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MIMO – OFDM Channel Estimation and Maximization Using Optimal LMMSE

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ABSTRACT

The Orthogonal Frequency Division Multiplexing (OFDM) helps in transmission of signals over wireless channels, when go with MIMO (Multiple Input Multiple Output) technology it combats the fading and improves the link reliability without sacrificing bandwidth efficiency. The combination of OFDM and MIMO is a boon for wireless communication aims at high data rate. Optimal Linear Minimum Mean Square Error (OLMMSE) detection algorithm is proposed for MIMO-OFDM Code Division Multiple Access system and is compared with Linear Minimum Mean Square Error (LMMSE) detection algorithm. The proposed algorithm has good performance and does not significantly increase the computational complexity. The total capacity of MIMO system is given by sum of individual capacity of all parallel channels. In order to maximize the total capacity one has to allocate power optimally to each channel or stream using Singular Value Decomposition (SVD) of MIMO channel matrix. The optimal solution for these MIMO SVD system, in terms of achievable rate, requires waterfilling to optimally allocate power to different channel Eigen modes. For wireless communication the OFDM adapts the Low Density Parity Checker (LDPC) codes and the analysis shows that at high rate OLMMSE signalling provides twice the diversity of MIMO –OFDM.

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INTRODUCTION

The next generation communication depends on MIMO-OFDM technique. Most of recent researches aims at effective performance of the communication systems even in adverse system impairments. OFDM provides high data rate transmission as well as high band width efficiency. OFDM is robust to multipath delay.

It has been used in wireless LAN standards such as American IEEE802.11a and the European equivalent in multimedia wireless services such as Japanese Multimedia Mobile Access Communications. The channel estimation for a communication system is necessary before the demodulation of OFDM signals since the radio channel is frequency selective and time-variant for wideband mobile communication systems.

The channel estimation is a critical issue for MIMO-OFDM systems, especially if multilevel modulation is employed in order to achieve high spectral efficiencies. The scope of this paper is limited to pilot-based channel estimation. The channel estimation is performed by exploiting the transmission of training sequences.

So far, research on pilot-based channel estimation for MIMO-OFDM system has mainly focused on least squares (LS) channel estimation. The problem of designing an optimal training sequence for the LS estimator has been investigated. Conventional LS channel estimation does not assume any a priori information about the channel vector to be estimated, except for the finite length of the channel impulse response (CIR) in the time domain that is inherent in the choice of an OFDM modulation. This assumption simplifies the channel-estimation process, but leaves room for improvement. For instance, modifications of the LS channel estimator that take into account additional information about the channel (i.e., equal power-delay profile for different transmitting antennas) have been proposed, and proved to outperform the LS method.

MIMO stream separation and modulation classification of separated signals are applied in military purposes (Yu Liu, A.M., 2013). The likelihood based classification is optimal in obtaining minimum probability of error (Dobre, O.A., 2007). This is computationally complex and require exhaustive search through unknown parameters. In

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feature based method specific features are extracted from the signal and compared with pre-calculated values. It is computationally efficient. Cumulant based feature is adopted in. MIMO MC is challenging due to interference between received signal and the multiplicity of unknown channels. It has the ability to recognize a number of modulations, high correct classification rate and robustness with respect to inaccurate carrier phase estimation is achieved (Swami, A. and B.M. Sadler, 2000). MIMO OFDM blind channel estimation has been studied in (Shin, C., 2007). ICA is a class of blind source separation [BSS] methods for separating linear mixtures of signals into independent components (Hyvarinen, J., Karhunen, E. Oja, 2001).

Decode and forward relays are proposed in (Ke Xiong, 2014) where the source and the relay nodes are employed with multiple antennas and the destination employs single antenna. It provides optimum and low computational complexity. Deterministic CSI maximize the cut-bound on system capacity. Epigraph method and dual methods are used in earlier papers. The gradient descent search algorithm is used in (Simoens, S., 2007). The statistical CSI along with numerical algorithm achieves approximate optimal solutions (Chen, Z., 2010). To minimize the pair wise error probability distributed beamforming techniques were used. By using Balanced Linear Precoding (BLP) in MIMO DF relay channels complexity can be reduced. This algorithm is iterative and has non-explicit expressions on optimal solutions. But the drawback in this is optimality of the obtained solution cannot be guaranteed for all cases (Suraweera, N.D. and K.C.B. Wavegedara, 2011). Another strategy called partial relaying where the precoding designs with resource allocation problem. It controls the number of streams to be forwarded to the destination. The jamming resilient OFDM communication is capable to communicate against the powerful jammer (Ryu, J.Y. and W. Choi, 2011). Advancement in MIMO interference cancellation technique upgrades the communication capability.

