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Improved Chnnel Estimation for Wireless Communication Systems

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***Abstract*—We consider LTE-Advanced uplink system where user equipment (UE) transmits its data to eNodeB. In the uplink system, demodulation reference signal (DM-RS) is transmitted for the channel estimation on the center symbol of the resource block allocated to the UE. Also, sounding reference signal (SRS) is transmitted on the last symbol of the resource block periodically. In this paper, we propose an improved channel estimation scheme by using the SRS: lease square (LS)-based scheme. Simulation results show that the proposed channel estimation scheme has better performance than the DM-based conventional scheme.**

***Keywords*—LTE-Advanced system, uplink, channel estimation, demodulation reference signal, sounding reference signal.**

I. Introduction

In the 3rd generation mobile communication systems, code-division multiple-access (CDMA) was the baseline technology for the data transmission in both uplink and downlink systems. However, using the CDMA-based technology there was several drawbacks such as high inter-user interference, difficulties in applying the multiple antenna technologies and in utilizing wider system bandwidth, etc.

As one of the solutions to solve these problems with CDMA-based technologies, orthogonal frequency division multiplexing (OFDM) technology has received a lot of attention because of its many advantages such as high spectral efficiency, robustness to the channel frequency selectivity,

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ease to apply multiple antenna technology, etc [1]-[4]. In 2007, the 3rd Generation Partnership Program (3GPP) members started to make mobile communication specifications based on OFDM technology. The 3GPP Long-Term Evolution (LTE) specifications were the results of the 3GPP standardization work for the evolution system of the 3rd generation system [5]. LTE-Advanced system is the evolution of LTE system and it has been considered as the 4th generation mobile communication systems.

In LTE-Advanced systems, OFDM technology has been used as a baseline transmission technology for downlink data transmission and uplink reference signal transmission. Also, resources used for the transmission of data and control are composed of 12 consecutive subcarriers and 7 OFDM symbols when normal length is used for cyclic prefix (CP).

For the coherent detection of the transmitted data and channel quality report, channel estimation is necessary for the uplink. In LTE-Advanced system, demodulation reference signal (DM-RS) is transmitted in the center OFDM symbol of the RB for the coherent detection of the data and the sounding reference signal (SRS) is transmitted in the last OFDM symbol of the RB for the uplink channel quality estimation.

In conventional channel estimation schemes for LTE-Advanced uplink systems, DM-RS is used for channel estimation assuming that the channel variation is negligible in time domain within RB [6]-[7]. DFT-based de-noising operation can be applied to reduce the effect of additive white Gaussian noise (AWGN) [8]-[9]. In the uplink system, each UE transmits DM-RS in the allocated RBs only. Since many UEs have to share the uplink system bandwidth, only a few RBs are allocated to each UE. Therefore, the length of the DM-RS might be too short to obtain a good channel estimation performance.

In this paper, we propose an improved channel estimation scheme for LTE-Advanced uplink system using the SRS: least square (LS)-based scheme. In general, SRS is transmitted periodically in the last symbol of the subframes over the wider bandwidth than the DM-RS transmission bandwidth. In the LS-based proposed scheme, frequency domain channel coefficients are estimated using the subcarriers allocated to transmit the SRS. Then, the SRS-based channel estimate is combined with DM-RS-based channel estimate. Through the simulation results, we show that the proposed scheme has better channel estimation performance than the conventional DM-RS-based channel estimation schemes.

The rest of the paper is organized as follows. Section II briefly describes the system model for the LTE-Advanced uplink system. In section III, we propose an SRS- based

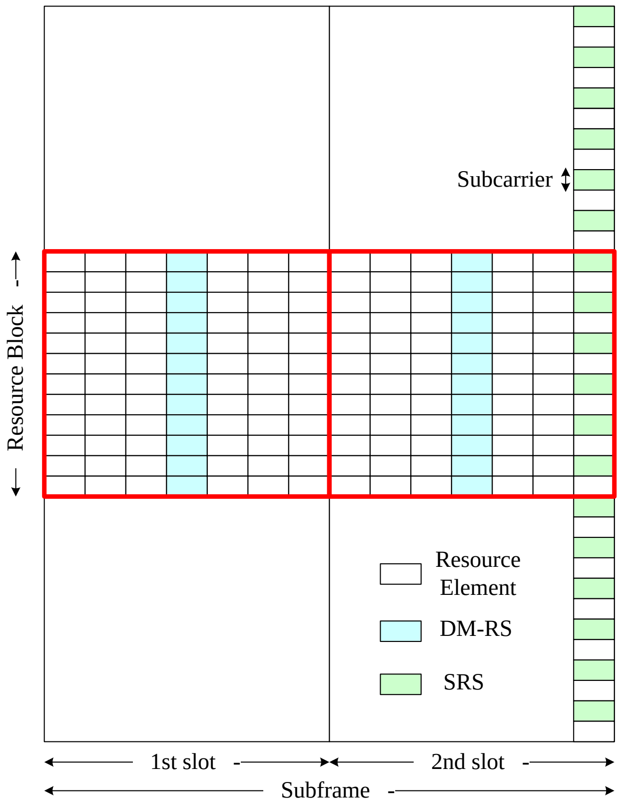

Figure 1. Uplink subframe structure.

channel estimation scheme. In section IV, simulation results are given to evaluate the performance of the proposed scheme. Section V concludes the paper.

