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Study of the VariousChannel Estimation Schemes in Wireless Mimo-Ofdm Networks

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ABSTRACT
The Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing system is used widely use.so it is essential to understand the data transmission in such system. As the characteristics of the transmission channel always changing with time, it is necessary to know the channel and channel estimation schemes in wireless networks. The channel estimation schemes are required to make the channels according to required parameters for the data transmission. Several channel estimation schemes are available and can be used with different algorithms. In this paper various channel estimation schemes were discussed and their performance in fading channel.

Keywords: *MIMO, OFDM, Channel Estimation, Wireless Networks, Pilot Symbol, and Blind Estimation*

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I. INTRODUCTION

The wireless communication system is rapidly increasing technology in the new information age. The system uses different techniques and modulation schemes to provide high speed data transmission. The multiple input multiple output (MIMO) system is recent technology that is being used in many wireless systems to increase its capacity. The study shows that MIMO system when used in wireless system can increase the capacity by fraction of number of transmit antennas and receive antennas in flat fading and narrow fading antennas.This capacity increment in MIMO system is based on the assumption that all channels between transmitter and receiver antennas are accurately known. Hence the channel estimation is required.

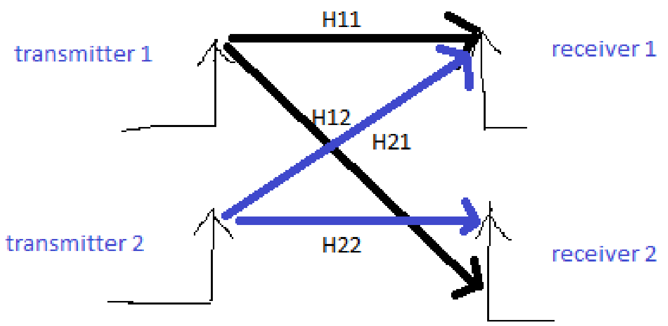

Fig. 1 MIMO System with two channels

Orthogonal frequency division multiplexing (OFDM) is another promising technology for high speed transmission in wireless communication. OFDM is used by dividing entire channel into many narrow-band channels. These channels are transmitted in parallel to maintain high data rate and to increase symbol duration to tackle ISI.There are several advantages of OFDM like high spectral efficiency, simple implementation, reduced effects of inter-symbol interference (ISI) and improved performance in frequency selective fading environment.

The advantages of both the techniques are combined together to have a MIMO-OFDM networks. Channel estimation is very important for MIMO-OFDM communication system. The channel estimation can be get through training or pilot based, blind and semi blind approaches.

But there are few problems in channel estimation in OFDM system. The first is that the pilot symbol used for channel estimation are very difficult to arrange. The pilot symbols are reference tones used by both transmitter and receiver. Second issue is construction of estimator which has low complexity and high channel tracking ability. The OFDM system can be taken as two dimension signal. But the one dimensional estimators are used for the OFDM system to get low complexity and accuracy of the channel. The blind channel estimation is obtained by evaluating the statistical information of the channel and certain properties of the transmitted signals.In OFDM there are several symbols that are repeated at the beginning of the transmission which are known as cyclic prefix. By adding these cyclic prefix some redundancy is created which can be used for the blind channel estimation. Blind channel estimation does not have overhead loss and it can be apply to time varying channels only as it requires long data record. In training based method training symbols also known as pilot symbols are multiplexed with the data for channel estimation. These symbols are already known to receiver side. But this method definitely affects the data rate. The semi blind method is mix of blind and training methods. It uses the training symbols as in training method and also the other natural signals to get the channel estimation.

This paper discusses different methods for channel estimation in detail. In the following part we also discuss few algorithms used in channel estimation.

II. CHANNEL ESTIMATION SCHEMES

The data transmitted in communication system is often get distorted or corrupted due interference in channel medium. Thus it is necessary to find out the influence of channel characteristics on the received data quality. This can be done through channel estimation. There are two major categories of the channel estimation schemes which are supervised or trained and unsupervised or blind. The blind channel estimation uses received symbols for estimation. But they are not useful in case of slow time varying channels and also they are very complex in computation. The pilot channel estimation however uses pilot symbols sent as prefix to transmitted data which are known to the receiver. They are simple in implementation and can be used with number of channels. The downside is that the use of pilot bits at start of the data stream affects the data rate.