It is widely acknowledged that the propagation in a wireless scenario can be modelled by a multipath channel, where each path has some features related to the large scale geometry of the environment (such as propagation delay, angles of departure and arrival, power-delay profile), and some others related to small-scale (i.e., on the order of a fraction of the wavelength) variations, namely the fading amplitude. Accordingly, the first class of features varies over a much larger time scale than the coherence time of the fading process.

Our purpose is in two aspects. First, we try to assess analytically to what extent LS channel estimation can be improved if knowledge about the multipath channel structure is taken into account in deriving the channel estimator. Toward this goal, the lower bound on the channel-estimation error proposed for MIMO time-domain transmission is extended to multicarrier systems and to a more realistic multipath scenario where each path may have a different Doppler spectrum. Second, based on the above mentioned analysis. The practical channel estimators are designed so that perform close to the performance limit set by the lower bound with affordable computational complexity, even in presence of channel modelling mismatches.

The channel estimation of block-type pilot arrangement can be accomplished using LS or MMSE. The gain of MMSE estimate is more for the same mean square error of channel estimation over LS estimate. To mitigate the drawback of MMSE, we can apply a low-rank approximation to linear MMSE by using the frequency correlation.

Another type of channel estimation is comb-type pilot channel estimation which has its own algorithm by which the channel can be estimated at pilot frequency and the channel can be interpolated. LS, LMS, MMSE can be employed for estimation. The performance of MMSE much better than LS. By deriving the optimal low rank estimator along with singular value decomposition we can reduce the complexity of MMSE.

There are many types of channel interpolation techniques that can be employed in comb type based channel estimation, some of them are linear, second order, low-pass, cubic spline interpolation, and time domain interpolation. The advantages of those interpolation techniques are: Second-order interpolation performs better when compared to linear interpolation. Time-domain interpolation provides lower BER when compared to linear interpolation.

2.System Model:

A. Block Diagram:

In the general block diagram of OFDM transmitter and receiver we introduce the elliptic curve cryptography to encode the data as shown in Fig 1. The randomly generated data is then subjected to parallel to serial conversion. The modulation technique used here is Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM). The QAM is 16 or 64 QAM. The subcarriers are generated cyclic prefix and guard bits are added and transmitted. The subcarrier generated is 512.

The channel consider here provides high noise environments such as Raleigh, Rician, Pedestrian B, and Vehicular A channels. Whereas pedestrian B channel provide high noise variance and Vehicular A channel provides unpredictably high noise variance.

At the receiver side Low Density Parity Check (LDPC) is employed. This will be useful in removing errors in first few bits.

B. Decode and Forward Relay:

The use of relays in MIMO will improve the beamforming and achieves optimal solutions in terms of capacity (achievable data rate) and power allocation.

The Decode and Forward relay simply DF relay is employed in cooperative communications. That is the information from the source is forwarded by the relay to the destination via different path. The relay nodes are advantageous in providing coverage extension, spectral efficiency improvement and in energy saving.

The overheard transmission from the source is decoded at the relay. There are 2 cases, in case I: if it is correct decoding, then it will be forwarded to the destination. In the case II: if unrecoverable error occurs, the relay cannot contribute to the cooperative transmission.

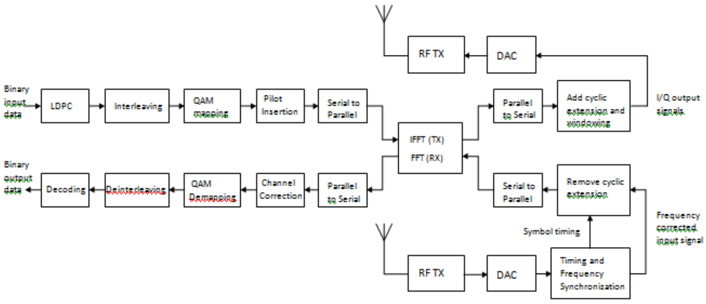

Fig. 1: The proposed block diagram.

