which allows us to deploy antenna array at the transmitter. Imparting transmit diversity help on combating impairments in wireless fading channels. It is feasible to implement multiple antennas at the transmitter side and complexity is also low as well as the increased cost can be compensated over multiple users.

1.2 SPACE TIME CODES

Space time codes are used for communication over Rayleigh fading channels using multiple transmit /receive antennas. Space Time Codes are classified into as: Space time trellis codes (STTC) and Space Time Block Codes (STBC) .Space Time Trellis Codes give excellent performance in slow fading environments. But the decoding complexity of Space time trellis codes increases exponentially with rate of transmission even if the number of transmit antennas is fixed.

Alamouti introduced Space Time Block Codes which are easier to design but performance loss is there as compared to Space Time Trellis codes. These codes have very simple maximum likelihood decoding algorithm based on linear processing at the receiver. STBC can be constructed for any number of transmit antennas and these codes have simple decoding algorithms based on linear processing at the receiver. Space Time Block Codes provide full spatial diversity and half of the maximum possible transmission rate allowed by the theory of space time coding. In this paper we provide a comparison of performance of STBC with channel coding and without channel state estimation to the performance of STBC with channel coding and channel estimation at the receiver.

1.2 CHANNEL CODING

Channel Coding is a technique that is used for controlling errors that occur in the transmission of data over noisy channels. The basic idea is to introduce redundancy in the data by using an error correcting code. With the help of redundancy the receiver can detect a limited number of errors and can correct these errors without retransmission. This is known as Forward Error Correction (FEC).FEC allows the receiver to correct errors without having any need to retransmit the data is not possible or it is costly.

1.3 CONVOLUTIONAL CODES

Convolution codes represent a technique within the various different tpes of channel codes. Channel codes (also called error-correction codes) permit reliable communication of an information sequence over a channel that adds noise, introduces bit errors, or otherwise distorts the transmitted signal.

Convolution codes are mainly specified by 3 parameters ;(n, k, m).

n=number of output bits
k=number of input bits
m=number of memory registers

The quantity k/n called the code rate is a measure of the efficiency of the code. Commonly k and n parameter range from 1 to 8, m from 2 to 10 and the code rate from 1/8 to 7/8.

Also there is code specified by the manufactures with parameters (n, k, L) where L is constraint length of the code and is defined by

$$L = K (m - l)$$

The constraint length L represent the number of bits in the encoder memory that affect the generation of the n output bits.

1.2.1 Code parameters and the Structure of the convolution code.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 3, May - 2012

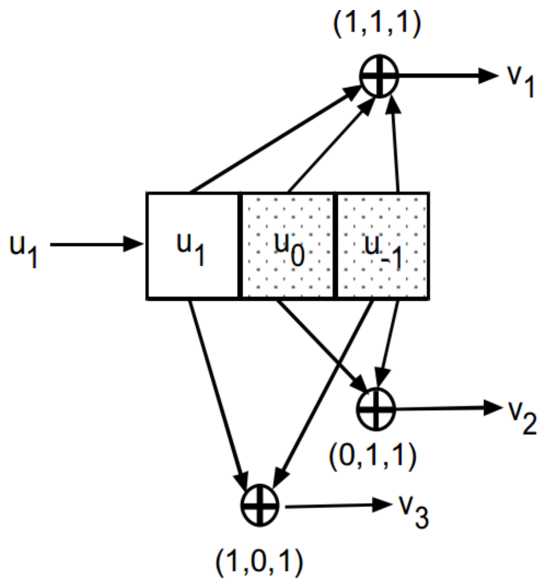

Fig. 1 Convolution code.

The above code (3, 1, 3) represent 3 memory registers, 1 input bit and 3 output bits. This is rate 1/3 code. Each input bit is coded into 3 output bits. The constraint length of the code is 2. The 3-output bits are produced by the 3 modulo-2adders by adding up certain bits in the memory registers.

The selection of which bits to produce the output bit is called the generator polynomial (g) for that output bit. For example, the first output bit has a generator polynomial of (1, 1, 1).

The output bit 2 has a generator polynomial of (0, 1,1) and the third output bit has a polynomial of (1,0,1). The output bits just the sum of these bits.

$$v_1 = \text{mod2}\ (u_1 + u_0 + u_{-1})$$

$$v_2 = \text{mod2}\ (u_0 + u_{-1})$$

$$v_3 = \text{mod2}\ (u_1 + u_{-1})$$

The polynomials give the code its unique error protection quality. One (3,1,4) code can have completely different properties from another one depending on the polynomials chosen.

The channel is not ideal. Propagation can introduce errors to the signal caused by path loss and path fading. So channel coding is introduced to overcome these problems.

In convolution codes, each block of bits is mapped into a block of bits but these bits are not only determined by the present information bits but also by the previous information bits. This dependence can be captured by a finite state machine.

