A DFT based channel estimation technique in orthogonal-frequency-division-multiplexing (OFDM): A Review

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Abstract—**Channel estimation is one of the most significant technologies in orthogonal-frequency-division-multiplexing(OFDM) . Inter-carrier-interference (ICI) occurs in OFDM which must be removed. There are various methods to reduce ICI in OFDM . Channel estimation techniques are used to investigate to reduce ICI in OFDM .In this paper we will discuss Channel estimation methods and DFT based channel estimation shows better results among other methods.**

Keywords—Orthogonal frequency division multiplexing (OFDM) Inter carrier interference(ICI), self cancellation (SC),Extended Kalman filtering (EKF) , The least-square (LS) and minimum-mean-square-error (MMSE), Discrete forier Transform(DFT)

I. INTRODUCTION

In a basic communication system, the data are modulated onto a single carrier frequency. The available bandwidth is then totally occupied by each symbol. This kind of system can lead to inter-symbol-interference (ISI). OFDM is a frequency division multiplexing technique used as a multi carrier modulation method. Because of high capacity transmission of OFDM, it has been applied to digital transmission system, such as digital audio broadcasting (DAB) system, digital video broadcasting TV (DVB-T) system. The basic principle of OFDM is to split a high rate data-stream into multiple lower rate data streams that are transmitted simultaneously over a number of sub carriers. OFDM uses the spectrum much more efficiently by spacing the channels much closer. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers. OFDM sends multiple high-speed signals concurrently on orthogonal carrier frequencies. This results much more efficient use of bandwidth as well as robust communications during noise and other interferences

The block diagram of OFDM system is given in figure 1 as shown

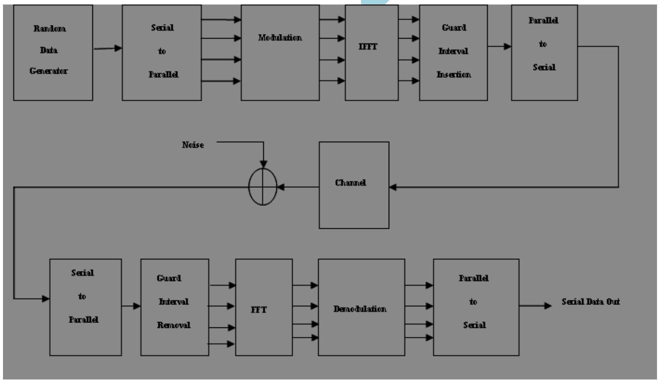

Fig.1

The high speed data rates for OFDM are accomplished by the simultaneous transmission of data at a lower rate on each of the orthogonal sub-carriers. Because of the low data rate transmission, distortion in the received signal induced by multi-path delay in the channel is not as significant as compared to single-carrier high-data rate systems. As a narrowband signal sent at a high data rate through a multipath channel will experience greater negative effects of the multipath delay spread, because the symbols are much closer together. Multipath distortion can also cause inter-symbol interference (ISI) where adjacent symbols overlap with each other. This is prevented in OFDM by the insertion of a cyclic prefix between successive OFDM symbols. This cyclic prefix is discarded at the receiver to cancel out ISI.

II. INTERCARRIER

There exists two problems with OFDM, first one is high peak to average power ratio and other is its sensitivity to frequency offset between the transmitted and received signals, which may be caused by Doppler shift due to relative motion between transmitter and receiver, or by the difference between the transmitter and receiver local oscillator frequencies. This carrier frequency offset causes loss of orthogonality between sub-carriers and then the signals transmitted on each carrier are not independent of each other.

The orthogonality of the carriers is no longer maintained, which results in inter-carrier interference. ICI problem would become more complicated when the multipath fading is present. If ICI is not properly compensated it results in a power leakage among the sub carriers, thus this degrades the system performance. The various methods that can be used to minimize the ICI are frequency domain equalization, time domain windowing scheme, ICI self cancellation scheme, maximal likelihood estimation, extended kalman filtering etc.

III. METHODS TO REDUCE ICI

A. ***ICI Self- Cancellation Method***
In ICI Self- Cancellation method, at the transmitter side, one data symbol is modulated onto a group of adjacent subcarriers with a group of weighting coefficients.

