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PILOT BASED CHANNEL ESTIMATION OF MIMO OFDM SYSTEM

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ABSTRACT

Combination of MIMO technique with OFDM has become important and attractive technology in future wireless communication systems and can be used to both improve capacity and quality of mobile wireless systems. Accurate and efficient channel estimation plays a key role in MIMO-OFDM communication systems, which is implemented by using pilot or training sequences by virtue of low complexity and considerable performance. In this paper, we discuss some methods for channel estimation based on training symbols in MIMO-OFDM systems. The results show the comparison of one method over the other methods in terms of complexity and BER.

Keywords: MIMO;OFDM;LS;MMSE; RLS;LMS.

1. INTRODUCTION

Multiple-input multiple-output (MIMO) system is one in which multiple antennas are used in both transmitter and receiver sides is an emerging scheme that is potentially able to provide high data-rate communications with bandwidth efficiency. Also, orthogonal frequency division multiplexing (OFDM) technique, which uses super symbols with a cyclic prefix inserted between them, overcomes the intersymbol interference (ISI) phenomenon that is one of main challenging issues in reliable wireless transmissions at high data-rate. In addition, several standards such as the IEEE 802.11a, the IEEE 802.16a, digital audio broadcasting (DAB) and terrestrial digital video broadcasting (DVB-T) have already adopted the OFDM technique. Thus, a combination of the MIMO scheme and the OFDM technique termed MIMO-OFDM that exploits space and frequency diversities is a good candidate transmission system for future wireless communications.

Channel estimation is a crucial and challenging issue in coherent modulation and its accuracy has a significant impact on the overall performance of communication system. The channel estimation in

MIMO systems becomes more complicated in comparison with single-input single-output systems due to simultaneous transmission of signals from different antennas that cause co channel interference.

The channel state information can be obtained through training based, blind and semi blind channel Estimation. The blind channel estimation is carried out by evaluating the statistical information of the channel and certain properties of the transmitted signals. Blind Channel Estimation has its advantage in that it has no overhead loss; it is only applicable to slowly time-varying channels due to its need for a long data record.

In training based channel estimation algorithms, training symbols or pilot tones that are known a priori to the receiver, are multiplexed along with the data stream for channel estimation. Channel estimation based on pilot, it can be classified as preamble method and PSAM method (Pilot Symbol Assisted Modulation or comb-type pilot method) in accordance with the difference of insertion position of pilots.

In. Semi-blind channel technique is hybrid of blind and training technique, utilizing pilots and other natural constraints to perform channel estimation.

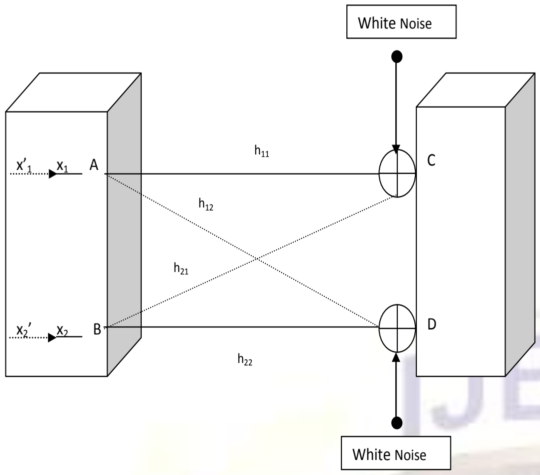
Based on the criterion of realization, it can be classified as Minimum Mean Square Error (MMSE), Least Square (LS) and Maximum Recursive Least Square Method , Least Mean Square and so on. From the filters adopted and the structure, it can be categorized as two-dimensional filtering [7], [8], two one-dimensional concatenation filtering and so on.

The organization of the paper is as follows: Section 2 describes System Model of MIMO OFDM and section 3 describes Channel Estimation.
Section 4 provided the Performance of MMSE, LS, LMS and RLS and simulation results are presented.
Conclusion is provided in Section5

2. SYSTEM MODEL

Consider a MIMO system equipped with N_t transmit antennas and N_r receive antennas. The block diagram of typical MIMO 2x2 is shown in figure 2.1 where x_1 and x_2 are the input (transmitted) signals of time slots 1 in location A and B respectively.

