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DFT Based Channel Estimation Analysis in OFDM Supported Wireless Communication system

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Abstract

Time-varying channel estimation is an important activity in next generation wireless communication. Channel estimation is required mainly for the significant signal processing operation in multiple input multiple output (MIMO)-orthogonal frequency division multiplexing (OFDM) systems such as precoder designing at transmitter & relay and relay selection scheme in cooperative communication system. In this paper we investigate and compare various efficient channel estimation schemes for OFDM system. In this paper the channel estimation techniques based on block type Pilot arrangement for OFDM system are investigated. Finally, the discrete Fourier transform (DFT) based channel estimation technique is performed which gives better performance over least square(LS) and minimum mean square error(MMSE) based channel estimation. The bit error rate (BER) of DFT based channel estimation is less than the BER of LS and MMSE based channel estimation with same signal to noise ratio (SNR).

Keywords: *OFDM system, Channel Estimation, LSE, MMSE, DFT.*

1. Introduction

Multicarrier modulation such as OFDM is a powerful technique to turn the frequency selective wireless channel into a set of frequency flat narrowband channels. This reduces the complexity of the equalization task considerably [1]. An important factor in the transmission of data is the estimation of wireless channel which is essential before the demodulation of OFDM signals since the channel suffers from frequency selective fading and time varying factors for a particular mobile communication system [2]. Large-scale penetration of wireless systems into our daily lives will require significant reductions in cost and increased in bit rate and/or system capacity. Appropriate solutions for exploiting the multipath properly, could be based on new techniques that recently appeared in literature, which are based on Multiple Input Multiple Output (MIMO) technology [3].

Recently, an elegant channel estimation method for OFDM mobile communication systems has been proposed by Sajjad Ahmed Ghauri [4]. He has discussed the channel estimation in OFDM and its implementation in MATLAB using pilot based block type channel estimation techniques by LS and MMSE algorithms. His paper starts with the comparisons of OFDM using BPSK and QPSK on different channels, followed by modeling the LS and MMSE estimators on MATLAB. In the end, results of different simulations have

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compared to conclude that LS algorithm gives less complexity but MMSE algorithm provides comparatively better results.

In this paper, we present a different approach for channel estimation such as LS and MMSE methods. Finally perform the DFT based channel estimation over LS and MMSE methods. DFT based estimation provides better performance than LS and MMSE methods.

The rest of this paper is organized as follows. In Section 2, we introduce the brief description of our system and in Section 3, different kind of Channel estimation techniques in OFDM system are described. The performance analysis is presented in Section 4, and finally we conclude this paper in conclusion section.

2. System description

All Signals are orthogonal if they are mutually independent of each other. Orthogonality is a property that allows multiple information bearing signals to be transmitted perfectly over a common channel and detected without interference. Loss of orthogonality results in blurring between these signals and degradation in communication. Time division multiplexing (TDM) allows transmission of multiple information bearing signals over a single channel by assigning unique time slots to each state information signal. Because of this, TDM is orthogonal in nature. In the frequency domain, most FDM systems are orthogonal as each of the separate transmitted signals are well spaced out in frequency preventing interference. Although these methods are orthogonal, the term OFDM has been reserved for a special form of FDM. The difference between OFDM and conventional FDM is illustrated in Figure2.1 [6].

