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Analysis of Channel Estimation in OFDM Communication System

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Abstract

Orthogonal Frequency Division Multiplexing (OFDM) has been considered as a widely used multicarrier (MC) scheme used in 4G and beyond wireless communication system due to its high data rate and capacity with large spectrum efficiency. In OFDM, channel estimation can be treated as main obstacle to achieve high bit error-rate performance. Some popular estimation algorithms, such as; Least Square (LS) and Minimum Mean Square Error (MMSE) have been used to determine channel estimation of pilot subcarriers. In literature, the performance of such estimators has been evaluated by using comb-type pilot scheme. In this paper we proposed a Lattice-type scheme, which efficiently used the pilot allocation The performance is to be measured by MSE and SER. Simulation results shows that that MMSE estimator shown better performance in time domain nature of channel.

Keywords: *SER, MMSE, LS, OFDM, Lattice Type Pilot Scheme.*

I. INTRODUCTION

In Wireless communication, to compensate the requirement of high speed, large bandwidth and high throughput the orthogonal frequency division multiplexing (OFDM) technique has been successfully used in wireless networks. It provides the suitable output in multi-path fading. OFDM transmitted high data rate over a recurrence selective wireless medium with huge maximal multi-path propagation delay correlated with the symbol period. Therefore, OFDM is another option to Single Carrier approach.

Generally, two types of channel estimation schemes are being used in OFDM system, First technique is based on blind channel estimation and another one is pilot based channel estimation. The probabilistic nature of the received signals is utilized in blind channel estimation schemes whereas, in pilot based scheme, the pilot signals (priorily known to the receiver)are multiplexed along with the input data for channel estimation. In other popular algorithms such as; in block type, OFDM symbols with pilots at all subcarriers are being sent alternatively to estimate the channel. On the other hand, each OFDM symbol has pilot tones at the periodically located subcarriers in comb type estimation.

The most commonly used scheme to measure the performance of channel estimation is LS, MMSE and ZF. These all schemes have their own advantages, drawbacks and limitations. The scheme we have to use in this scheme is LS and MMSE because pilot symbols are available.

This paper, focuses the performance analysis of channel estimation and their comparison with the help of LS and MSE estimator over the time domain nature of channel using lattice type scheme. In section II, the introduction of multi carrier system is discussed, Estimation schemes are described in section III, the proposed scheme has been discussed in section IV and the simulation results have been analyzed in section V.

II. MULTICARRIER SYSTEM

OFDM is a most commonly used multicarrier system where frequency subcarriers are to be transmitted. OFDM block diagram in Fig.1 can be explained as: At transmitter symbols are followed by serial to parallel conversion then insert pilot symbols. After that, pilot symbols multiplexed with data carriers.

$$x(n) = \mathrm{IFFT}\{X(l)\}$$

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$$x(n) = \sum_{l=0}^{N-1} X(l)\, \mathrm{Exp}(j2\pi ln/N)$$

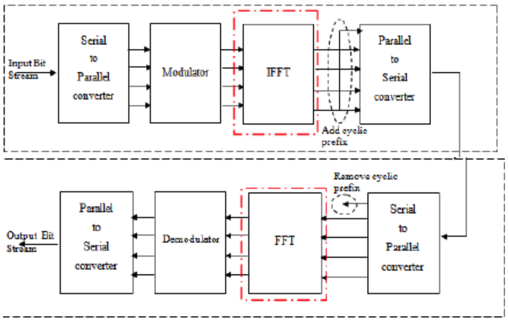

Fig.1

Where 'N' denoted the FFT point.

$$x(n) = \mathrm{IFFT}\{X(l)\}$$

$$x(n) = \sum_{k=0}^{N-1} X(l)\, \mathrm{Exp}(j2\pi kn/N)$$

To remove ISI, we add cyclic prefix represented by N_L.

$$x_L(n) = \begin{cases} x(N+n) \\ x(n) \end{cases}$$

The received signal $y_L(n)$ as:

$$y_L(n) = x_L(n)\otimes h(n)+v(n)$$

Before going to FFT cyclic prefix must be extracted as:

$y(n) = y_L(n+N_L)$ n=0,1,2………..N-1.