B. ***Maximal Likelihood Estimation :***
This method estimates the frequency offset and cancels this offset at the receiver.

C. ***Extended Kalman Filter* :** The Extended Kalman Filtering (EKF) technique is another method to estimate the frequency offset in the received signal.

D. ***Time Domain Window Method*:** When the signal is transmitted in a band limited channel, certain portion of the signal spectrum will be cut off, which will cause ICI occurrence. To overcome the interference the spectrum of the signal wave form need to be more concentrated. This is achieved by windowing the signal.

E. ***Frequency Domain Equalization:*** frequency domain equalization process is used for reduction of ICI by using suitable equalization techniques. This technique can only reduce the ICI caused by fading distortion which is not the major source of ICI.

F. ***Channel estimation Techniques***: The channel estimation can be performed by either inserting pilot tones into all of the subcarriers of OFDM symbols with a specific period or inserting pilot tones into, has been developed under the assumption of slow fading channel. The Second one is Comb-type pilot channel estimation. In this type, every OFDM symbol has pilot tones at each OFDM symbol. The first one, block type pilot channel estimation the periodically-located subcarriers, which are used for a frequency-domain interpolation to estimate the channel along the frequency axis. And third one is Lattice Type in which pilot tones are inserted along both the time and frequency axes with given periods. The pilot tones scattered in both time and frequency axes facilitate time/frequency-domain interpolations for channel estimation.

G. ***Training Symbol-Based Channel Estimation:*** Training symbols can be used for channel estimation, usually providing a good performance. However, their transmission efficiencies are reduced due to the required overhead of training symbols such as preamble or pilot tones that are transmitted in addition to data symbols. The least-square (LS) and minimum-mean-square-error (MMSE) techniques are widely used for channel estimation when training symbols are available We assume that all subcarriers are orthogonal (i.e., ICI-free). Then, the training symbols for N subcarriers can be represented by the following diagonal matrix:

$$X = \begin{bmatrix} X[0] & 0 & \cdots & 0 \\ 0 & X[1] & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \cdots & 0 & X[N-1] \end{bmatrix}$$

where X[k]_ denotes a pilot tone at the kth subcarrier, with $E\{X[k]\}=0$ and $Var\{X[k]\}=\sigma_x^2$, $k=0,1,2,\cdots,N-1$. Note that X is given by a diagonal matrix, since we assume that all subcarriers are orthogonal. Given that the channel gain is H[k] for each subcarrier k, the received training signal Y[k] can be represented as

H. **LS Channel Estimation**

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

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

By setting the derivative of the function with respect to $\hat{H}$ to zero,

$$\frac{\partial J(\hat{H})}{\partial \hat{H}} = -2(X^H Y)^* + 2(X^H X\hat{H})^* = 0$$

we have $X^H X\hat{H} = X^H Y$, which gives the solution to the LS channel estimation as

$$\hat{H}_{LS} = (X^H X)^{-1} X^H Y = X^{-1} Y$$

Let us denote each component of the LS channel estimate $\hat{H}_{LS}$ by $\hat{H}_{LS}[k], k=0,1,2,\cdots,N-1$.

Since X is assumed to be diagonal due to the ICI –free condition, the LS channel estimate $\hat{H}_{LS}$ can be written for each subcarrier as

$$\hat{H}_{LS}[k] = \frac{Y[k]}{X[k]}, k=0,1,2,\cdots,N-1$$

The mean-square error (MSE) of this LS channel estimate is given as

$$MSE_{LS} = E\{(H - \hat{H}_{LS})^H (H - H_{LS})\}$$
$$= E\{(H - X^{-1}Y)^H (H - X^{-1}Y)\}$$
$$= E\{(X^{-1}Z)^H (X^{-1}Z)\}$$
$$= E\{Z^H (XX^H)^{-1} Z\}$$
$$= \frac{\sigma_z^2}{\sigma_x^2}$$

Note that the MSE in Equation is inversely proportional to the $SNR\sigma_x^2/\sigma_z^2$, which implies that it may be subject to noise enhancement, especially when the channel is in a deep null. Due to its simplicity, however, the LS method has been widely used for channel estimation