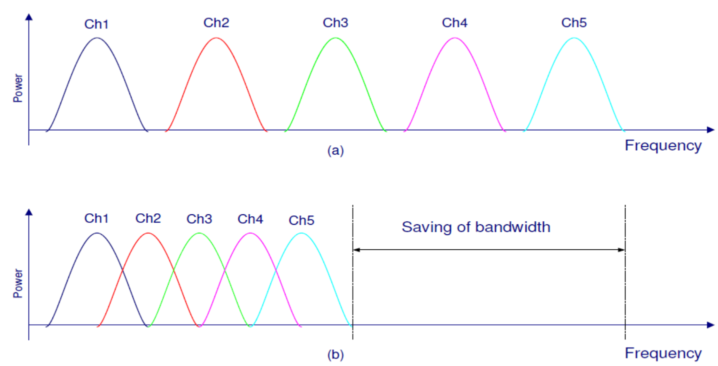

Figure 2.1. (a) FDM system (b) OFDM system

OFDM is a block transmission technique. In the baseband, complex-valued data symbols modulate a large number of tightly grouped carrier waveforms. The transmitted OFDM signal multiplexes several low-rate data streams (each data stream is associated with a given subcarrier). The inter-symbol interference (ISI) and inter-carrier interference (ICI) within an OFDM symbol can be avoided completely with a small loss of transmission energy using the concept of a cyclic prefix.

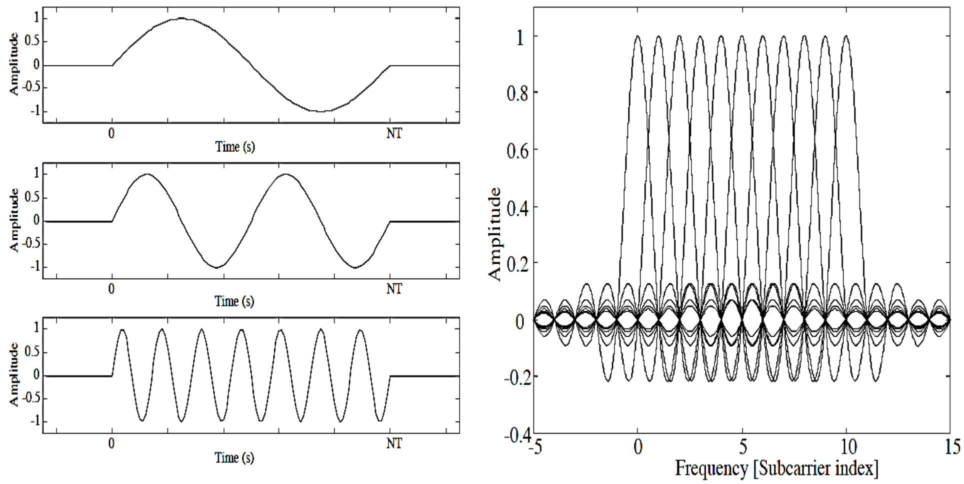

Figure 2.2.The real parts of three of the basis functions (Left) and the concept of densely packed subcarriers in OFDM (right)

The system block diagram is given below.

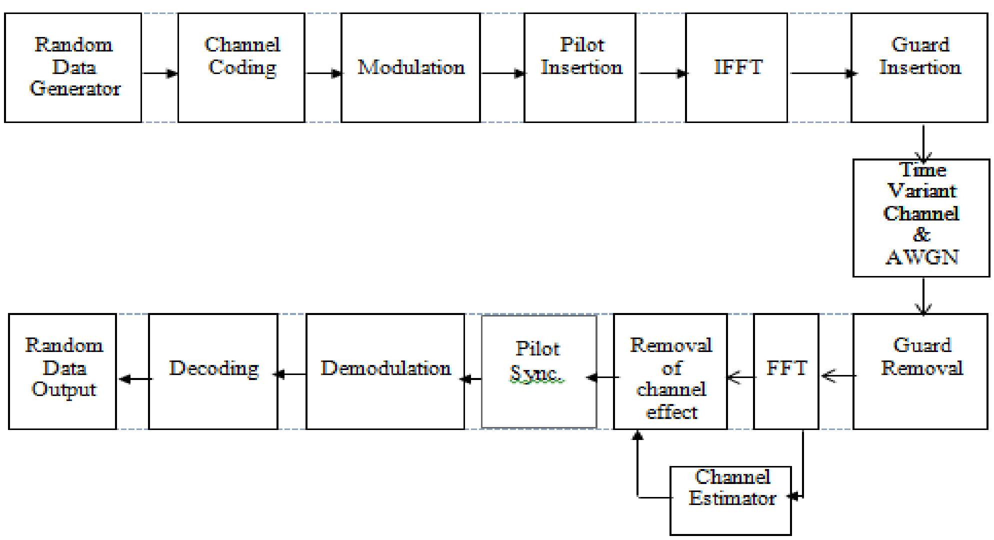

Figure 2.3.Block diagram of OFDM system with channel estimator

3. Channel estimation in OFDM system

There are basically two types of Channel estimation in OFDM.