3.MIMO Channel Estimation and Maximization:

Optimal Linear minimum mean square error (OLMMSE) detection algorithm is proposed for the multiple-input multiple-output orthogonal frequency division multiplexing code division multiple access (MIMO-OFDM) systems. We can obtain a threshold rate which is a function of data-block length and channel maximization. Below the threshold full spatial-temporal diversity can be achieved. Analysis shows that at high rates the CDD (Cyclic Delay Diversity) degenerates to the diversity of the MIMO SC-FDE (Single Carrier – Frequency Domain Equalization), whereas OLMMSE signalling provides twice the diversity of MIMO OFDM.

The cyclic extension of an OFDM symbol can eliminate ISI effect on original OFDM symbol .The length of cyclic prefix is chosen ¼ of the length of symbol .The overall spectral efficiency of the system is sacrificed due to appending overhead which causes the cyclic delay diversity. The proposed Optimal Linear MMSE algorithm is used to reduce or eliminate the CCD and Inter symbol Interference (ISI).

RESULTS AND DISCUSSIONS

The MIMO OFDM channel is examined which is a high noise channel as in Raleigh, AWGN and vehicular environment. The severity of the channel and its impact on the transmitter and receiver antenna is analysed in terms of SNR Vs BER.

An Optimal LMMSE per channel equalizer is developed for an OFDM/OQAM (Orthogonal QAM) system considering a time varying channel (Rayleigh, Rician, Ped B, Vehicular A) under the assumption that the channel is perfectly known at the receiver. Analyzed the equalizer with a doubly dispersive channel (MIMO) with high spectrum (High SNR) and a low cyclic delay profile (CCD), and where the transmitter and receiver filters are employed.

The Fig 2 shows that the bit error rate is decreasing linearly as SNR increases. Also there is performance improvement in the case of OLMMSE when compared to LMMSE. The equalizer minimizes the error between actual output and desired output. Continuous Blind is a digital signal processing technique in which the transmitted signal can be known from the channel state information at the receiver. Sparse data is a dense data, typically used in outdoor communication scenarios, the Committed Information Rate (CIR) is intrinsically sparse due to several significant scatterers.

The graph Fig 3 shows the plot for the performance measure in terms of bit error rate for various types of channels. The vehicular channel provides high noise variance. The SNR improves linearly as the mean square error decreases in our proposed system. As the number of antennas increases the mean square error is reduces linearly and the signal to noise ratio improves.

Fig 4 shows that as the number of antennas increases the performance of the system is also increases. It is obvious that in 12 x 12 MIMO system the MSE decreases linearly as the SNR increases.

In Fig 5, 4:2:1 scenario refers to the system employs 4 transmitting antennas, 2 relay nodes and 1 receiving antenna, i.e. the destination node deployed only with single antenna. 4:2:4 scenario refers to the system where all the three nodes transmitter, relay and the receiver nodes are equipped with multiple antennas.

The Singular Value Decomposition (SVD) algorithm is used for the optimal beamforming design in 4:2:4 scenario where the maximum achievable information rates attained is 5.8(bits/sec).

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The waterfilling algorithm is employed so that the capacity and the achievable information rate is further improved.

Capacity is the measure of maximum information that can be transmitted reliably over a channel. Claude Elwood Shannon developed the following equation for theoretical channel capacity is B log (1+SNR). It includes the transmission bandwidth B and signal to noise ratio. The Shannon capacity of MIMO system depends on the number of antenna.

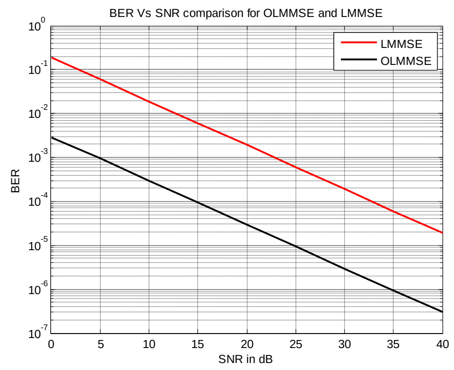

Fig. 2: BER Vs SNR for MIMO OFDM for OLMMSE and LMMSE.