Therefore, $y(l)= \mathrm{FFT}\{y(n)\}$

$$y(l) = \frac{1}{N}\sum_{n=0}^{N-1} y(n)\, \mathrm{Exp}(-j2\pi ln/N)$$

Let us consider that there is no ISI, because length of $h(n)<N_L$(cyclic prefix interval).i.e.;

$$y(l)=\mathrm{FFT}\{x(n)\otimes h(n)+V(n)\}$$

$Y(l) = X(l)H(l)+V(l)$, l=1,2,…N. The estimation of received pilot symbols as: $X(l)= Y(l)/\hat{H}(l)$Where $H^{\wedge}(l)$ is the channel estimator and $Y(l)$ is the signal at receiver.

III. ESTIMATION SCHEMES

1. L-S Channel Estimator:

In the mathematical analysis of the LS$\hat{H}(l)$select in such a way that the following cost function is minimized:

$$q(\hat{H}) = \min.\|(Y - X\hat{H})\|^2$$

$$= (Y - X\hat{H})\,(Y - X\hat{H})^H$$

$$\frac{\partial q(\hat{H})}{\partial \hat{H}} = 0 = -2(X^HY)^* + 2(XX^H\hat{H})^*$$

Hence; we get $X^HX\hat{H} = X^HY$

$$\hat{H}_{LS} = (X^HX)^{-1}\, X^HY$$

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

$$\hat{H}_{LS}[l]= \frac{Y[l]}{X[l]}$$

Therefore, mean square error (MMS) of the L-S estimator as:

$$MSE = E\{(H-\hat{H})(H-\hat{H})^H\}$$

$$MSE = E\{(H-X^{-1}\, Y)(H-X^{-1}\, Y)^H\}$$

$$MSE = E\{Z^H(XX^H)^{-1}\, Z\}$$

$$MSE = E\{ZZ^H/XX^H\}$$

$$MSE = \sigma^2{}_Z/\sigma^2{}_X \qquad -(1)$$

It is observed that from equation (1), the MSE is having inverse relationship with the value of SNR $\sigma^2{}_Z/\sigma^2{}_X$, that clearly indicates if the channel is in deep fade noise is significantly increased. However, LS has fewer complexes and high value of MSE is the disadvantage of the LS estimator.

2. MMSE Channel Estimator:

Consider that channel is Gaussian with $N(0,\sigma^2)$ and uncorrelated. The MMSE estimate of H as:

$p(\hat{H}) = E\{\|(e)\|^2)$

Where $e = H - \hat{H}$ and $\hat{H}= V\bar{H}$

$p(\hat{H}) = E\{\|(H - \hat{H})\|^2\}$ -(2)

From the definition of orthogonally principle that the estimation error vector $e = H - \hat{H}$, is orthogonal to $\bar{H}$ such that

$$E\{e\, \bar{H}^H\} = E\{(H - \hat{H})\bar{H}^H\}$$

$$E\{(H-V\bar{H})\, \bar{H}^H\}$$

$$E\{(H\bar{H}^H) - V\, E\{\bar{H}\bar{H}^H\}$$

$$E\{e\, \bar{H}^H\} = R_{H\bar{H}}-VR_{\bar{H}\bar{H}} = 0$$

Where $R_{H\bar{H}}$ is the cross-correlation matrix of order NxN. Mathematically, $\bar{H}$ is as:$\bar{H}= X^{-1}Y = H + X^{-1}Z$

$$W = R_{H\bar{H}}\, R^{-1}{}_{\bar{H}\bar{H}}$$

$$\hat{H}= W\bar{H} = R_{H\bar{H}}\, R^{-1}{}_{\bar{H}\bar{H}}\, \bar{H}$$

$$\hat{H}_{MMSE}= R_{H\bar{H}}\, (R_{H\bar{H}} + \sigma^2{}_Z/\sigma^2{}_X\;\; I)^{-1}\, H$$

Hence, a major drawback associated in MMSE estimator is its more complex in terms of computational.

IV. PROPOSED SCHEME

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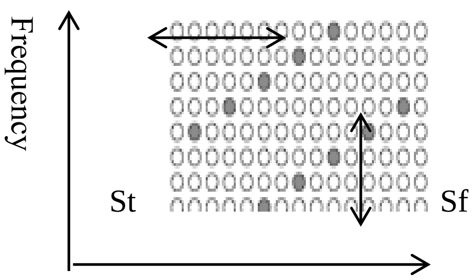
The proposed scheme suggests that the pilot tones have been inserted and transmitted along the time and frequency domain simultaneously, with in given time frame interval. In fig 2, the lattice-type pilot scheme has been presented. This is clearly shown that, the pilot tones are distributed in both time and frequency domains. Assume thatS_t and S_f indicates the periods of pilot symbols in time and frequency domain respectively. For frequency-selective channel characteristics, the pilot symbol arrangement must satisfy the criterion

$$S_t \leq \frac{1}{f_D} \text{ and } S_f \leq \frac{1}{\sigma_{max}}$$

Where f_D is the Doppler spread and σ_{max} is maximum delay spread respectively.



