Analysis of adaptive channel estimation techniques in MIMO-OFDM system

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ABSTRACT

Multiple input multiple output (MIMO) can be used to improve information carrying capacity in orthogonal frequency division multiplexing (OFDM).In MIMO-OFDM system channel estimation task becomes more difficult due to the change in channel parameter. Hence, to find appropriate channel estimation method which is able to follow changes at moment is matter of high significance. In this paper types of adaptive algorithm for channel estimation in MIMO-OFDM system is discussed. The adaptive filter can be least mean square (LMS), recursive least square (RLS) or KALMAN which does not require prior knowledge of second order statistic (SOS) of channel and noise. The adaptive RLS channel estimation with adaptive forgetting factor outperforms in frequency selective fading. The LMS adaptive estimation can be used to improve the channel performance.But the low convergence speed and serious estimation error led to the combination of LMS with KALMAN filter for more accurate estimation. However, computational complexity is increased since the result is transferred to the KALMAN filter. To improve bit error rate (BER) performance the KALMAN filter for different guard interval (GI) is studied. The adaptive filter based algorithm mostly uses least square (LS) or Minimum mean square error (MMSE) as initial channel estimation to reduce computational complexity. Finally, the mean square error of the various adaptive algorithm is compared, LMS+KALMAN outperforms the others.

Keywords : MIMO-OFDM, adaptive Filters, bit error rate (BER), least square(LS) estimator ,mean square error (MSE).

1 INTRODUCTION

TO achieve high transmission rate and high spectral efficiency, MIMO system with combination of orthogonal frequency division multiplexing is under high consideration. MIMO offers spatial diversity and therefore increase the capacity while OFDM allow systems to work in time varying or frequency selective environment.The combination of MIMO-OFDM have been adopted in different standards like Wi-Max, 3G-LTE and 4G due to their ability to enable high data rate transmission over multipath and frequency selective fading channels. The combination of MIMO-OFDM offers a third dimension of coding which achieves frequency diversity. In addition to this, multiple antennas can also be utilized in order to mitigate co-channel interference, which is another major source of disruption in (cellular) wireless communication systems. The implementation of the Guard interval in orthogonal frequency division multiplexing (OFDM) preserves orthogonality between subcarriers and hence eliminates the Inter Symbol Interference (ISI). In wireless communication channel, multi path effect causes the transmitted signal to arrive at different time interval. The overall received signal is combined in receiver to recover transmitted signal. In MIMO-OFDM system alamouti's space time code (STBC) is code in time and space to improve reliability through multiple transmit and receive antenna in [1].For high data rates and high spectral efficiency, MIMO-OFDM has become need for future wireless communication. The comb type pilot-channel estimation, estimate the channel at pilot frequencies and then to interpolate the channel in [4].Different interpolation scheme such as linear Interpolation, Gaussian interpolation, low-pass interpolation are used. The pilot based channel estimation suffers from poor spectral efficiency, since pilot tones are inserted at specific time period to estimate channel.

The combination of the MIMO system with OFDM provides the solution for future broadband and mobile wireless system. In practice, however, accurate channel state information in terms of channel impulse response (CIR) or channel frequency response (CFR) is required to guarantee the diversity gain and the projected increase in data rate. The channel state information can be obtained through either blind channel estimation or training sequences based channel estimation, which is based on the training data sent at the transmitter and known a priori at the receiver. The blind channel estimation has no overhead loss, only applicable to slow time varying channel. In conventional training based method channel is estimated by sending the sequences of OFDM block. The training symbols are kept orthogonal to each other**.** Then the channel state information is estimated based on the received signals corresponding to the known training OFDM blocks prior to any data transmission in [4].The set of pilot tones instead of sequences of training block were used to estimate the channel. In order to reduce computational complexity an efficient pilot-insertion pattern for channel estimation in OFDM system were proposed.The pilot tone structure is not explicit in terms of space time codes (STC) as in [1].The pilot aided channel estimation is sensitive to frequency selecting, it needs interpolation in time and frequency. The pilot and their position for different antenna are orthogonal to each other. The channel estimator of MIMO system can be absolutely converted into absolute channel estimator of SISO. The channel state informa-tion at (CSI) of the pilot position can be used to find out CSI of the other carriers through interpolation. In frequency selective channel the pilots are placed in different carriers at different symbol period, channel parameter of different frequencies can be estimated.

