Eigenvalue-Decomposition-Based Recursive Least-Squares Algorithm for OFDM Communications over Fast Time-Varying Channels

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1. Introduction

Beyond IMT-2000 era, OFDM-based mobile radio systems such as MC-CDMA and OFDMA have been studied energetically. Adaptive array consisting large number of elements and having fast convergence rate would be an essential requirement to implement such OFDM systems in fast time-varying channels.

Eigenvalue Decomposition has been introduced to adaptive array systems in purpose of reducing the total computational load [1]. On the other hand we have experienced that Maximal Ratio Combining can be performed sufficiently, only referring to previous three samples [2]. In this paper, considering the result achieved in [2], we propose an algorithm call Eigenvalue-Decomposition-based Recursive Least-Squares (ED-RLS), where eigenvalue decomposition is been used to achieve a fast convergence rate in adaptive array and also verify the system performance by a computer simulation. Finally we describe an OFDM communication system, where the proposed ED-RLS algorithm could be applied.

2. Eigenvalue Decomposition based RLS

Fig.1 illustrates the configuration of the proposed ED-RLS beamforming algorithm, which can be applicable in an environment where there is one desired signal and one interference signal, both having multipath. In the proposed scheme, first we calculate the correlation matrix among the array element signals by carrying out the sliding average of past K symbols. The correlation matrix of the array output signal at time t is given by

$$\mathbf{R}_{XX}(t) = \frac{1}{K}\sum_{i=0}^{K-1}\mathbf{X}(t-iT_s)\cdot\mathbf{X}^H(t-iT_s) \tag{1}$$

where T_s, and $\mathbf{X}(t)$ denote the symbol duration, and received array signal, respectively. Here $\mathbf{X}(mT_s)$ is defined as

$$\mathbf{X}(mT_s) = \mathbf{A}\cdot r^m + \mathbf{B}\cdot i^m + \mathbf{n} \tag{2}$$

where $\mathbf{A}$ and $\mathbf{B}$ denote the complex channel respond vector of the desired and interference signals and r^m, i^m and $\mathbf{n}$ denote the desired and interference signals and noise, respectively. Then we divide the received signal into two orthogonal components by eigenvalue decomposition. Here we use the eigenvectors of the highest and the second highest eigenvalues of the correlation matrix $\mathbf{R}_{XX}(t)$, as the orthogonal weight vectors. Finally we extract the desired signal $\overline{r^m}$, by performing RLS estimation for only these two orthogonal components.

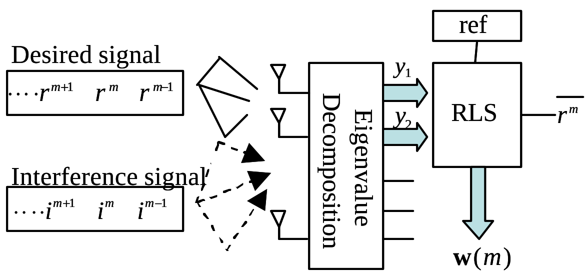

Fig 1 Basic configuration of ED-RLS algorithm

As it is well known that the number of convergence steps of RLS algorithm depends on the number of the weights which have to be updated, by dividing the M-element array output signal only into two orthogonal streams, a fast convergence rate can be expected.

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3. Simulation Conditions and Results

3.1 Simulation Conditions

System parameters are given in Table 1. System performance is measured by the mean-squared error, which is averaged over thousand bits. Further the desired signal itself has been used as the reference signal.

Table 1 System parameter

	Power [dB]	Incident Angle
Desired signal	0dB	30°
Interference signal	10dB	40°
Noise power	-10dB/element/desired signal power	
No. of array elements	16	

3.2 Simulation Results

Fig.2 illustrates the convergence characteristic for conventional RLS and ED-RLS algorithm. Simulation result verifies that the convergent time can be reduced very sharply by applying the proposed ED-RLS algorithm.

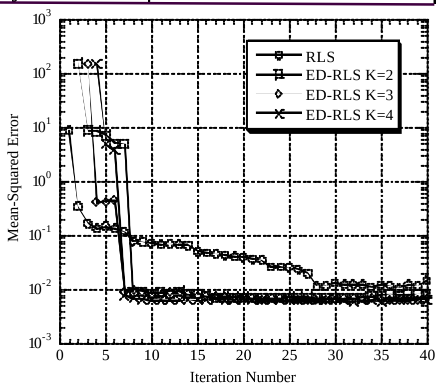

Fig. 2 convergent characteristic for RLS and ED-RLS algorithm

4. ED-RLS based OFDM communication

4.1 Transmitted OFDM Symbol

Fig.3 illustrates the transmitted signal of an OFDM communication system which is intended to be applied in proposed ED-RLS algorithm, where some subchannels are used as pilot signals. Here r_k^m denotes the k^{th} reference signal of the m^{th} symbol.

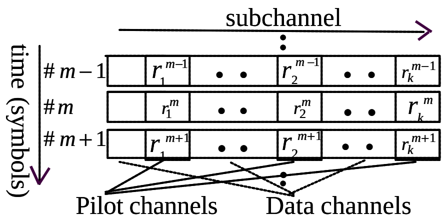

Fig. 3 Transmitted OFDM symbol

4.2 Receiving Scheme of OFDM Application

Fig.4 illustrates the receiving scheme of the proposed ED-RLS algorithm with application to OFDM system. In the receiver, first we demodulate the received signal of each array element separately. Secondly we combine the array output signals by performing ED-RLS algorithm. Here it should be noted that we perform ED-RLS only to the subchannels that are used as pilot channels, and interpolate the weight vectors of the data subchannels, which are in between the pilot subchannels.

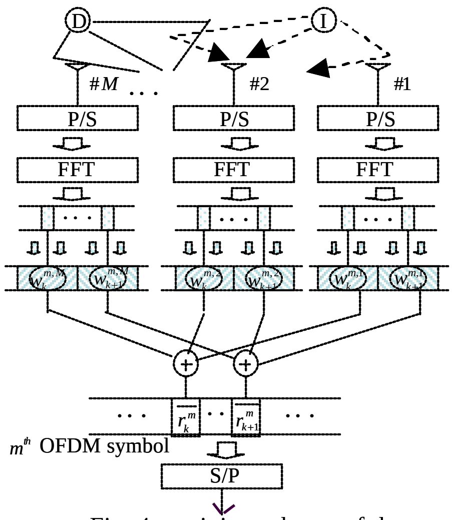

Fig. 4 receiving scheme of the proposed OFDM system

5. Conclusion

A beamforming algorithm with a fast convergence rate, which can be applicable to an OFDM communication system, has been proposed and the performance of the proposed scheme is evaluated by a computer simulation. We could gain an essential convergence in the seventh step in a 16-element array configuration, in an environment with -10dB of SNR and 10dB interference signal power.

References

[1] Y. Kamiya, Y. Karasawa, S. Denno, and Y. Mizuguchi, "A Software Antenna: Reconfigurable Adaptive Arrays Based on Eigenvalue Decomposition," IEICE Trans. Commun., Vol. E82-B, NO. 12, pp. 2012-2019, Dec. 1999.

[2] P.S. Wijesena and Y. Karasawa, "Beam-Space Adaptive Array Antenna for Suppressing the Doppler Spread in OFDM Mobile Reception," Interim International Symposium on Antennas and Propagation, 00087, Nov. 2002.