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Literature Review on Channel Estimation in MIMO-STBC Systems

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Abstract: - Wireless communications is an emerging field, which has seen enormous growth in the last two decades. The next generation of broadband wireless communication systems is expected to provide users with wireless multimedia services such as high speed internet access, wireless television and mobile computing. The rapidly growing demand for these services is driving the communication technology towards high data rates, higher mobility, and higher carrier frequencies that are needed to enable reliable transmissions over mobile radio channels. In this research study the literature review paper has been presented in order to enhance the performance of Channel Estimation in MIMO-STBC.

Keywords- pilot symbol assisted modulation; MIMO system; STBCcodes.

I. INTRODUCTION

Since 1980s, the wireless evolution has so far gone through two generations. First-generation (1G) wireless systems (e.g., AMPS, TACS and NMT) use analog transmission and support voice services only. Second generation systems (e.g., GSM, IS-95) upgrade to digital technologies and cover services such as facsimile and low data rate (up to 9.6 kbps), in addition to voice. The enhanced version of 2G systems (e.g., GPRS, HDR), sometimes referred to as 2.5G systems, support more advanced services like medium rate (up to 100kbps) circuit or packet switched data. Third generation(3G) systems (e.g., UMTS, CDMA 2000) will provide significantly higher data rates (64kbps-2Mbps) than 2.0G systems. OFDM and Space-time (ST) coding are potential candidates for the physical layer of fourth generation (4G) mobile systems.

Orthogonal frequency division multiplexing (OFDM) is a high spectral efficiency type of multi carrier modulation systems, which have many advantages over single carrier 2 systems, especially for high data rate transmission in time dispersive channels. In OFDM, the entire channel is divided into many narrow parallel sub channels, thereby increasing the symbol duration and reducing or eliminating the inter symbol interference (ISI) caused by the multipath environments. OFDM modulation is adapted for many Wireless LAN (e.g., IEEE 802.11, HIPERLAN/2) and digital video/audio broadcasting standards.

Among various transmit-antenna diversity schemes, very popular one is the ST coding that relies on multiple antenna transmissions and appropriate signal processing at the receiver to provide diversity and coding gains over un-coded single antenna transmissions. ST coding has been recently adopted in 3G cellular standards such as WCDMA and CDMA 2000.

In order to incorporate the advantages ST coding and OFDM, ST coded OFDM systems have been analyzed for broadband wireless communications over frequency selective fading channels. Space time coded OFDM systems promises an enhanced performance in terms of power and spectral efficiency. A multiple input multiple output (MIMO) system provides multiple independent transmission channels, thus, under certain conditions, leading to a channel capacity that increases linearly with the number of antenna elements. The capacity of the ST coded OFDM system (in terms of number of users or data rate) can be increased by increasing the number of ST coded OFDM terminals at the transmitter. This ST coded multiple transmit and multiple receive antenna OFDM system as ST coded MIMO-OFDM system. In this research work the signal detection and channel estimation methods for ST block coded (STBC) MIMO-OFDM systems are analyzed. A background on previous work of ST coding, ST coded OFDM systems and the channel estimation methods for ST coded OFDM systems are presented.

OFDM Structure

All communication systems are, in its simplest form, composed of a transmitter, receiver and a channel. However, an OFDM system is more complicated. The OFDM system is shown in Fig. 1.1. A brief description of the model is provided below.

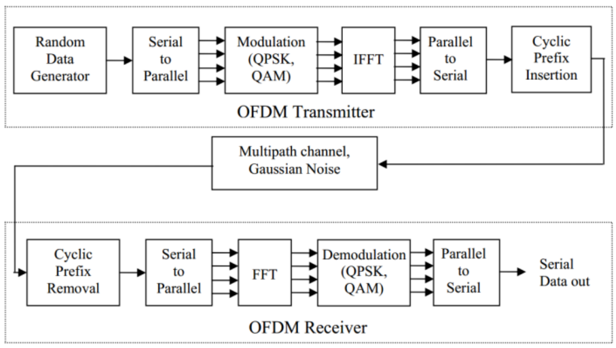

Fig. 1.1: OFDM Model used for simulations

The principle of any Frequency Division Multiplexing (FDM) system is to split the information to be transmitted into N parallel streams, each of which modulates a carrier using an arbitrary modulation technique. The total signal bandwidth is therefore, $N \cdot \Delta f$, where Δf is the frequency spacing between adjacent carriers. In order to analyze an FDM system, N independent transmitter and receiver pairs have to be realized in the form of sinusoidal generators, making the system very complex and equally costly. However, the advent of the Discrete Fourier Transform (DFT) made this transmission scheme more plausible. The Fast Fourier Transform (FFT) and the Inverse Fast Fourier Transform (IFFT) are the more efficient implementations of the DFT, are utilized for the baseband OFDM modulation and demodulation process as indicated in Fig. 1.1. OFDM time domain waveforms are chosen such that mutual orthogonality is ensured even though subcarrier spectra may overlap. To prevent ISI, the individual blocks are separated by guard intervals wherein the blocks are periodically extended.

