OFDM Channel Estimation Based on the FFT Processing and Linear Interpolation

Hamidreza Rabiee[1], Javad Haddadnia[2*], Omid Rahmani Seryasat[3],

[1,] Department of Electrical and Computer Engineering, Hakim Sabzevari University, Sabzevar, Iran
[2.] Associate Professor, Electrical and Computer Engineering Department, Hakim Sabzevari University & Center for Research of Advanced Medical Technologies, Sabzevar University of Medical Sciences, Sabzevar, Iran
[3,] Department of Electrical and Industrial Engineering, Takestan branch, Islamic Azad University, Takestan, Iran; Department of Electrical and Computer Engineering, Hakim Sabzevari University, Sabzevar, Iran

[*]Corresponding author: Haddadnia@sttu.ac.ir

Abstract. In this paper, a new training-based channel estimation algorithm for orthogonal frequency division multiplexing (OFDM) systems is proposed in fast fading channels. This method is based on the FFT processing and linear interpolation. In the first step, channel response is calculated at pilot subcarriers by least square (LS) method. Then whole channel frequency response (CFR) is achieved by linear interpolation. In the next step, channel impulse response (CIR) is obtained by getting inverse Fourier transform of CFR. studying of CIR shows the most of energy concentrated into a few of taps. By zeroing other taps, effect of noise on channel is reduced, and then data is detected. Computer simulation show that proposed method improved performance compared to conventional estimation methods.

[Hamidreza Rabiee, Javad Haddadnia, Omid Rahmani Seryasat. **OFDM Channel Estimation Based on the FFT Processing and Linear Interpolation.** *Life Sci J* 2013;10(2s):175-180] (ISSN: 1097-8135). http://www.lifesciencesite.com.30

Keywords: Channel Estimation, OFDM, Linear Interpolation, FFT, IFFT.

1- Introduction

Wireless communication and data transmission systems are demanded these days and are used in many applications. These Systems have many challenges and restrictions. Channel estimation and destruction by channel, power limitation on data transmission, complexity of mobile receivers, and limited band width that should be shared between multiple users are some of these challenges. Among of wireless techniques, orthogonal frequency division multiplexing (OFDM) has many advantages and especially is noticed in frequency selective Rayleigh-channels. OFDM is a general technique in signal transmission on the wireless communication that converts a frequency selective channel to a collection of flat frequency selective sub-channels that leads to simplicity of receiver structure [1].

In this systems, inter-symbol interference (ISI) can be removed by using of a cyclic prefix (CP).Cyclic prefix is inserted between consecutive transmitted blocks and should be increased beyond the maximum delay expansion of channel. A good delineation of this parameter lead to simpler channel synchronization and the effect of channel appear as a simpler scalar multiplication in the frequency domain.

In OFDM systems, detection of transmitted data and capacity of system highly depends on channel state information (CSI) in transmitter and receiver. In other words, coding, modulation and interference prevention methods can be applied in these systems with knowledge of channel characteristics. If channel is estimated accurately, undesirable effects on channel response will be avoided.

In recent years, several channel estimation methods have been proposed. Reviewing these methods reveals that achieving more accuracy leads to more complexity. So, a simple and precise method is needed. The CSI can be obtained through two methods: 1) blind channel estimation 2) training-based channel estimation.

Blind channel estimation explores the statistical information of channel and certain properties of transmitted signal and needs a large amount of data. Hence this method is not proper in fast fading channels. Training-based channel estimation is based on the training data, which is inserted into main data, sent at the transmitter and known a priori at the receiver [2].

In this paper, training- based channel estimation is applied. Pilot symbols, which is known in transmitter and receiver, are used for initial estimation or training. For inserting the pilot in OFDM symbols, two major methods were proposed: Block-type and Comb-type.

Comb-type pilot initialization has been applied for fast channel variations and Block- type is proper for slow channel variations [4, 5, 6].
In training-based channel estimation, two usual algorithms for channel coefficients obtaining in pilot subcarriers are available: 1) minimum mean square error (MMSE), 2) Least square (LS) [7].

