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Performance Evaluation of Advanced STBC MIMO Wireless Communication System with Channel Estimation Based Block Coding

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Abstract: This paper is about the improvement in the system performance of STBC MIMO System with the help of channel estimation technique based Block coding using pilot carriers and also to investigate the performance of STBC MIMO system in a multipath fading channel. These techniques are carried out with conventional Least Square (LS) & Minimum Mean Square (MMSE) estimation algorithms. The performance of the system is evaluated on the basis of BER & MSE level.

Keywords: STBC, MIMO, OFDM etc.

I. INTRODUCTION

In the last two decade or so, there has been huge growth and development in the wireless communication environment [5]. In wireless communication, there is a requirement, not only for voice and data services but also for multimedia services. Transmit diversity scheme employing Space-Time Block Code (STBC) helps to increase the number of antennas [1].

Space-time coding is the combination of coding, modulation and signal processing for achieving transmit diversity [6]. Space-time block coding (STBC) is based on Alamouti transmitter diversity scheme and one of the most efficient coding techniques that can be applied [6] with transmitter diversity systems. Its coding is a technique used in wireless communications to transmit multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data-transfer.

Space-time block codes were designed to achieve the maximum diversity order for the given number of transmitting and receive antennas subject to the constraint of having a simple Linear decoding algorithm. This has made space-time block codes a very popular and most widely used scheme [2].

Space-Time Block code (STBC) is used in Multiple Input Multiple Output (MIMO) system to improve the performance by maximizing diversity gain [1].

The scheme uses two transmit antennas and one receive antenna and may be defined by the following three functions:

- Encoding and decoding transmission sequence information Symbols at the transmitter
- Combining signals with noise at the receiver
- Maximum likelihood detection

CHANNEL ESTIMATION

To be able to estimate the original transmitted STBC symbol, we need accurate channel state information.Channel state information can be obtained by using transmitted data and pilot tones. Channel state information is given by channel estimation algorithms.

II. PRESENT WORK

The methodology involved in this work is shown in the figure1:

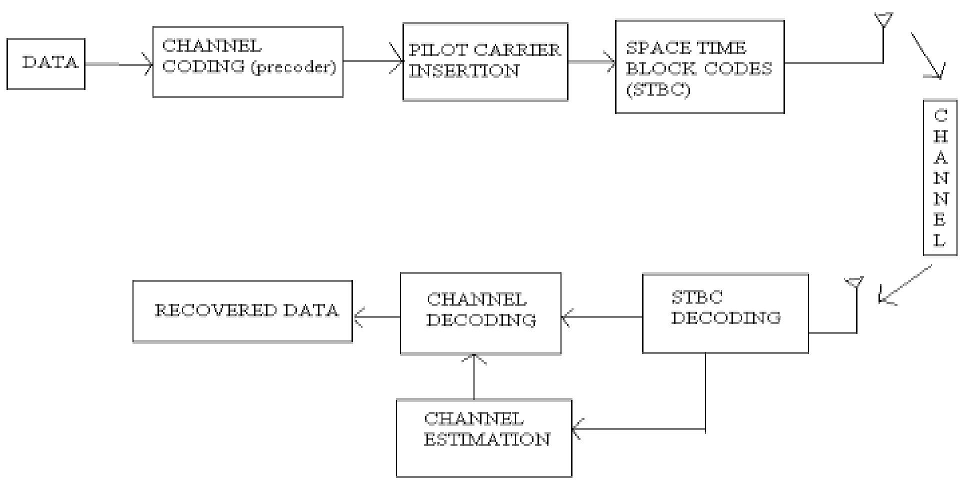

Fig 1 Block diagram of STBC MIMO using channel estimation

The algorithm is as follows

(1) The first step is Channel coding in which input data is given to the precoder. Channel coding aims to find codes which transmit quickly, contains many code words and can correct or at least detect many errors. In order to increase the performance of the STBC MIMO system, channel coding is applied to the sequential binary input data. In this thesis, we used the IEEE 802.11 a standard’s convolution encoder for forwarding error correction (FEC). In most applications, interleaving is also used along with FEC to correct burst errors. Since our main focus in this thesis was to study channel estimation techniques, we did not use any interleaved. FEC or Channel Coding is a technique used for controlling errors in data transmission over unreliable or noisy communication channels. The central idea is the sender encodes the message in a redundant way by using an error correcting code. The redundancy allows the receiver to detect a limited number of errors that may occur anywhere in the message and often correct these errors without retransmission.FEC gives the receiver the ability to correct errors without needing a reverse channel to request retransmission of data, but at the cost of fixed, higher forward channel Bandwidth.

