

# An Improved Algorithm for Channel Estimations of OFDM system based Pilot Signal

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**Abstract**—This paper presents a new algorithm for the channel estimation of the OFDM system based on a pilot signal for the new generation of high data rate communication systems. In orthogonal frequency division multiplexing (OFDM) systems over fast-varying fading channels, channel estimation and tracking is generally carried out by transmitting known pilot symbols in given positions of the frequency-time grid. In this paper, we propose to derive an improved algorithm based on the calculation of the mean and the variance of the adjacent pilot signals for a specific distribution of the pilot signals in the OFDM frequency-time grid then calculating of the entire unknown channel coefficients from the equation of the mean and the variance. Simulation results shows that the performance of the OFDM system increase as the length of the channel increase where the accuracy of the estimated channel will be increased using this low complexity algorithm, also the number of the pilot signal needed to be inserted in the OFDM signal will be reduced which lead to increase in the throughput of the signal over the OFDM system in compared with other type of the distribution such as Comb type and Block type channel estimation.

**Keywords**—Channel estimation, orthogonal frequency division multiplexing (OFDM), Comb type channel estimation, Block type channel estimation.

## I. INTRODUCTION

ORTHOGONAL frequency division Multiplexing (OFDM) is a special form of the multi-carrier modulation. Multi-carrier modulation splits a wideband signal into a number of narrowband signals, sends them through corresponding narrow band channels, and combines the data received at the receiver.

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In frequency selective fading channels wideband signals suffer inter-symbol interference while those narrowband signals only experience at fading.

Therefore, OFDM systems are strong candidates for an air interface of future fourth-generation mobile wireless systems. In order to achieve the potential advantages of OFDM systems, the channel coefficients should be estimated carefully. To reduce inter-carrier interference we need to estimate the channel and the parameters used to approximate the channel variations.

The channel estimation can be improved using more pilot symbols [1]. Most of the channel estimation techniques for OFDM systems are based on pilot tones sent along side with data. OFDM systems are usually used in the time varying frequency selective fading channel where the channel variant across the sub-carriers of the OFDM symbols. Therefore, the pilot samples which are embedded in the OFDM symbol used to estimate and calculate the channel coefficient. Pilot samples are distributed uniformly in time and frequency axes [2], where this distribution should be known for the receiver to extract the channel coefficient from those pilots using the LS.

The most common types of the distribution of the pilot in the OFDM symbols are the comb and block type, where comb type channel estimation uses Part of the sub-carriers are always reserved as pilot for each symbol, while the block type channel estimation uses all sub-carriers are used as pilot in a specific period [3].

In this paper, we proposed a new distribution of the pilot samples across the OFDM symbols which consider the sequence of the channel variation through the symbols where an improved algorithm will be used for the estimation of the channel which is suitable for such distribution of the pilot which is based on the calculation of the mean and the variance of those pilot.

## II. SYSTEM MODEL

In this section, the transmitter and receiver of the OFDM system will be described including the pilot insertion block with the pilot distribution which is used in this system.

### A. Transmitter Structure

As illustrated in Fig. 1, the vector of data  $s$  is first mapped accordingly to the constellation and the vector of data symbols. Then For pilot symbol aided channel estimation,  $N_f$  and  $N_t$  pilot symbols are inserted periodically with the distance  $D_f$  and  $D_t$  in frequency and time grid respectively with the insertion of a single pilot sample of the last sample of each

symbol adjacent to the uniformly distributed pilot samples symbol, as shown in Fig. 2, as the serial vector of the result data converted to  $N \times K$  vectors by a serial-to-parallel converter where  $N$  is the number of total sub-carriers in one OFDM symbol and  $K$  is the total number of OFDM symbols in the frame. At this time, each OFDM symbols vector in the frame  $x_N = [x_1(k) \ x_2(k) \ x_3(k) \ \dots \ x_M(k)]$  will be modulated using  $N$  point Inverse Fast Fourier Transform (IFFT). At the terminal end of the transmitter, the resulted OFDM vector in the frame will be sent serially through the time varying frequency selective channel. The channel will be described using baseband equivalent impulse response as  $h(k) = [h_1(k) \ h_2(k) \ \dots \ h_{L_f}(k)]^T$  where  $L_f$  is the length of channel [4].

