Comparative analysis of V-BLAST and Space time Block coded Spatial Modulation in Rayleigh and AWGN Channels

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Abstract: Multiple Input Multiple Outputs MIMO; Space-Time Coding (STC) improves the BER by adding diversity in the presence of a channel fading. The V-BLAST and D-BLAST techniques are designed to improve the data rate. The performance of these techniques is highly dependent on the MIMO channel environment. Space-time block coded spatial modulation (STBC-SM) combines spatial modulation (SM) and space-time block coding (STBC) to take advantage of the benefits of both. In the STBC-SM scheme, the transmitted information symbols are expanded not only to the space and time domains but also to the spatial (antenna) domain. This corresponds to the on/off status of the transmit antennas available at the space domain, and therefore, high spectral efficiency along with diversity advantage of STBC. The performance of the STBC-SM, V-BLAST and D-BLAST are compared at high and low SNR environment. It is observed that STBC-SM performs better than V-BLAST and D-BLAST but with more decoding complexity.

Keywords: OFDM, MIMO, WLAN, STC, BER, VBLAST, UBLAST.

I. INTRODUCTION
Multiple-antenna systems that operate at high rates require simple yet effective space–time transmission schemes to handle the large traffic volume in real time. At rates of tens of bits per second per hertz, Vertical Bell Labs Layered Space–Time (V-BLAST), where every antenna transmits its own independent sub stream of data, has been shown to have good performance and simple encoding and decoding. Yet V-BLAST suffers from its inability to work with fewer receive antennas than transmit antennas—this deficiency is especially important for modern cellular systems, where a base station typically has more antennas than the mobile handsets.

Furthermore, because V-BLAST transmits independent data streams on its antennas there is no built-in spatial coding to guard against deep fades from any given transmit antenna. On the other hand, there are many previously proposed space–time codes that have good fading resistance and simple decoding, but these codes generally have poor performance at high data rates or with many antennas.

We propose a high-rate coding scheme that can handle any configuration of transmit and receive antennas and that subsumes both V-BLAST and many proposed space–time block codes as special cases. The scheme transmits sub streams of data in linear combinations over space and time. The codes are designed to optimize the mutual information between the transmitted and received signals. Because of their linear structure, the codes retain the decoding simplicity of V-BLAST, and because of their information-theoretic optimality, they possess many coding advantages. We give examples of the codes and show that their performance is generally superior to earlier proposed methods over a wide range of rates and signal-to-noise ratios (SNRs).

II. PROBLEM DEFINITION
In this, a generalized space-time coded continuous phase modulated (STC-SM) framework is developed. It allows for a wide variety of space-time trellis codes, including high-rate codes. An integrated design is obtained by defining all code structures on the same integer ring. This integrated
design enables performance measures to be readily evaluated. This work is an extension of the ideas in where integrated ring convolution code designs are implemented for various single thread STB systems. Yang and Taylor investigate ring convolution code design for a subset of STB called continuous phase frequency shift keying (STBC), and Remold and Liu [extend this concept to more general CPM. In [29, 30], Griffin and Taylor use a ring convolution code to differentially encode STBC, and investigate ring convolution code design for differentially demodulated STBC. The examples and performance results presented in this thesis are primarily focused on STBC modulated space-time codes.

A Rayleigh fading channel model with additive white Gaussian noise (AWGN) is assumed. The proposed STC-SM schemes are narrowband. Therefore, we assume the Rayleigh fading to be non-frequency selective (flat-fading). At the receiver, we assume there is ideal knowledge of channel information and transmitter parameters, such as, symbol timing and carrier frequency. In real-world systems, estimates of such parameters are required and obtaining these can involve much work. This is beyond the scope of this thesis. Also, the effects of inter-symbol interference are not considered.

The new STC-SM design will be implementable in real world wireless communication systems at affordable costs and has considerable potential for commercial development in the area of rapidly deployable wireless data networks. The scheme could be developed to operate within the APCO 25 Standard which is a voluntary standard for narrowband public safety digital radio.