- Pilot Based Channel Estimation: Known symbol called pilots are transmitted [7].
- Blind Channel Estimation: No pilots required. It uses some underlying mathematical properties of data sent [7].

In this paper we are going to study BER performance evaluation of Pilot Based Channel estimation in OFDM. The Blind channel estimation methods are computationally complex and hard to implement. The Pilot based channel estimation methods are easy to implement but they reduces the bandwidth efficiency. There are mainly two problems in the design of channel estimators for the wireless systems. The first problem is concerned with the choice of how the pilot information should be transmitted. Pilot symbols along with the data symbols can be transmitted in a number of ways and different patterns yield different performances. The second problem is the design of an interpolation filter with both low complexity and good performance. Focusing on the one dimensional estimation based on pilot insertion, we follow mainly block type pilot insertion and comb type pilot insertion without forgetting those used on two dimensional estimations. In this paper we are going to implement only block type pilot based channel estimation in OFDM.

3.1. Block type pilot based channel estimation

In this type, OFDM symbols with pilots at all subcarriers (referred to as pilot symbols herein) are transmitted periodically for channel estimation. Using these pilots, a time-domain interpolation is performed to estimate the channel along the time axis. Let $\mathrm{s_t}$denotes the period of pilot symbols in time. As the coherence time is given in an inverse form of the Doppler frequency $\mathrm{f_{doppler}}$ in the channel. The pilot symbol period must satisfy the following inequality [8].

$$S_t \leq \frac{1}{f_{Doppler}} \ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

Since pilot tones are inserted into all subcarriers of pilot symbols with a period in time, the block type pilot arrangement is suitable for frequency-selective channels.

3.2. LS channel estimation

The least-square (LS) [9] channel estimation method finds the channel estimation in such a way that the following cost function is minimized [8].

$$J(\widehat{\mathbf{H}}) = \left\|\mathbf{Y} - \mathbf{X}\widehat{\mathbf{H}}\right\|^2$$

$$=\left(\mathbf{Y} - \mathbf{X}\widehat{\mathbf{H}}\right)^H\left(\mathbf{Y} - \mathbf{X}\widehat{\mathbf{H}}\right)$$

$$=\mathbf{Y}^H - \mathbf{Y}^H\mathbf{X}\widehat{\mathbf{H}} - \widehat{\mathbf{H}}^H\mathbf{X}^H\mathbf{Y} + \widehat{\mathbf{H}}^H\mathbf{X}^H\mathbf{X}\widehat{\mathbf{H}} \text{..........}(2)$$

By setting the derivative of the function with respect to $\widehat{\mathbf{H}}$ to zero, we get the LS channel estimation as

$$\widehat{\mathbf{H}}_{LS} = \mathbf{X}^{-1}\mathbf{Y} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

Here, $\mathbf{X}$ is the diagonal matrix of training symbols; $\mathbf{Y}$ is the received training signal vector; $\mathbf{H}$ is a channel vector and $\widehat{\mathbf{H}}$ is the estimated channel vector.

3.3. MMSE channel estimation

Consider the LS solution in Equation (3), $\widehat{\mathbf{H}}_{\mathrm{LS}} = \mathbf{X}^{-1}\mathbf{Y} \triangleq \widehat{\mathbf{H}}$. Using the weight matrix $\mathbf{W}$, define $\widehat{\mathbf{H}} \triangleq \mathbf{W}\widehat{\mathbf{H}}$, which corresponds to the MMSE estimate[10].