2.1 Trainingbased or pilot aided channel estimation

This is the supervised method of channel estimation which uses pilot symbols or reference signal. Though the reference signal is without any information it is known to both the transmitter and receiver.

The number of channel estimation processes in MIMO-OFDM system is equal to the number of channels in the system. Thus it is performed on each channel that connects a transmitter (M) to receiver (N).

The insertion process of pilot sequence in MIMO-OFDM is different than other systems. Here the symbol '0' is also inserted with pilot sequence. The pilot symbol and '0' are inserted alternately and it is then given to the transmitter. Thus when first transmitter in MIMO transmits the pilot symbol, the second transmitter will not transmit anything or we can say it transmits the '0' symbol and vice versa. Thus with the help of this pilot symbol next pilot symbol can be find out. It is therefore a after and before cycle of pilot symbols.

Depending upon the type of transmission pilot channel estimation are divided in two types BLOCK and COMB.

2.1.1Blockpilot channelestimation

This method is usually used in block faded channel in which channel remains constant over few OFDM blocks. In this method pilot symbols are transmitted over all subcarriers in periodic intervals of OFDM blocks. In this system if there is no change in channel over period of a block then there is no channel estimation error as pilot symbols are transmitted on all carriers. The receiver decodes the received data with estimated channel condition until next pilot symbols arrive. The algorithms like least square (LS) or minimum mean square error (MMSE) can be used for estimation.

- Leastsquareestimation: In this method the channel knowledge is not required to be known and it is less complex. But the method has very high mean square error.
- Minimum mean square error: The MMSE estimator uses second order statistics of the channel condition to minimize the mean square error.It has better result than LS estimator especially when SNR is low. But it has very high computational complexity if there is need of matrix inversion each time the data changes.
- Estimation with decision feedback: In block pilot based estimation the estimators are calculated per block basis and it is then used until the next pilot symbols come. The decision feedback system is used in channel estimation to improve performance based on feedback from the subcarriers to update the estimators. For first round the receiver gets channel condition from pilot symbols which is based on LS, MMSE. For every block each coming pilot symbol and its each subcarrier estimated transmitted signal is found from previous estimators.
- This data is mapped to the binary value through demodulation technique. And then the original data is obtained back using signal mapper. Estimated channel is then updated using new data and is used in the next symbol.

2.2Comb Pilotchannelestimation

This type of channel estimation has high re-transmission rate as the pilot signals are uniformly distributed within each block. Thus providing better resistance to the fast fading channels. The pilot symbols are not inserted in every sub-carrier, so the channel response of non-pilot sub-carriers has to be calculated using interpolation with the neighboring pilot sub-carriers. It shows that the comb type pilot channel estimation gets affected by the frequency selectivity. Thus we have to ensure that the pilot spacing must be smaller than the coherence frequency of the channel.

- LS estimator with 1D interpolation: In this method channel is estimated at data subcarriers by interpolating vector W with length m with the vector H with length n without using any additional information of channel statistics. Some 1D interpolation methods are as given below
- Second order interpolation: This method is better than linear interpolation and channel estimation is performed by taking weighted linear interpolation of the three adjacent pilot symbols.
- Low pass interpolation: This method uses low pass finite length impulse response (FIR) filter for interpolation. Zeros are inserted in the original signal before passing it through the low pass FIR filter. The filter then allows original signal to pass through without any change. This method minimizes mean square error between interpolated points and their ideal values.
- Time domain interpolation: This interpolation method is high resolution method. It uses zero padding along with DFT and IDFT. To start with original symbol is converted to time domain using IDFT and it is then interpolated to finite points using some piecewise constant method. Then by taking DFT of this resulted signal can give back the signal in frequency domain.
- Spline cubic interpolation:This method gives continuous and smooth polynomial function which is fitted to the given set of points.

Low pass interpolation and spline cubic interpolation give best results in low as well as middle SNR.While it outperforms the spline cubic interpolation in high SNR systems. But both are computationally complex. Time domain interpolation is also computationally complex to the same level as that of low pass and spline cubic interpolation. But second order and linear interpolation are less complex. Hence low pass and spline cubic methods are recommended in most cases as they provide best of performance and complexity.