III. OBJECTIVE OF PROJECT

Space-time coded systems developed in the last ten years have been designed primarily using linear modulation. Non-linear continuous phase modulation has desirable constant envelope properties and considerable potential in space-time coded systems. The work in this thesis is focused on developing and analyzing an integrated space-time coded continuous phase modulated (STC-SM) system. The coding of the space-time encoder and the modulation is incorporated into a single trellis encoder. This allows state combining, which leads to complexity reduction due to the reduced number of states. Design criteria for STC-SM are summarized and the Euclidean distance is shown to be important for code design. The integrated STC-SM system design enables systematic space time code searches that find optimal space-time codes, to be easily implemented. Optimal rate-1/2 and rate-2/3 space-time codes are found by maximizing the system’s minimum squared Euclidean distance. These codes can provide high throughput and good coding gains over un-optimized full rank codes, such as delay diversity, in a quasi-static flat fading environment. Performance bounds are developed using a union bound argument and the pair wise error probability. Approximations of the bounds are evaluated. These truncated upper bounds predict the slopes of the simulated performance curves at low error rates.

A. ADVANTAGES

1. Space-time block coding utilizes multiple transmit antennas to create spatial diversity.
2. This allows a system to have better performance in a fading environment.
3. Good performance with minimal decoding complexity.
4. Can achieve maximum diversity gain equivalent to space-time trellis codes
5. Receivers that use only linear processing.

B. APPLICATIONS

1. Metropolitan Area Networks (MANs),
2. In Digital Television (DTV),
3. Wireless Local Area Networks (WLANs),
4. Mobile Communications.

C. EXISTING SYSTEM:

In V-BLAST systems, a high level of inter-channel interference (ICI) occurs at the receiver since all antennas transmit their own data streams at the same time. This further increases the complexity of an optimal decoder exponentially, while low-complexity suboptimum linear decoders, such as the minimum mean square error (MMSE) decoder, degrade the error performance of the system significantly.
D. DISADVANTAGES OF EXISTING SYSTEM:

- ML decoding complexity grows exponentially with the constellation size
- Difficult implementation
- Expensive for future wireless communication system

IV. V-BLAST:

V-BLAST stands for Bell Laboratories Layered Space Time and V stands for Vertical which relates to the blocking structure. V-BLAST is a wireless communication technique which uses multi-element antennas at both transmitter and receiver. It is an extra ordinarily bandwidth efficient approach for wireless networks. Its spectral efficiency ranges from 20 to 40 bps/Hz while efficiency of traditional wireless communication techniques ranges from 1 to 5 bps/Hz (mobile cellular) to around 10 to 12 bps/Hz (point to point fixed microwave system). In a wireless system, radio wave does not simply propagate from transmit antenna to receive antenna, but bounce and scatter randomly off objects in the environment. This scattering is known as multipath, as it results in multiple copies of the same transmitted signal. In conventional wireless systems, multipath represents a significant impediment to accurate transmission, because the images arrive at the receiver at slightly different times and can thus interfere destructively, canceling each other out. For this reason, multipath is traditionally viewed as a serious impairment. Using the V-BLAST approach, however, it is possible to exploit multipath, that is, to use the scattering characteristics of the propagation environment to enhance, rather than degrade, transmission accuracy by treating the multiplicity of scattering paths as separate parallel sub-channels. For 30 kHz channel bandwidth, data rate ranges from 0.5 Mbps to 1 Mbps while with traditional techniques data rate range is of only 50 kbps. This above comparison shows how important V-BLAST is for the future high-speed wireless communication networks.