In this paper, a new channel estimation method based on the training data is proposed for OFDM systems and comb-type pilot arrangement is applied. In this method CFR will be estimated.
In first step, channel coefficients at pilot subcarriers are obtained by LS algorithm. Then whole CFR is obtained by linear interpolation of achieved coefficients of channel. In the next step, noise effect on the whole CFR is reduced by a kind of FFT processing and zeroing some taps of CIR. Simulation results demonstrate that proposed method improved performance compared to conventional methods and noise effect is reduced very well.
The rest of this paper is organized as follow. In section 2, we briefly describe OFDM systems and channel model. Then in section 3, proposed method is presented. Finally we show simulation results in section .

2- OFDM Systems and Channel Model

In OFDM systems, data is transmitted on narrow-band sub-carriers in frequency domain. Figure 1 shows some of these sub-carriers in frequency domain. Sub-carriers have overlap in frequency channel interference (ICI) can be completely removed.

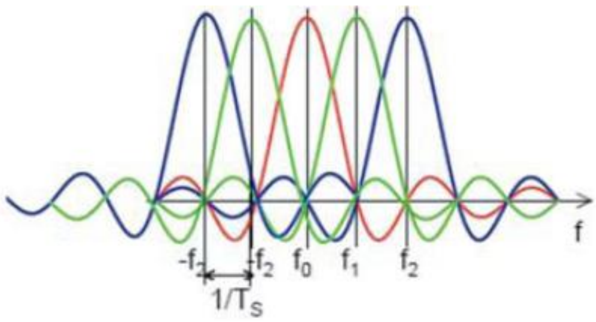

Fig. 1. Sub-carriers in an OFDM system

Fig. 2 shows a block diagram of an OFDM system that how data transmitted and received.

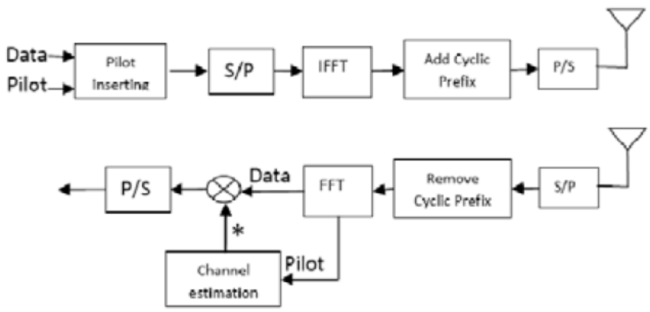

Fig. 2. Block diagram of an OFDM system [1]

In these systems, after pilot insertion between data sequence at the transmitter, the resultant data is modulated using inverse discrete Fourier transform (IDFT) on N parallel sub-carriers. The number of points of the IDFT/DFT is equal to the total number of sub-carriers.

Every subcarrier can be formulated as follow:

$$S_c(t) = A_c(t).e^{j[\omega_c t+\Phi_c(t)]} \qquad (1)$$

Where, $A_c(t)$ is the amplitude and $\Phi_c(t)$ is the phase of sub-carrier: An OFDM signal is constructed from some of these sub-carriers, so it can be described as follows:

$$S_s(t) = \frac{1}{N}\sum_{n=0}^{N-1} A_n(t).e^{j[\omega_n t+\Phi_n(t)]} \qquad (2)$$
$$\omega_n = \omega_0 + n\Delta$$

$A_c(t)$ and $\Phi_c(t)$ get different values in different symbols, but they constant in every symbol and only depend on frequency of carriers. It means that in every symbol we have:

$$\Phi_n(t) \Rightarrow \Phi_n$$
$$A_n(t) \Rightarrow A_n \quad (3)$$

If signal is sampled with 1/T (T is the duration of a symbol) and equation (3) is inserted into equation (2), we will have:

$$S_s(KT) = \frac{1}{N}\sum_{n=0}^{N-1} A_n(t).e^{j[(\omega_n + n\Delta\omega)KT + \Phi_n]} \quad (4)$$

