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Optimal Training Channel Estimation in MIMO Wireless Communication

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***Abstract—* Multiple-input Multiple-output (MIMO) Wireless Communication systems provide large capacity allowing high data rates transmission with low probability of error. Multiple-input Multiple-output systems have been recognized as a key technology for future wireless communication. Proper channel estimation improves better results for performance parameters for MIMO wireless communication. MIMO technologies have a wide application in communication systems.**

***Index Terms*— Data rates, MIMO System, Wireless Communication.**

I. INTRODUCTION

MIMO offers significant increase in data throughput and link range without additional bandwidth or transmit power. It achieves this by higher spectral efficiency and link reliability or diversity [7]. Wireless broadband communication systems are characterized by very dispersive channels. Channel estimation is a crucial task for reliable wireless transmission system. Accurate Channel estimation plays a key role in MIMO Wireless system [3]. In most practical system this task is carried out by using different techniques. Channel estimation techniques are commonly divided into three categories: Training-based, blind and Semi-blind estimation. In the former, the estimation is entirely based on transmission of training sequences [1], [6]. The other extreme is blind estimation, which only exploits some known structure of the received data. The combination of these two techniques is called semi-blind techniques [1]. One of the most popular and widely used approaches to the MIMO channel estimation is to employ training sequences (pilot signals) and then to estimate the channel based on received data and knowledge of training symbols [3], [8]. In comparison to single antenna system with only one channel to be estimated, in a MIMO System with four transmit and four receive antennas sixteen channels have to be estimated. The increased number of required training symbols may reduce the higher the data rate of a MIMO System [11], so optimal training-based channel estimation in MIMO System is required. In MIMO, there are different training-based channel estimators, which offer different tradeoff in terms of performance and priori required knowledge of channel parameters [8]. Examples are Least square (LS), Scaled least square (SLS), Minimum mean square error (MMSE), Relaxed Minimum mean square error (RMMSE) and Multiple LS approaches (BLUE approach). Perfect Channel State Information at the Receiver (CSIR) in MIMO Wireless can be possible by using these techniques for Correlated and Uncorrelated Channels at different value of SNR.

II. MIMO SYSTEM

Wireless communication is the transfer of information over a distance without the use of electrical wires. MIMO is an antenna technology for wireless communication in which multiple antennas are used at both the transmitter (source) and the receiver (destination).The antenna at each end of communication circuits are combined to minimize errors and optimize data speeds. MIMO is one of several form of smart antenna technology [13].

Fig. 1 Block Diagram of MIMO System

Where, N= no. of transmitting antenna, M=no of receiving antenna and H=channel [13]

$$S= H P+ V \quad \textbf{(1)}$$

Where, S is the matrix of the received signals,

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P is the input signal matrix, V is the noise matrix
and H is the channel matrix and H can be recovered from the Knowledge of the value of S&P by using matrix operations [1], [3], [4], [6], [8].

In recent years MIMO systems have been topics of growing interest. MIMO techniques can greatly increase the spectral efficiency of wireless system.Previosly for channel estimation in MIMO system different techniques were employed. One of the most widely used Training-based approaches are LS, SLS, MMSE, RMMSE and Multiple LS Methods. LS method does not require any knowledge about the channel. In this method Mean square error (MSE) is proportional to the square of number of transmitting antennas. Due to the more MSE, LS Method is rarely used. Only this error can compensate by increasing the transmitted power in training mode in LS Method, [3], [8].

$$\text{Min } J_{LS} = \frac{\sigma n^2\, t^2 r}{P} \quad \textbf{(2)}$$

σn^2 = Receiver noise power, P = Signal power, t = No. of transmitting antenna, r = No. of receiving antenna.

The refined version of LS estimation is called SLS method. This offers a substantially improved performance relative to the LS method. A SLS estimator performs noticeably better than LS method and has only slight performance degradation at low SNR.SLS estimation error is less than LS method and this error is determined by channel itself. MMSE method is able to outperform both LS & SLS estimators. This method requires the full priori knowledge of transmit channel, co-relation matrix and receiver noise powers. Therefore LS/SLS training can be used in conjunction with the MMSE estimator in high SNR scenarios.MSE of this method is low and it is better than LS and SLS method, but it requires the full priori knowledge of co-relation matrix (RH) and receiver noise powers (σn^2) [3],[8]. To reduce the amount of required knowledge of the channel second-order statistics, the relaxed MMSE is introduced which represents a simplified approximation verson of MMSE method [3].

