Adaptive Design Method for LTE-Advanced Reference Signals

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***Abstract*—In this paper, we presented a novel adaptive design method for LTE-A reference signals. Different reference signals mapping patterns display different performance at different environment such as low or high mobility and modulation rank. We proposed that different RS mapping pattern is chosen according to application environment of achieving the optimum performance of the system. The downlink reference signals were taken as an example to proof the novel method is effective by simulation performance.**

I. INTRODUCTION

The third-Generation Partnership Project Long-Term Evolution (3GPP-LTE) specification provides a framework for increasing capacity, improving spectrum efficiency, improving coverage, and reducing latency compared with current High Speed Packet Access (HSPA) implementations. In addition, transmission with multiple input and multiple output (MIMO) antennas and Orthogonal Frequency Division Multiplexing (OFDM) will be supported for greater throughput, as well as enhanced capacity or range. In 3GPP-LTE system a reference signal RS that is modulated into reference symbols to be employed for the purpose of for channel estimation and measurements in the terminals.

The demodulation RS (DM-RS) and Channel Statement Information RS (CSI-RS) design [1] are Two types of reference signals (RS) used for LTE-Advanced. One is the reference signal targeting physical downlink control channel (PDSCH) DM-RS, and the other is the reference signal targeting CSI estimation. The optimum RS will improve the system performance. Therefore, particular attention has been given to the RS Pattern design for effective channel estimation. Different RS mapping patterns display different performance at low or high mobility and modulation rank [2-4]. LTE uses adaptive modulation and coding (AMC) to improve data throughput. This technique varies the downlink modulation coding scheme based on the channel conditions for each user. When the link quality is good, the LTE system can use a higher order modulation scheme (more bits per symbol), which will result in more system capacity. On the other hand, when link conditions are poor due to problems such as signal fading, the LTE system can change to a lower modulation scheme to maintain an acceptable radio link margin. LTE also support low and very high mobility speed.

Therefore, a constant pattern is hard to obtain the optimum estimation results when the system has to work in different environment. In this paper, we propose an adaptive RS design method for LTE-Advanced. By choosing different RS mapping pattern according to mobile speed and modulation, the optimum performance of the system was achieved. Then, we take the DM-RS pattern design as example to show the benefit provided by the novel scheme.

II. ADAPTIVE RS DESIGN METHOD

A. System Model

Suppose the source sends a signal to the receivers with the frame structure shown in Fig. 1, where we consider an OFDM system with M subcarriers and total transmit bandwidth B. The duration of one OFDM symbol is T. A packet consists of N_x frames, which consist of N_d OFDM data symbols and one pilot in each subcarrier. With perfect synchronization, the corresponding system model is then given by

$$Y_k(n,m) = H_k(n,m)X_k(n,m) + Z_k(n,m) \quad (1)$$

where $k \in \{1,2,\cdots N_x\}$, $n \in \{1,2,\cdots N_d\}$ and $m \in \{1,2,\cdots M\}$ are the frame index, the symbol index and subcarrier index, respectively; furthermore, $Y_k(n,m)$ and $X_k(n,m)$ are the receive and transmit symbols, respectively, $H_k(n,m)$ denotes the channel coefficients, and $Z_k(n,m)$ is additive white Gaussian noise with

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variance σ_Z^2. We consider time-varying Rayleigh fading channel. The channel time-frequency domain coefficient $H_k(n,m)$ are related to the delay-Doppler spreading function $S_k(n,m)$ of the channel via a 2-D Fourier transform [5],

$$H_k(n,m) = \frac{1}{\sqrt{MN_d}} \sum_{\tau=0}^{M_\tau-1} \sum_{l=-\frac{M_v}{2}}^{\frac{M_v}{2}} S_k(n,m) e^{-j2\pi(\frac{m\tau}{M} - \frac{nl}{N_d})} \tag{2}$$

where τ, l denote discrete delay and discrete Doppler, respectively. M_τ dentotes the channel's maximum delay spread and M_v characterizes the maximum Doppler spread. Since in practice $M_\tau \ll M$ and $M_v \ll N_d$, $H_k(n,m)$ is a 2-D lowpass function.

B. *Adaptive RS Design Method*

In this section, we take DM-RS pattern as an example to show our new design method. Because the different RS mapping patterns display different performance at low and high mobility, block-type RS mapping patterns serve the true for slow changed channel and comb-type RS mapping patterns hold true for fast changed channel. We take the performance in [6] as example, in which M=52 sub-carriers which consists of OFDM symbols, bandwidth B=10MHz, and carrier frequency 2GHz. The four options DM-RS patterns are shown in fig. 2.

To have a better understanding on some other environment parameters, we consider the performance of the DM-RS patterns in [6] under urban and rural environment. We compare Rank1 performance under different mobile speed and environment. The simulation conditions are shown in Table 1. Fig 3 and Fig 4 show the performance comparisons for Rank 1 and Rank2. All patterns perform similarly in urban and rural environment. Among the four options Opt.2 structure provides a large gain at the mobile speed less than 30 km/h for rank 2 transmissions and Opt.2 structure also have good performance for rank 1 transmission. However, Opt.1 and Opt.3 displays better performance at the mobile speed 60 km/h and 120 km/h for rank 2 transmissions, in the same time, the performance of Opt.2 structure is worse, specially for 64QAM.

