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Performance Improvement of IEEE 802. 11a Receivers Using DFT based Channel Estimator with LS Channel Estimator

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Abstract:

In this paper the performance of one of the most widely deployed Wireless Local Area Networks (WLANs) based on IEEE 802. 11a standard has been analyzed using different modulation technique and convolution coding rates. The IEEE 802. 11a standard uses Orthogonal Frequency Division Multiplexing (OFDM) technique. In this analysis the channel estimation is pilot symbol based. A particular method proposed in literature, known as the Least Square Method (LS), along with its enhancement using Discrete Fourier transform (DFT) based estimator is investigated in this work. Three categories of channel profiles are considered for simulation, namely highly frequency selective, moderately frequency selective and frequency flat channels. The performances using these methods are compared by measuring raw bit-error-rate (BER) & mean square error (MSE), using 16 QAM modulation technique with different code rate in three different fading channel profile.

Keywords: Bit error rate (BER), Discrete Fourier transform (DFT), Least square (LS), Mean square error (MSE), Orthogonal Frequency Division Multiplexing (OFDM), Wireless Local Area Networks (WLANs).

I. Introduction

In the last decade of 20th century, wireless communication witnessed a huge proliferation and pervasive deployment in almost all spheres of life. Technology such as WLAN started gaining importance in home, corporate and public environments. The evolution of wireless technology has always been stimulated by the need for higher data rates. Orthogonal Frequency Division Multiplexing (OFDM) originated from the need of efficient higher data rates communications through frequency-selective fading channels. It divides an entire frequency selective channel into many narrow sub bands and makes the frequency response relatively flat in each individual sub band. The IEEE standard 802. 11a, deals with wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications works in the 5 GHz band using OFDM modulation technique and supports data rates up to 54 Mbps. However, several aspects have to be taken into account at the time of implementation of such OFDM based WLAN receivers. One of the most critical issues is the estimation of the channel at the receiver side. This paper deals with the efficient channel estimation problem at the receiver by using pilot symbols, and a DFT based channel estimation scheme is proposed for the OFDM-based WLAN systems. Simulation results are used to illustrate the performance of the proposed scheme.

II. System model

In this paper a typical IEEE 802. 11a system is considered. The OFDM symbol is composed of data and pilots subcarriers that are transformed to the time domain through the 64 point IFFT block. Generally in IEEE 802. 11a 48 sub-carriers, out of 64 are being used to provide the data rates specified in the standard [1]. Additionally, 4 sub-carriers are used as pilots that are helpful to minimize the frequency and phase errors along with estimating the channel. The specifications are given in Table 1[1].

Table 1: Specifications of IEEE 802. 11a

Parameters	Values
FFT size	64
Number of used subcarriers	52
FFT sampling frequency	20 MHZ
Subcarrier spacing	312. 5 KHz
Cyclic prefix duration	0. 8µs
Data symbol duration	3. 2 µs
Used subcarrier index	-26 to-1, +26 to +1

The OFDM transmission scheme is an implementation of multicarrier transmission which transforms a frequency selective wide-band channel into a group of non-selective narrow-band channels that makes its robust against large delay spreads by preserving orthogonality in the frequency domain. The block diagram of the IEEE 802. 11a OFDM receiver with channel estimator is shown in Fig 1.

