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Channel Estimation in OFDM

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ABSTRACT

Orthogonal frequency division multiplexing (OFDM) is a special case of multi-carrier transmission and it can support high data rate requirement of multimedia based wireless systems. Since channel estimation is an integral part of OFDM systems, it is complicated to understand the basis of channel estimation techniques for OFDM systems so that the most proper method can be applied. The estimation of channel at pilot frequencies is based on LS and MMSE estimation techniques by using BPSK modulation scheme, and multi-path Rayleigh fading channels as channel models. The purpose of this paper is to use a Mat lab simulation of OFDM to see how the Bit Error Ratio (BER) of a transmission varies when Signal to Noise Ratio (S/N Ratio) and Multi propagation effects are changed on transmission channel.

Index Terms— BER, ISI, OFDM, S/N

INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has Presently been applied widely in wireless communication due to its high bandwidth efficiency and high data rate transmission capability and its robustness to multi-path delay. It has been used in wireless LAN standards such as American IEEE802.11a and in multimedia wireless services such as Japanese Multimedia Mobile Access Communications. A proper estimation of channel is necessary before the demodulation of OFDM signals since the radio channel is frequency selective and time-varying for wideband mobile communication systems [1].

In an OFDM scheme a large number of sub channels or sub-carriers are used to transmit digital data. Each sub-channel is orthogonal to every other. They are closely spaced and narrow band. The separation of the sub-channels is as minimal as possible to obtain high spectral efficiency. OFDM is being used because of its capability to handle with multipath interference at the receiver the main effects of multi propagation [2] is Frequency selective fading and Inter Symbolic Interference (ISI). In OFDM the large number of narrow band sub-carriers provides sufficiently "flat" channels. Therefore the fading can be handled by simple equalizing techniques for each channel. Furthermore the large amount of carriers can provide same data rates of a single carrier modulation at a lower symbol rate. The symbol rate of each channel can be dropped to a point that makes each symbol longer than the channel's impulse response, this eliminates ISI. The two main drawbacks of OFDM are the large dynamic range of the signals being transmitted and the sensitivity to frequency errors.

Using Mat lab simulation we can implement an OFDM transmission. Using the simulation we can easily change the values of S/N ratio and change the multi propagation effects on the transmission. Then we can analyze the results of each transmission and see how the BER is changed. The modulation scheme used is BPSK were we see the performance of LS & MMSE channel estimation techniques

1. OFDM SIMULATION

Code used in this paper is for checking the performance of LS & MMSE channel estimation techniques by using BPSK Modulation scheme. A scheme of every part of the implementation can be seen in Fig 1. In the end of the transmission, when the receiver receives the data, a comparison of the transmitted and the received data is done in order to calculate the Bit Error Ratio (BER).This paper does not explain in detail the simulation Code but it focuses on the results which we get after simulation

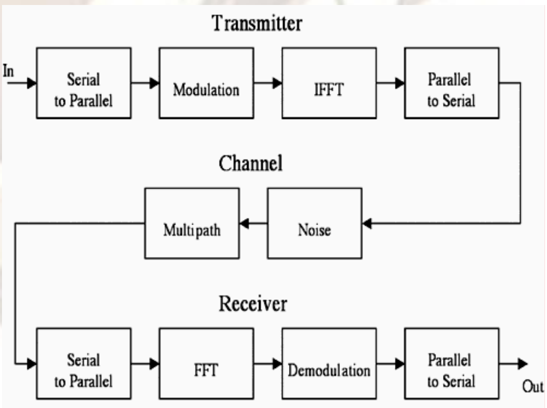

Fig.1: Mat lab Flow Chart

2. CHANNEL ESTIMATION

The two basic channel estimations in OFDM systems are illustrated in Figure 2. The first one, block-type pilot channel estimation, is developed under the assumption of slow fading channel, and it is performed by inserting pilot tones into all subcarriers of OFDM symbols within a specific period. The second one, comb-type pilot channel estimation, is introduced to satisfy the need for equalizing when the channel changes even from one OFDM block to the subsequent one. It is thus performed by inserting pilot tones into certain subcarriers of each OFDM symbol, where the interpolation is needed to estimate the conditions of data subcarriers [1].

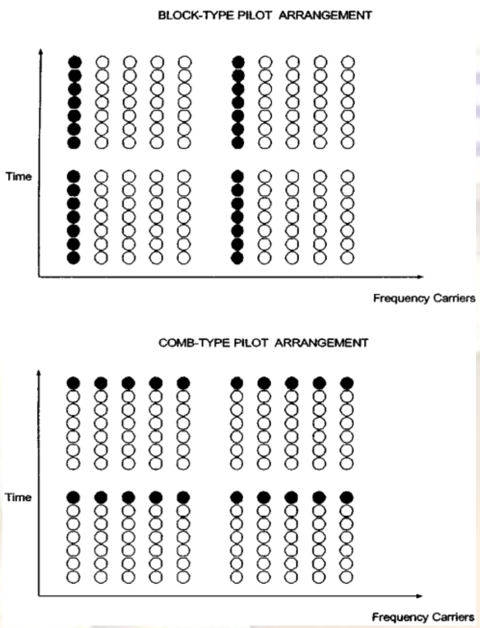

Fig.2: Pilot arrangement.