Mehrzad Biguesh and Alex B. Gershman proposed RMMSE method in which correlation matrix (RH) is modeled by a scaled identity matrix. They showed that when noise variance is known, even if the correlation among different sub-channels is ignored, the performance of this method is superior to LS estimation in MSE sense [2]. RMMSE Method gives less mean square error and this estimator is a function of RH and σn^2, and perform better than LS and SLS Estimators. If these all methods are combined, then it is called multiple LS channel estimator. Further this method reduces the estimation error by a factor of ρ_{tot} /ρ. For example, if each training has the same power (Pk=P: k=1, 2, 3-----K), then $\rho_{tot=K}\rho$ and the estimation error is reduced by a factor of K [3].m ρ=power of each training signal, $\rho_{tot=\text{Total power}}$ of training signal. A number of Training-based channel estimation methods including Optimal training sequences have been proposed [3], [8]. However most of these works are based on the assumption that MIMO Channels are independent identically distributed (iid) Rayleigh channels. The use of spatial channel correlation can be used to improve MIMO Channel estimation also; the Jakes fading model is used to represent correlated MIMO Channels [5].For low value of SNR, spatial correlation decreases channel estimation errors and improve the capacity [4].

III. PROPOSED WORK

Multiple antennas technologies, also referred to as multiple input–Multiple Output (MIMO) systems, are currently adopted in a growing range of applications and meet the demand for high data rate and link robustness. Channel estimation is most important task for MIMO Wireless Communication system. For slow varying fading channels, a training sequence is usually appended at the beginning of data burst (Preamble based training). For fast varying fading channels, the pilot symbols are inserted in the data streams a technique called pilot symbol assisted transmission [7].
Several methods are proposed in order to inform the receiver about the channel between transmitter and receiver. These methods generally estimate the channel by using following approaches:

1) The blind and semi-blind approaches, where the receiver assumes almost no knowledge or some bare information about the transmitted signals.
2) The training based approach where the receiver knows portion of the sequences of transmitted symbols.
3) The methods which embed or superimpose the training sequences into transmitted data.

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However all these methods are not able to provide the receiver with a perfect channel measurement? Training based methods are widely used for perfect channel measurement, such as LS, SLS, MMSE, RMMSE and Multiple LS methods [10]. We observe that at low SNRs ($P/\sigma n^2$), LS estimators have substantially lower MSEs than LS estimator; while at high SNRs the performances of both these estimators are nearly identical [3], [8].MMSE estimator performs better than LS and SLS techniques. The MMSE estimator has the best performance among all the methods, but it requires more a priori knowledge about the channel than any of other techniques. Therefore, the SLS and RMMSE estimators (which are required to know about the channel much less than MMSE estimator) provide a good tradeoff between the achieved performance and the required channel knowledge [3], [8]. MSEs of RMMSE method is less than LS and SLS estimators. At low SNRs this method is better than LS method, while at High SNRs the performances of all the methods are identical [8]. In cases of multiple LS estimators reduce error by a constant factor of ρ_{tot} / ρ.

Generally MSE for Training-based schemes can be calculated by,

$$J_{MMSE} = \left\| H - HMMSE \right\|_F^2 \qquad \textbf{(3)}$$

It has been observed that the Training-based channel estimation methods perform better for correlated than for independent identically distributed (iid) channels [5]. On the basis of required accuracy of the channel estimation, optimal training sequences of minimum length are determined and it is given by

$$N_p \geq N_T (L+1) + L \qquad \textbf{(4)}$$

Where, Np = the number of training symbols per transmit antenna and per frame [11].

The training sequences very much effect the channel capacity, and by implementing the Optimal training sequence length improved MSE and capacity both [12]. Using mathematical calculations Optimal training matrix can be recovered for training based schemes, also MSE for MIMO channel estimation can be minimized for the same. These training based schemes can be optimal at high SNRs, but suboptimal at low SNRs [9]. Therefore we have to design optimal training at low SNRs for training based methods, it means the variation of SNRs ($P/\sigma n^2$) and MSE for training based schemes for correlated and uncorrelated channels.

IV. CONCLUSION

Optimal training matrix can be recovered for training based schemes; also MSE for MIMO channel estimation can be minimized for the same. These training based schemes can be optimal at high SNRs, but suboptimal at low SNRs [9]. Therefore we have to design optimal training at low SNRs for training based methods, it means the variation of SNRs ($P/\sigma n^2$) and MSE for training based schemes for correlated and uncorrelated channels. Proper channel estimation improves better results for performance parameters for MIMO wireless communication. It is proposed by mathematical calculations to design Optimal training signals in matrix form, so that MSE (Mean square error) will be minimized and number of training sequences will be Optimal at high and low value of SNRs (Eq. 1, 3, 4) for spatially Correlated and uncorrelated channels.

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