3.4. DFT-based channel estimation

The DFT-based channel estimation technique has been derived to improve the performance of LS or MMSE channel estimation by eliminating the effect of noise outside the maximum channel delay. Let $\widehat{H}[k]$ denotes the estimate of channel gain at the *k*th subcarrier, obtained by either LS or MMSE channel estimation method. Taking the IDFT of the channel estimate$\{\widehat{H}[k]\}_{k=0}^{N-1}$,

$$\mathrm{IDFT}\{\widehat{H}[k]\} = h[n] + z[n] \ldots\ldots\ldots\ldots(4)$$
$$\triangleq \hat{h}[n],$$

Where z[n] denotes the noise component in the time domain. Ignoring the coefficients $\hat{h}[n]$ that contain the noise only, we can define the coefficients for the maximum channel delay L as [3]

$$\hat{h}_{DFT}[n] = \begin{cases} h[n] + z[n], n = 0,1,2 \ldots L-1 \\ 0, \qquad otherwise \end{cases} \ldots\ldots\ldots(5)$$

and transform the remaining L elements back to the frequency domain as follows[9]

$$\widehat{H}_{DFT}[k] = DFT\{\hat{h}_{DFT}[n]\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(6).$$

The Algorithm of the performed task is given below.

Step.1: Encode the message data S by Convolution coding into E; where E is the encoded message data.

Step.2: Modulate the encoded data E by QAM modulation to M; where M is the modulated data.

Step.3: Insert some known bit (pilot bit) into the modulated data.

Step.4: Compute the IFFT of the output data found in step.3.

Step.5: Insert guard period between the output data of step.4.

Step.6: Transmit the output data of step.5 through a channel.

Step.7: Remove the guard period from the received data and find FFT.

Step.8: Apply the different kinds of channel estimating techniques (LS, MMSE & DFT) on the output data of step.7.

Step.9: Remove the channel effect from the output of step.7 with the help of the output found in step.8.

Step.10: Extract the message data from the output of step.9 by performing pilot removal, Demodulation and Decoding operations.

Step.11: Compute BER by comparing the output of step.10 with the message data for each channel estimation technique.

4. Simulation and results

In this paper, we have used MATLAB 7.5 software for simulation for the Bit Error Rate (BER) performance of the different estimation techniques like LS and MMSE and DFT. Figure 4.1 shows the least square error estimation and the DFT based estimation in block type.

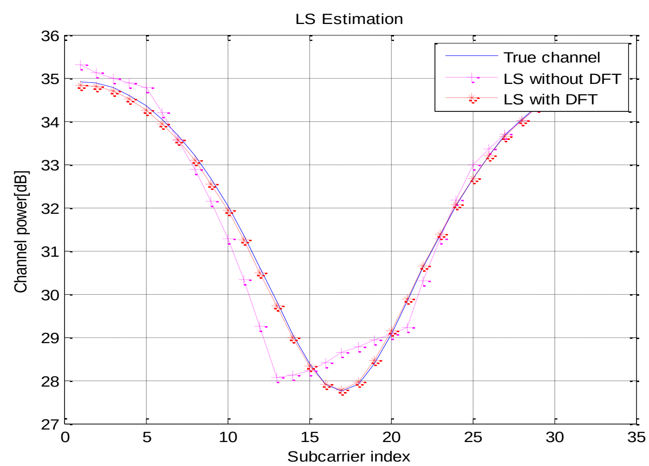

Figure 4.1 LS estimation with & without DFT

From the above figure it is seen that the LS estimation with DFT is more closer to the true channel. That means DFT based estimation(LS with DFT) performs better than the LS estimation(LS without DFT) which is observed by the following BER curve. Figure 4.2 shows the BER VS. SNR comparison of DFT and LS estimations.