In block-type pilot-based channel estimation, as shown in Figure 2, OFDM channel estimation symbols are transmitted periodically, and all subcarriers are used as pilots. Since LS estimate is susceptible to noise and ICI, MMSE is proposed while compromising complexity. Since MMSE includes the matrix inversion at each iteration [3].

2.1 LS Estimator

The LS estimator minimizes the parameter $(\bar{Y}-\underline{X}\bar{H})^H(\bar{Y}-\underline{X}\bar{H})$ where $(\bullet)^H$ means the conjugate transpose operation. It is shown that the LS estimator of $\bar{H}$ is given by [1].

$$\hat{H}_{LS}=\underline{X}^{-1}Y=[(X_K/Y_K)]^T \quad (1)$$

2.2 MMSE Estimator

The MMSE estimator employs the second-order statistics of the channel conditions to minimize the mean-square error .Denoted by $\underline{R}_{gg}$, R_{HH}, R_{YY} the auto covariance matrix of $\bar{g}$, $\bar{H}$ and $\bar{Y}$,respectively and $\underline{R}_{gy}$ the cross covariance matrix between $\bar{g}$ and $\bar{Y}$.[1]Also denoted by σ^2_N the noise variance $E\{(|\bar{N}|^2\}$.Assume the channel vector $\bar{g}$ and the noise $\bar{N}$ are uncorrelated it is derived that

$$R_{HH}=E\{\bar{H}\bar{H}^H\}=E\{(\underline{F}\bar{g})(\underline{F}\bar{g})^H\}=\underline{F}\,\underline{R}_{gg}\underline{F}^H \quad (2)$$

$$\underline{R}_{gY}=E\{\bar{g}\,\bar{Y}^H\}=E\{\bar{g}(\underline{X}\underline{F}\bar{g}+\bar{N})^H\}=\underline{R}_{gg}\underline{F}^H\underline{X}^H \quad (3)$$

$$R_{YY}=E\{\bar{Y}\bar{Y}^H\}=\underline{X}\underline{F}\underline{R}_{gg}\underline{F}^H\underline{X}^H+\sigma^2_N\underline{I}_N \quad (4)$$

Assume $\underline{R}_{gg}$ thus (R_{HH}) and σ^2_N are known as receiver in advance, MMSE estimator of $\bar{g}$ is given $\hat{g}_{MMSE}=R_{gY}\,R_{YY}^{-1}\,\bar{Y}^{HH}$ note that $\bar{g}$ is not Gaussian , $\hat{g}_{MMSE}$ it is not necessarily a minimum mean-square error estimator, but it is still the best linear estimator in the mean-square error sense. At last, it is calculated that

$$\hat{H}_{MMSE}=\underline{F}\,\hat{g}_{MMSE}\;\underline{F}[(\underline{F}^H\underline{X}^H)^{-1}\underline{R}_{gg}^{-1}\sigma^2_N+XF]^{-1}\bar{Y}$$

$$=\underline{F}\,\underline{R}_{gg}[(\underline{F}^H\underline{X}^H\underline{X}\underline{F})^{-1}\sigma^2_N+\underline{R}_{gg}]\,\underline{F}^{-1}\hat{H}_{LS} \quad (5)$$

$$=\underline{R}_{HH}[\underline{R}_{HH}+\sigma^2_N(\underline{X}\,\underline{X}^H)^{-1}\hat{H}_{LS}$$

3. PLOTS OF BER AS A FUNCTION OF S/N RATIO

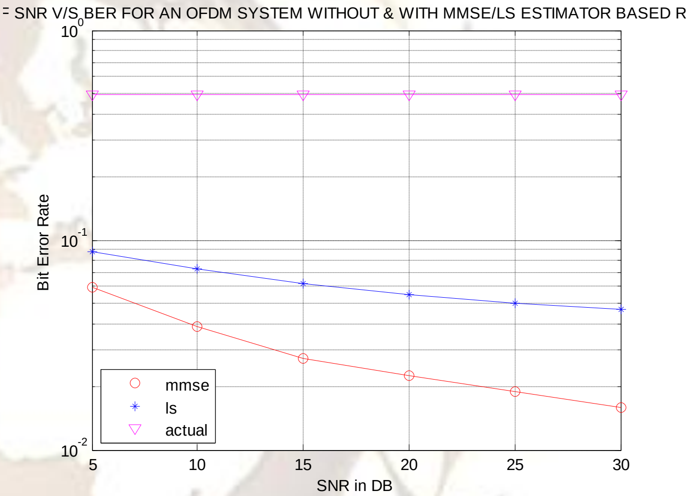

Fig.3: SNR V/S BER for an OFDM system without & with MMSE/LS estimation based receiver using BPSK modulation scheme

Conclusion

The estimators given in this paper can be used to efficiently estimate the channel in the OFDM system giving us certain knowledge about the channel statistics. Moreover its complexity of MMSE is large as compared to LS estimator. The above results of simulation are done by using 64 subcarriers in OFDM system. We can also see the effect of implementing the estimators such as the LS & MMSE in the OFDM system. The above results show us the SNR VS BER plot for with and without MMSE/LS based receiver using BPSK modulation scheme

Acknowledgement

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