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Multistage Enhancement of Channel Quality using Channel Estimation Techniques for effective BER/SNR using 16 QAM for Mobile Communication

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Abstract----In this paper we present an improved and robustchannel estimation algorithm for OFDM mobile communication systems based on the use of pilot subcarriers.Specifically we present an iterative channel estimation technique to improve the performance of channel estimators.In iterative receiver structures,soft information becomes available after the decoding stage.This information is used to enhance the quality of the channel estimates for the nextiteration.The low complexity proposed receiver including LMS algorithm, has a higher efficiency than conventional methods(without channel estimation,LS& LMMSE) and it can work in lower amount of SNRs.We derive a generalized estimator based on the linear minimum mean square error (LMMSE) principle for deterministic pilot information combined with soft information. The performance is presented in terms of Bit-error rate (BER) for a system using 16-quadrature amplitude modulation (QAM).Simulation results validate that the proposed channel estimation scheme can achieve tremendous performance as the existing channel estimation methods.

Keywords—Channel estimation(CE),OFDM(Orthogonal Frequency Division Multiplexing)*.*

I. INTRODUCTION

Worldwide Interoperability for Microwave Access(WIMax) is a promising technology that was predicted to be the great leap toward broadband metropolitan area wireless network.This technology is specified in IEEE std.802.16 in which OFDM,OFDMA techniques are used as modulation methods.In the recent years there has been a lot of interest in applying Orthogonal frequency division multiplexing in wireless and mobile communication systems because of its high rate transmission capability with high bandwidth [4]-[5] efficiency and robustness to multipath fading and delay.OFDM based systems are strong candidates for air interface of future fourth generation mobile wireless systems which provides high data rate and mobility.

In order to achieve the potential advantages of OFDM based systems,the channel cofficients should be estimated with minimum error.To estimate the channel cofficients and correct received signal,the pilot based approach [2]-[3] is inserted in frequency,are widely used in which pilot subcarriers are inserted at the transmitter side and channel cofficientsthat belong to the pilot subcarriers are estimated using the LS (Least Square) method.Then these estimates are interpolated overthe entire frequency-time grid using 2D or two 1D wiener filtering [6].These estimation methods are performed assuming the statistical properties of the channel are perfectly known at the receiver side.

Channel estimation can be improved using more pilot symbols but it causes data rate reduction or bandwidth expansion[6].Therefore in this case iterative techniques provide an improvement on the channel estimator performance without requiring additional pilots.The idea is to feed back information from the output of the channel decoder to the estimation stage.The estimator can improve its performance because it gets not only the information from the pilots but also reliability information of the coded bits.

In this paper we consider pilot symbol aided iterative channel estimation method for OFDM based systems using the LMS technique.We evaluate the estimation accuracy of the proposed estimation method and bit error rate performance of the proposed system.The proposed system with LMS technique provide better results for bit error rate as compared to the MMSE and LS channel estimators.The MMSE estimator has good performance but high complexity.The LS estimator has low complexity but its performance is not as good as that of MMSE estimator.So in this case iterative LMS technique provide better results with less complexity.

II. SYSTEM DESCRIPTION

A. System Model

In this section we will examine the transmitter and receiver structureof OFDMsystemsincluding the pilot distribution.Then we will describe thepilot symbolaided channel estimation techniques with the DFT based interpolation in frequencyaxis and linear interpolation in time axis.

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We will consider the system as illustrated in Figure1,the vector of data bits is first encoded with an error correcting code such as convolutional code to obtain the vector of coded data bits.This vector is mapped accordingly to the constellations and vector of data symbols is obtained.After the guard band is inserted,an N-point Inverse Discrete Fourier Transform (IDFTn)block transforms the data sequence into time domain.Following the IDFT block,a cyclic extension of time length Tg choosen to be larger than the expected delay spread is inserted to avoid Inter Symbol Interference(ISI) [7-10].The Digital to Analog Converter (D/A) contains low pass filters.The channel is modeled as an impulse response h(t) followed by the complex additive white Gaussian Noise ω(t) as shown in figure1.

$$h(t,\tau)= \sum_{m=1}^{M} \alpha_m(t)\, \delta_D(\tau - \tau_m(t)),$$

where τ_m(t) and $\alpha_m(t)$ are the delay and the complex amplitude of the m^{th} path, respectively.

