# A Novel Literature Review on Channel Estimation in MIMO-STBC Systems

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***Abstract- Multiple-Input Multiple-Output (MIMO-STBC) systems play a very important role in fourth generation (4G) wireless systems by exploiting spatial diversity, higher data rate, greater coverage and improved link robustness without increasing total transmission power or bandwidth. MIMO wireless communication systems and hence need to be estimated accurately for efficient data detection at receiver. Consequently accurate and robust estimation of wireless channel is of crucial importance for coherent demodulation in MIMO system. This review work aims to explore and design novel matrix decomposition based semi-blind channel estimation techniques with data detection for reduced complexity and near optimal performance. Performance evaluations in terms of BER analysis of proposed semi-blind channel estimation techniques compared with above mentioned conventional techniques have been taken to verify the utility of the this work.***

***Keywords- QAM Modulation; MIMO system and STBC codes.***

## I. INTRODUCTION

MIMO systems have been recently under active consideration because of their potential for achieving higher data rate and providing more reliable reception performance compared with traditional single-antenna systems for wireless communications. A space-time (ST) code is a bandwidth-efficient method that can improve the reliability of data transmission in MIMO systems [2], [5]. It encodes a data stream across different transmit antennas and time slots, so that multiple redundant copies of the data stream can be transmitted through independent fading channels and by doing so more reliable detection can be obtained at the receiver. A MIMO system takes advantage of the spatial diversity that is obtained by spatially separated antennas in a dense multipath scattering environment. Further that may be implemented in a number of different ways to obtain either a diversity gain to combat signal fading or to obtain a capacity gain. To maximize spatial diversity, the same information can be transmitted from multiple transmit antennas and received at multiple antennas simultaneously hence the probability that the information is detected accurately is increased. The simplest way of achieving diversity is through repetition coding that sends the same information symbol in different time slots from different transmit antennas. Examples include delay diversity, Space-Time Block Code (STBC) and Space-Time Trellis Code (STTC), Orthogonal Space-Time Block Code (OSTBC). MIMO systems provide more spatial freedoms or spatial multiplexing so that different information can be transmitted simultaneously over multiple antennas, thereby boosting the system throughput.

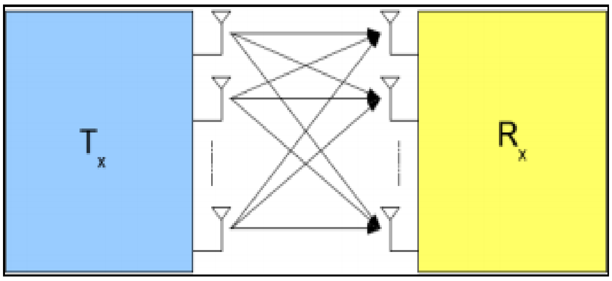


Fig. 1.1: MIMO Communication System

Wireless communications have expanded enormously over the last decade. The expectation is that the growth will continue. Future wireless communication systems are expected to support high-speed and high-quality multimedia services. To increase the quality and capacity of wireless communications by means of higher data throughput and simultaneous increase in range and reliability, Multiple-Input Multiple-Output (MIMO) systems have been proposed to exploit signals from multiple antennas at both the transmitter and receiver [1]-[4]. Even as a relatively new technique, MIMO has already been employed by the third generation (3G) wireless standards in the form of space-time coding, and it is regarded as an essential component of the fourth generation (4G) and other future systems. Current industry trends suggest that large-scale deployment of MIMO wireless systems will initially be seen in WLANs and in wireless metropolitan area networks (WMANs).

Corresponding standards currently under definition include the IEEE 802.11n WLAN and IEEE 802.16 WMAN standards.

## II. SYSTEM MODEL OF WIRELESS CHANNEL

The characteristic of wireless channels is the fact that there are many different paths between the transmitter and the receiver. The existence of various paths results in receiving different versions of the transmitted signal at the receiver. These separate versions experience different path loss and phases. Fig. 2.1 demonstrates the trajectory of different paths in a typical example.