II. System Model

Fig. 1 shows a structure of the RB in a subframe with normal CP length for LTE-Advanced uplink system. An RB is composed of 12 adjacent subcarriers in frequency domain and 7 OFDM symbols in time domain. A subframe is composed of two slots. A time-frequency resource grid is called resource element. DM-RS is transmitted on the center OFDM symbol in RB and SRS is transmitted on the last symbol of the RB.

In this paper, we consider that the velocity of the desired UE is negligible. Therefore, we assume that the channel responses in the symbol of the DM-RS and the SRS transmission are the same.

We define the DM-RS and SRS transmitted at the *k*-th subcarrier by D_k and S_k, respectively. We assume that the subcarriers $k \in K_{DM} = \{J_d, \ldots, J_d + L_d - 1\}$ are allocated to the desired UE and the DM-RS is transmitted on the same subcarriers. The parameter J_d represents the first subcarrier allocated to the desired UE and the parameter L_d is the number of the subcarriers allocated to the desired UE. Similarly, the subcarriers $k \in K_{SRS} = \{J_s, \ldots, J_s + L_s - 1\}$ are allocated for the transmission of the SRS of the desired UE.

The parameter J_s is the first subcarrier allocated for the SRS transmission and the parameter L_s is the number of the subcarriers allocated for the SRS transmission. We assume $J_s \le J_d$ and $L_s \ge L_d$. This assumption means that the bandwidth of the SRS transmission is larger than that of the DM-RS transmission and the former include the latter.

The received signal of the DM-RS at the *k*-th subcarrier is written as

$$X_k = H_k D_k + Z_k, \quad k \in K_{DM}, \tag{1}$$

where H_k is the channel coefficient at the *k*-th subcarrier and Z_k means AWGN with mean 0 and variance 1. The received signal of the SRS at the *k*-th subcarrier is written as

$$Y_k = H_k S_k + U_k, \quad k \in K_{SRS}, \tag{2}$$

where U_k is AWGN.

III. Proposed Channel Estimation Scheme

First, we explain conventional channel estimation schemes: LS-based estimation and DFT-based estimation using DM-RS. Then, we explain a proposed channel estimation scheme using SRS.

A. *Conventional Channel Estimation*

In the conventional channel estimation schemes, coarse estimate of the channel coefficients is obtained by the LS-based method as follows:

$$\hat{H}_{k,DM} = \frac{X_k}{D_k} = H_k + \frac{Z_k}{D_k}, \quad k \in K_{DM}. \tag{3}$$

We define the estimated channel vector by $\hat{\mathbf{h}}_{DM} = [\hat{H}_{J_d,DM}, \hat{H}_{J_d+1,DM}, \ldots, \hat{H}_{J_d+L_d-1,DM}]^T$.

In order to reduce AWGN, DFT-based de-noising operation is performed on $\hat{\mathbf{h}}_{DM}$. First, $\hat{\mathbf{h}}_{DM}$ is extended by padding zeros at the unallocated subcarriers as follows:

$$\hat{\mathbf{h}}_{DM,ext} = [0, \ldots, 0, \hat{H}_{J_d,DM}, \ldots, \hat{H}_{J_d+L_d-1,DM} 0, \ldots, 0,]^T. \tag{4}$$

Therefore, the time-domain channel response is obtained by

$$\hat{\mathbf{g}}_{conv} = [g_{1,conv}, g_{2,conv}, \ldots, g_{L_d,conv}]^T = \mathbf{W}_N^H \hat{\mathbf{h}}_{DM,ext}, \tag{5}$$

where $\mathbf{W}_N$ is DFT matrix of size $N \times N$ and its (m,n) element is given by $e^{j2\pi mn/N} / \sqrt{N}, \ m,n = 0, \ldots, N-1$.

The de-noised time-domain channel response $\tilde{\mathbf{g}}_{conv}$ is given by $\tilde{\mathbf{g}}_{conv} = [g_{1,conv}, \ldots, g_{M,conv}]^T$ where M is usually chosen as the CP length.

TABLE I. SIMULAITON PARAMETERS

Parameters	Values
Number of sucarriers	128
CP length (M)	16
L_d	12

The frequency domain channel coefficients after de-noising are given by

$$\tilde{\mathbf{h}}_{conv} = [\tilde{H}_{1,conv}, \tilde{H}_{2,conv}, \ldots, \tilde{H}_{N,conv}]^T = \mathbf{W}_M \tilde{\mathbf{g}}_{conv}, \quad (6)$$

where $\mathbf{W}_M$ is a submatrix of matrix $\mathbf{W}_N$ and its size is $N \times M$. Then, the conventional DFT-based channel estimate for the desired user is given by

$$\hat{\mathbf{h}}_{DM-dft} = [\tilde{H}_{J_d,conv}, \tilde{H}_{J_d+1,conv}, \ldots, \tilde{H}_{J_d+L_d-1,conv}]^T. \quad (7)$$

B. *Proposed Channel Estimation*

The SRS is usually transmitted on the wider bandwidth than that of the DM-RS on every second subcarriers. In general, the number of subcarriers on which SRS is transmitted is larger than that of subcarriers on which DM-RS is transmitted. Therefore, the channel estimation performance using SRS will be better than that using DM-RS.