(2) The output of a precoder then goes to Pilot carrier insertion block. We can estimate our data using pilot carriers. The training-based channel estimation can be performed by either of two types of pilot arrangement:

(i) Block type pilot
(ii) Comb type pilot

Block type pilot:

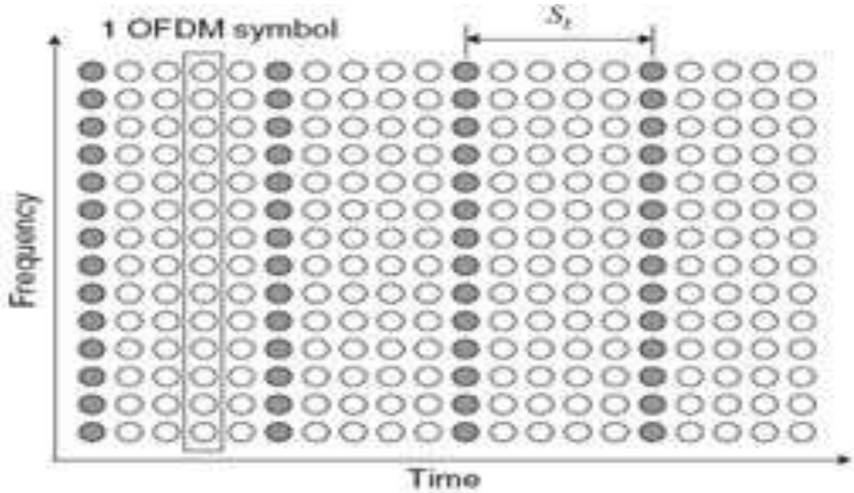

Fig 2: Block type pilot arrangement

In block type pilot estimation, pilot tones are inserted into all frequency bins within the periodic intervals of OFDM blocks. This estimation is suitable for slow fading channels. A block fading channel is a channel which is constant over a few OFDM symbols. In this channel, pilots are transmitted on all sub-carriers in periodic intervals of OFDM blocks. This type of pilot arrangement is shown in figure 2(a), is called as block type arrangement.

COMB TYPE PILOT

In comb type pilot estimation, pilot tones are inserted into each OFDM symbol with a specific period of frequency bins.A fast fading channel has channel impulse response changes rapidly within symbol duration and the channel changes between adjacent OFDM symbols. The channel estimates from the pilot subcarriers are interpolated to estimate the channel at the data carriers

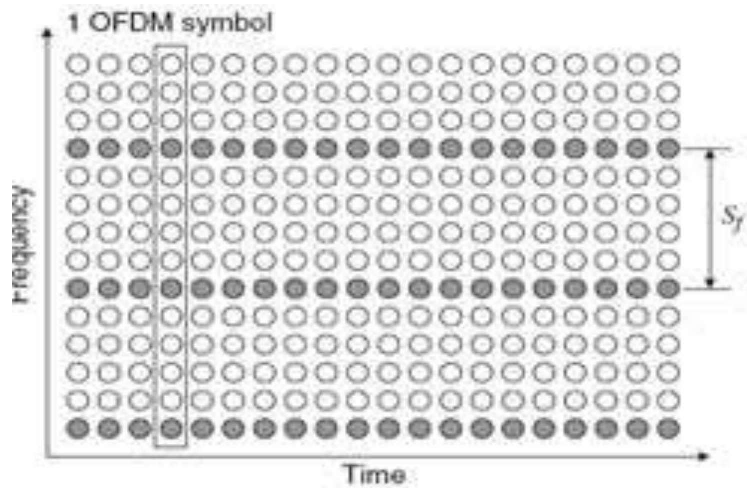

Fig 3: Comb type pilot arrangement

3) STBC are used for communication over Ricean fading MIMO channels. Space–time block coding is a technique used in wireless communications to transmit multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data-transfer. The fact that the transmitted signal must traverse a potentially difficult environment with scattering, reflection, refraction and so on and may then be further corrupted by thermal noise in the receiver means that some of the received copies of the data will be 'better' than others. This redundancy

results in a higher chance of being able to use one or more of the received copies to correctly decode the received signal. In fact, space–time coding combines all the copies of the received signal in an optimal way to extract as much information from each of them as possible.