Fig.2.1 General Architecture of a MIMO 2x2:



The x'_1 and x'_2 are associated input signals of timeslot 2.

It is assumed that the channel coherence bandwidth is larger than the transmitted signal bandwidth, so that the channel can be considered as narrow band or flat fading. Further more the channel is assumed to be stationary during the communication process of a block hence by assuming the block the Rayleigh fading model for flat MIMO channels, the channel response is fixed within one block and it changes from one block to another randomly. During the training period the received signal in such a system can be written in the matrix form as

$Y = HX+N$

Where Y,X,N are complex N_R –vector of received signal on the N_R receive antennas. The possibly complex N_T – vector of transmitted signals on the N_T transmit antennas and the complex N_R -vector of additive receiver noise respectively. The elements of the noise matrix are complex Gaussian random variables with zero mean and $\sigma_n{}^2$ variance and the correlation matrix of N is given by

$R_N = E\{N^H N\} = \sigma_n{}^2 N_R I_{Np}$

Where N_P is the number of transmitted training symbols by each transmitter antenna. The matrix H in the model 1is N_R X N_T matrix of complex fading coefficients. The (m-th, n-th) element of the matrix H denoted by $h_{m,n}$ represents the fading coefficient value between the m-th receiver antenna and the n-th transmitter antenna. Assume that MIMO system has an equal number of transmit and receive antennas. The elements of H and noise matrix are independent of each other. For estimating the channel matrix $N_p \geq N_t$ training symbols are to be transmitted by each transmitter antenna. The function of a channel estimation algorithm is to recover the channel matrix H based on the knowledge of Y and X.

From the figure 1, the received signals in locations C and D are as follows:

$Y_{n1} = h_{11}x_1+h_{21}x_2+n_1$

$Y_{n2} = h_{12}x_1+h_{22}x_2+n_2$

$Y'_{n1} = h_{11}x'_1+h_{21}x'_2+n'_1$

$Y'_{n2} = h_{12}x'_1+h_{22}x'_2+n'_2$

where Y_{n1} and Y_{n2} are the output signals of time slot 1in locations C and D respectively.

Y'_{n1} and Y'_{n2} are associated output signals of time slot 2. n_1, n_2, n'_1, n'_2 are independent additive white Gaussian noises.

3. CHANNEL ESTIMATION

Based on those assumptions such as perfect synchronization and block fading, we end up with a compact and simple signal model for both the single antenna OFDM and MIMO-OFDM systems. In training based channel estimation algorithms, training symbols or pilot tones that are known to the receiver, are multiplexed along with the data stream for channel estimation. The idea behind these methods is to exploit knowledge of transmitted pilot symbols at the receiver to estimate the channel.

For a block fading channel, where the channel is constant over a few OFDM symbols, the pilots are transmitted on all subcarriers in periodic intervals of OFDM blocks. This type of pilot arrangement, depicted in Fig. 3(a), is called the block type arrangement. For a fast fading channel, where the channel changes between adjacent OFDM symbols, the pilots are transmitted at all times but with an even spacing on the subcarriers, representing a comb type pilot placement, Fig. 3(b) The channel estimates from the pilot subcarriers are interpolated to estimate the channel at the data subcarriers.

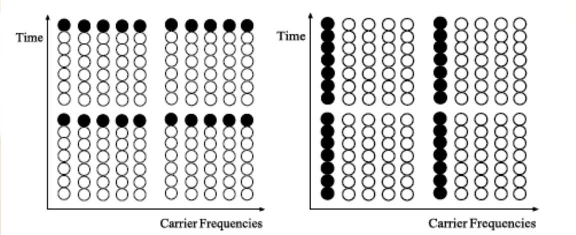


Figure 3.a Block Pilot 3.b. Comb Pilot

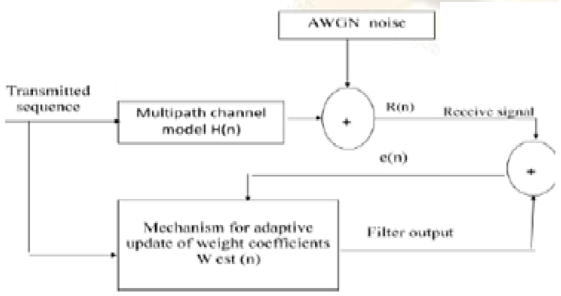
4. PERFORMANCE EVALUATION

4.1 Adaptive channel estimation

The most important research topic in the wireless communications is the adaptive channel estimation where the channel is rapidly time-varying. An adaptive algorithm is a process that changes its parameters as it gain more information of its possibly changing environment.