A rate ½ convolution coder, k=1 and n=2 with memory length 2 and constraint length 3.

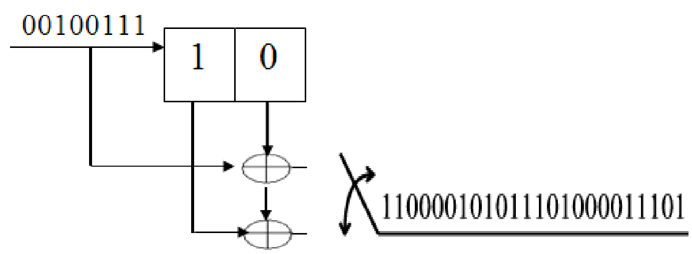

Fig. 2

Since the length of the shift register is 2, there are 4 different rates. The behavior of the convolution coder can be captured by a 4 state machine. States: 00, 01, 10, 11.

1.4 MAXIMUM LIKELIHOOD DECODING

During the transmission, the information encoded by convolution encoder is received in the distorted at the receiver. The decoding of the received information is done using maximum likelihood decoding known as Viterbi Decoding. In this process the decoder searches all the possible paths in the trellis and a comparison is done between the metrics in each path and the input sequence. The path with the minimum distance metric is selected as the output.

In general, a convolution Code CC (n, k, K) has $2^{(K-1)k}$ possible states. At any instant, there are 2^k merging paths for each node and the one with the minimum distance is selected and is reffered as surviving path. At each instant, there are $2^{(K-1)k}$ surviving paths are stored in the memory. When all the input sequence are processed, the decoder will select a path with the minimum metric and output it as the decoding result.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 3, May - 2012

1.4 CHANNEL ESTIMATION

Due to the multipath channel there is some inter-symbol interference (ISI) in the received signal. Therefore a signal detector (like MLSE or MAP) needs to know channel impulse response (CIR) characteristics to ensure successful equalization (removal of ISI). Note that equalization without separate channel estimation (e.g., with linear, decision-feedback, blind equalizers is also possible, but not discussed in this report. After detection the signal is deinterleaved and channel decoded to extract the original message.

1.4.1 LS CHANNEL ESTIMATION

If the channel vector g is Gaussian and uncorrelated with the channel noise n, then the LS estimate is given by

$$\hat{\mathbf{h}}_{LS}=\mathbf{F}\mathbf{Q}_{LS}\mathbf{F}^{H}\mathbf{X}^{H}\mathbf{y} \qquad \text{...... (1)}$$

Where

$$\mathbf{Q}_{LS}= (\mathbf{F}^{H}\mathbf{X}^{H}\mathbf{X}\mathbf{F})^{-1}$$

So eqn (1) reduces to

$$\hat{\mathbf{h}}_{LS} = \mathbf{X}^{-1}\mathbf{y} \qquad \text{...... (2)}$$

The LS estimator is equivalent to what is also referred as Zero Forcing Estimator.

1.4.1 THE TRANSMISSION MODEL

In this paper we consider a wireless communication system having n antennas at the base station and m antennas at the remote. At each time slot t ,signal c_t^i ,i=1,2,….n are transmitted from n transmit antennas simultaneously. We have assumed the channel to be flat fading and we assume $\alpha_{i,j}$ be the path from transmit antenna i to receive antenna j. The wireless channel is assumed to be quasi static so as the path gains remain constant for a frame of length l and vary for other frame. The received signal at antenna j at a time t is given by

$$r_t^j = \sum_{i=1}^{n} \alpha_{i,j} c_t^i + \eta_t^j \qquad \text{......... (2)}$$

where are the noise samples of zero mean complex Gaussian random variable with variance n/(2SNR) per complex dimension. Assuming that perfect channel state information is available at the receiver the receiver computes the decision metric.

$$\sum_{t=1}^{l}\sum_{j=1}^{m}\left| r_t^j - \sum_{i=1}^{n} \alpha_{i,j} c_t^i \right|^2 \qquad \text{--------- (3)}$$

over all of the received code words and decides in the favour of codeword that has the minimum metric.