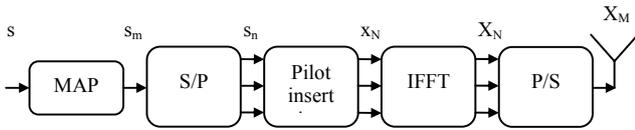


Fig. 1 The transmitter structure of the OFDM system

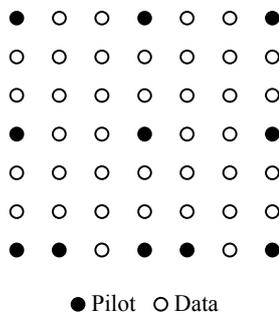


Fig. 2 Pilot distribution for OFDM systems in the frequency-time grid

### B. Receiver Structure

At the receiver side shown in Fig. 3, the received signal will be demodulated using  $N$  point (FFT), where the resulted signal will be as follow:

$$y_n(k) = x_n(k)H_n(k) + n_n(k) \quad k = 1, 2, \dots, K \quad n = 1, 2, \dots, N \quad (1)$$

Where  $n_n(k)$  is the FFT sample of the additive white Gaussian noise, and  $H_n(k)$  is the frequency domain of the channel coefficient for the  $n$ th sub-carrier and the  $k$ th OFDM symbol.

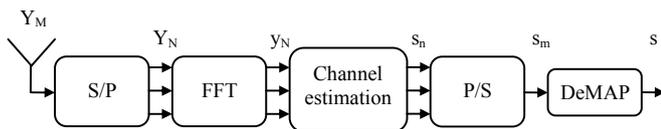


Fig. 3 The Receiver structure of the OFDM system

Now, the obtained signal at the pilot signal position will be used to extract the channel coefficient of that known pilot

signal using LS channel estimation in frequency domain as the receiver know the signal at that point as:

$$\tilde{H}_p(k) = \frac{y_p(k)}{x_p(k)} = H_p(k) + \frac{n_p(k)}{x_p(k)} \quad (2)$$

Where  $x_p(k)$  is the pilot sample in the OFDM signal,  $\tilde{H}_p(k)$  is the coefficient of the channel at that pilot sample [5].

### C. An Improved Algorithm for Channel Estimation Based on Pilot Sample

Using those extracted channel coefficients at that pilot to estimate the rest channel coefficients for the OFDM signal. In order to obtain estimated channel coefficients for all sub-carriers the mean and the variance of two adjacent channel coefficient extracted from those pilot samples, and then using the equation of the mean and variance to calculate the estimated channel coefficients as follow:

- 1) Calculating of the mean and the variance of the two channel coefficient which has been extracted from the pilot sample in the same time period of OFDM symbol as follow:

$$Mean(h_{p,p+1}) = \frac{1}{N_p} \sum_{i=1}^{N_p} h_i \quad (3)$$

$$\sigma^2(h_{p,p+1}) = \frac{1}{N_p} \sum_{i=1}^{N_p} (h_i - \bar{h}_{p,p+1})^2 \quad (4)$$

Where  $N_p$  is the number of pilot used in the equation.

- 2) Multiplying the calculated variance by a factor  $\xi$  where  $\xi=0.556$ .
- 3) Calculating the value of the two entire samples between the two pilots using the following equation:

$$h_{e1,2} = \frac{c_1}{2} \pm \sqrt{c_2 + \left(\frac{c_1}{2}\right)^2} \quad (5)$$

Where  $h_e$  is the estimated coefficient of the channel while  $c_1$  and  $c_2$  will be calculated as follow:

$$c_1 = N \times Mean - (h_p + h_{p+1}) \quad (6)$$

$$c_2 = \frac{N_p \times \bar{h}^2 + N_p \times \xi \times \sigma^2 - (h_p + h_{p+1} + c_1)}{2} \quad (7)$$

- 4) Now for the calculation of the channel coefficient between OFDM symbol the same cited procedure will be used but with aid of the past calculated coefficient to calculate the mean and the variance and modified by  $\alpha$  and  $\beta$  factor respectively. Where  $\alpha$  and  $\beta$  factor will be explained with aid of schemes. In this paper we will propose that those factors will be known.