(4) Encoded data is transmitted through the channel and then STBC decoding is done. Maximum Likelihood Decoding (MLD) based is achieved in a simple way through decoupling of the signals transmitted from different antennas rather than joint detection. This uses the orthogonal structure of the space-time block codes and gives an MLD algorithm which is based only on linear processing at the receiver.

(5) Channel decoding is done using Viterbi decoding by implementing a soft decision algorithm to demodulate digital data from an analog signal corrupted by noise. Many FEC coders can also generate a BER signal which can be used as feedback to fine-tune the analog receiving electronic.

(6) Channel estimation is employed in between STBC decoding& Channel decoding. To remove the ISI (due to multipath fading channels) from the received signal, many kinds of detection algorithms are used at the receiver side. These detectors should have knowledge on Channel Impulse Response (CIR) which can be provided by channel estimator. The channel estimation is based on the known sequence of bits which is unique for certain transmitter and which is repeated in every transmission burst. Thus the channel estimator is able to estimate channel impulse response for each burst separately from the known transmitted bits and corresponding received samples.Channel estimation techniques using pilot carriers (Comb type pilot placement & Block type pilot placement) are carried out with conventional Least Square (LS) & Minimum Mean Square (MMSE) estimation algorithms.

(7)After channel decoding, the original data is recovered back. Trellis decoding is performed to choose the best shortest path to optimize the system.

III RESULTS

Case (i): The proposed method is simulated and its performance is checked on the STBC MIMO system with and without estimation algorithms. Estimation algorithms like Least Square (LS) estimation and Minimum Mean Square estimation (MMSE) are used. In this STBC MIMO system, the G2 code is used in which two transmitters and two receivers are present. The figure below gives the response of any of the two receivers showing the variation of Symbol Error Rate (SER) with increasing Signal to Noise Ratio (SNR)

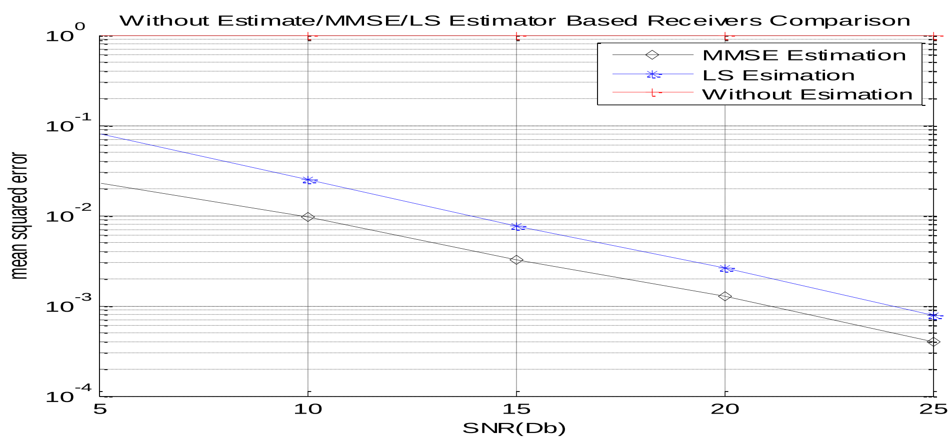

Fig 4 Comparison between without estimation, with LS estimation & with MMSE estimation

Case (ii): The curve shows that as SNR increases, SER decreases at the different rates for LS estimated system, MMSE estimated system & without the estimated system. The graph is plotted between the SER and SNR to show the response of the STBC MIMO system using an arbitrary number of transmitters keeping the number of receivers constant.Here different cases are taken like G2(having 2 transmitters), G3, G4,H3,H4(having 4 transmitters) but with different rates means no. of symbols per time slots and in all the above cases number of receivers used are same(i.e. 2).Figure 4.2 presents the response of all the transmitters at any one of the two receivers.The graph shows that the as SNR increases, SER decreases.The best response comes from the G3 case which has the lowest SER