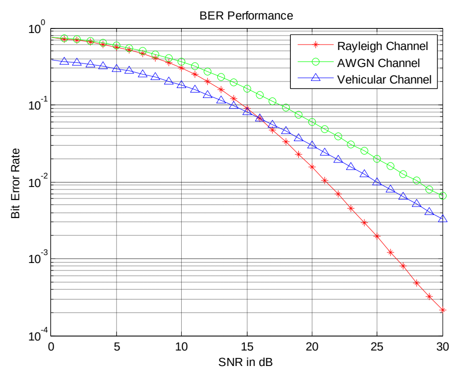

Fig. 3: The performance of various channels.

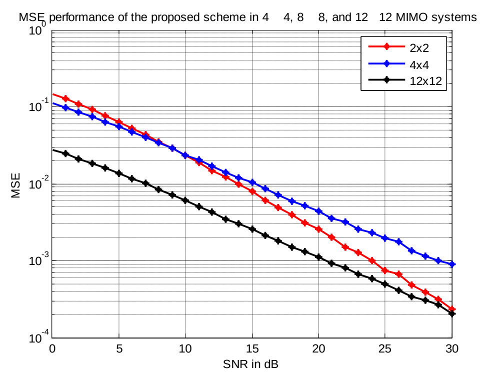

Fig. 4: The performance of the proposed scheme under various number of transmitter and receiver antennas.

In Fig 6 the process of water filling algorithm is similar to pouring the water in the vessel. The waterfilling technique provides the details about the inverse of the power gain of a specific channel and the power allocated or the water. The total amount of water filled is proportional to the Signal to Noise Ratio of channel.

The capacity of a MIMO is the algebraic sum of the capacities of all channels and given by the formula below.

$$\text{Capacity} = \Sigma \log(1 + PowerAllocated * H)\ ni \qquad (1)$$

We have to maximize the total number of bits to be transported .As per the scheme following steps are followed to carry out the water filling algorithm

We proposed water filling algorithm for MIMO fading channel. Multiple access points or small base stations send independent coded information to multiple mobile terminals through orthogonal Code division multiplexing channels. It improves the capacity significantly by deploying proper power allocation in the network.

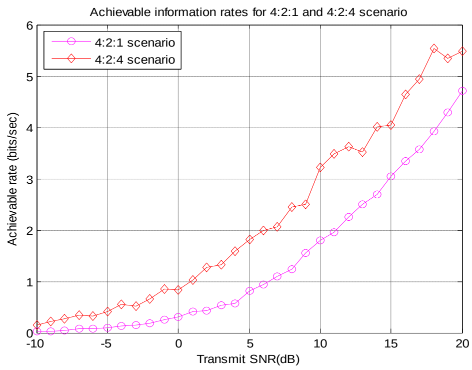

Fig. 5: The achievable information rate when deploying multiple antennas at the receiver side in cooperative communication.

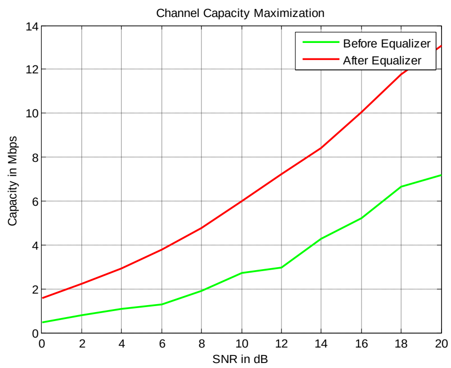

Fig. 6: The comparison of channel capacity by using water filling technique.

The singular value decomposition and water filling algorithm have been employed to measure the performance of MIMO OFDM integrated system. When Nt transmit and Nr represented antennas are employed, outage capacity is increased. In MIMO OFDM we transmit different stream of data through different antennas. We show that as we increase the power budget in the water filling algorithm the mean capacity of the system increased.

5. Conclusion:

The channel estimation and maximization schemes are exploited through which the performance as well as the correlations of wireless MIMO channels is analysed for different time varying channel model. The highly time varying channels are estimated effectively and the performance improvements are also shown through the better channel estimation with high accuracy. The capacity of the channel is also maximized by using the waterfilling algorithm.

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