II. MULTIPATH CHANNEL MODEL

Channel Characteristics

It is known that the performance of any wireless system is affected by the medium of propagation, namely the characteristics of the channel. In telecommunications, a channel is a separate path through which signals can flow. In the ideal situation, a direct line of sight between the transmitter and receiver is desired. Usually, the received signal is a combination of attenuated, reflected, refracted, and diffracted replicas of the transmitted signal. To top it off, the channel adds noise and if the receiver is in motion, then the Doppler Effect has to be taken into consideration. Some of these are illustrated in Fig. 1.2

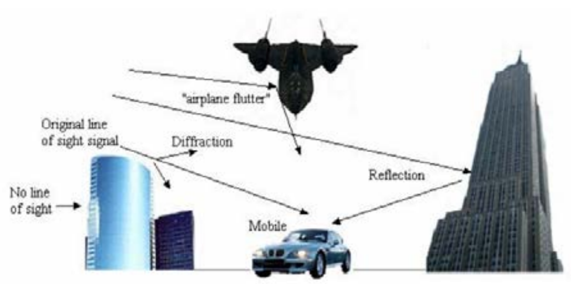

Fig. 1.2: Some channel characteristics

Some of these characteristics are as follows:

Attenuation:

This is the drop in the signal power when transmitting from one point to another and it can be caused by the transmission path length, obstructions in the signal path, and multipath effects.

Multipath Effects:

As the name implies, multipath is the result of the original signal reaching the receiver at different times within a specific transmission time slot. The transmitted signal can take several paths to reach the receiver, that is, directly, after being diffracted or after it had been reflected off of another object. In order to simplify things, assume that the reflected and diffracted signal undergo no phase changes upon contact with the objects blocking their paths. Now the receiver will pick up the line of sight signal, and then shortly after that the diffracted signal and then the reflected signal. These are the original signals, but are delayed bit when it encountered the obstructions. This can be visualized as the original signal shifted a few times. Now each signal adds on to each other, linearly or non-linearly, and this is what the receiver picks up. Frequency selective fading occurs when reflections cause the cancellation of certain frequencies at the receiver so there may be a dip or a faded signal at the receiver. Delay Spread: Delay spread is the time spread between the arrival of the first and last multipath signal seen by the receiver. In a digital system, the delay spread can lead to inter-symbol interference (ISI). This is due to the delayed multipath signal overlapping with the following symbols.

Doppler Shift:

When a wave source and a receiver are moving relative to one another the frequency of the received signal will not be the same as the source. When they are moving toward each other the frequency of the received signal is higher than the source, and when they are moving away from each other the frequency decreases. Doppler shift can cause significant problems if the transmission technique is sensitive to carrier frequency offsets (for example COFDM) or the relative speed is higher (for example in low earth orbiting satellites).

III. LITERATURE SURVEY

E. Ben Slimane, S. Jarboui, Z. Ben Mabrouk and A. Bouallègue, [1] in this research study, 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. Authors develop 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. Simulation 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.

S. M. Alamouti, [2] this paper presents a simple two-branch transmit diversity scheme. Using two transmit antennas and one receive antenna the scheme provides the same diversity order as maximal-ratio receiver combining (MRRC) with one transmit antenna, and two receive antennas. It is also shown that the scheme may easily be generalized to two transmit antennas and M receive antennas to provide a diversity order of 2M. The new scheme does not require any bandwidth expansion or any feedback from the receiver to the transmitter and its computation complexity is similar to MRRC.

V. Tarokh, H. Jafarkhani,and A. R. Calderbank, [3]Authors introduce space–time block coding, a new paradigm for communication over Rayleigh fading channels using multiple transmit antennas. Data is encoded using a space–time block code and the encoded data is split into n streams which are simultaneously transmitted using n transmit antennas. The received signal at each receive antenna is a linear superposition of the n transmitted signals perturbed by noise. Maximum likelihooddecoding is achieved in a simple way through decouplingof the signals transmitted from different antennas rather than joint detection. This uses the orthogonal structure of the space–time block code and gives a maximum-likelihood decoding algorithm which is based only on linear processing at the receiver. Space–time block codes are designed to achieve the maximum diversity order for a given number of transmit and receive antennas subject to the constraint of having a simple decoding algorithm.