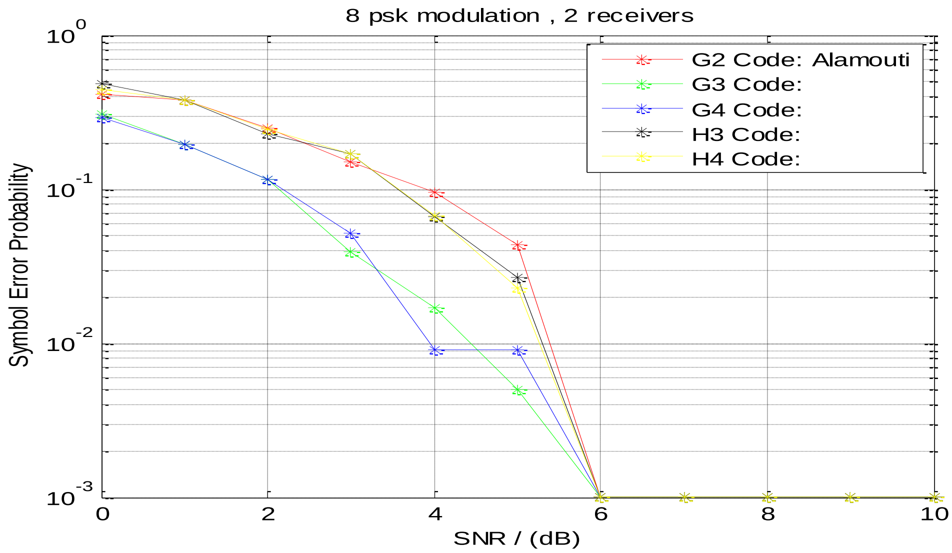

Fig 5 8 PSK modulation, 2 receivers

We have seen the response of the receiver side and figure below presents the behavior of the transmitter side taking the case G2(having 2 transmitters and 2 receivers).

Case(iii): Here again the graph is plotted between SER and SNR and shows the variation of the receivers at any one of the two transmitters.At low SNRs, both the receivers show same response but the variation comes at larger values of SNRs.

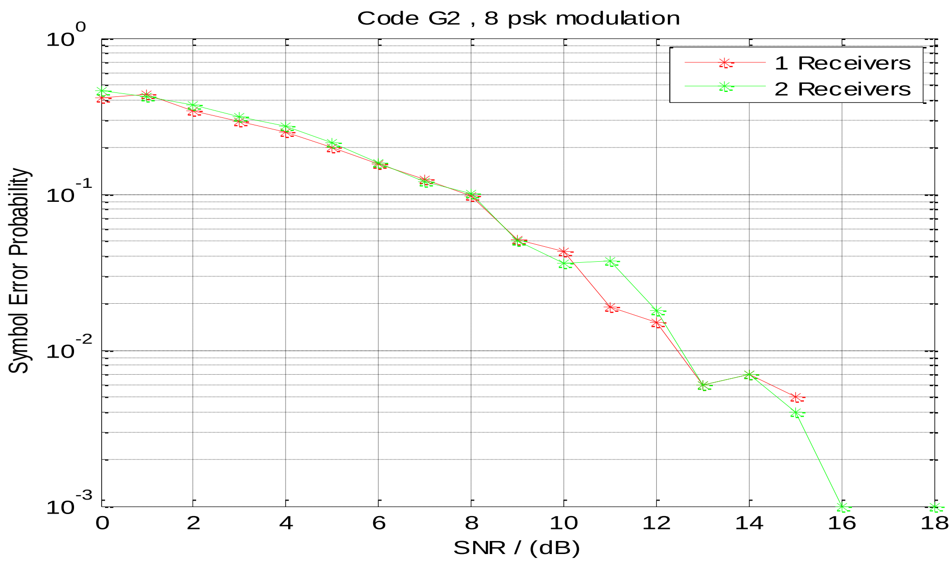

Fig 6 Code G2, 8 PSK modulations

We have analyzed the various cases taking different no. of transmitters and receivers and STBC MIMO system is analyzed to get minimum SER with increasing SNR.

Case (IV): Now the channel estimation is combined with STBC MIMO and also an error correcting code is inserted in the system to optimize the communication system. A Gaussian pulse is applied with suitable roll-off point and cut in point to the system as shown in figure 7.