B. ADVANTAGES OF PROPOSED SYSTEM:

- Synchronization of all transmit antennas is not required
- Significant improvements in BER performance
- Useful for high-rate, low complexity, emerging wireless communication systems such as WiMAX.
- Spectral efficiency

V. INTRODUCTION TO MIMO SYSTEM:

Wireless networks and devices are ubiquitous and the ultimate goal of wireless communication is to facilitate any-place any-time communications. To achieve this desired goal, future wireless systems must provide higher bandwidth efficiency and data rates. This requirement is particularly challenging for systems that are power, bandwidth and complexity limited. In 1999, the use of multiple transmit and/or receive antenna was proposed and shown to be very effective in reaching to the upper bound of capacity (Shannon capacity). Previously, wireless engineers treated multipath propagation as a problem to be mitigated whereas MIMO wireless technology exploits multipath propagation to improve the quality of service measures such as the bit error rate (BER) or the data rate (bits/sec). In other words, MIMO effectively takes advantage of random fading and multipath delay spread to increase the data transfer rate. Exploiting the benefits of MIMO channels requires the use of Space-Time (ST) codes. The ST code design, a major challenge in MIMO systems, involves finding an optimal way of encoding and transmitting multiple copies of a data alternative to existing techniques such as SM and VBLAST. The proposed new transmission scheme employs both APM techniques and antenna indices to convey information and exploits the transmit diversity potential of MIMO channels. A general technique has been presented for the construction of the STBC-SM scheme for any number of transmit antennas in which the STBC-SM system was optimized by deriving its diversity and coding gains to reach optimum performance.

A. PROPOSED SYSTEM:

In this paper, we have introduced a MIMO transmission scheme, called STBC-SM, as an
stream across multiple antennas to improve the rate and reliability of data transfer.

A MIMO wireless system with multiple TX and RX antennas.

Figure: A MIMO wireless system with multiple TX and RX antennas.

**A. DESIGN OF STBC-SM SYSTEM:**

Consider a MIMO system with \( M \) transmits and \( N \) receives antennas operating over a frequency-flat channel that remains constant for at least \( T \) signaling intervals. The information bit stream is encoded into a ST code word of dimension \( T \times M \). The ST code word is defined by \( S = [s_1; s_3; \ldots; s_T] \), where \( s_t \) is the transmitted vector symbol over the \( t \)th time slot. In this time slot, the complex symbols \( s_{ti} \) are transmitted over antennas \( i = 1; \ldots; M \), and \( y_{tj} \) is received on receiver antennas \( j = 1; \ldots; N \). As well, \( h_{ij} \) is denoted as the fading coefficient from the \( i \)th transmit antenna to the \( j \)th receive antenna. The input-output relation is given by

\[
y_{tj} = \sum_{i=1}^{M} h_{ij}s_{ti} + n_{tj}, \quad t = 1, \ldots, T; j = 1, \ldots, N,
\]

where the additive noise at time \( t \) in the receive antenna \( j \) denoted by \( n_{tj} \) is independently, identically distributed \( CN(0; 1) \).

The average signal-to-noise ratio (SNR) per receive antenna is \( \frac{\rho}{M} \). Eqn can be written in a matrix form as

\[
Y_t = \sqrt{\frac{\rho}{M}} S_t H_t + W_t,
\]

where \( Y_t \) is the \( T \times N \) complex received signal matrix, and \( S_t \) is the \( T \times M \) complex transmitted signal matrix at the time index \( t \). \( H_t \) is the \( M \times N \) channel transfer function, and \( W_t \) denotes a \( T \times N \) additive noise matrix with \( CN(0; 1) \) elements.

**STC (SPACE TIME CODE) DESIGN**

ST code design is an active area of research in MIMO systems. Design may depend on many parameters such as the signaling scheme, the availability of the CSI at the receiver, the rate of data transmission and the method of detection. However, a general formula to derive ST code design criteria has been proposed.