2 System Model

The use of OFDM modulation technique in wireless communication system, provide diversity to improve quality. The OFDM transform broadband, frequency selective channel into multiplicity of single narrow band channel in [7]. Since the OFDM symbol experience delay though the channel and hence guard interval is inserted between the symbols. The guard interval is cyclically extended part of the signal which is inserted at the starting of each symbol to avoid inter symbol

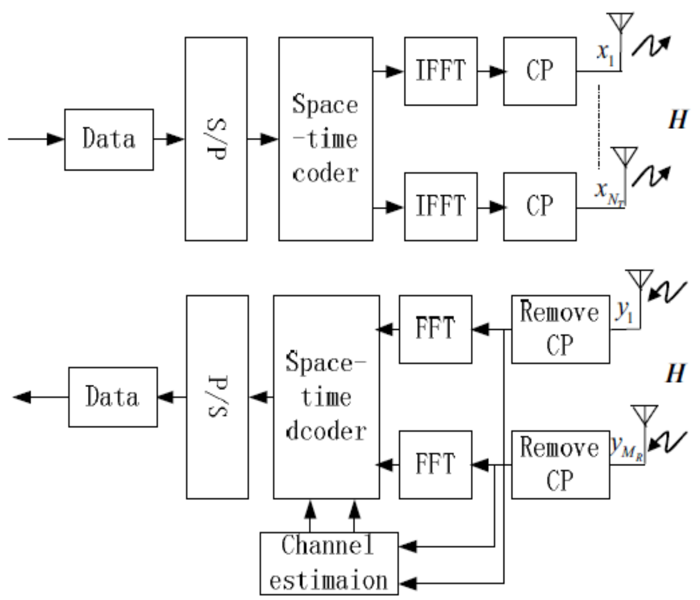

Fig.1 MIMO-OFDM System for adaptive channel estimation in [2]

Interference (ISI).The high rate of information sending of MIMO provide very efficient transmission and also co-channel interference is reduced by decomposing MIMO Channel into slow rate parallel single input single output sub channel (SISO). The system diagram is depicted in Fig. 1, in which there areN_T send antennas and M_R receiver antennas. The information is sent from an antenna by performing IFFT action and cyclic prefix (CP) insertion. The receiver performs FFT action after removal of CP and revealing is done after this action.

3 Adaptive filter based algorithm

The channel estimation based on the adaptive filters in [6], [7] and [8] adopt the channel state parameter accurately. The-work depicted does not prior knowledge of channel statistics Moreover, channel estimator requiring prior knowledge of the second-order statistic of the channel and noise.

3.1 LMS Filter Method

The LMS algorithm can be used for simultaneous estimation of the all the subcarriers. The channel is initially estimated using LS method, and then linear interpolation is used for overall channel estimation. Due to simplicity in channel estimation LS method is used as channel estimation in most of the receiver Algorithm design in [7]. To reduce this error floor, more taps have to be used, which not only increases computational complexity but also makes estimation problem more ill-conditioned and thus enhances noise. As an alternative there are different iterative algorithms which are used to improve channel estimation.

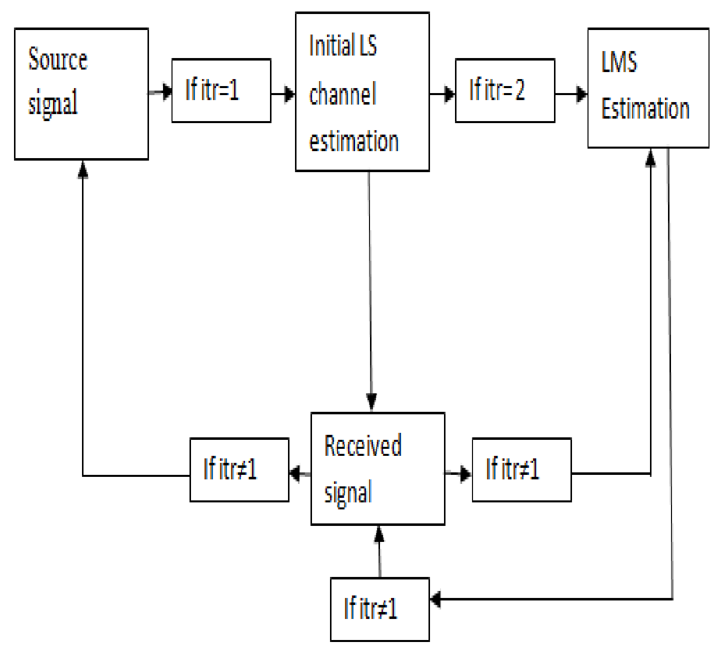

Fig.2 LMS based algorithm in [7]

TABLE I
ADAPTIVE LMS ALGORITHM IN [7]

PARAMETER	EQUATION
Co-efficients of vector $\hat{H}_n$	$\hat{H}_n = \hat{H}_{n-1} - \mu \times e \times X^*$

In LMS algorithm of [7] side information which can derived from each iteration would be used for next iteration. The Step-size μ is also influence the channel estimation through this method and should be chosen precisely. The channel coefficients is estimated using method of LMS recurrence. With careful choice of step size parameter yield identical result close to that of LS method.