The channel estimation methods like least square estimation and recursive least square which uses adaptive estimator which are able to update parameters of the estimator continuously, so that knowledge of channel and noise statistics are not required. The LMS and RLS CE algorithm requires knowledge of the received signal only. This can be done in a digital communication system by periodically transmitting a training sequence that is known to the receiver.

Fig.4.1.The adaptive channel estimation scheme:



4.2 MMSE estimators

If the channel vector g is Gaussian and uncorrelated with the channel noise n, the MMSE estimate of g becomes

$\hat{g}$ MMSE = Rgyy R_{yy}^{-1}y

where

$R_{gy} = E\{gy^H\} = R_{gg}F^HX^H$

$R_{yy} = E\{yy^H\}=XFR_{gg}F^HX^H + \sigma_n^2 I_N$

are the cross covariance matrix between g and y and the auto covariance matrix of y which are assumed to be known.

$\hat{g}$ MMSE generates the frequency domain MMSE estimate $\hat{h}$ MMSE by

$\hat{h}$ MMSE = $\hat{g}$ MMSE = $FQ_{MMSE}F^HX^H{}_y$

Where QMMSE can be shown to be

QMMSE=$Rgg[(F^HX^HXF)^{-1}\ \sigma_n^2+Rgg]^{-1}(F^HX^HXF)^{-1}$.

4.3 LS estimators

The Least square (LS) estimator used in the channel to estimate the impulse response g minimizes the factor $(y-XFg)^H(y-XFg)$ and generates

$\hat{h}$LS = $FQ_{LS}F^HX^Hy$

Where $Q_{LS} = (F^HX^HXF)^{-1}$

$\hat{h}$LS reduces to the following corresponding estimator structure

$\hat{h}$LS = $X^{-1}y$,

LS estimator is equivalent to the zero-forcing estimator

4.4 Least Mean Square

The signal X(n) is transmitted via a time-varying channel H(n), and corrupted by an additive noise. The main aim of most channel estimation algorithms is to minimize the mean squared error i.e., between the received signal and its estimate .In the Fig 4.1, we have unknown multipath fading channel, that has to be estimated with an adaptive filter whose weight are updated based on some criterion so that coefficients of adaptive filter should be as close as possible to the unknown channel. The output from the channel can be expressed as:

Y(n)=X(n)H(n)+W(n)

Output of adaptive filter is given as

$P(n)=W_{esti}(n)X(n)$

Where W_{esti} =estimated channel coefficient at time n. The priori estimated error signal needed to update the weights of the adaptive filter is

$e(n)=Y(n)-P(n)= X(n)\,H(n)+W(n) - W_{esti}(n)X(n)$

Where e(n) minimized the mean square error.

Now Cost function for adaptive filter structure given as j(n)=E[e(m)e*(m)]

$j(n)=\zeta_r^{2-C(n)}\ -C(n)\ W_{esti}\ (n)-\ W_{esti}\ (n)C(n)+D(m)\ W^T_{esti}\ (n)W_{esti}(n)$

Where ζ_r^2 is variance of received signal.

C(m)=[(X(n)Y(n)] is the cross correlation vector between input vector and received vector.

$D(m)=E[X(n)X^T(n)]$ is the corelation matrix between input Gradient of cost function j(n) is given as

$\Delta j(n)=-2C(n)+2D(m)\ W_{esti}\ (n)$

$= -2X(n)Y^*(n)+2X(n)X(n)\ W_{esti}\ (n)$

By using this **least mean square** equation is given as

$\mathbf{W_{esti}\ (n+1)= W_{esti}\ (n)-1/2\eta X(n)e^*(n)}$

Where, Westi (n+1)=weighted vector and η=LMS step size

4.5 Recursive Least Square

Recursive Least Square RLS algorithm required all the past sample of input and estimated output at each iteration. The objective function of a RLS CE algorithm is defined as an exponential weighted sum of errors square.