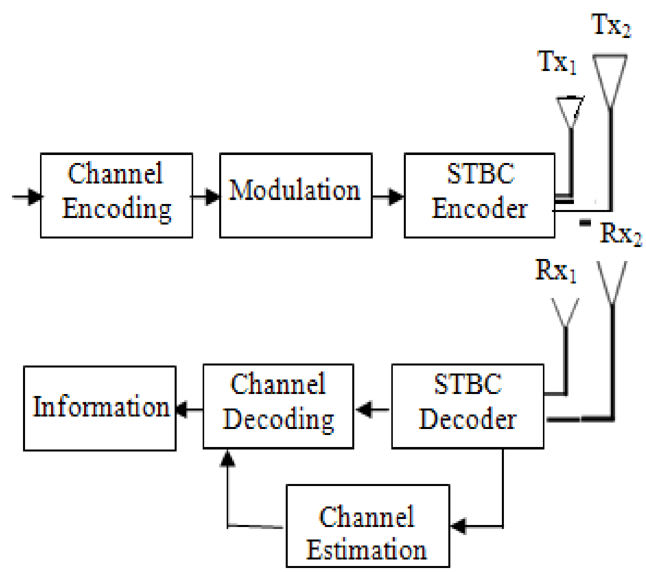

Fig.3: Proposed system STBC using channel coding

1.4.1 SIMULATION RESULTS

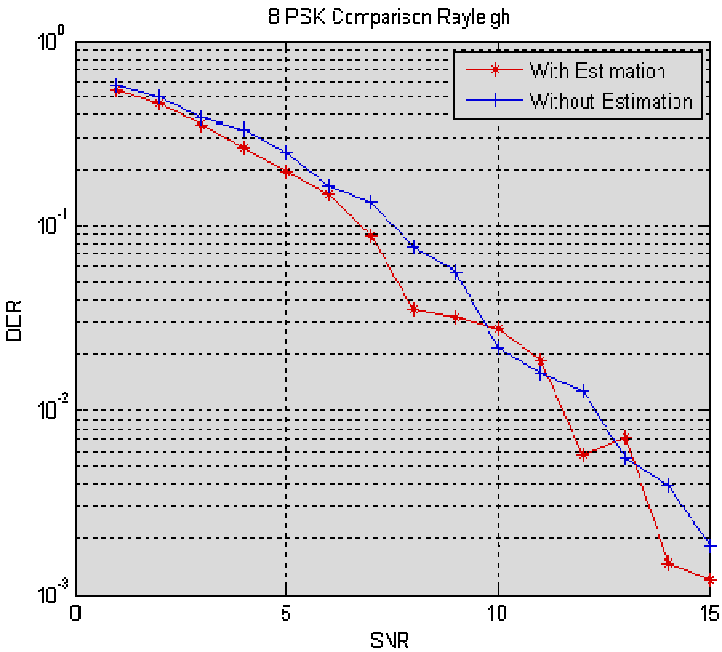

Fig. 4 BER Comparison for 8 PSK Rayleigh Distribution.

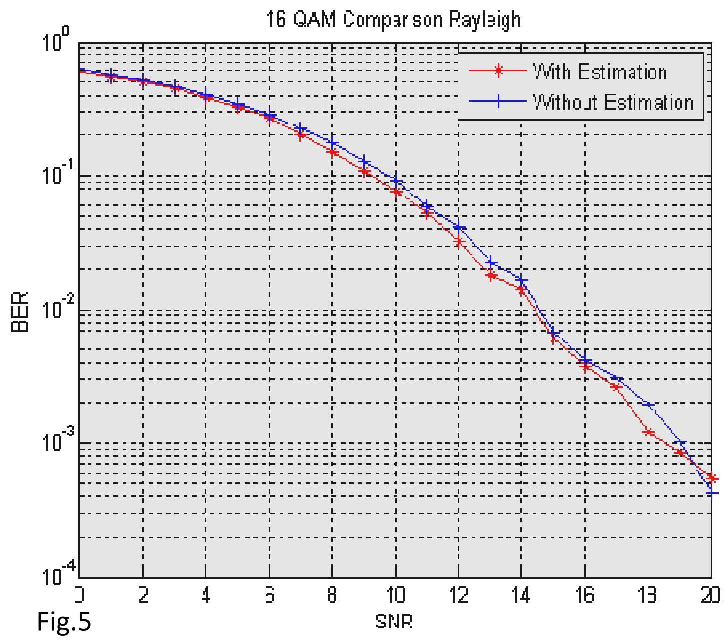

Fig.5
BER Comparison of 16 QAM Rayleigh Distribution.

In this section, we provide the simulation results as designed in above sections. Fig.3 illustrates a block diagram of the system. The information is encoded using convolution encoder and space time block codes and pilot symbols are inserted using the zero forcing technique.

After this using different modulation schemes the constellation symbols are transmitted from different antennas.The transmitted bits are estimated by the receiver using the signals of the received antennas. Fig. 4 and 5 shows the bit error rate plotted against the SNR (dB).The results are shown for 2*2 MIMO schemes along with channel coding schemes. It is seen that with channel coding using 8 PSK we get improvement in the Bit Error Rate as compared to that of without estimation. The results are compared with QAM with and without channel estimation and it is seen that using the channel estimation techniques we get an improvement in BER as compared to without channel estimation.

Thus we can see that with the use of convolution codes along with Space Time Block Coding reduces the BER as compared to that without convolution codes .The additional gain is achieved using channel estimation techniques at the receiver .This gives better performance at the expense of a higher complexity.

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