It is clear that if $\omega_0 = 0$, equation (3) is converted to an IDFT transform. Therefore, OFDM modulation is an IDFT transform inherently. In continuation cyclic prefix is inserted. Cyclic prefix is a crucial feature of OFDM that is used to prevent the inter-symbol interference (ISI) and inter-channel interference (ICI). ISI and ICI are produced by the multi-path channel through which the signal in propagated. Cyclic prefix protects orthogonality between sub-channels. The duration of the cyclic prefix should be longer than the maximum delay spread of the multi-path environment.

$$x_T(n) = \begin{cases} x(N+n), n = -N_{cp}, -N_{cp}+1, \dots, 1 \\ x(n), n = 0, 1, \dots, N-1 \end{cases} \quad (5)$$

To add cyclic prefix, a part of the end of the OFDM time-domain waveform is added to the beginning of it. Cyclic prefix is caused that circular convolution is converted to linear convolution. Therefore the effect of the channel on each sub-carrier can be presented by a single complex multiplier that is shown in equation (6):

$$Y(k) = S(k).H(k) + W(k) \quad (6)$$

Where, $H(k)$ is the Fourier transform of channel impulse response (CIR).
The frequency selective channel is modeled as a finite impulse response (FIR) filter as follows:

$$h(n) = \sum_{i=0}^{L} g_i.\delta(n - \lambda_i)$$

(7)

While L is number of paths and g_i is the channel gain in i^{th} path and is independent complex Gaussian random process with zero mean and unit variance, and λ_i is the delay of the i^{th} path. Therefore,

$$H(k) = FFT\{h(n)\} = \frac{1}{N}\sum_{n=0}^{N-1} h(n).e^{-j(2k\pi/N)}$$
$$k = 0, 1, \dots, N-1$$

(8)

3- Proposed channel estimation algorithm

In this paper, training-based channel estimation is applied and comb-type pilot arrangement is used for training data. Block diagram of proposed method is briefly shown in figure 3.

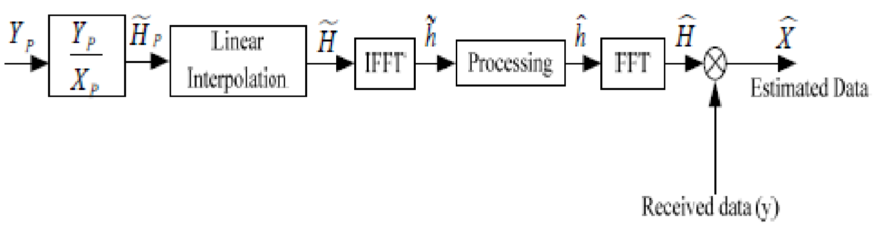

Fig. 3. Proposed channel estimation structure block diagram

3.1- step 1: Obtaining Channel Coefficients at Pilot Subcarriers

After removing cyclic prefix and getting DFT from received signal, channel coefficients in pilot subcarriers are estimated by LS algorithm.

$$H_p(k) = \frac{Y_p(k)}{X_p(K)}, k \in pilot - index$$

(9)

3.2- step2: Obtaining Whole CFR by Linear Interpolation

After obtaining channel response at pilot subcarriers, whole CFR can be achieved by interpolating of these coefficients. In this method, linear interpolation is used too, because of its low complexity.

$$\tilde{H}_p(k) \rightarrow (\text{interpolation})\tilde{H}$$

(10)

3.3- step 3: FFT Processing for Reducing Noise Effect on the Achieved CFR

Achieved channel coefficient don't have enough accuracy because AWGN noise is added to transmitted signal and degrades it and decrease accuracy. In [9], in order to reduce noise effect, a FFT processing has been proposed. We have applied that method with some changes.

In this improved method, the magnitudes of channel taps, which are achieved from channel coefficients at pilot subcarriers, have been considered. Figure 4 shows a typical magnitude of channel impulse response (CIR) with noise effect. it is obvious that a large amount of energy is concentrated into a subset of taps.