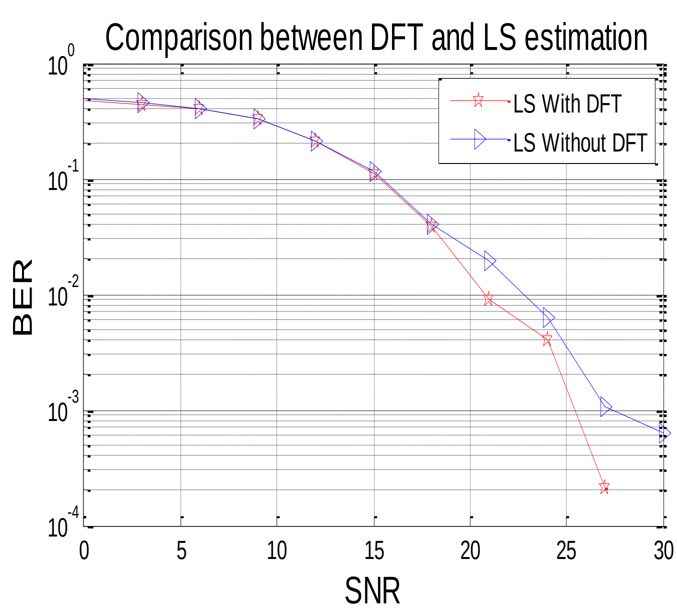

Figure 4.2BER VS. SNR comparison between DFT and LS estimation.

Figure 4.3 shows the MMSE estimation and the DFT based estimation in block type.

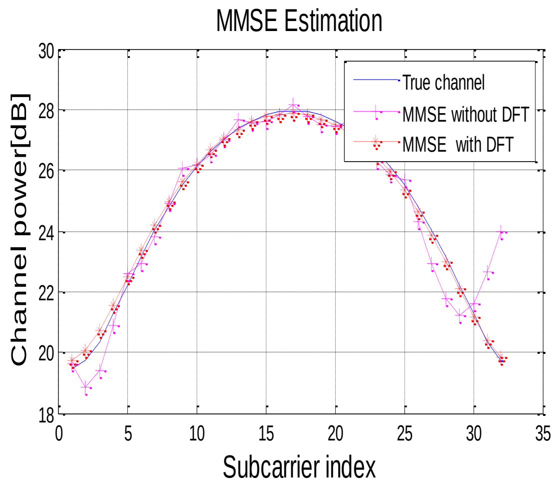

Figure 4.3 MMSE estimation with & without DFT

According to the above figure, DFT based estimation(MMSE estimation with DFT) is more closer to the true channel than the MMSE estimation. The performance of DFT based estimation can be seen by the following BER VS. SNR characteristic.

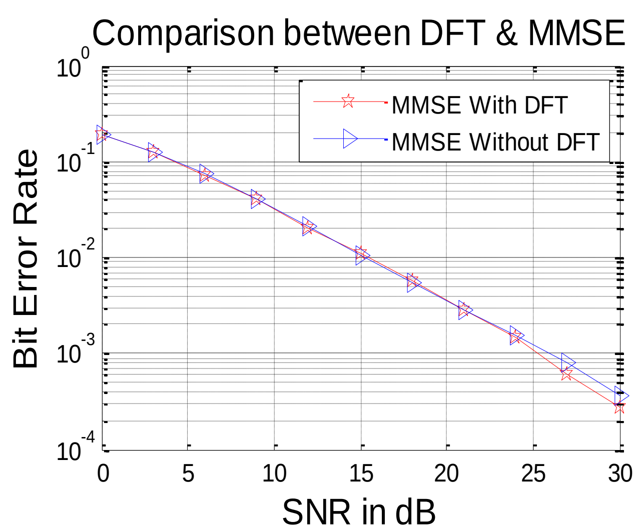

Figure 4.4 BER VS. SNR comparison between DFT and MMSE estimation

5. Conclusion

In this paper, it is observed that the DFT operation gives better performance over LS and MMSE. With same SNR, the BER of DFT based channel estimation is less than the BER of LS and MMSE based channel estimation. The MMSE estimator has good performance but high complexity. The LS estimator has low complexity, but its performance is not as good as that MMSE estimator basically at low SNR.

Block Type Pilot arrangement is suitable for frequency-selective channels. For the fast-fading channels, however, it might incur too much overhead to track the channel variation by reducing the pilot symbol period.

As the use of pilot symbols for channel estimation decrease the spectrum efficiency of the wireless communication systems, it will be beneficial if we can adaptively change the number of pilot tones depending on the channel condition through some feedback information.

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