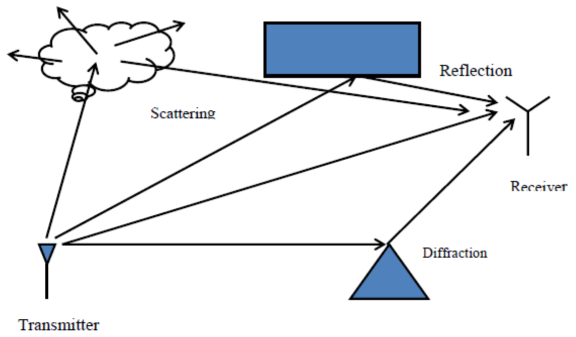


Fig. 2.1: Different Paths in Wireless Channel

If there is a direct path between the transmitter and the receiver, it is called the line of sight (LOS). A LOS does not exist when large objects obstruct the line between the transmitter and the receiver. If LOS exists, the corresponding signal received through the LOS is usually the strongest and the dominant signal. At least, the signal from the LOS is more deterministic. While its strength and phase may change due to mobility, it is a more predictable change that is usually just a function of the distance and not many other random factors.

A LOS is not the only path that an electromagnetic wave can take from a transmitter to a receiver. An electromagnetic wave may reflect when it meets an object that is much larger than the wavelength. Through reflection from many surfaces, the wave may find its path to the receiver. Of course, such paths go through longer distances resulting in power strengths and phases other than those of the LOS path. Another way that electromagnetic waves propagate is diffraction. Diffraction occurs when the electromagnetic wave hits a surface with irregularities like sharp edges.

Finally, scattering happens in the case where there are a large number of objects smaller than the wavelength between the transmitter and the receiver. Going through these objects, the wave scatters and many copies of the wave propagate in many different directions. There are also other phenomenon that affects the propagation of electromagnetic waves like absorption and refraction.

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The effects of the above propagation mechanisms and their combination result in many properties of the received signal that is unique to wireless channels. These effects may reduce the power of the signal in different ways. There are two general aspects of such a power reduction that require separate treatments. One aspect is the large-scale effect which corresponds to the characterization of the signal power over large distances or the time-average behaviours of the signal. This is called attenuation or path loss and sometimes large-scale fading. The other aspect is the rapid change in the amplitude and power of the signal and this is called small-scale fading, or just fading. It relates to the characterization of the signal over short distances or short time intervals. Small-scale fading and its statistical models are explained in next section.

*Fading*

Fading, or equivalently small-scale fading, is caused by interference between two or more versions of the transmitted signal which arrive at the receiver at slightly different times. These signals, called multipath waves, combine at the receiver antenna and the corresponding matched filter and provide an effective combined signal. This resulting signal can vary widely in amplitude and phase. The randomness of multipath effects and fading results in the use of different statistical arguments to model the wireless channel. To understand the behaviour and reasoning behind different models, the cause and properties of fading are studied and described.

*MIMO CHANNEL*

Multiple-Input Multiple-Output (MIMO) systems yield vast capacity increases when the rich scattering environment is properly exploited [1]. When examining the performance of MIMO systems, the MIMO channel must be modeled properly. The primary MIMO channel model under consideration is the quasi-static, frequency nonselective,Rayleigh fading channel model. Fig. 2.2 shows a block diagram of a MIMO system with Nt transmit antennas and Nr receive antennas. The channel for a MIMO system can be represented by

$$H = \begin{bmatrix} h_{11} & \cdots & h_{1N} \\ h_{21} & \cdots & h_{2N} \\ h_{31} & \cdots & h_{3N} \\ h_{M1} & \cdots & h_{MN} \end{bmatrix}$$

Where hij is the complex channel gain between transmitter j and receiver i. Each channel gain hij is assumed to be independently identically distributed (i.i.d) zero mean complex Gaussian random variables with unit variance [1].