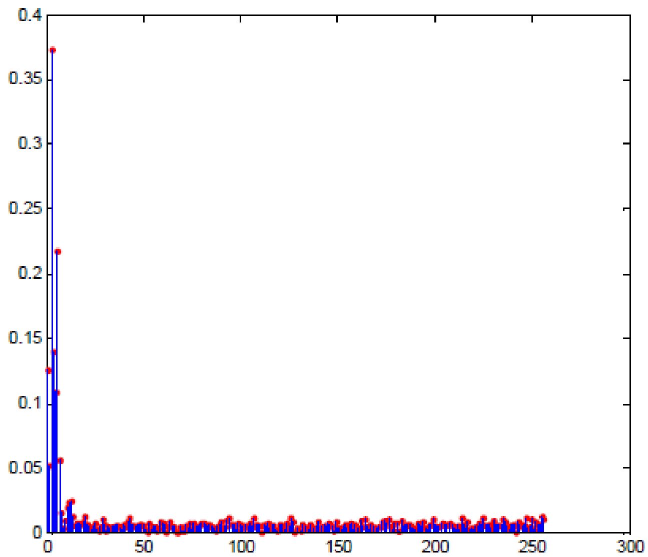

Fig. 4. Typical magnitude of CIR

By zeroing the taps out of this subset, only major taps remain and noise effect on these coefficients is reduced. We use below algorithm to determine taps which have major energy. At first, magnitude of CIR is calculated by getting IFFT of H_p .

$$\tilde{e}(n) = \left| \sum_{k=0}^{N-1} \tilde{H}(k).e^{j(2k\pi n/N)} \right|$$

$$n = 0,1,\ldots, N-1$$

(11)

Where N is number of OFDM carriers. Then total energy is calculated.

$$\tilde{E}_{Total} = \sum_{n=0}^{N-1} \tilde{e}(n)$$

(12)

And then major taps are specified

4- Simulation results

In this paper, simulations are performed for an OFDM system with 256 subcarriers. Data modulation is QAM and comb-type pilot arrangement is used. The number of pilot subcarriers per OFDM is 32 and cyclic prefix length is 32. Channel coefficients in pilot subcarriers are estimated by using LS algorithm and channel interpolation is performed by linear interpolation. The studied channel model is frequency selective Rayleigh model with 5 paths and channel changes per every OFDM symbol. Proposed algorithm is used to reduce the noise effect on channel estimation and improve performance. This method is compared with Spline interpolator and GRBFN interpolator. For evaluating of performance of proposed channel estimator, mean square error (MSE) criteria based on estimation errors versus SNR are presented in figure 5. In this figure, the comparison of several channel estimation methods is shown: LS estimation with Sp-line interpolation, LS estimation with GRBFN interpolation, LS estimation with linear interpolation and applying step 2 of proposed algorithm is better than the other mentioned methods.

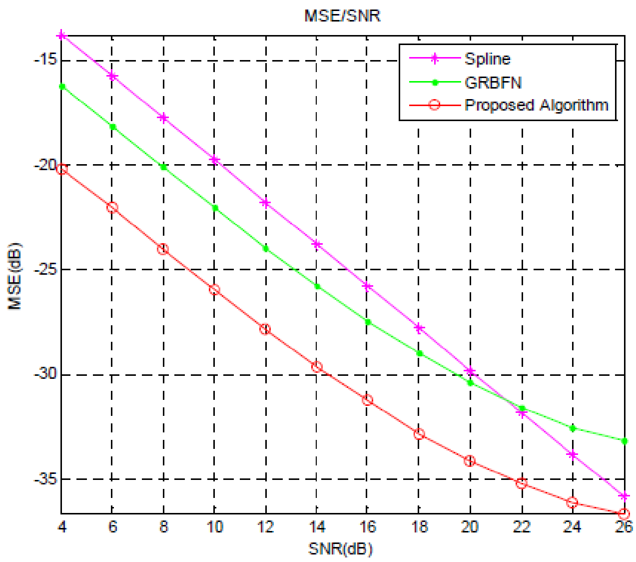

Fig. 5. MSE values of the channel estimators versus SNR

In another performance evaluation for channel estimator, bit error rate (BER) criteria based on estimation errors versus SNR are presented in figure 6. This figure shows the comparison of mentioned methods and demonstrates that proposed algorithm is better than other methods.

