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Review of Channel Estimation Techniques in OFDM

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Abstract—

Channel estimation techniques are used in OFDM to investigate the channel to reduce Inter-carrier-Interference (ICI) in OFDM.DFT based channel estimation results better performance among other methods.

Keywords—

Orthogonal frequency divison multiplexing (OFDM) Inter carrier interference (ICI), The least-square (LS) and minimum-mean-square-error (MMSE), Discrete furrier Transform (DFT)-Based Channel Estimation.

I. INTRODUCTION

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, 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. The orthogonality of the carriers is no longer maintained, which results in inter-carrier interference The various methods that can be used to minimize the ICI are frequency domain equalization, time domain windowing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.We investigate the channel estimation in OFDM,the received signal is usually distorted by the channel characteristics. In order to recover the transmitted bits, the channel effect must be estimated and compensated in the receiver. Each subcarrier can be regarded as an independent channel, as long as no ICI (Inter-Carrier Interference) occurs, and thus preserving the orthogonality among subcarriers. The orthogonality allows each subcarrier component of the received signal to be expressed as the product of the transmitted signal and channel frequency response at the subcarrier. Thus, the transmitted signal can be recovered by estimating the channel response just at each subcarrier.DFT channel estimation technique improve the performance of least-square(LS) and minimum-mean-square-error(MMSE) channel estimation

II. CHANNEL ESTIMATION TECHNIQUES

A dynamic estimation of channel is necessary before the demodulation of OFDM signals since the radio channel is frequency selective and time-varying for wideband mobile communication. A dynamic estimation of channel is necessary before the demodulation of OFDM signals since the radio channel is frequency selective and time-varying for wideband mobile communication system. 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 each OFDM symbol. The first one, block type pilot channel estimation, has been developed under the assumption of slow fading channel. Even with decision feedback equalizer, this assumes that the channel transfer function is not changing very rapidly. The estimation of the

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channel for this block-type pilot arrangement can be based on Least Square (LS) or Minimum Mean-Square (MMSE).

The MMSE estimate has been shown to give 10–15 dB gain in
signal-to-noise ratio (SNR) for the same mean square error of
channel estimation over LS estimate . In , a low-rank approximation is applied to linear MMSE by using the frequency correlation of the channel to eliminate the major drawback of MMSE, which is complexity. The later, the comb-type pilot channel estimation, has been introduced to satisfy the need for equalizing when the channel changes even in one OFDM block. The comb-type pilot channel estimation consists of algorithms to estimate the channel at pilot frequencies and to interpolate the channel. The estimation of the channel at the pilot frequencies for comb-type based channel estimation can be based on LS,MMSE or Least Mean-Square (LMS). MMSE has been shown to perform much better than LS. Depending on the arrangement of pilots, three different types of pilot structures are considered: block type, comb type, and lattice type .

A block type of pilot arrangement is depicted in Figure 1.1. 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

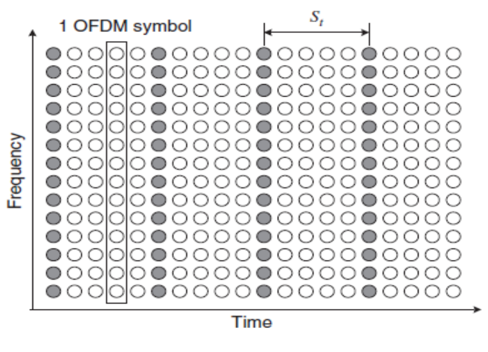

Figure 1.1 Block-type pilot arrangements

the channel along the time axis. Let St denote the period of pilot symbols in time. In order to keep track of the time-varying channel characteristics, the pilot symbols must be placed as frequently as the coherence time is. As the coherence time is given in an inverse form of the Doppler frequency Doppler in the channel, the pilot symbol period must satisfy the following in equality:

$$s_f \leq \frac{1}{\sigma_{Doppler}} \qquad (1.1)$$

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. For the fast-fading channels, however, it might incur too much overhead to track the channel variation by reducing the pilot symbol period. Comb-type pilot arrangement is depicted in Figure 1.2. In this type, every OFDM symbol has pilot tones at the periodically-located subcarriers, which are used for a frequency-domain interpolation to estimate the channel along the frequency axis. Let Sf be the period of pilot tones in frequency. In order to keep track of the frequency-selective channel characteristics, the pilot symbols must be placed as frequently as
coherent bandwidth is. As the coherence bandwidth is determined by an inverse of the maximum delay spread, symbol period must satisfy the following inequality:

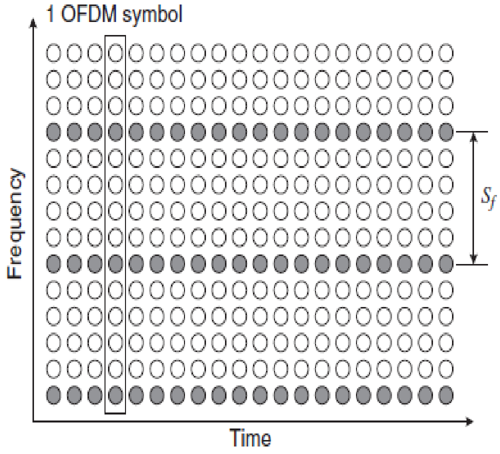

Figure 1.2 Comb-type pilot arrangements

$$s_f \le \frac{1}{\sigma_{\max}} \qquad (1.2)$$

As opposed to the block-type pilot arrangement, the comb-type pilot arrangement is suitable for fast-fading channels, but not for frequency-selective channels.