This pulse has zero mean and unit variance means that all the energy is accumulated near the origin. The amplitude of the pulse is maximum in the middle (near zero) and the amplitude decreases as the distance from origin increases. Moreover, as the figure shows the pulse is symmetrical about the origin. The graph is plotted on the amplitude and time axis. As the

Gaussian pulse has the property of decreasing amplitudes with time so the figure below presents less amplitude at more time. If the signal gets corrupted by noise in the channel then the whole energy of the wave will shift to either right or left side of the origin and wave loses its property and no more remain a Gaussian pulse, hence the data is lost. So, it is concluded that to transmit data accurately to the receiver, whole energy should be centered at the origin.

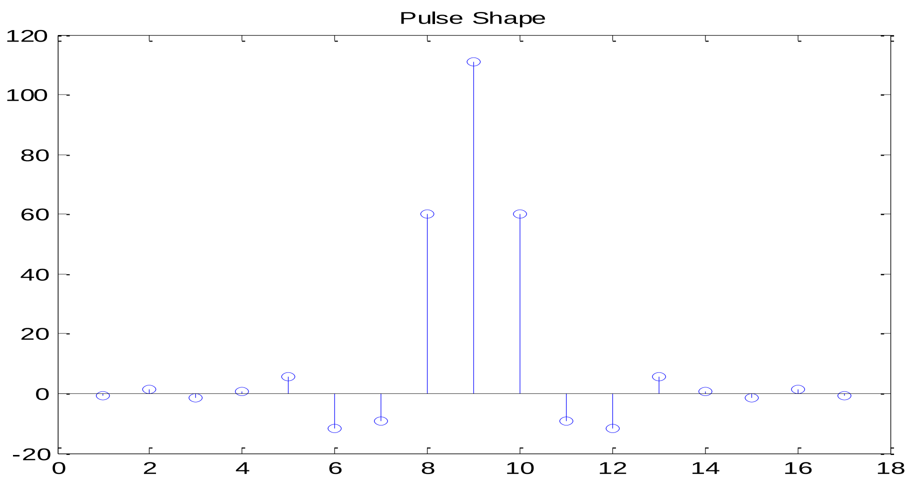

Fig 7 A pulse shape

Case (v): Figure 8 shows the Gaussian pulse used in the system. The data is sent through the system in the form of signals and at the receiver side, the maximum likelihood decoding is done to decode the signal back. We are using multiple transmitters to send the data signals and multiple receivers are used to receive the signals and in conjunction, STBC coding is applied. Using STBC, multiple copies of the data stream are transmitted by different paths to the receiver and using Viterbi decoding the best shortest path is chosen from sender to the receiver. The graph is plotted between the no. of states versus steps. There are various transitions of states in the path from sender to receiver. Viterbi decoding implements a soft decision algorithm to demodulate digital data from an analog signal corrupted by noise.

The Viterbi algorithm is a dynamic programming algorithm for finding the most likely sequence of hidden states called the Viterbi path that results in a sequence of observed events. A Viterbi decoder uses the Viterbi algorithm for decoding a bitstream that has been encoded using a convolution. There are other algorithms for decoding a convolutionally encoded stream (for example, the Fano algorithm). The Viterbi algorithm is the most resource-consuming, but it does the maximum likelihood decoding. It is most often used for decoding convolution codes with constraint lengths k<=10, but values up to k=15 are used in practice.

The convolution coder is often used in digital transmission systems where the signal to noise ratio is very low rendering the received signal error prone. The convolution coder achieves error-free transmission by adding enough redundancy to the source symbols. The choice of the convolution code is application dependent and varies with the frequency characteristics of the transmission medium as well as the desired transmission rate.

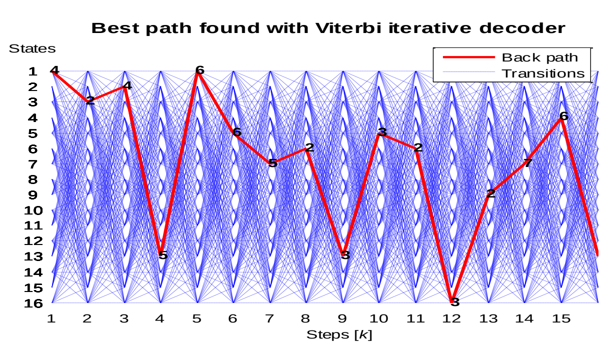

Fig 8 Best path found using viterbi decoder

The here trellis diagram is used to search the optimized path from source to destination and in turn, maximum likelihood decoding is applied using Viterbi algorithm. Viterbi decoding allows asymptotically optimal decoding efficiency with increasing constraint length of the convolution code but at the expense of exponentially increasing complexity. A convolution code can be turned into a block code if desired by "tail-biting".