3.2 RLS Filter Method

For multi user CDMA system RLS channel estimator require prior knowledge of second order statistic (SOS) of channel and noise. The preamble symbols for RLS channel estimation is designed into orthogonal sequences in [6].In order to process signals simply, the preamble sequences in different subcarriers but in the same OFDM symbol are same in one antenns and these preamble sequences from different antennas are orthogonal to each other. For example 4 transmit antenna should have FFT matrix of order N_TxN_T.

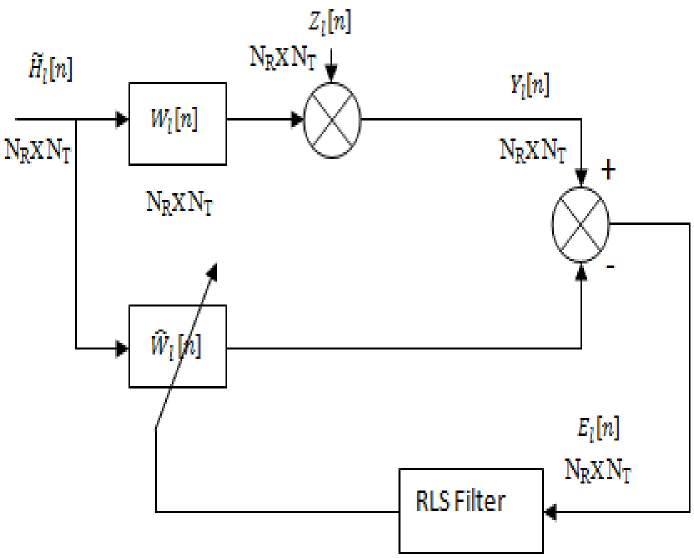

Fig.3 RLS Filter based algorithm in [6]

TABLE II
ADAPTIVE RLS ALGORITHM IN [6]

PARAMETER	EQUATION
Gain Vector $K_l[n]$	$K_l\,[n] = \dfrac{Q_l\,[n-1]\tilde{H}_l[n]}{\lambda + \tilde{H}_l[n]Q_l\,[n-1]\tilde{H}_l[n]}$
Estimation error $E_l[n]$	$E_l[n] = Y_l[n]\ - \hat{W}^H(n)\tilde{H}_l[n]$
Weight update $\hat{w}_l\,[n]$	$\hat{W}_l\,[n] = \hat{W}_l\,[n-1] - K_l\,[n]E_l^*\,[n]$
Estimated Channel matrix $\hat{H}_l$[n]	$\hat{H}_l[n] = \hat{W}_l^H\,[n]\tilde{H}_l[n]$

The second step is RLS filtering. The final step is to perform FFT to obtain channel parameter in time/frequency domain.
The purpose of using RLS algorithm is to reduce the computational complexity and mean square error. This estimation does not need prior knowledge of channel and the channel is estimated adaptively by adjusting weight. Since channel is assumed to be varies negligibly within one OFDM symbol, equal forgetting factor value to the whole to the whole preamble is applied in case of conventional forgetting factor. In case of two-step forgetting factor, low forgetting factor value is applied to the few first preamble symbol to make channel highly demanded on channel statistic. The adaptive forgetting factor can have some fixed positive learning rate. The algorithm with adaptive forgetting factor can be robust against frequency selective fading in [4].