An SRS-based coarse estimate of the channel coefficient is obtained by the LS method as follows:

$$\hat{H}_{k,SRS} = \frac{Y_k}{S_k} = H_k + \frac{U_k}{S_k}, \quad k \in K_{SRS}. \quad (8)$$

The channel coefficient for the subcarriers on which SRS is not transmitted is obtained by interpolation using $\hat{H}_{k,SRS}$ as follows:

$$\hat{H}_{k,SRS} = \frac{\hat{H}_{k-1,SRS} + \hat{H}_{k+1,SRS}}{2}, \quad k \in \bar{K}_{SRS}, \quad (9)$$

where $\bar{K}_{SRS} = \{J_s+1, J_s+3, \ldots, J_s+2L_s-1\}$. The channel coefficients for the subcarriers allocated to the desired UE are given by $\hat{H}_{k,SRS}, k \in K_{DM}$. Then, the LS-based proposed scheme is given by

$$\hat{H}_{k,SRS-LS} = \frac{\hat{H}_{k,DM} + \hat{H}_{k,SRS}}{2}, \quad k \in K_{DM}. \quad (10)$$

We denote the LS-based proposed scheme with vector notation:

$$\hat{\mathbf{h}}_{SRS-LS} = [\hat{H}_{J_d,SRS-LS}, \hat{H}_{J_d+1,SRS-LS}, \ldots, \hat{H}_{J_d+L_d-1,SRS-LS}]^T. \quad (11)$$

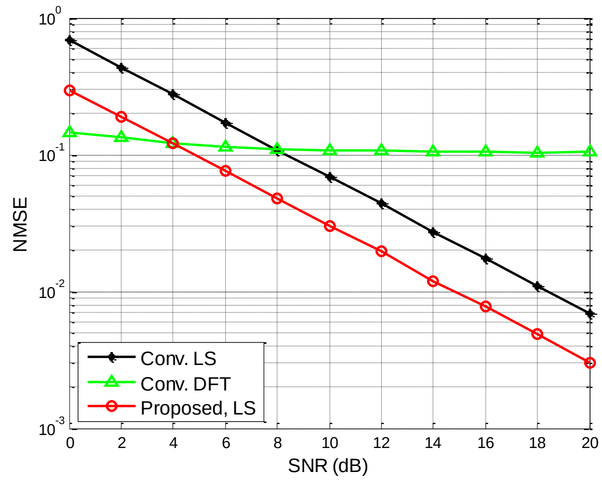

Figure 2. NMSE comparison when $L_s = 18$.

IV. Simulation Results

In this section, we perform computer simulations to investigate the performance of the proposed channel estimation scheme.

For simulation purpose, we used simple six-tap channel model in the time domain with exponential power delay profile [10]

$$|g_l| = \exp\left(-\frac{l}{10}\right), \; l = 0, 1, \ldots, 5, \quad (12)$$

and phase characteristics uniformly distributed between 0 and 2π for each channel tap. The simulation parameters are given in Table I where the number of subcarriers allocated to the desired UE is $L_d = 12$.

We consider the normalized mean-square error (NMSE) of channel estimate in order to compare the channel estimation performance, which is defined as

$$NMSE = \frac{\|\mathbf{h} - \hat{\mathbf{h}}\|^2}{\|\mathbf{h}\|^2}, \quad (13)$$

where $\hat{\mathbf{h}}$ means the channel estimate.

Fig. 2 shows the NMSE of the proposed schemes and the conventional schemes. In this figure, 'Conv. LS', 'Conv. DFT', and 'Proposed, LS' means the LS- based conventional scheme, DFT-based conventional scheme, and LS-based proposed scheme, respectively. In the proposed scheme, the number of subcarriers allocated to the SRS transmission is $L_s = 18$. From the figure, we can observe that the LS-based proposed scheme has better NMSE performance than the LS-based conventional scheme. The DFT-based conventional scheme has the best performance when the signal-to-noise ratio (SNR) is low. However, LS-based proposed scheme has better performance than the DFT-based conventional scheme when the SNR is high. It is because the number of subcarriers assigned to the desired UE is too small to apply DFT-based channel estimation scheme

V. Conclusion

In this paper, we proposed an improved channel estimation scheme for LTE-Advanced uplink system: LS-based proposed scheme. In the proposed scheme, SRS is used to improve channel estimation performance which is periodically transmitted on the last symbol of the subframes using wider bandwidth than that of the DM-RS. In the LS-based proposed scheme, SRS-based LS estimate is combined with the DM-RS-based LS estimate. Through the simulation results, we showed that the proposed scheme has better channel estimation performance than the conventional schemes.

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