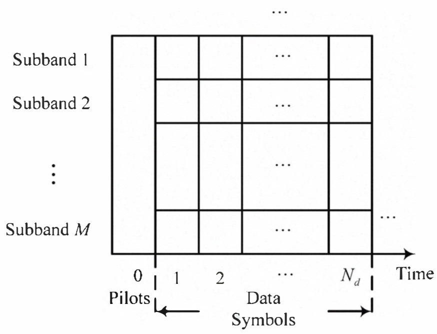
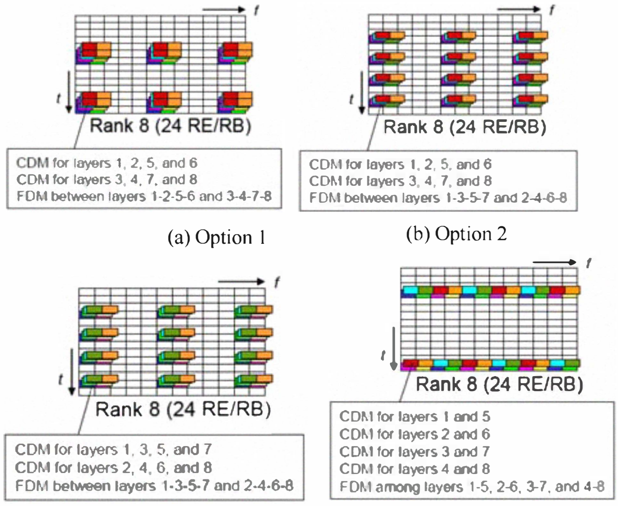


Fig. 1 Frame structure of the transmission from the sender to the receivers

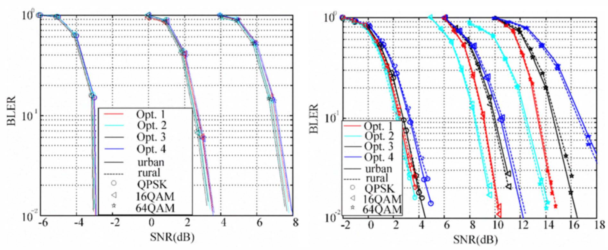


(a) Option 1 (b) Option 2

(c) Option 3 (d) Option 4

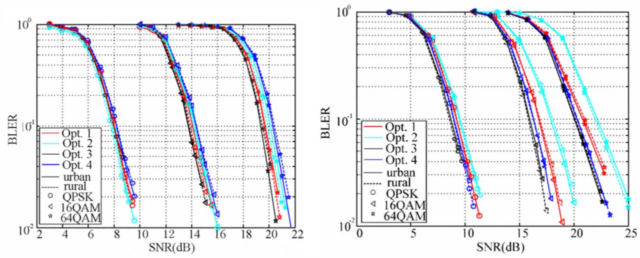
Fig. 2 The four options DM-RS patterns

Based on the above discussion, the proposed DM-RS design method choose optimum DM-RS mapping pattern according to the modulation and the feedback parameters which include the mobile speed which will be estimated by the velocity estimation introduced in [7]. The new adaptive DM-RS design method is showed in Fig. 5.



(a) Rank1, 30km/h (b) Rank1, 350km/h

Fig. 3 Performance comparisons of DM RS under rural and urban environment



(a) Rank2, 3km/h (b) Rank2, 120km/h

Fig. 4 Performance comparisons of DM RS under rural and urban environment

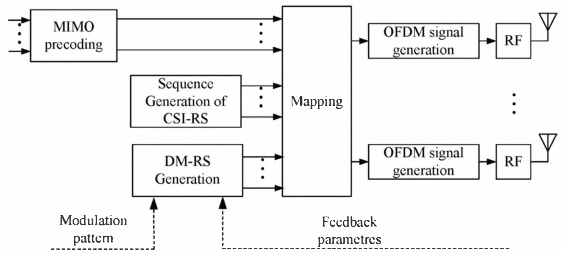


Fig. 5 Adaptive DM RS Model

III. SIMULATION EVALUATION

In order to evaluate the proposed method, we compare the performance of the proposed scheme to the performance in [6]. The simulation conditions are shown in Table 1. In Fig. 6, the average throughput of proposed scheme under the different mobile speed and modulation (16QAM and 64QAM) is compared to the average throughput of proposed scheme in [6] for rank 2 transmission. The solid lines show the average throughput when one of four options was chosen and dash line denotes the average throughput of new scheme, in which the optimum option will be chosen according to the modulation and feedback parameters.

IV. CONCLUSIONS

This paper investigated the novel adaptive RS design method and makes following proposals: By choosing different RS mapping pattern according to different mobility environment and modulation, the throughput gain is achieved. Our simulation results support our opinions.

ACKNOWLEDGMENT

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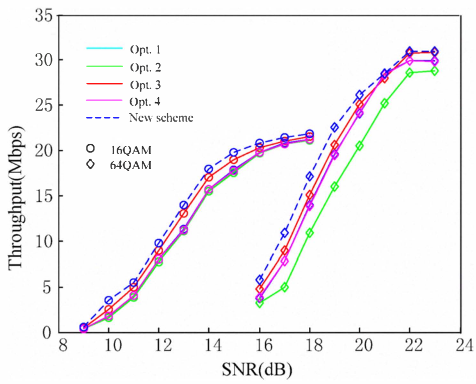

Fig. 6 Comparison of the average throughput of the new scheme to [3] for Rank 2 transmissions

Table 1 Simulation condition

System bandwidth	BW = 10 MHz
Number of subcarriers	600
Channel coding / decoding	Turbo coding (*R*, *K* = 4) / Max-Log-MAP decoding
Modulation and coding scheme (MCS)	QPSK, *R* = 1/2 16QAM, *R* = 1/2 64QAM, *R* = 1/2
Precoding	Not applied
Antenna configuration	1-by-2 SIMO, 2-by-2, 4-by-4 MIMO
Channel model	Typical Urban channel
Channel estimation	MMSE channel estimation in frequency domain and coherent averaging in time domain for $f_D \leq 55.5$ Hz 2D-MMSE channel estimation for $f_D > 55.5$ Hz
Signal detection	MMSE detection

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