Where,

$\overline{x}$=OFDM symbol ω=Additive WhiteGaussian Noise

h=Channel Transfer Function $\overline{Y}$=Received signal

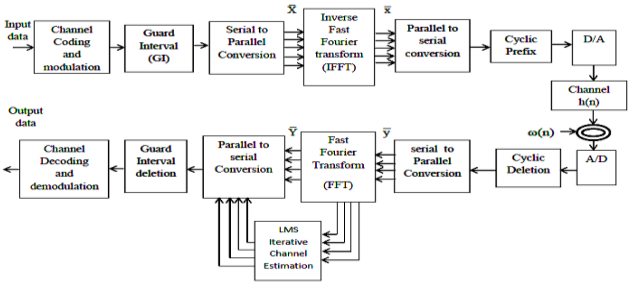

Figure1:A digital implementation of OFDM Baseband System

For pilot symbol aided channel estimation,pilot symbols are inserted periodically with the particular distances in frequency and time grid.The two basic 1-D channel estimations in OFDM systems are illustrated in Figure2.The First one is,block type pilot channel estimation,is devolped under the assumption of slow fading channel and is performed by inserting pilot symbols within a specific period.The second one,comb-type pilot channel estimation isintroduced to satisfy the need for equilizing when the channel changes even from one OFDM block to the subsequent one and it is performed by inserting pilot subcarriers of each [6] OFDM symbol where the interpolation is needed to estimate the condition of data subcarriers.

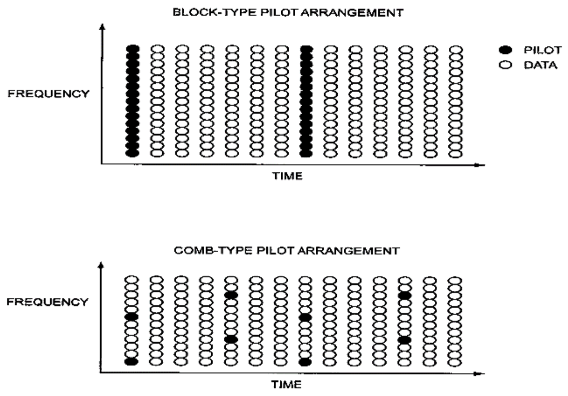

Figure 2 Types of Pilot insertion in OFDM systems

Symbol Vector $(\overline{X})$ is converted to the transmitted vector $(\overline{x})$ with length $K*N$by a serial to parallel converter where K is the number of total subcarriers in one OFDM symbol and N is total number of OFDM symbols in frame.Each OFDM symbol vector in the frame $\overline{x}=[x(n)]=[x1(n),x2(n),x3(n)\ldots\ldots xk(n)]$ is modulated into K subcarriers by an IFFT and then Guard interval (GI) is inserted.Then OFDM frame is transmitted through the time varying frequency selective channels.This channel is described using baseband equivalent impulse response as $\overline{h}=[h(n)]=[h1(n),h2(n),h3(n)\ldots\ldots hl(n)]$ where$l$is the length of channel.We assume$\overline{n}= [\omega(n)]=[\omega1(n), \omega2(n), \omega3(n)\ldots\ldots \omega c(n)]$ as additive white Gaussian noise added over channel.Define the input matrix:

$$\mathrm{F} = \begin{bmatrix} {W_N}^{00} & \cdots & {W_N}^{0(N-1)} \\ \vdots & \ddots & \vdots \\ {W_N}^{(N-1)0} & \cdots & {W_N}^{(N-1)(N-1)} \end{bmatrix}$$

Here,

${W_N}^{n,k} = \frac{1}{\sqrt{N}} e^{-j2\pi\, nk/N}$ is called Twiddle Factor.