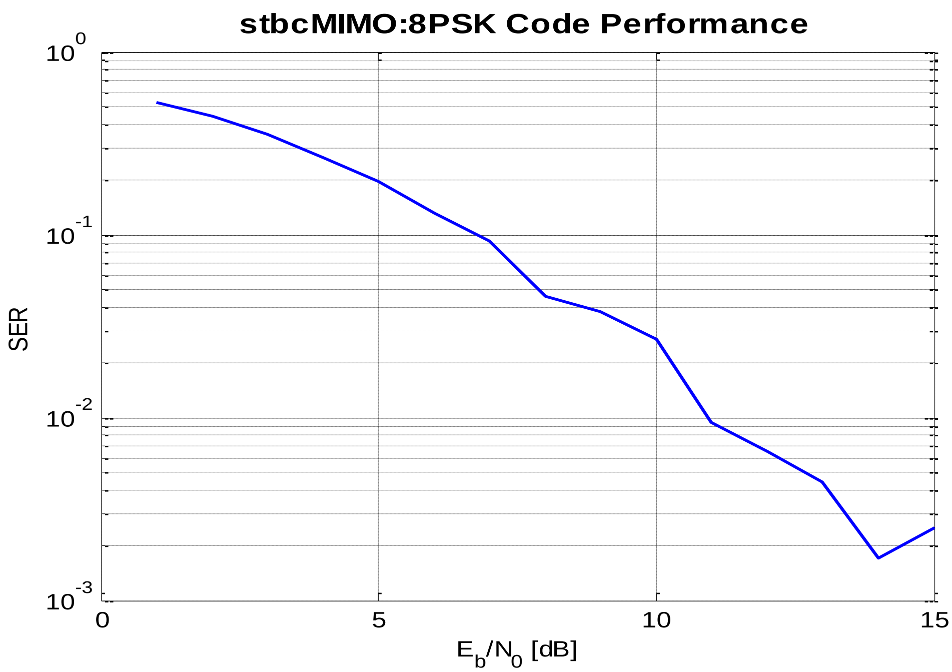

Fig 9 STBC system using LEAST SQUARE estimator

Case (VI): Finally, the graph is plotted to show the comparison of the STBC MIMO system with estimator algorithm and without estimation algorithm. Here the Least Square (LS) estimator is used and performance analyses have shown that the SER is minimum in the system using estimator.

In this work, we presented the simulation results of STBC MIMO communication systems utilizing the channel estimation methods discussed in the previous chapter. The communication systems were developed using Matlab, and SER versus SNR curves was generated to evaluate the performances of the systems.

CONCLUSION

The aim of this work was to investigate the performances of STBC system with channel estimation techniques utilized by multiple inputs multiple outputs. This objective was accomplished by studying block-type and comb-type channel estimation algorithms and simulating their performances over several communication channels operating in multipath fading environments.

In the simulations of the STBC MIMO systems, we observed that the LS channel estimator (using only a few dominant taps of the channel) performed better than the system without channel estimator for all SNRs since the energy in the excluded taps became dominant compared to the channel noise.

The BER performance of the LS channel estimator degraded more than the performance of the comb-type channel estimator as the Doppler shift of the channel increased. This was due to the fact that the block-type channel estimator used previous blocks of data in the channel estimation process. In particular, at low Doppler frequencies (i.e., almost time-invariant channels) the block-type performed better than the comb-type channel estimator while the opposite was true at high Doppler frequencies. The STBC method performed satisfactorily at low SNRs. However, at high SNRs, the estimation methods based STBC system on full channel model performed significantly better.

FUTURE SCOPE

When the performances of the systems utilizing the developed channel estimation algorithms were compared with the performances of the systems using perfect knowledge of the channel coefficients, all simulations indicated that there was still room for improvement.

In order to degrade the effects of lack of synchronization, frequency offset estimation and tracking must be performed. In a further study, this feature may be combined with the channel estimation algorithms developed in this topic.

The OFDM system parameters used in this work were not chosen from any specific industry standard. In a future study, the developed channel estimation algorithms may be implemented with the standards, such as IEEE 802.11a or IEEE 802.16a.

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