Under the quasi-static assumption, the channel remains constant over the length of a frame, changing independently between consecutive frames. When the antenna elements are spaced sufficiently apart (at least half a wavelength, for indoor applications) and there are enough scatterers present that the received signal at any receive antenna is the sum of several multipath components, the channel paths are modeled as independent and uncorrelated. The channel undergoes frequency nonselective fading when the coherence bandwidth of the channel is large compared to the bandwidth of the transmitted signal [3]

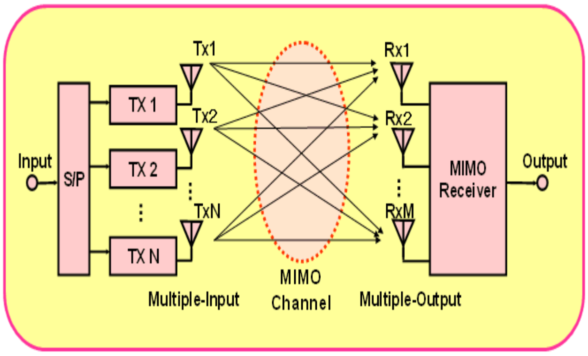


Figure 2.2: MIMO Channel

## III. Literature Review

In 2014, Mr. Ben Slimane, E. Jarboui, and S, A, Investigated the challenges regarding the provision of channel state information (CSI) in multiple-input multiple-output (MIMO) systems based on space time block codes (STBC) over slow time-varying Rayleigh fading channels are addressed. They developed a novel MIMO channel estimation algorithm that adopts a pilot symbol assisted modulation (PSAM) which has been proven to be effective for fading channels. In this approach, pilot symbols are periodically inserted into the data stream that is sent through the orthogonal STBC encoder. At the receiver, authors propose a straightforward MIMO channel estimation method before being used by STBC decoder. Results indicate that the proposed pilot-assisted MIMO concept provides accurate channel estimates. The impact of Doppler frequency on performance scheme is also investigated by simulation [06].

In 2012, Minggang Luo, Liping Li and Bin Tang, gave the study about Blind modulation recognition is a challenging problem in Multiple Input Multiple Output systems in association with Space-Time Block Code. A modulation classifier is presented based on Maximum Likelihood (ML) without utilizing the Channel State Information (CSI) and coding matrix. The modulation recognition based on the ML classifier is discussed for independent constellations by using Independent Component Analysis. Simulations show that their algorithm can work with high recognition probabilities in MIMO-STBC communication systems when CSI and coding matrix are unavailable [7].

In 2012, Minggang Luo and Liping Li, demonstrated Blind separating the intercepted signals is a research topic of high importance for both military and civilian communication systems. In this research work, an extending algorithm is presented by applying a rotation transform to maximize the independence between the real and imaginary parts without using a precoder at the transmitter side. Results show that the new algorithm can separate complex PSK-modulated signals with high Symbol Error Rate performance when Channel State Information and coding matrix are unavailable [8].

In 2010, Quadeer, AA. Sohail and M.S. have done research on Channel estimation which is an important part of any receiver design. This work presents an improved iterative joint channel estimation and data detection algorithm for Space Time Block Coded Multi Input and Multi Output OFDM systems in fast fading environments. The algorithm utilizes both time and frequency correlation information. Researchers showed how the Cyclic Prefix (CP) can be used to enhance the joint channel estimation and data detection process. The two variations of the Expectation Maximization (EM) based Forward Backward (FB) Kalman filter algorithm utilizing the CP information and provide their performance comparison. Results show that the proposed use of CP to aid the EM based FB Kalman algorithm results in improved performance [9].

In 2010, Jie Wang, Xiaoxu Chen and Tao Liu with Yuehuan Gong, presented an iterative Maximum Likelihood Decoding (MLD) scheme for Multiple Input Multiple Output (MIMO) systems using Space-Time Block Codes (STBC) in strong directional interference scenario. The proposed work avoids matrix-inversion computation needed in ordinary reception schemes and estimates noise-subspace-projected channel matrix instead of real channel matrix to perform decoding through noise subspace projection which reduces bad effect of channel estimation error on decoding performance, realizes MLD of STBC block by block instead of frame by frame and greatly reducing searching calculations by decoding iteratively. Results show the performance of the proposed work. Compared with other suppression schemes, the proposed scheme has better SER performance and is less sensitive to the length of pilot symbols [10].

In 2009, Hsiao, C, Chi-Yun Chen and Tzi-Dar Chiueh, demonstrated in their work A dual mode 2times2 MIMO OFDM & OFDMA receiver were implemented with shared hardware resources. This dual mode receiver functions well in both static and mobile channels. The equalization supports both static and dynamic channel estimation. 2times2 MIMO STBC and V-BLAST are supported as well. A low cost ICI [11].