Table 1: Summary of Literature Review

Sr. No.	Title	Authors	Year	Methodology
1	Pilot assisted channel estimation in MIMO-STBC systems over time-varying fading channels	E. Ben Slimane, S. Jarboui, Z. Ben Mabrouk and A. Bouallègue	2014	Propose a straightforward MIMO channel estimation method before being used by STBC decoder.
2	A simple transmit diversity technique for wireless communications	S. M. Alamouti	Oct 1998	Presents a simple two-branch transmit diversity scheme.
3	Space-time block codes from orthogonal designs	V. Tarokh, H. Jafarkhani,and A. R. Calderbank	Jul. 1999	Introduce space–time block coding, a new paradigm for communication over Rayleigh fading channels using multiple transmit antennas.
4	Training-based MIMO channel estimation: a study of estimator trade-offs and optimal training signals	M. Biguesh and A. B. Gershman	March 2006	Consider the popular linear least squares (LS) and minimum mean-square-error (MMSE) approaches and propose new scaled LS (SLS) and relaxed MMSE techniques.
5	An analysis of pilot symbol assisted modulation for Rayleigh fading channels [mobile radio]	J. K. Cavers	Nov 1991	Author presents pilot-symbol-assisted modulation (PSAM) on a solid analytical basis.

The classical mathematical framework of orthogonal designs is applied to construct space–time block codes. It is shown that space–time block codes constructed in this way only exist for few sporadic values of n. Subsequently, a generalization of orthogonal designs is shown to provide space–time block codes for both real and complex constellations for any number of transmit antennas. These codes achieve the maximum possible transmission rate for any number of transmit antennas using any arbitrary real constellation such as PAM. For an arbitrary complex constellation such as PSK and QAM, space–time block codes are designed that achieve 1/2 of the maximum possible transmission rate for any number of transmit antennas. For the specific cases of two, three, and four transmit antennas, space–time block codes are designed that achieve, respectively, all, 3/4, and 3/4 of maximum possible transmission rate using arbitrary complex constellations. The best tradeoff between the decoding delay and the number of transmit antennas is also computed and it is shown that many of the codes presented here are optimal in this sense as well.

M. Biguesh and A. B. Gershman, [4] In this paper, Authors study the performance of multiple-input multiple-output channel estimation methods using training sequences. Authors consider the popular linear least squares (LS) and minimum mean-square-error (MMSE) approaches and propose new scaled LS (SLS) and relaxed MMSE techniques which require less knowledge of the channel second-order statistics and/or have better performance than the conventional LS and MMSE channel estimators. The optimal choice of training signals is investigated for the aforementioned techniques. In the case of multiple LS channel estimates, the best linear unbiased estimation (BLUE) scheme for their linear combining is developed and studied.

J. K. Cavers, [5] the author presents pilot-symbol-assisted modulation (PSAM) on a solid analytical basis, a feature missing from previous work. Closed-form expressions are presented for the bit error rate (BER) in binary-phase-shift-keying (BPSK) and in quadrature-phase-shift-keying (QPSK), for a tight upper bound on the symbol error rate in 16 quadrature-amplitude-modulations (16-QAM), and for the optimized receiver coefficients. The error rates obtained are lower than for differential detection for any combination of signal-to-noise ratio (SNR) and Doppler spread, and the performance is within 1 dB of a perfect reference system under slow-fading conditions and within 3 dB when the Doppler spread is 5% of the symbol rate

IV.PROBLEM IDENTIFICATION

In previous research study, PSAM estimation method had been proposed for MIMO based on orthogonal STBC codes. The transmitter just inserts known equally and optimally spaced pilot symbols in data information block. The combined signal is coded using orthogonal STBC code. The transmitted signal is corrupted by slow fading and additive noise. The slow fading channel is modeled by Jakes model; also it is chosen to be constant over the STBC code word period. The receiver estimates andinterpolates the channel measurements provided by the pilot symbols in order to obtain the amplitude and the phase reference for detection. Simulation results show that the channel estimation based on PSAM technique was providing the improvements in terms of BER for the two MIMO schemes. Further these results can be improved with the help of our proposed work.

V. CONCLUSION

Wireless communication is one of the most active areas of research over the past and the current decades. A variety of services have been oared in such a context, starting from Voice, continuing to Data and now to Multimedia. Significant reductions in cost and time can also be achieved using wireless solutions, providing even several benefits to the users in terms of mobility and edibility in the placement of terminals. In fact, wireless mobilesystems have begun to permeate all areas of our daily life and are therefore required to provide high-speed, high-capacity and high-quality services with performances closer to those afforded by wire line systems. This evolution has been made possible by academic and industrial Research and Development (R&D) labs with the implementation of three generations of cellular systems.

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