

Recursive Least Square Based Reduced-Rank Blind Channel Estimation Algorithm for CDMA Systems

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Abstract

Generally, the high speed data transmission and reliable communication systems is often desired. For this reason, the channel estimation becomes an important topic in the communication community. In the last few decades, many works have done over the reduced-rank channel estimation approaches. Although many of them provide good performance but they incur high computational complexity, so it is infeasible to implement in real-time. In this paper, we proposed an adaptive recursive least square based reduced-rank channel estimation algorithm for code division multiple access systems. The performance of this algorithm is compared with the full-rank recursive least square algorithm. Numerical simulation results show that the proposed algorithm provides reasonable performance improvement and lower complexity at a situation where the number of sample is small.

Keywords: Adaptive reduced-rank RLS algorithm, code division multiple access, channel estimation, full-rank RLS algorithm, 4G and long term evolution.

INTRODUCTION

There have been significant research efforts for the adaptive filters and their application in diverse areas [1-3]. In the last few years, the reduced-rank signal processing technique has been applying on different applications where the numbering of filtering elements are quite high [2,3]. The performance and complexity of this type algorithm depend on the full-rank receive signal and the total number of filter elements [1, 5-7]. If the filter elements are large, the huge number of samples or received symbols is required to adapt the system. In case of mobile communication, the adaptive filter requires significant number of filter elements when the signals are highly affected by noise as well as interference [8-13].

For solving the above aforementioned problem, the adaptive reduced-rank technique is one of the potential schemes for the mobile communication system.

Basically, the reduced-rank channel estimation technique provides reasonable bit error rate performance with a lower algorithmic complexity at lower sample situation [4-6]. Problem of feature selection is the source of reduced-rank channel estimation [7]. Indeed, the main goal of channel estimation is to represent the received information in an effective way that needs a small number of symbols [7].

Basically, there are different adaptive reduced-rank channel estimation techniques such as eigenvalue decomposition techniques [8, 9], the multistage wiener filter (MWF) [10,11], the auxiliary vector filtering (AVF) approach [12,13] and adaptive interpolated FIR filter with time-varying interpolators [14-18]. Unfortunately, there are different problems and performance with the above adaptive reduced-rank

channel estimation techniques. The main problem of the above techniques is that all methods depend on the received signal quality and filter elements [19-23].

Furthermore, the variable step size based least mean square and its different channel estimation algorithmic forms for 4G LTE (long term evolution) system are presented in [24-27]. The mean and mean square performances are compared with the existing methods. Moreover, the pilot signal based weighted least square algorithms for different communication systems are presented in [28, 30, 34]. The idea is extended for MIMO-OFDM 4G communication systems [26]. The designed challenges for 4G communication systems are also presented in [29-32].

In this paper, we develop an adaptive reduced-rank channel estimation technique based on the interpolation, decimation and reduction approach. In this scheme, the filtering element is reduced so that the computational complexity is significantly decreased. Therefore, it provides reasonable convergence rate. In this work, we proposed a recursive least square (RLS) algorithm based on interpolation, decimation and reduction. We apply this algorithm to the code division multiple access systems and compare the performance with the full-rank RLS scheme [16, 38].

The rest of the paper is organized as follows. Section II represents the channel estimation framework, section III demonstrates the simulation results, section IV describes the computational complexity, and section V represents the conclusion and future work.

CHANNEL ESTIMATION ALGORITHM

In this section, we describe the adaptive reduced-rank channel estimation technique based on interpolation, decimation and

reduction filtering. The main function of this reduced-rank channel estimation technique is to extract the most important features from the received information so that the system needs to process small number of samples. Consequently, the dimensionality of the processed signal and algorithmic complexity are decreased. The detail RLS algorithm is demonstrated in Fig.1 [1]. The RLS iteratively computes the filter coefficients that minimize a cost function related to the input signals [33-37].