Also define $\overline{H}=DFTn(\overline{h})=F\overline{h}$and $\overline{N}=F\overline{n}$

Afterremoving the Cyclic prefix and applying FFT,the received signal is obtained as,

$$\overline{Y}=DFT(IDFT(\overline{X}*\overline{h}+\overline{n}))\ (1)$$

The system described by (1) can be written as a set of N independent gaussian channels as shown in figure (3)

$$Y_k = H_k\, X_k + N_k (2)$$

Where k=0,1,2,3…..N-1

As a matter of convenience we write (2) in matrix notation:

$$\overline{Y}=X\overline{H}+N \qquad (3)$$

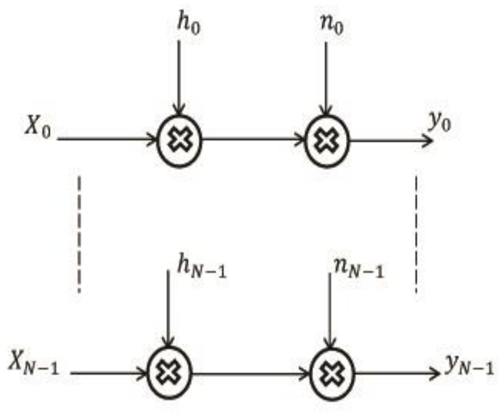

Figure 3:Parallel Gaussian channels

In the channel estimation unit,the estimate of $\overline{H}$ is obtained with the channel information given by $\overline{H}$,channel equalization is performed by$X=\overline{Y}/\overline{H}$.Finally $X$is demodulated and original signal is restored.

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B. PilotAidedChannelEstimation:

In pilot aided channel estimation scheme,pilot symbols are added at the transmitter side in which all subcarriers are used as pilots.If we assume that channel is constant then there will no channel estimation error since the pilots are sent at all carriers.The estimation can be performed by two methods.The first one is LS(Least Square) and the second one is MMSE(Minimum Mean Square Error).

LS Estimator:

The first step in the channel estimation process is to remove the modulation of the pilot symbols. Thus an initial estimate of the CTF (Channel Transfer Function) at pilot positions is obtained.The estimate of[12]channel transfer function is obtained by using LS estimator.The LS estimate is represented by:

$$\hat{H}_{LS}=X^{-1}Y$$

Which minimizes the parameter :

$$(Y-XFh)^H(Y-XFh)$$

LS estimators are calculated with very low complexity,but they suffer from a high mean-square error.

MMSE Estimator:

If the time domain channel vector h is Gaussian and uncorrelated with the channel noise ω,the frequency domain MMSE [12-13] estimate of h is given by:

$$\hat{H}_{MMSE}=FRhYR_{yy}{}^{-1}Y$$

Where,

$$R_{HH}=E\{H\bar{H}\bar{H}^H\}=E\{(F\bar{g})(F\bar{g})^H\}=FR_{gg}F^H$$

$$R_{gy}=E\{\bar{g}\ \bar{Y}^H\}=E\{\bar{g}(XF\bar{g}+\bar{N})^H\}=R_{gg}F^HX^H$$

$$R_{YY}=E\{\bar{Y}\ \bar{Y}^H\}=XFR_{gg}F^HX^H+\sigma^2I_N$$

$R_{hy}$is the cross covariance matrix between h and $y$and R_{YY} is the auto covariance matrix of $Y.R_{HH}$is the autocovariance matrix of H and σ^2 represents the noise variance $E\{|W(k)|^2\}$.The MMSE estimator yields much better performance than LS estimators especially under the low SNR scenarios.A major drawback of the MMSE estimator is its high computational complexity, especially if matrix inversions are needed each time the data in X changes.

C. Proposed Iterative Channel Estimation

In order to improve the channel estimation accuracy we provide iterations to the estimated channel.The channel which was estimated in each iteration would be used for next iteration.

Channel information is required at receiver for signal detection.There are a large number of methods to obtain initial estimation and many iterative algorithms to improve the performance of estimation.We know that pilot symbols are inserted at the transmitter side in order to obtain estimate of the channel at the receiver side.This estimation in each iteration can be used as side information and feed back to system to achieve better result for next iteration.[14-15]

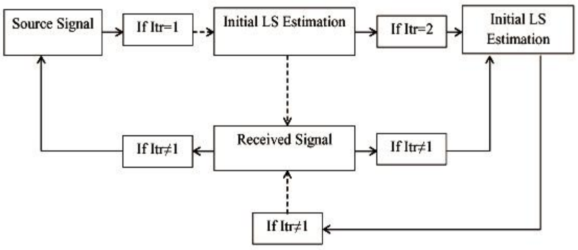


Figure 4:Implementing LMS Iterative alogirithm

The iterative algorithm which is used in this paper is LMS algorithm that uses channel estimation of last iteration that helps to improve the results in next iteration.