Time
Fig.2

V. RESULT AND DISCUSSION

In this section we are simulate the channel estimation using estimators discussed in section-III. We are used following simulation parameters for OFDM system shown in table-1.

Table-1: Simulation parameters

Parameters	Specification
FFT (In Number)	256
Cyclic Prefix(CP)Length	16
Number of Subcarriers	256
Total Symbol after CP	272
Pilot Spacing	4
Pilots Tones	128
Pilot Scheme	Lattice Type
Signal Modulation	16-QAM
Channel Taps	8
Doppler Spread	80HZ
Maximum Delay Spread	2.5μs

Simulation result of mean square error of least square (LS) and minimum mean square error (MMSE) estimator is given in fig 3 and fig 4.

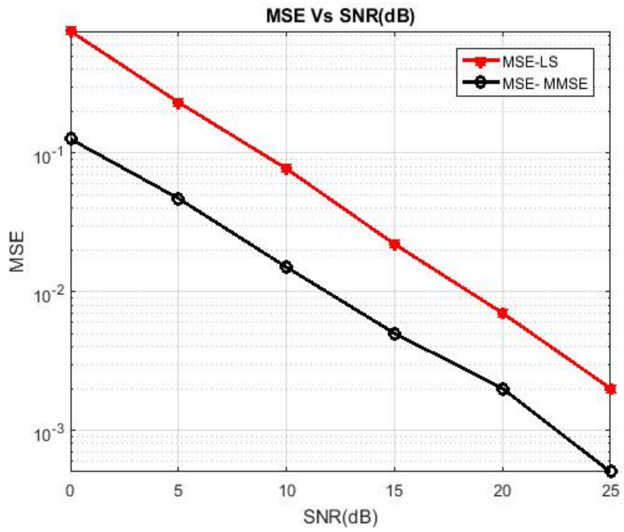


Fig.3

Table-2

SNR(dB)	MSE_LS	MSE_MMSE
0	0.755	0.126
5	0.232	0.047
10	0.077	0.015
15	0.022	0.005
20	0.007	0.002
25	0.002	0.0005

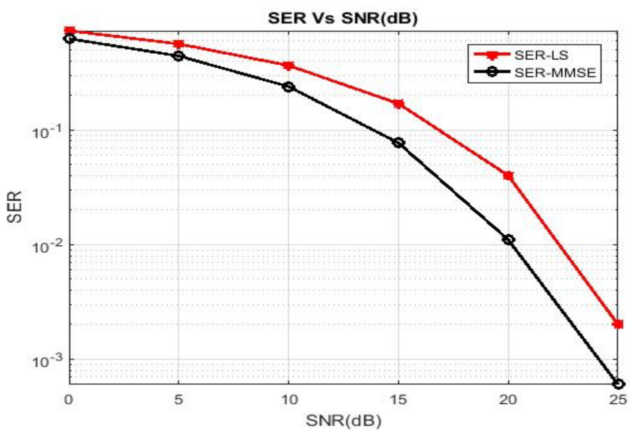


Fig.4

Table-3

SNR(dB)	SER_LS	SER_MMSE
0	0.734	0.625
5	0.563	0.442
10	0.365	0.239
15	0.17	0.077
20	0.04	0.011
25	0.002	0.0006

In figure 3 the SNR increases as MSE decreases for LS and MMSE both while Figure 4 shows that symbol error rate (SER) decreases as SNR increases progressively for both LS and MMSE estimators. MMSE estimator gives the better performance as compared to LS estimator for a particular value of SNR (dB).

VII. CONCLUSION AND FUTURE SCOPE

This paper shows the channel performance analysis of LS and MMSE over a time domain characteristics. By using lattice type scheme and transmitted signal covered all multipath propagation characteristics. But on the receiver side all channel argument should be minimized to reconstruction of the transmitted signal. Hence, above given performance analysis of MMSE gives better performance over LS channel estimator in time domain nature of channel.

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