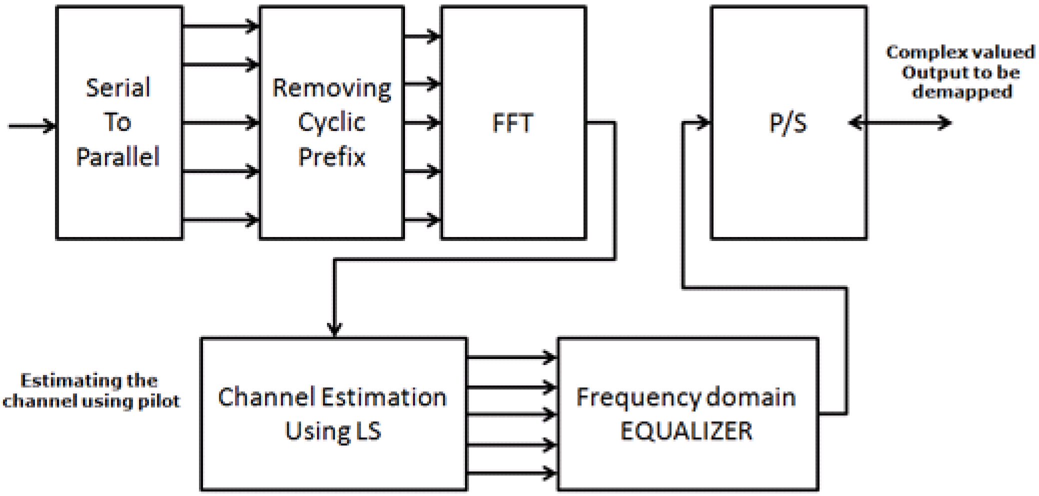


Fig.1. Block diagram of IEEE 802.11a receiver

III. Pilot based channel estimation

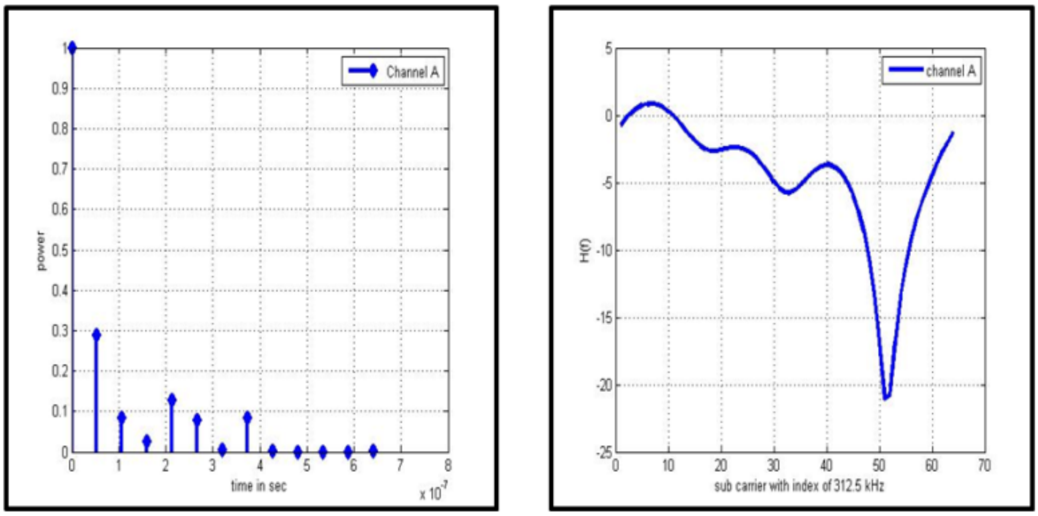
Generally the algorithm of channel estimation can be divided into three aspects: estimation based on the assistant of pilot frequency, estimation based on the supervision of judgment, and estimation of blind or half-blind channel. The perfect algorithm that is extensive used is the channel estimate based on the assistant of pilot frequency. This algorithm demands to insert symbol of pilot frequency in some fixed position of signal, offers the receiver to estimate the channel according to certain algorithms. It is observed that the algorithm based on the assistant of pilot frequency gets better precision within short time. Even if it brings loss of certain bandwidth and power, it is still adopted by most wireless communication systems. In the algorithm of pilot frequency assistant, the most basic one is Least Square (LS).

Model of wireless channel

To investigate the performance of a wireless communication system, a fading channel simulator must be implemented. A multipath fading channel can be mathematically modeled as a FIR filter having path gains as tap weights or filter weights. The impulse response of a multipath fading channel can be mathematically written as Eq 1.

$$h(t;\tau) = h_0(t)\delta(\tau - \tau_0(t)) + h_1(t)\delta(\tau - \tau_1(t)) + \ldots\ldots + h_{L-1}(t)\delta(\tau - \tau_{L-1}(t)) \qquad (1)$$