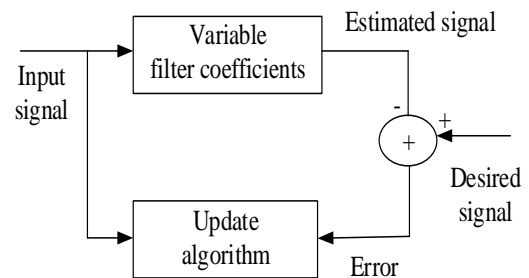


Figure 1: RLS algorithmic process [1].

This dimensionality reduction is performed by mapping the received information into a new data set of lower dimensionality [1]. Consider the received information (i) of size $M \times 1$ and the dimensionality reduction is done by a projection matrix S of size $M \times D$ [20]:

$$\bar{r}(i) = S^H r(i), \quad (1)$$

where $r(i)$ is the received information, and $\bar{r}(i)$ is the received data after dimensionality reduction.

The design of the projection matrix S is the main problem for the reduced-rank channel estimation technique. In this algorithm, we design the projection matrix based on the interpolation and decimation. Here, the rank reduction is done by eliminating insignificant data during filtering. After that by using an interpolator, the eliminated data samples are recreated. The input data can express as follows [1]:

$r(i)=[r_o^{(i)} r_1^{(i)} \dots r_{M-1}^{(i)}]^T$ and the interpolator filter $V(i)=[v_o^{(i)} \dots v_{N_I-1}^{(i)}]$, then the interpolated matrix $r_I(i)$ can be express as follows:

$$r_I(i) = V^H(i) r(i), \quad (2)$$

Dimensionality reduction is performed by a decimation matrix S of size $D \times M$ where $D=M/L$, M is the number of samples and L is the decimation factor. Here, we consider D as a fixed parameter. So, the rank-reduction is performed as follows:

$$\bar{r}_D = S r_I(i). \quad (3)$$

In the following section, the simulation results are presented.

SIMULATION RESULTS

In this section, the numerical simulation results of the proposed algorithm are demonstrated. We apply this adaptive reduced-rank filtering scheme to the CDMA system [16]. The simulation is conducted using the Matlab software. For the simulation, we consider the processing gain is 32, unity bit energy, the number of transmitted symbol is 1500 and the number of scattering element is 20.

The performance of the proposed algorithm is compared with the full-ranked RLS and theoretical value. It can be seen that the theoretical BER achieves the convergence very fast as expected. The reduced-rank RLS provides similar convergence rate compared with full rank RLS.