$C(m)=\ \Sigma\ \lambda^{\ n-m}\ e^H(n)e(n)+\delta\lambda^m H^H(n)H(n)$ Where δ=positive real no. called regularization parameter, e(n) is the prior estimation error, and λ is the exponential forgetting factor with 0 < ëλ < 1. The prior estimation error is the difference between the desired response and estimation signal. Prior estimation error is given as

$e(n)= W^H(n)x(n)$

The objective function is minimized by taking the partial derivatives with respect to W(n) and setting the results equal to zero.

$W(n)=R^{-1}(n)\ R_{sh}(n)$

Where $R^{-1}(n)$ =auto covariance matrix

$R_{sh}(n)$= cross covariance matrix

Now from this **Recursive Least Square** equation is given as

$\mathbf{H(n)=H(n-1)+K(m)[W(n)-H^H(n-1)X(n)]^H = H(n-1)+K(m)\varepsilon^H(n)}$

Where $\varepsilon(n)= W(n)-H^H(n-1)X(n)$ and $K(m)= R^{-1}(n)X(n)$ OFDM system parameters used in the simulation are indicated in Table I.

We assume to have perfect synchronization since the aim is to observe channel estimation performance. We have chosen the guard interval to be greater than the maximum delay spread in order to avoid inter-symbol interference. The simulation parameters to achieve those results are shown in the table.

Table 1. Simulation Parameters

Parameter	Specification
Code length	100
Pilot length	20
IFFT	64
Tx and Rx Antenna	2 x 2
Guard time	1

The simulation results for the channel estimation for the MIMO-OFDM system are given fig.5. In this paper we compare the least mean square and recursive least square channel estimation techniques on the basis of different modulation schemes. Comparison of LMS and RLS are shown in following fig by using above parameter. The complexity of RLS estimator is larger than LMS estimator but give better performance than LMS.

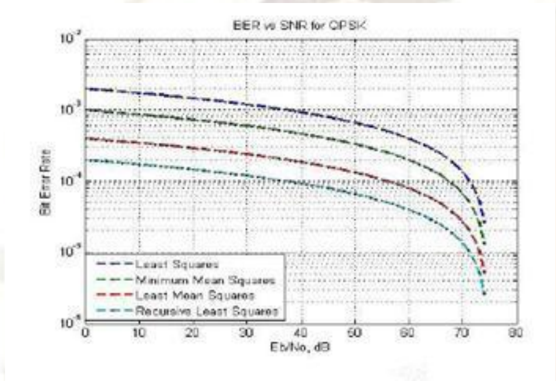


Fig 4.5.1.BER VS SNR of QPSK

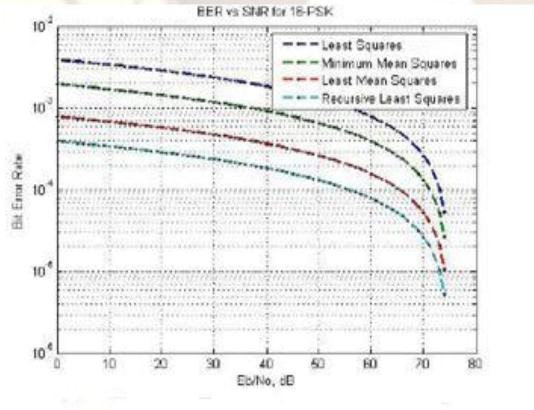


Fig4.5.2.BER VS SNR of 16-PSK

5. CONCLUSION

In this paper channel estimation based Least square, Minimum Mean Square Least mean square(LMS) and Recursive Least square of MIMO OFDM based systems are studied.. The complexity of RLS is larger than other estimators. The RLS estimator has good performance but high complexity. The LS,MMSE and LMS estimator has low complexity but its performance is not as good as that RLS at low SNRs. Simulation results show that estimation for MIMO OFDM provides less BER than other systems. Lastly by comparing the performance of RLS with LMS, it is observed that the RLS is more resistant to the noise in terms of the channel estimation.

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