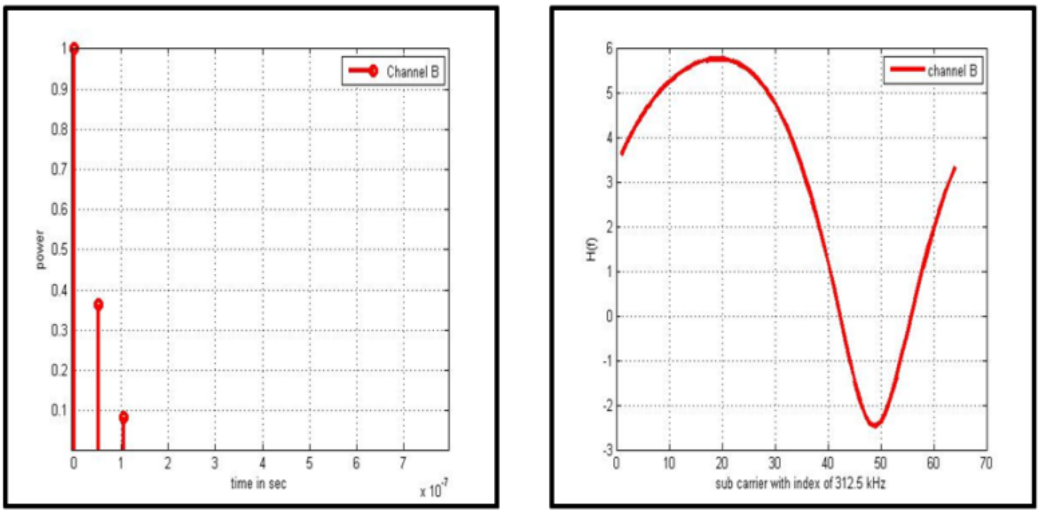
Where $h(t;\tau)$ is the time-varying impulse response of the L path fading channel. $h_i(t)$ and $\tau_i(t)$ denote the time-varying complex gain and excess delay of the i^{th} path respectively. In this work three types of multipath channels are simulated. Channel A is having 13 taps and happen to be a frequency selective channel with low coherence bandwidth, channel B is having 3 taps with quite more coherence bandwidth than profile A, channel C is a frequency flat channel having high coherence bandwidth. The frequency responses and multipath delay profile of these three channels are shown in fig 2, 3, 4.



Multipath delay profile of channel A

Frequency Response of channel A

Fig-2: PDP and frequency response of channel A



Multipath delay profile of channel B

Frequency Response of channel B

Fig-3: PDP and frequency response of channel B

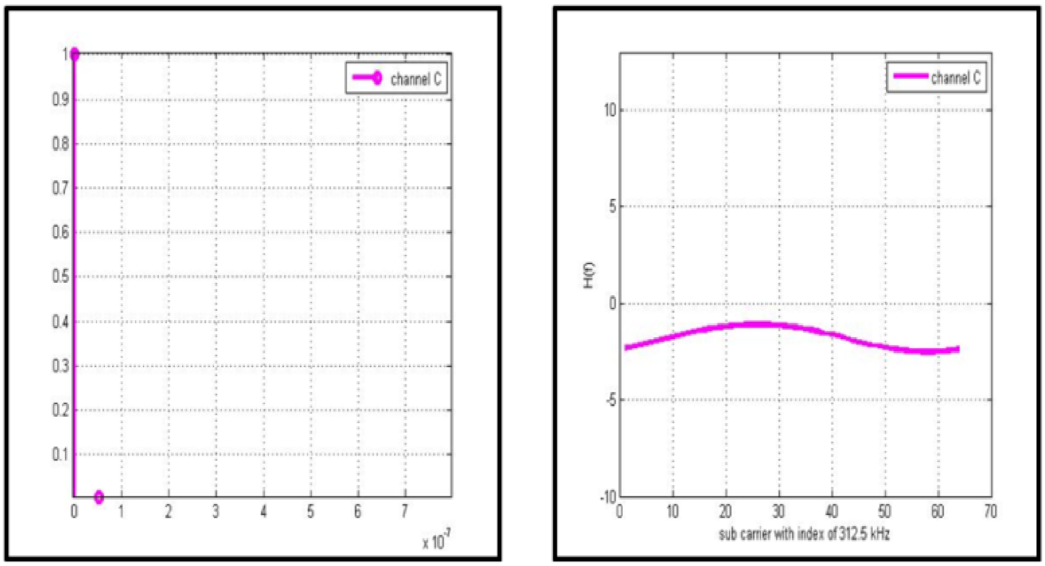


Fig-4: PDP and frequency response of channel C

Ls channel estimation algorithm

The least-square (LS) channel estimation method finds the channel estimate $\hat{\boldsymbol{H}}$ in such a way that the following cost function is minimized as shown in eq 2.

$$j(\hat{H}) = \|Y - X\hat{H}\|^2 = (Y - X\hat{H})^H (Y - X\hat{H})$$
$$= Y^H Y - Y^H X\hat{H} - \hat{H}^H X^H Y + \hat{H}^H X^H X\hat{H} \qquad (2)$$