3.3 KALMAN Filter Method

The channel estimation algorithms based on KALMAN were proposed in [2], [8], [9].To make choice between optimal guard interval adaptive filer like KALMAN provides the advantages for Guard interval optimization in [8]. The KALMAN filter -

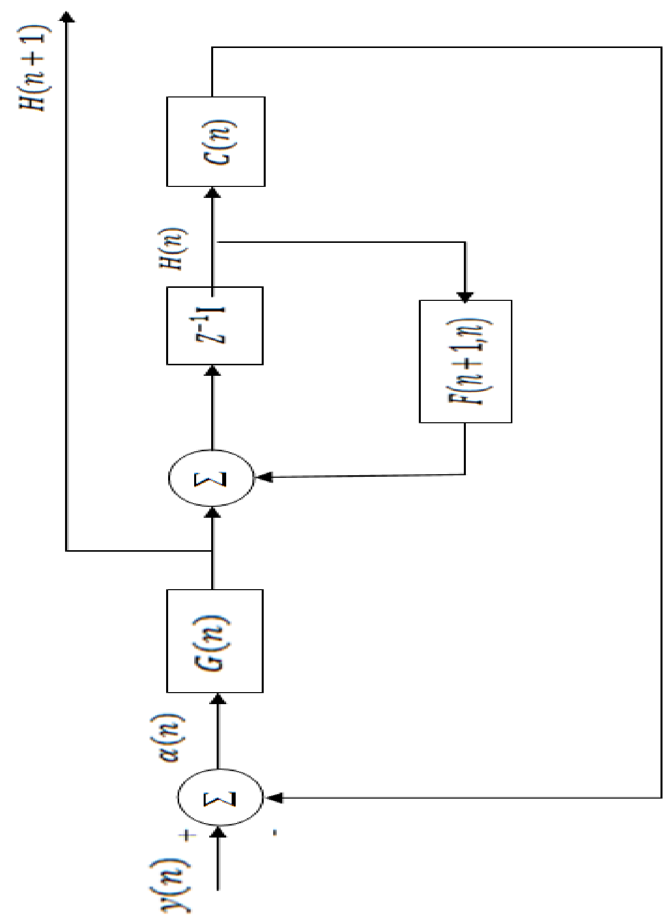

Fig.4 KALMAN Filter based algorithm

based estimation is more accurate than other adaptive filter strategy compared to the LMS and RLS, since it gives most accurate estimation of noise and channel statistics.The channel is first estimated using least square (LS) estimator in [2]. The state matrix F is calculated for remaining symbols.Then Kalman estimator is constructed to compute the different parame-

Source: Fictitious data, for illustration purposes only ter in order to determine channel matrix.

TABLE III
KALMAN FILTER ALGORITHM IN [9]

PARAMETER	EQUATION
State Matrix F(n)	$F(n+1,n) = E\{H(n+1)H^H(n)\}$
Kalman gain G(n)	$G(n) = F(n+1,n)K(n,n-1)C^H \times [C(n)K(n,n-1)C^H(n)Q_2(n)]^{-1}$
Innovation α(n)	$\alpha(n) = Y(n) - C(n)H(n)$
Estimated Channel matrix H(n)	$H(n+1) = F(n)H(n) + G(n)\alpha(n)$

Some interpolation algorithm is used to interpolate frequency response of the all subcarriers in frequency selective fading. However, a lots of matrix reverse is needed in the KALMAN based algorithm and is wastage of scared frequency resource.

3.4 LMS+KALMAN Filter Method

The stability of LMS algorithm makes it suitable to be used with KALMAN algorithm. The overall goal is to achieve better channel performance. The LMS+KALMAN algorithm is two-stage tracking structure. In training stage equalization of input signal is done through LMS and result is sent to the KALMAN filter to calculate error and transform matrix in [2]. Secondly, in the tracking stage the channel matrix is adjusted adaptively. Again, the channel is first tracked by using LMS and the result of the same is transferred to the KALMAN filter. A computational complexity is increased in [8], but the performance of the whole channel estimation is improved effectively.

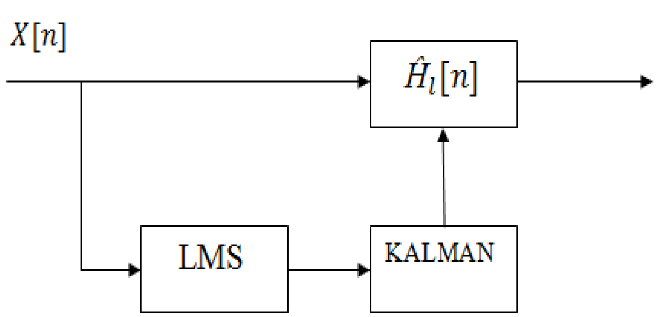

Fig. 5 Adaptive channel estimation based on LMS +KALMAN [5]

4 Result

The table IV shows the simulation result for bit error rate (BER) versus SNR in MIMO-OFDM system with 2 transmitters and 2 receiver antenna. The modulation scheme used is QPSK, total number of subcarriers is 64 with tap of channel L=4 in [7]. The result in table shows that with careful choice of step size parameter μ the channel estimation with LMS estimation out-performs to that of LS estimation. At lower SNR values the BER of the LS and LMS is approximately same. But at higher SNR (25dB) values of BER are almost reduces to more than half compared to its values at 20dB.