- ML estimator:In this method channel estimation is given by maximum likelihood estimator of $\hat{g}_{L+1}$ and non-square DFT matrix $F(S)_{A,B}$ where S is space between pilot subcarriers.
- PCMB estimator: In this estimator channel information is important and must be known to the estimator. Thus resolvable paths M and time delays $\{\tau_m T_s\}$ are essential for channel estimation. We can computer estimate of M by criterion of minimum description length (MDL). Initial multipath time delays are obtain using the estimation of signal parameters by rotational invariance method and to track channel multipath time delays an inter-path interference cancellation delay locked loop is used.

Between these three channels estimation schemes LS estimator with 1D interpolation is less complex but it has higher mean square error and signal to noise ratio when compared to other two methods. PCMB and ML estimators are similar in performance but PCMB is slightly better in terms of MSE at lower SNR.

2D estimators:These estimators use 2D filters for channel estimations. In this method pilot symbols are inserted in both time and frequency domain. These estimators are better than 1D estimators but are very complex and has processing delays. It is proposed that with use of two 1D interpolations on frequency and time can reduce the complexity.

Iterative channel estimator:They use 2D filters for channel estimation by dividing them in 2D blocks. Pilots are inserted in each block and estimation is carried out in block by block basis. These iterative estimators have better performance even at low SNR but are computationally very complex and have iteration delays.

2.3. Blind Channel Estimation

The main problem with wideband wireless communication system is multipath propagation. The transmitted signal can be recover at the receiver end if the channel information is known in advance at the receiver. The method of cancelling effects of channel on transmitted signal is known as the equalization. The equalizer can be formed either by estimating the channel or without estimating it. But in both the condition it is necessary that transmitter should send some reference signal with data stream which is also known to receiver. This can however seriously affect the longevity of the devices as most of these devices are battery powered. Transmission of reference signal also leads to low transmission rates. Thus use of blind channel estimation technique makes sense as it reduces the training requirement by significant amount. It uses some of the properties of transmitted signal to make estimation by blind channel estimation.

Blind channel estimation does not require any reference signal and instead it uses some statistical and structural properties of the transmitted signal. This information can be acquired from received signal. The information used is channel amplitude and phase response.

The communication signals are non-gaussian and hence their higher order statistic (HOS) are non-zero. They can beused for equalization. Earlier blind estimators are based on HOS. But they do not provide practical solution as they need large data samples and have high variance. This is very severe in case of time varying channel and when data rate is high or low.

In multiple output system the signal statistics like autocorrelation function are periodic. It is shown by Gardner that second order statistics of received signal can be used to obtain non-minimum phase channel estimations cyclic autocorrelation function preserves phase information. But in such system some channel type may not be identified. But with antenna arrays at the receiver of the multiple output system are well separated then severity of limitation can be minimized. It is because the sub-channels are uncorrelated.
We can also combine the training data with blind estimators which will result in semi blind estimation of channels. It is very useful as it combines benefits of both pilot estimator and blind estimator. They can lower data rates by using less number of training samples and also can have low variance as they also use statistical information from received signal.

2.4. Blind Source Separation (BSS)

Blind source separation is the method of recovering original signal from observed mixture of signals. In many cases statistically independent channels are mixed together in unknown channel and only output signal can be measured. Thus separation of source signal from mixed output is needed in order to perform the channel estimation. Thus blind source separation is extended work of blind estimation.
It is very difficult to recognize source signal without any prior knowledge of the filtering or mixing process. But we can estimate original source signal to some extent of ambiguity which is known as permutation or delay of estimated source signal. This is possible because these ambiguities reserves waveforms of original source. But in large number of systems these ambiguities are not essential as the information is not stored in amplitude but it is in time frequency pattern of the source signal.
There are many approaches for source separation as given below:

- First approach uses cost function of the signal of statistical independence, sharpness. When source is statistically independent without temporal structure the use of HOS is very essential in source separation.
- If source has temporal structure second order statistics are used for source separation. But the second order statistics do not separate sources with identical power spectra.
- We can also use non-stationarity and second order statistics for BSS with the help of decorrelation of wide class of source signals. They provide separation of colored Guassian sources with identical power spectra shapes. But they don’t separate non-stationarity properties.
- We can also use time and frequency diversities or space time diversities for source separation.