They showed that in the high SNR regime \( (\frac{\rho}{M} >> 1) \), the upper bound on pairwise error probability of mistaking transmitted code word \( S_i \) for another code word \( S_j \) is expressed as

\[
P(S_i \rightarrow S_j) \leq \frac{1}{\det(G_{i,j})} \left( \frac{\rho}{4M} \right)^{-r(G_{i,j})N}
\]

Where \( G_{i,j} = (S_i S_j)(S_i S_j)^H \). From (3.6), two important criteria can be derived for ST code construction. First, the *rank criterion* aims to
maximize the diversity order, i.e. to maximize \( r(G_{i;j})N \). Hence, to extract the maximum diversity, one should maximize the minimum rank of the difference matrix between an pair of codewords \( S_i \) and \( S_j \) and possibly make it full rank (\( r(G_{i;j}) = M \)) by designing a proper ST codebook. Second, the determinant criterion deals with the optimization of the coding gain for the ST code. To obtain a high coding gain, one should maximize the minimum of the determinant of \( G_{i;j} \) over all possible codewords \( S_i \) and \( S_j \). Both these criteria lead ultimately to the minimization of the error probability.

![Block Diagram of STC Transmission](image)

**Space Time Block Code (STBC)**

The main two requirements for next generation communication systems are high data rate and high reliable communication. Spectral efficiency is available because systems are band limited and user’s demands are growing continuously. Application of multiple input multiple output (MIMO) technique is the best technique to improve link capacity, and potentially increase spectral efficiency.

Recently, operators, manufacturers, and the research community are focusing their efforts to include MIMO techniques in most of the 31st-century standards such as LTE, WiMAX, WiFi, and cognitive radio. It is known that a wireless communication link in a fading environment with MIMO techniques can greatly increase the capacity and reliability when using space-time coding. An efficient transmit diversity scheme is called Space time block coding (STBC) is used to combat detrimental effects of wireless fading channels because of its simple decoding maximum-likelihood (ML) algorithm accomplishing full diversity at a radio receiver. A transmit diversity technique using space time block coding (STBC) is an important technique for future wireless systems, since it can provide high diversity gain by exploiting the multi-path environment without requiring additional bandwidth. The concept of spatial modulation (SM) to remove the inter channel interference (ICI) completely between the transmit antennas of a MIMO link is introduced in. The information is conveyed not only by the amplitude/phase modulation (APM) techniques, but also by the antenna indices. Space-time block coded spatial modulation (STBC-SM) is introduced in which combines spatial modulation (SM) and space-time block coding (STBC) to take advantage of the benefits of both while avoiding their drawbacks. In the STBC-SM scheme, the transmitted information symbols are expanded not only to the space and time domains but also to the spatial (antenna) domain which corresponds to the on/off status of the transmit antennas available at the space domain, and therefore both core STBC and antenna indices carry information. A low-complexity maximum likelihood (ML) decoder is used for the STBC-SM scheme, which profits from the orthogonality of the core STBC.

A STBC for two transmit antennas is proposed by Alamouti. The code matrix is given by

\[
X_2 = \begin{bmatrix}
  x_1 & x_2 \\
  -x_2^* & x_1^*
\end{bmatrix}
\]

Where, \( x1, x3 \) \ Î QAM/PSK constellation. It is assumed that, channel is flat fading over two time slots and a single receive antenna, the received signals are expressed by

\[
\begin{bmatrix}
  r_1^* \\
  r_2^*
\end{bmatrix} = H_2 \cdot \begin{bmatrix}
  x_1 \\
  x_2
\end{bmatrix} + \begin{bmatrix}
  n_1 \\
  n_2^*
\end{bmatrix}
\]

where \( r \) and \( n \) are the received signal and the complex Gaussian noise added at the \( i \)-th time slot respectively. \( H \) is the channel matrix, and it is denoted as \( H \) for two transmit antenna schemes and given by
where $j$ $h$ is the channel gain of the path from the $j$-th transmit antenna to the receiver. The received signals can be decoded using the following simple linear decoding method.

\[
\begin{bmatrix}
\hat{x}_1 \\
\hat{x}_2
\end{bmatrix} = \frac{1}{\alpha^2} H_2^H \cdot \begin{bmatrix}
r_1 \\
r_2
\end{bmatrix}
\]

B. OUTPUTS:

D. Alamouti STBC

E. STBC-SM

F. BER plot of STBC-SM
G. MODULE 1: BER Performance for 64-QAM Modulation

The above graph explains about Bit Error Performance for the QAM type modulation technique of 64-bit. The blue colored line indicates the theoretical calculation for the same. And the pink colored line indicates the simulation results. It shows that the theoretical and simulation results are same.