I. MMSE Channel Estimation

Consider the LS solution in Equation , $\hat{H}_{LS} = X^{-1}Y \triangleq \tilde{H}$. Using the weight matrix W, define $\hat{H} \triangleq W\tilde{H}$, which corresponds to the MMSE estimate. Referring to Figure 2 MSE of the channel estimate $\hat{H}$ is given as

$$J\left(\hat{H}\right) = E\left\{\|e\|^2\right\} = E\left\{\left\|H - \hat{H}\right\|^2\right\}$$

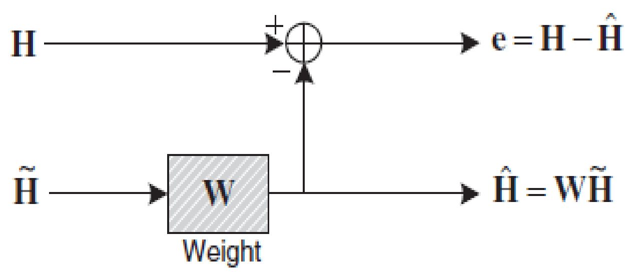

Fig.2 MMSE channel estimation.

Then, the MMSE channel estimation method finds a better (linear) estimate in terms of W in such a way that the MSE in Equation is minimized. The orthogonality principle states that the estimation error vector $e = H - \hat{H}$ is orthogonal to $\tilde{H} = XH + Z$

J. ***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. Figure 3 shows a block diagram of 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.

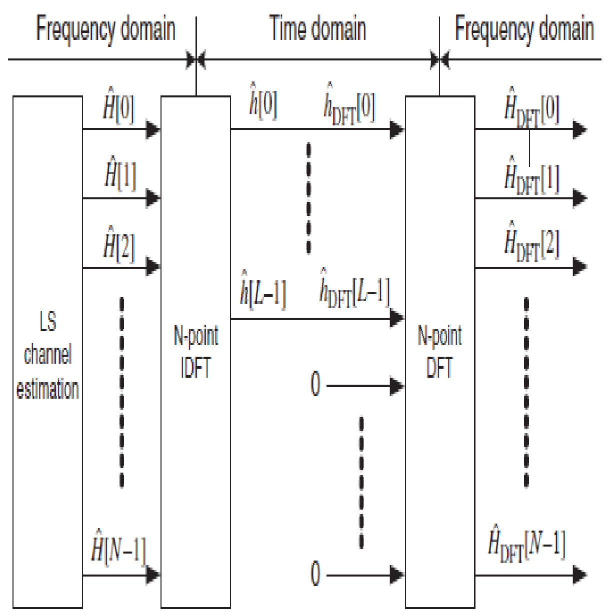

Fig.3 Block Diagram of DFT

Also, Figure 4 comparing the LS without DFT and with DFT .LS with DFT shows better performance than the LS estimation does at the cost of requiring the additional computation and information on the channel characteristics

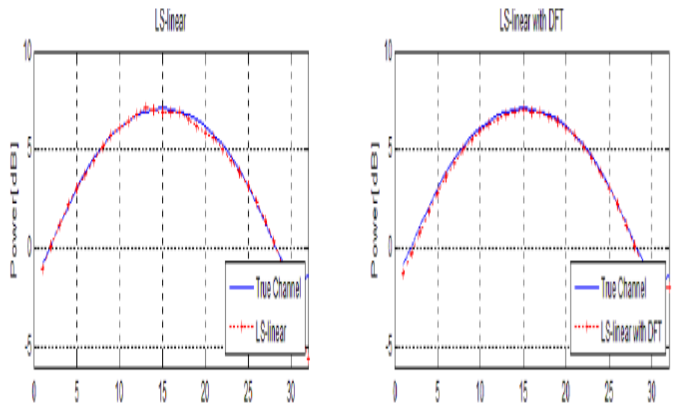

Fig.4 Results

IV. CONCLUSIONS

In this paper we investigate the ICI by using Channel est6imation techniques .The least-square (LS) and minimum-mean-square-error (MMSE) techniques are widely used for channel estimation when training symbols are available. .We investigated the DFT based channel estimation improves the performance of LS and MMSE channel estimation by elimination the effect of noise.

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