III. RESULT

All the estimation methods have varying performances in different conditions. The PCMB method of comb type pilot based methods is very good but is highly complex where as least square with low pass interpolation method is good and has low complexity. Similarly, for block type pilot based methods, OLR-MMSE performs well and it has moderate complexity.

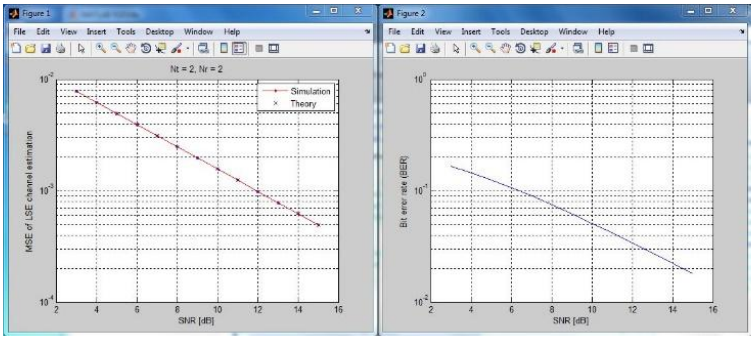

Fig. 22x2 MSE and BER of LSE channel estimation

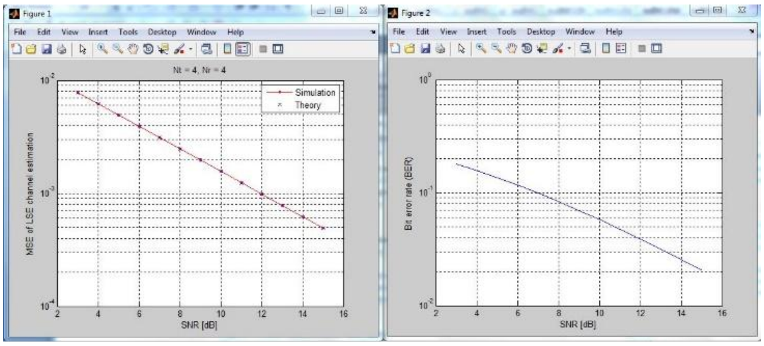

Fig. 3 4x4 MSE and BER of LSE channel estimation

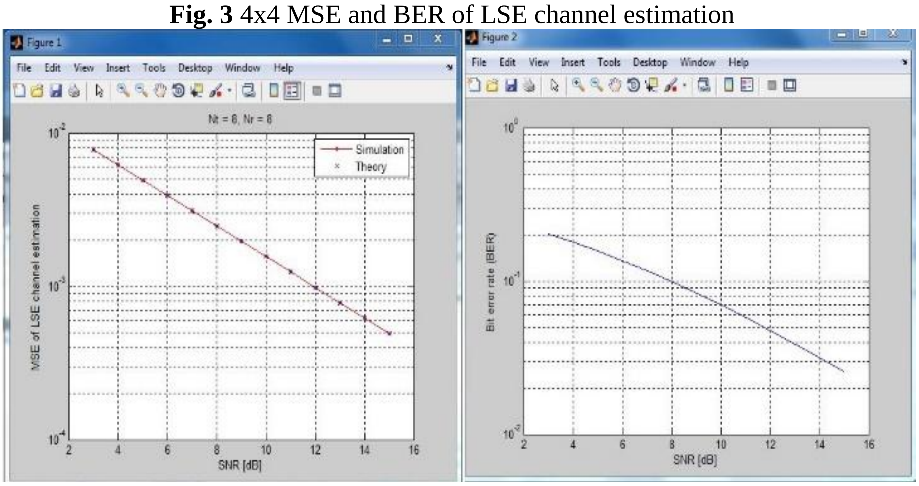

Fig. 4 8x8 MSE and BER of LSE channel estimation

IV. CONCLUSION

Here we have tried to study the different channel estimation schemes for MIMO-OFDM wireless communication. As MIMO-OFDM system is rapidly gaining popularity it is necessary to get the methods that will yield better results in different scenarios in terms of SNR and MSE.

Different methods discussed in this paper are pilot based and blind channel estimators. Here some subtypes of these two methods are also mentioned with their performancecomparison for channel estimation in terms of SNR and MSE.

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