### D. $\alpha$ and $\beta$ Factors

$\alpha$  and  $\beta$  Factors are the modification factor for the mean and variance of the two adjacent pilot sample of the same sub-carrier of the OFDM symbols. Where these two factors are limited to unity value as those factor are fluctuated around the value of one. By testing the Probability Density Function (pdf)

of these factors it was found that these two factors limited to one as the channel length  $L_f$  increase as shown in Fig. 4 and 5.

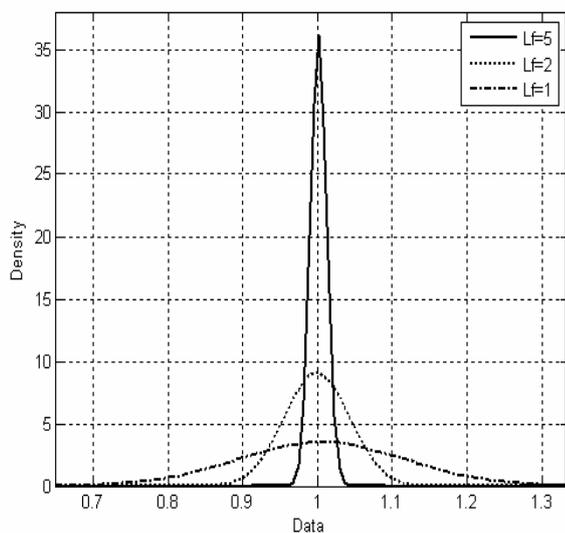


Fig. 4 Probability density function of  $\alpha$  factor for different length of the channel

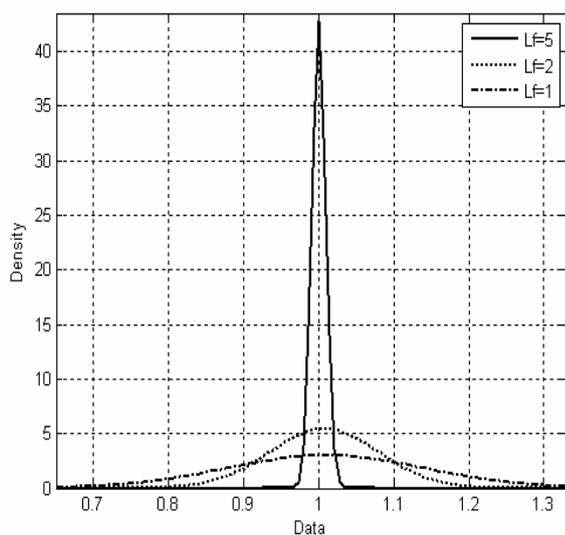


Fig. 5 Probability density function of  $\beta$  factor for different length of the channel

### III. SYSTEM PERFORMANCE

In this section, the performance of the OFDM system of the proposed channel estimation using an improved algorithm will be evaluated under different channel length  $L_f$  of Rayleigh fading channel. Where as can be seen that the performance of the system under 12 and 10 tabs of the channel fading are much better that under 6 and 4 tabs.

Fig. 6 shows the bit error rate (BER) performance of the estimated channel of the OFDM system according to the Signal to Noise ratio (SNR), where it is obviously that the performance of the system increased as the length of the channel increased.

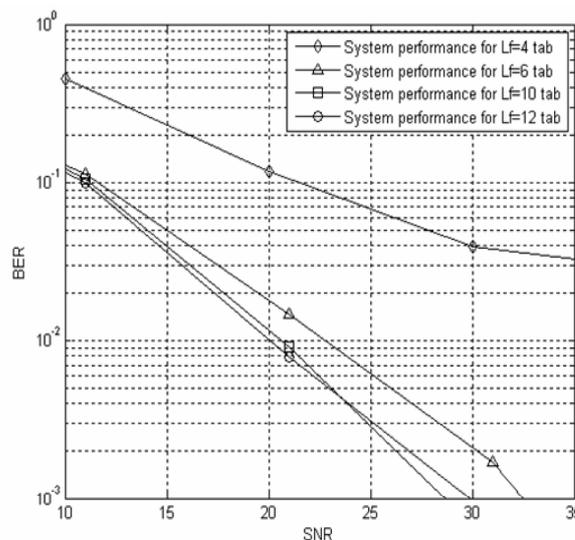


Fig. 6 performance of the OFDM system for different length of Rayleigh fading channel

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