Lattice-type pilot arrangement is depicted in Figure 1.3. In this type, 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. Let S_t and S_f denote the periods of pilot symbols in time and frequency, respectively. In order to keep track of the time-varying and frequency-selective channel characteristics, the pilot symbol arrangement must satisfy both Equations (1.1) and (1.2), such that

$$s_f \le \frac{1}{\sigma_{Doppler}} \text{ and } s_f \le \frac{1}{\sigma_{\max}}$$

where $f_{Doppler}$ and s_{max} denote the Doppler spreading and maximum delay spread, respectively.

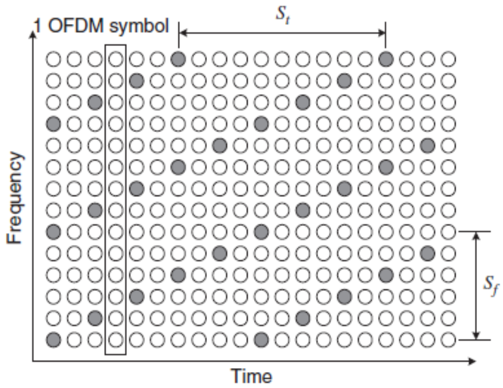

Figure1.3 Lattice-type pilot arrangement

II . 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

III. 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 $\hat{H}[k]$ denote the estimate of channel gain at the kth subcarrier, obtained by either LS or MMSE channel estimation method. Taking the IDFT of the channel estimate $\left\{\hat{H}[k]\right\}_{k=0}^{N-1}$

$$IDFT\left\{\hat{H}[k]\right\} = h[n] + z[n] \triangleq \hat{h}[n], \quad n = 0,1,\dots,N-1 \qquad (2.1)$$

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where z½n_ denotes the noise component in the time domain. Ignoring the coefficients $\hat{H}[k]$ that contain the noise only, define the coefficients for the maximum channel delay L as

$$\hat{h}_{DFT}[n] = \begin{cases} h[n] + z[n], n = 0,1,2,\cdots,L-1 \\ 0 \quad \quad otherwise \end{cases}$$

(2.2)

Figure 2.1 shows a block diagram of DFT-based channel estimation, given the LS channel

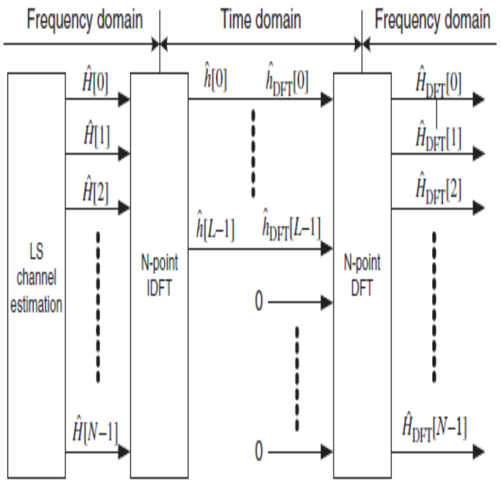

Figure 2.1

Figure 2.2 illustrates the channel estimates obtained by using the various types of channel estimation methods with and without DFT technique discussed in the above. Comparing Figures 2.2(a1), (b1), and (c1) with Figures 2.2(a2), (b2), and (c2) reveals that
the DFT-based channel estimation method improves the performance of channel estimation.

Also, comparing Figures 2.2(a1) and (b1) with Figure 2.2(c1), it is clear that the MMSE estimation shows better performance than the LS estimation does at the cost of requiring the additional computation and information on the channel characteristic\

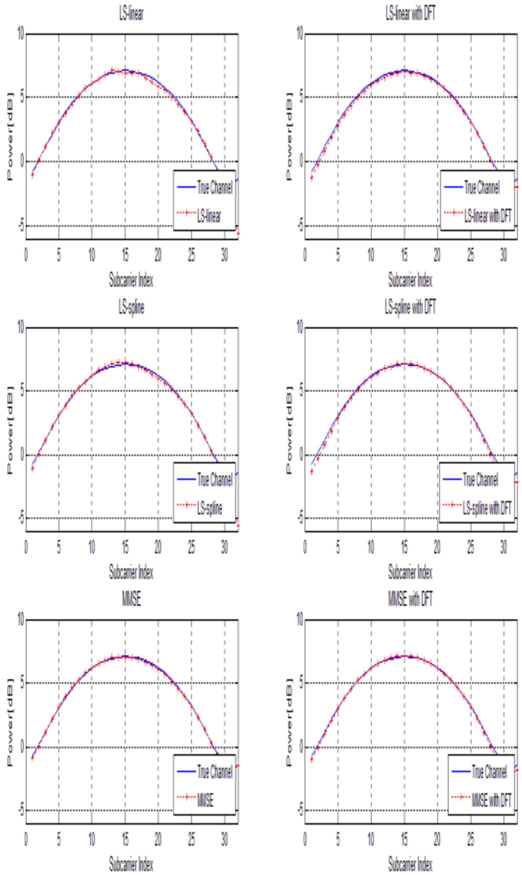

Fig.2.2

IV. Conclusions

In this paper we investigate the channel estimation in OFDM by various method. We compare the different channel estimation techniques .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. The further work can be done by extending the concept of channel estimation

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