Where X is the transmitted OFDM symbol in frequency domain, and Y is the result of FFT transform to the received OFDM symbol, H is response of channel in frequency domain. $\hat{H}$ represents the estimated value of H. By setting the derivative of the function with respect to $\hat{H}$ to zero the Eq 3 – is simplified as shown in eq 3.

$$\hat{H}_{LS} = X^{-1}Y, \hat{H}_{LS_k} = {Y(k)}/{X(k)} \qquad (3)$$

Then after estimating the channel in pilot indexes, different interpolation techniques are used to find out the channel at data indexes using estimated channel coefficients of pilot indexes. In this work two such interpolation techniques, Linear and Spline interpolations are used.

DFT-based channel estimation algorithm

The DFT-based channel estimation technique is used to improve the performance of LS channel estimation by eliminating the effect of noise outside the maximum channel delay. The estimated channel frequency response is converted into time domain and again its frequency response is estimated[3]. Let $\hat{H}_{LS_k}$ is the channel estimate at the pilot indexes, which is estimated by LS method. Taking the IDFT of the channel estimate results into Eq 4.

$$IDFT\{\widehat{H}(k)\} = h(n) + w(n) \cong \hat{h}(n) \tag{4}$$

Where n = 1, 2 …N-1 and $w(n)$ is the white noise in time domain. Now defining the channel coefficients in time domain up to the maximum channel delay as Eq 5.

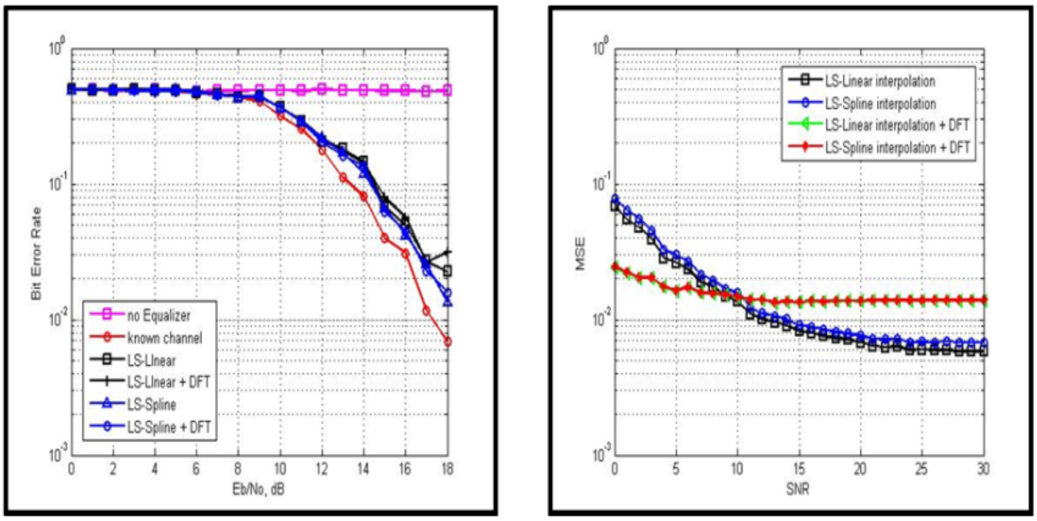
$$\hat{h}_n{}^{LS} = \begin{cases} h(n) + w(n), n = 0, 1, 2..L-1 \\ 0\ Otherwise \end{cases} \tag{5}$$

Then those L time domain channel estimates are again converted into frequency domain as shown in Eq 6.