It is given by:

$$\hat{H}_n=\hat{H}_n\text{-}1\text{-}h\mu^*X*$$

Where,

- n = The iteration state
- e = The signal error
- μ = A coefficient between 0-1

We apply the number of iterations until the determined criteria will be reached,which it could be an special MSE.

As illustrated in figure4,LMS algorithm is applied to receiver and the channel which was estimatedin each iteration would be used for next iteration additionally the output signal is fed to source signal for next channel estimation.Another important factor in channel estimation through this method is μ which influences on estimation and should be precisely choosen.The performance of LMS algorithm can be closely to LS algorithm by careful choice of μ.

III. SIMULATION AND EVALUATION

In this section we demostrate theperformance of proposed iterative channel estimation method for OFDM systems.In the simulation we consider an OFDM system operating with bandwidth of 8.75MHz,Length of FFT as 1024 and Guard Interval of 1/8.Total number of data bits are inserted uniformly at even and odd positions. System parameters used in the simulation are indicated in Table 1.

Parameters	Values
System bandwidth	8.75MHz
Sampling Frequency	10 KHz
Number of subcarriers	1024
Cyclic prefix	1/8
Modulation	16 QAM
Useful symbol Time	0.1024ms
OFDM Symbol Time	0.1152ms
Guard Time	0.0128ms=12.8us

Table 1.OFDM system parameters

In the simulation we present 16 QAM modulation scheme.Total number of data bits taken are 1024 and 3456 OFDM symbols.The generation of modulated OFDM datasymbols is illustrated in Figure5:

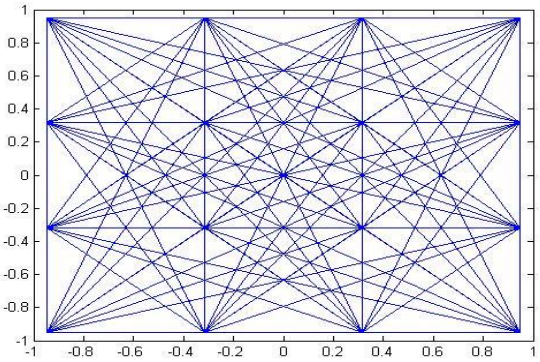


Figure 5: Modulated OFDM data symbols

The equispaced pilot symbols and data are now constructed in the OFDM frame at even and odd positions.Pilot symbols can be viewed as shown in figure 6.

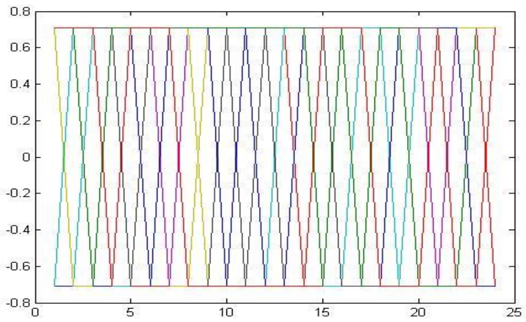


Figure 6: Pilot symbols representation.

And data symbols can be viewed as,

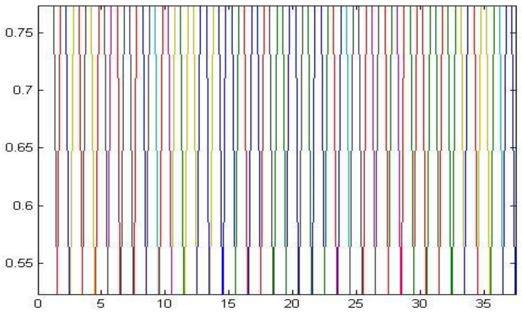


Figure 7. Data symbols representation

Both Pilot symbols and data symbols constructed in OFDM frame is shown in figure 8:

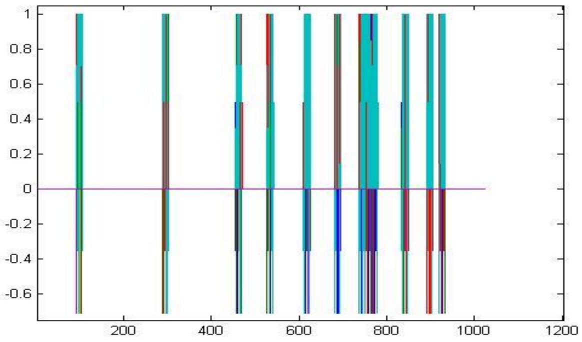


Figure 8: Data and pilot representation in OFDM frame

The formation of OFDM frame can be seen as shown in figure 9:

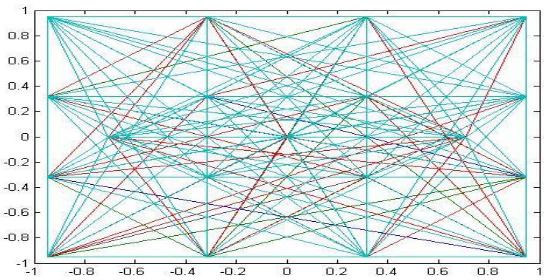
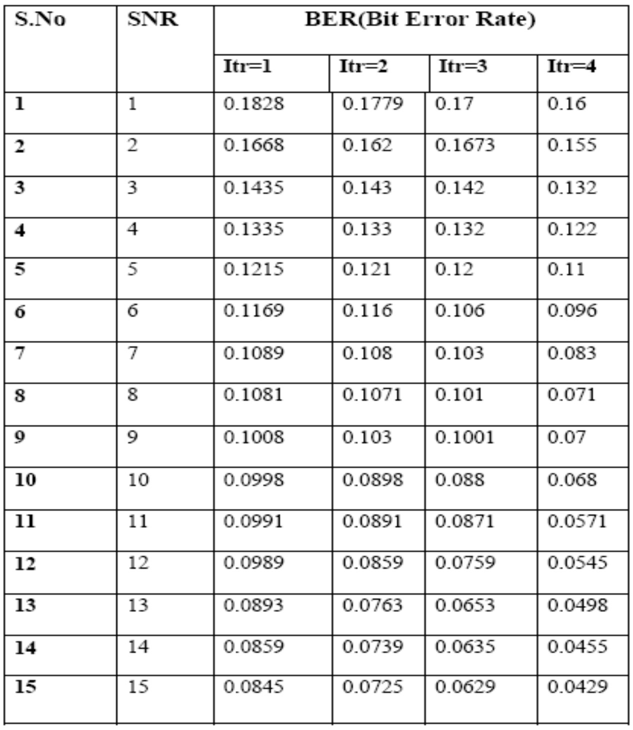


Figure 9:Formation of OFDM frame

The next process in OFDM signal generation is taking the Inverse Fast Fourier Transform which converts the data in time domain.After that Cyclic Prefix is inserted which is responsible to avoid inter symbol interference.CP=1/8 is taken in the simulation process.In this paper 128 bits of cyclic prefix is inserted in OFDM frame.Finally we do reshaping of resultant data.

The data is received after passing through Rayleigh Channel Model and Additive White Gaussian Noise is added to the channel.At the receiver side we proposed LMS Iterative Algorithm which takes the result of last iteration as a feedback to the system and helps to improve the channel estimation performance by reducing the Bit Error Rate.As we apply more number of iterations that will lead to reduce more Bit Error Rate whose performance can be seen from Table 2. In which LMS proves its efficiency as compared to No channel estimation,LS(Least Square) and LMMSE(Linear Minimum Mean Square Error) as shown in the following results from figure 10 to figure 13.