H. MODULE 2: BER Performance with BPSK Modulation

The above graph explains about Bit Error Rate for the BPSK type modulation. The blue colored line indicates the theoretical calculation for 1 Tx and 1 Rx, black indicates 1Tx and 2Rx’s, light blue 2Tx and 1Rx using Alamouti, and the pink colored line indicates the simulation results for 2Tx and 2Rx using Alamouti. Its shows BER are better using Alamouti.

I. MODULE 3: BER for M-PSK Modulation

The above simulation results show the comparison between system SNR and BER probability using M-PSK type of modulation technique. The symbol error probability and BER probability are the same.

J. MODULE 4: BER for BPSK Using Alamouti STBC

The above graph explains about Bit Error Performance for the BPSK type modulation. The blue colored line indicates the theoretical calculation for 1 Tx and 1 Rx, black indicates 1Tx and 2Rx’s using MRC, light blue 2Tx and 1Rx using Alamouti, and the pink colored line indicates...
the simulation results for 2Tx and 1Rx using Alamouti. It shows BER are better using Alamouti in STBC.

K. MODULE 5: BER Comparisons of Various systems

![BER Comparison of Various systems](image)

Fig: BER Comparison of Various systems

This shows all types of system performance like V-BLAST, STBC, ALAMOUTI, STBC-SM. Light green curve indicates for V-BLAST using 3Tx’s, purple for 4tx’s. Light blue and red indicates for 3,4Tx using STBC and yellow and pink shows 3,4Tx’s using Alamouti. Finally blue for 3Tx and black for 4Tx using STBC-SM. It clearly explains that compared to all systems STBC-SM has better BER performance.

VI. CONCLUSION

In this paper, we have introduced a novel high-rate, low complexity MIMO transmission scheme, called STBC-SM, as an alternative to existing techniques such as SM and V-BLAST. The proposed new transmission scheme employs both APM techniques and antenna indices to convey information and exploits the transmit diversity potential of MIMO channels. A general technique has been presented for the construction of the STBC-SM scheme for any number of transmit antennas in which the STBC-SM system was optimized by deriving its diversity and coding gains to reach optimum performance.

It has been shown via computer simulations and also supported by a theoretical upper bound analysis that the STBC-SM offers significant improvements in BER performance compared to SM and V-BLAST systems (approximately 3-5 dB depending on the spectral efficiency) with an acceptable linear increase in decoding complexity. From a practical implementation point of view, the RF (radio frequency) front-end of the system should be able to switch between different transmit antennas similar to the classical SM scheme. On the other hand, unlike V-BLAST in which all antennas are employed to transmit simultaneously, the number of required RF chains is only two in our scheme, and the synchronization of all transmit antennas would not be required.

We conclude that the STBC-SM scheme can be useful for high-rate, low complexity, emerging wireless communication systems such as LTE and WiMAX. Our future work will be focused on the integration of trellis coding into the proposed STBC-SM scheme.

VII. FUTURE SCOPE

Other modulation types, such as QAM, FSK, and DPSK, will be tested. Correlated fading between transmit and receive pairs and variable fading rates should be taken into account. Turbo principles can be used to facilitate the implementation of iterative channel estimation and decoding techniques. We are using hard decision decoding where received bits are compared with two values that are either 0 or 1. This system is also implemented with soft decision decoding which can give better performance. Other modulation types, such as QAM, FSK, and DPSK, will be tested. Further performance can be investigated by using in software defined radio (wireless technique) for various channel conditions or channel state information.

The higher rate space-time coded systems require more trellis states. The trellises of the systems with large modulation alphabets also have greater complexity due to the number of transitions from each state. Hence, further reducing decoder/demodulator complexity through existing or new algorithms is of interest.
REFERENCES


BIOGRAPHY

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