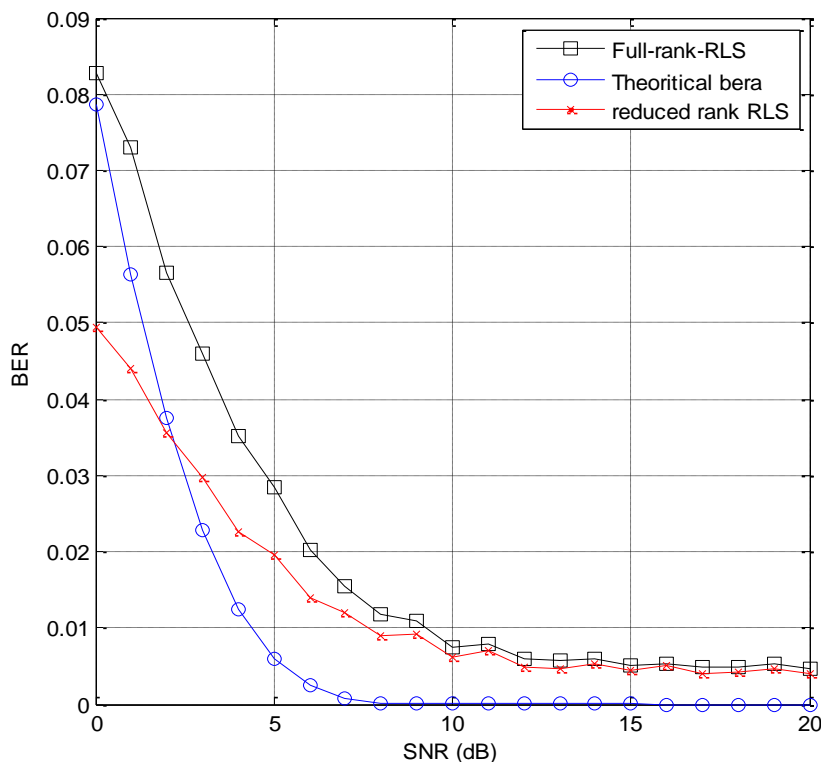


Figure 2: Comparison of BER performance of theoretical, full rank RLS, reduced rank RLS of a CDMA system for 5-tab channel when $f_d = 20$ Hz.

The Fig. 2 shows the bit error rate performance for 5-tab channel when

Doppler frequency $f_d = 20\text{Hz}$ of a CDMA system using full rank RLS and reduced rank RLS.

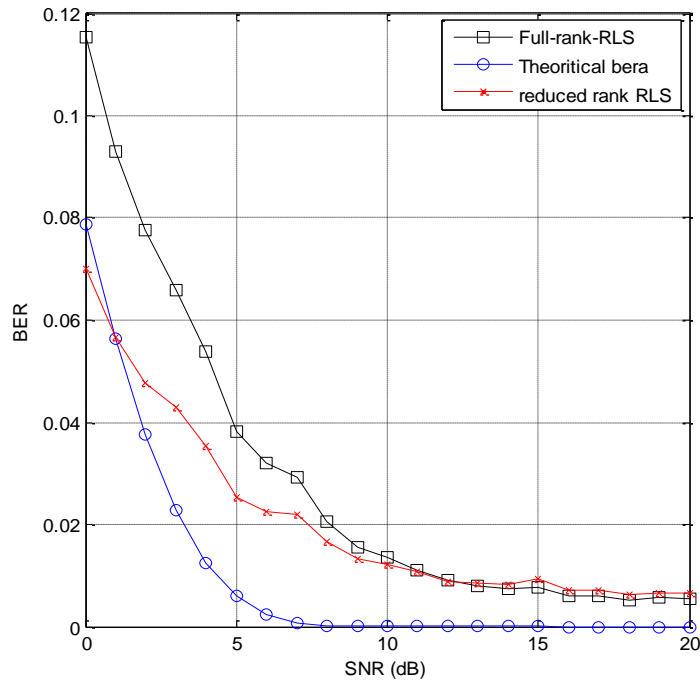


Figure 3: Comparison of BER performance of theoretical, full rank RLS, reduced rank RLS of a CDMA system for 5-tab channel when $f_d = 40\text{ Hz}$.

Fig. 3 shows the bit error rate performance for 5-tab channel when Doppler frequency

$f_d = 40\text{Hz}$ of a CDMA system using full rank RLS and reduced rank RLS.

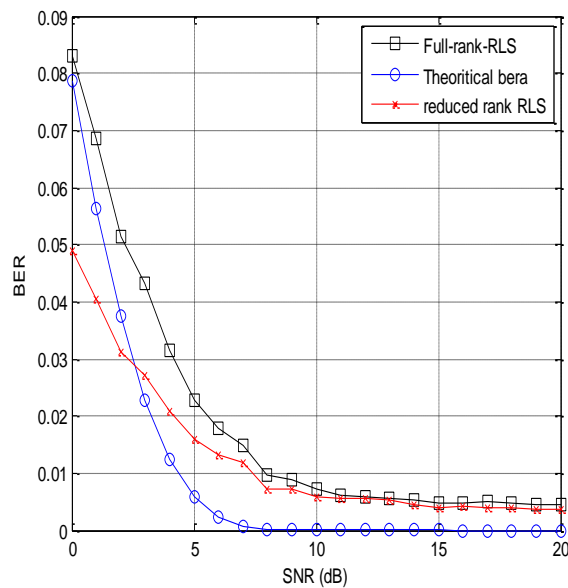


Figure 4: Comparison of BER performance of theoretical, full rank RLS, reduced rank RLS of a CDMA system for 3-tab channel when $f_d = 20\text{ Hz}$.