$$\widehat{H}_n{}^{LS} = DFT\{\hat{h}_n{}^{LS}\} \tag{6}$$

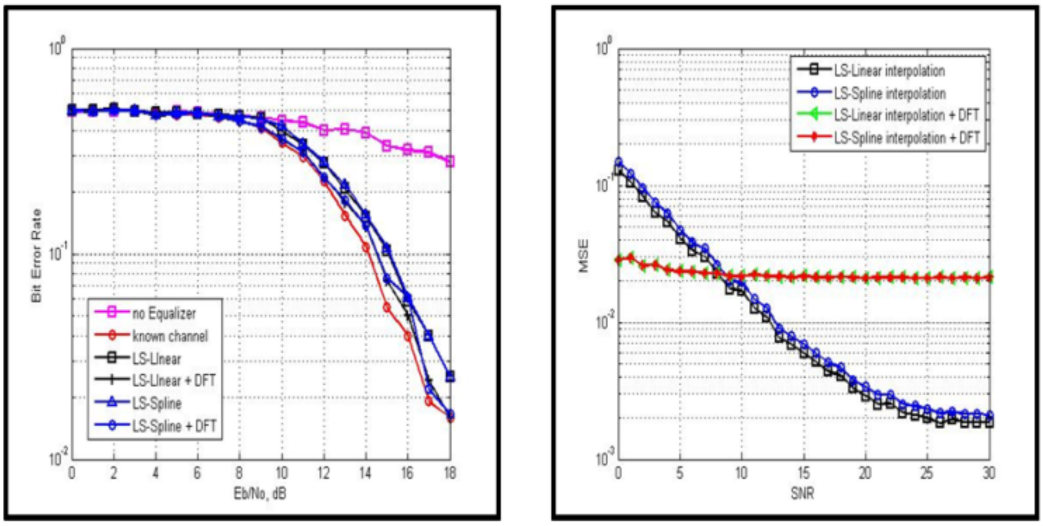
IV: Channel estimation for ieee 802. 11a receiver

Accurate channel estimation is important for the application of simple channel equalization and the accuracy of the channel estimation is crucial to the performance of the overall OFDM systems in terms of the Bit error rate (BER). In this paper, referencing to the IEEE 802. 11a standard, a pilot symbol based channel estimation scheme using the LS and DFT based algorithm is proposed for the OFDM-based WLAN systems. Simulation results indicate that the proposed scheme of DFT based algorithm exhibits good performance and is robust in harsh fading channel environments in low SNR conditions. Transmitted data is constructed according to IEEE 802. 11a WLAN standard in [1]. 16 QAM modulations is used with a convolution coding rate of ½ and ¾ The pilots are arranged as comb type [6]. The BER vs SNR and MSE vs SNR plots for all three channel profiles are shown in Fig 5, Fig 6, Fig 7 respectively.



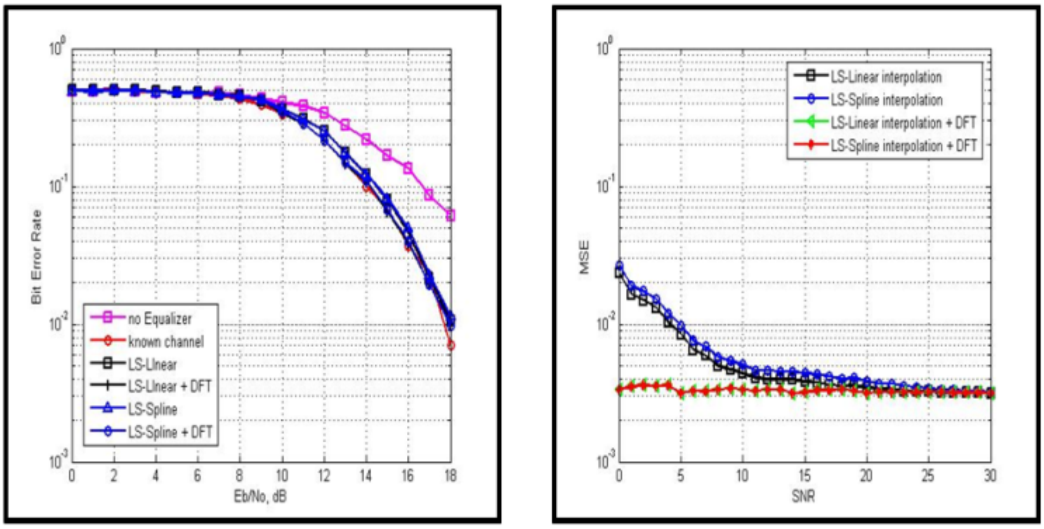
BER vs SNR MSE vs SNR

Fig-5: Performance in Channel A using different Channel Estimators



BER vs SNR MSE vs SNR

Fig-6: Performance in Channel B using different Channel Estimators



BER vs SNR MSE vs SNR

Fig-7: Performance in Channel C using different Channel Estimators

V: Conclusion

In this paper, an effective channel estimation procedure using pilot symbols and DFT algorithm with existing LS algorithm is analyzed and found that DFT based estimators along with LS estimators performs better in low SNR conditions where as In high SNR conditions the LS estimators performance is better.

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