In 2009, Paul, T.K. and Ogunfunmi, T., evaluated the comparative analysis of the physical (PHY) layers in the original main proposals for the 11n amendment (the TGn

Sync, WWiSE and TGn Joint proposals) is presented. The key architectural differences governing the performance of these proposals are outlined. Space-time block coding options (designed in an attempt to attain a good equilibrium between achieve high diversity gain and low receiver aim complexity), and pilot tone selection (for a reasonable tradeoff of robustness and link-level performance) [12].

In 2007, Xing Zhang and Wenbo Wang, have done their research work on MIMO system has captured considerably attention recently. They presented the analysis of multiuser scheduling in MIMO space-time block coding system with imperfect channel estimation. Three commonly used multiuser scheduling methods - max throughput, round robin (RR) and proportional fair (PF) - are implemented to the MIMO STBC system and their performances are analyzed with imperfect channel estimation. Results are obtained to show multiuser diversity and the impact of imperfect channel estimation on the multiuser scheduling performance in MIMO STBC systems. The result shows that more multiuser diversity gain is obtained as the increase of user number and the channel estimation errors has a great impact on the performance of max throughput and PF methods [13].

In 2007, Jung -Lang Yu; Yin-Cheng Lin, researched a novel semi-blind channel estimation for space-time block code multiple-input multiple-output zero-padded orthogonal frequency division multiplexing. By a adapted STBC method, the channel responses of MIMO STBC-OFDM systems had been shown to be identifiable up to two ambiguity matrices by the subspace channel estimation. They proposed a forward-backward averaging technique to enhance the performances of blind channel estimation and MMSE filter. Computer simulations are given to demonstrate the effectiveness of the channel estimation and receiver design for the ST-coded MIMO OFDM system [14].

## IV. PROPOSED METHODOLOGY

The project is based on theoretical research, mathematical modeling, simulations and implementation using MATLAB. The main objectives behind the present work is to design and develop novel semi-blind channel estimation technique(s) /joint semiblind channel estimation and data detection technique(s) which outperform conventional techniques by giving near optimal performance. Further to investigate the performance of newly developed novel semi-blind estimation technique(s for Rican flat fading MIMO channel using different Rice factors (K=5, 10 and 15). Computer simulations have been carried out to validate the proposed work. In order to attain these objectives and enable a comparison, a detailed comparative study of various conventional methods was carried out, involving the following investigations:

MMSE estimator aims to approach optimal result by exploiting the statistical dependence between the measured data and the estimated parameters. (3.1) is chosen to be an example, where h is to be estimated.

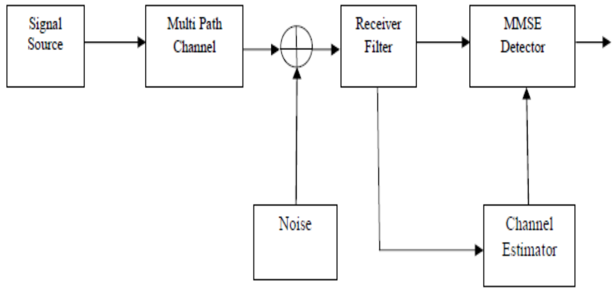


Figure 3.1: Block Diagram of a Noise-Corrupted System with MMSE Estimation

## V. CONCLUSIONS AND FUTURE SCOPE

It is known that reliability of MIMO systems depends upon knowledge of channel state information (CSI) at the receiver for data detection and decoding. Therefore the accurate and robust estimation of wireless channel is very important part of MIMO communication system.

The novel literature review on channel estimation in MIMO-STBC has been analyzed to conventional channel estimation techniques and investigated by taking BER concideration. The MIMO-STBC systems using flat fading Rayleigh and Rician channels for various parameters like combinations of receiver antennas, modulation schemes (m-PSK, where m = 2, 4, 8) and orthogonal pilots (4 pilots, 8 pilots and 16 pilots), following points have been concluded.

The upcoming work can be suggested as the development of a low complexity adaptive channel estimation technique for MIMO-OFDM based multicarrier system for frequency selective fading environment. In upcoming days there is need to calculate channel coefficient for fast frequency selective environment due to vehicular speed. For this, efficient channel estimation techniques are required to deal with such types of time-varying environment where channel coefficients are not fixed but keep changing after every time interval.

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