Fig 4 shows 3-tab channel when Doppler frequency 20Hz of a CDMA system. Fig. 5 shows the bit error rate performance for 5-

tab channel when Doppler frequency $f_d = 40\text{Hz}$ of a CDMA system using full rank RLS and reduced rank RLS.

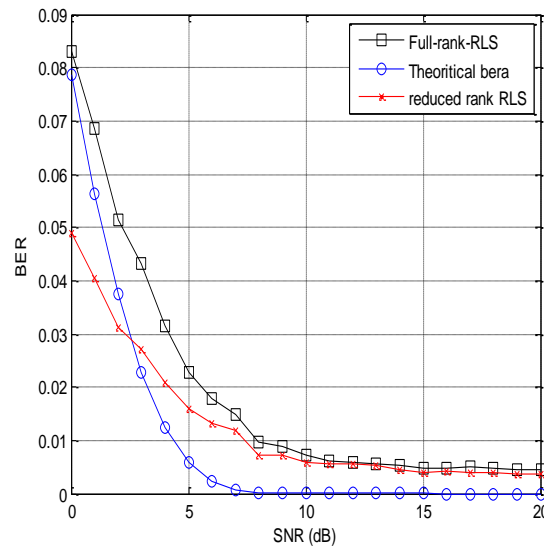


Figure 5: Comparison of BER performance of theoretical, full rank RLS, reduced rank RLS of a CDMA system for 3-tab channel when $f_d = 40\text{ Hz}$

COMPLEXITY ANALYSIS

Fig. 5 shows the arithmetic complexity of full-rank RLS and reduced-rank RLS scheme. It shows that the reduced-rank RLS requires less complexity compared

with the full-rank RLS approach. This is due to the fact that the rank of the received symbols is reduced, and the algorithm processes the less number of symbols to adapt the system.

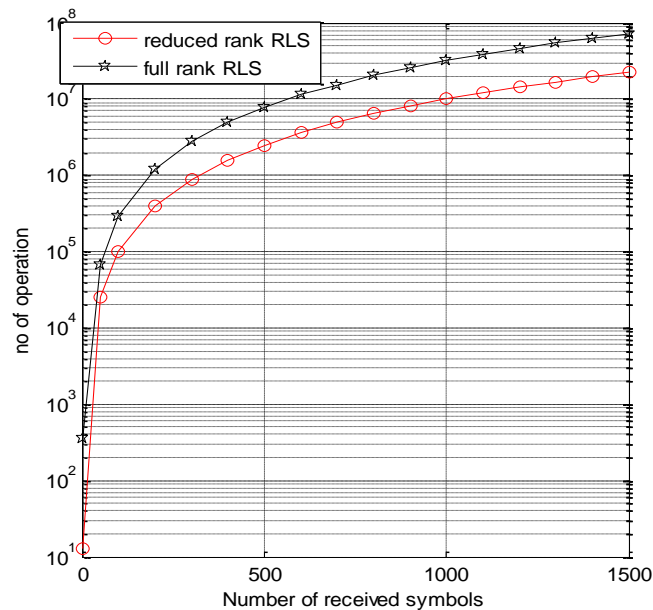


Figure 6: Comparison of arithmetic complexity full- rank RLS and reduced rank RLS schemes.

CONCLUSIONS AND FUTURE RESEARCH

This paper adapts the reduced-rank adaptive algorithm for a CDMA system. It shows that there is a trade-off between the system performance and complexity. It can be clearly shown that the reduced-rank filter is a powerful technique due to its effectiveness in low-sample-support situations where it can offer reasonable performance. This improvement is due to the dimensionality reduction carried out by this adaptive scheme that allows the use of adaptive algorithm with small number of filter elements. In future, the algorithm can also be applied to other applications such as MIMO systems, equalization and GPS jammer suppression. The proposed algorithm can also be applied to the direct sequence CDMA systems [20]. The algorithm can be extended and applied for different communication systems [24-38].

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