S.No	SNR	BER(Bit Error Rate)			
		Itr=1	Itr=2	Itr=3	Itr=4
1	1	0.1828	0.1779	0.17	0.16
2	2	0.1668	0.162	0.1673	0.155
3	3	0.1435	0.143	0.142	0.132
4	4	0.1335	0.133	0.132	0.122
5	5	0.1215	0.121	0.12	0.11
6	6	0.1169	0.116	0.106	0.096
7	7	0.1089	0.108	0.103	0.083
8	8	0.1081	0.1071	0.101	0.071
9	9	0.1008	0.103	0.1001	0.07
10	10	0.0998	0.0898	0.088	0.068
11	11	0.0991	0.0891	0.0871	0.0571
12	12	0.0989	0.0859	0.0759	0.0545
13	13	0.0893	0.0763	0.0653	0.0498
14	14	0.0859	0.0739	0.0635	0.0455
15	15	0.0845	0.0725	0.0629	0.0429

Table 2: BER Vs SNR for LMS Channel Estimation Technique with different iterations

Table 2. shows the performance of OFDM system using LMS iterative algorithm between Bit Error Rate and Signal to Noise Ratio.Table shows LMS iterative algorithm upto 4 iterations.

Following graphs shows the peformance of LMS iterative algorithmUpto four iterations which shows that LMS iterative algorithm performs better results than LS and LMMSE algorithms.

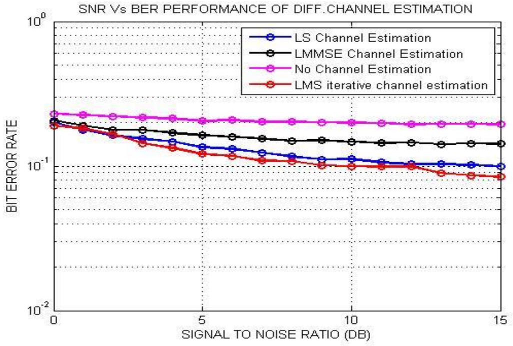


Figure 10 :Simulation results with iteration =1

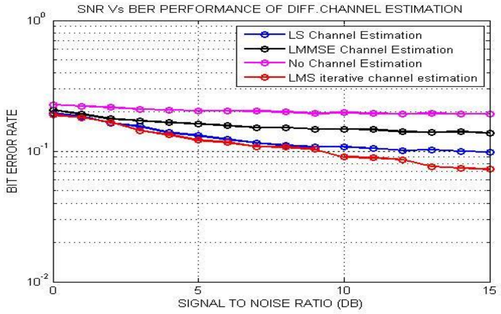


Figure 11:Simulation result with iteration=2

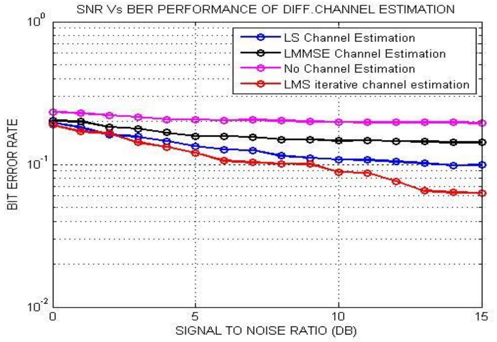


Figure 12:Simulation result with iteration=3

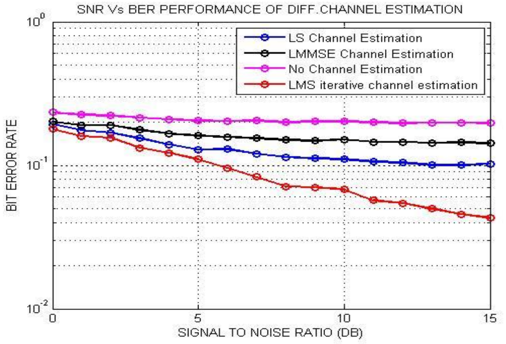


Figure 13 :Simulation result with iteration=4

IV. CONCLUSION

In this paper we proposed a receiver structure with low complexity.To improve the performance of receiver structure an efficient LMS iterative algorithm is added with the receiver,which includes the side information in each iteration as a feedback to the system to improve the BER performance of the system close to the ideal channel performance.LMS algorithm has a higher efficiency than conventional methods and it can work in lower amount of SNR.As we apply more number of iterations,BER reduces with increasing SNR value.

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