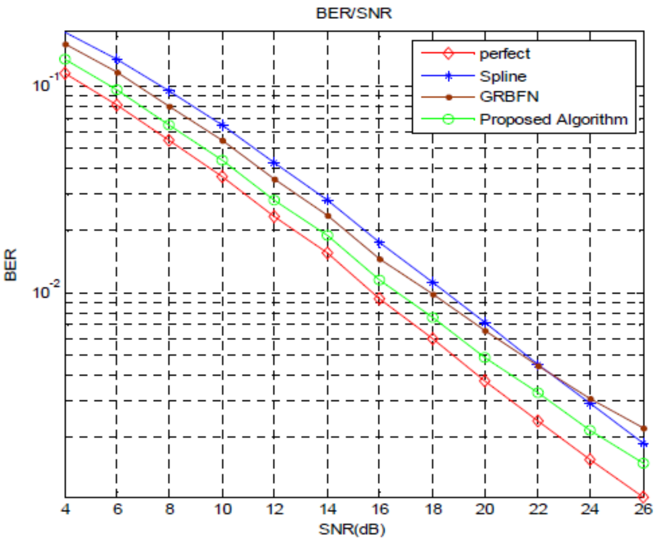

Fig. 6: BER values of the channel estimators versus SNR

5- Conclusion

In this paper we proposed a new channel estimation algorithm based on the FFT Processing and linear interpolation for OFDM systems at fast fading selective frequency channel. This proposed algorithm in compared to existing channel estimation methods offers lower complexity because of linear interpolator whereas it has better performance. Therefore, with doing some simple processing on data can be reduced estimation error and complexity. It is obvious that proposed algorithm has lower complexity but considering numerical can show a certain and it is proposed for future works.

REFERENCE

[1]. H. Bolcskei and A. Paulraj, "Space-frequency coded broadband OFDM system "in Proc. oj Wireless Commun. Networking Con!, Chicago, IL,Sept.23 28,2000,pp.1 6.

[2]. B. Han et al., "An Iterative Joint Channel Estimation and symbol Detection Algorithm Applied in OFDM System with High Data To Pilot Power Ratio," Proc. IEEE Int'l. Conf. Commun.,vol. 3, Anchorage, AK, May 2003, pp. 2076–80.

[3]. Yusi shen and Ed martinez , "Channel estimation in OFDM systems "FReescale Semiconductor Application Note 2006.

[4]. F. Tufvesson and T. Maseng, "Pilot Assisted Channel Estimation for OFDM in Mobile Cellular Systems," Proc. IEEE Vehic.Tech. Conf., vol.3, Phoenix, AZ, May 1997, pp. 1639–43.

[5]. S. Coleri, M. Ergen, A. Puri, and A. Bahai, "Channel estimation techniques based on pilot arrangement in OFDM systems," IEEE Trans. Broadcast., vol.48, no.3, pp.223–229, 2002.

[6]. M. Li, J. Tan, and W. Zhang, "A Channel Estimation Method Based on Frequency– Domain Pilots and Time–Domain rocessing for OFDM Systems," IEEE Trans. Consumer Electron., vol.50, no. 4, Nov. 2004, pp. 1049–57.

[7]. Y. Li, "Pilot-symbol-aided channel estimation for OFDM in wireless systems," IEEE Transactions on Vehicular Technology, 2000, 49(4): 1207-1215.

[8]. Baoguo Yang, K.B. Letaief, R.S. Cheng, Zhigang Cao, "Windowed DFT based pilotsymbol-aided channel estimation for OFDM systems in multipath fading channels," Proc IEEE VTC'2000, 2000. 1480-1484.

[9]. R.Hajizadeh, K.Mohamedpour, M.R. Tarihi, "Channel Estimation in OFDM System Based on the Linear Interpolation, FFT and Decision Feedback" 18th Telecommunications forum TELFOR 2010 Serbia, Belgrade, November 23-25, Pages: 484-488, 2010.