TABLE IV
Comparison of BER Vs SNR for 2x 2 MIMO- OFDM systems

Alogorithm	LS	LMS		
SNR	BER	BER (μ=0.001)	BER (μ=0.01)	BER (μ=0.1)
0	0.44	0.45	0.44	0.44
5	0.31	0.31	0.30	0.31
10	0.19	0.18	0.18	0.19
15	0.10	0.08	0.08	0.10
20	0.045	0.029	0.030	0.04 5
25	0.017	0.011	0.013	0.017
30	0.006	0.003	0.004	0.006

TABLE V
Comparison of MSE Vs SNR in Adaptive algorithm

SNR	MSE(dB) (LMS)	MSE(dB) (KAL-MAN)	MSE(dB) (LMS+KAL MAN)	MSE(dB)(RLS)
0	-6	-11	-12	-5
2	-9	-14	-15	-7
4	-12.5	-16.5	-18	-10
6	-14.5	-18.5	-20	-12
8	-16	-21	-21.5	-14
10	-18	-23	-23.5	-17
12	-2 0	-24	-24.5	-19
14	-21	-25	-25.5	-21
16	-22.5	-26	-26.5	-22.5
18	-24	-27	-27.5	-25.2
20	-25	-27.5	-28.5	-27.5
22	-25.5	-28.5	-29	-
24	-26.5	-29.5	-29.5	-
26	-27.5	-29.9	-29.9	-
28	-28	-30	-30	-
30	-29	-30.2	-30.2	-

The Mean square error (MSE) and SNR for LMS and KALMAN based algorithm is also compared.The MSE for LMS+ KALMAN algorithm at lower SNR has better performance compared to LMS algorithm. The Simulation results for MSE versus SNR in Rayleigh fading channel is shown for different adaptive filters. The filter with LMS+KALMAN outperforms the other.

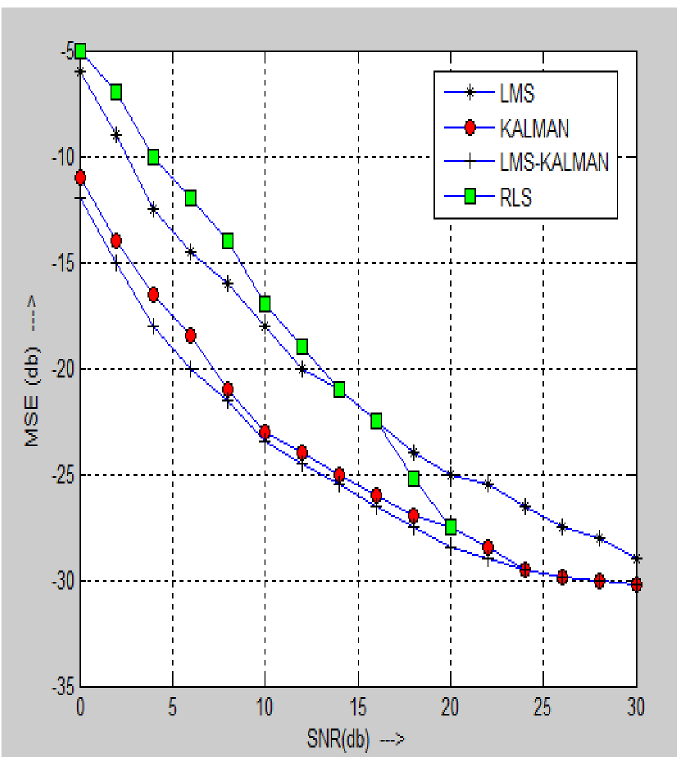

Fig.6 Simulation Result of SNR Vs MSE for various adaptive algorithms

5 Conclusion

In this paper we have analyse a comparison of an adaptive channel estimation technique in MIMO-OFDM system, by using different adaptive algorithm. The BER result of the adaptive channel estimation algorithm is compared with that of conventional LS estimation, also mean square error (MSE) is compared for adaptive algorithm. The LMS+KALMAN based algorithm has good performance than LMS or KALMAN. But computational complexity is also increased with the estimation accuracy, since a lot of matrix reverse in needed. The RLS-algorithm has also good MSE performance in frequency selective Rayleigh fading channel. An adaptive channel estimation algorithm uses LS or MMSE as initial channel estimation.

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