Enhanced Pre-Whitening TDLMS Adaptive Noise Canceller

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Abstract – *In this paper, we propose a new algorithm for adaptive noise cancellation. The main idea behind the proposed algorithm is to introduce a first-order adaptive decorrelation filter to decorrelate the error signal in the existing pre-whitening transform domain least mean square (PW-TDLMS) algorithm. The obtained decorrelated error signal is then used in the adaptation equation of the PW-TDLMS algorithm. The proposed adaptive noise canceller is applied to speech denoising and the obtained results are compared to those of the PW-TDLMS and discrete cosine transform-based algorithms. The comparison is performed in terms of the computational complexity, mean square error (MSE) convergence speed, reached steady state level, steady state excess MSE, misadjustment and output signal to noise ratio.*

Keywords: *Adaptive noise canceller, Pre-whitening transform domain LMS, Speech denoising.*

I. Introduction

The least mean square (LMS) algorithm is widely used in adaptive filtering because of its robustness and low computational complexity [1]. The convergence of this algorithm becomes slow when the input signal is correlated. In other words, the autocorrelation matrix of the latter is ill conditioned [2]. In order to overcome this problem, several algorithms have been proposed in the literature. In [3], Mboub et *al*. proposed a new whitening structure for acoustic echo cancellation. In [4], Douglas et *al*. presented two self-whitening algorithms that use equalization as a pre-whitening filter in gradient adaptations. In [5], Gazor et *al*. classified and studied the different types of adaptive decorrelation algorithms. They proved that the joint decorrelation of the input signal and the error signal allows the improvement of the performances of the decorrelated normalized LMS (DNLMS) algorithm compared to the LMS and NLMS algorithms for a colored input and a colored noise.

The decorrelation of the input signal is also made by transforming the input signal by an orthogonal and unitary transform, such as discrete Fourier transform (DFT), discrete Hartley transform (DHT) or discrete cosine transform (DCT), followed by a normalization of the transformed signal by its energy.

These two operations allow the reduction of the eigenvalue spread of the autocorrelation matrix of the input signal and consequently the improvement of the convergence performance of the resulting algorithm, which is the LMS algorithm in the transform domain (TDLMS) [6]. The orthogonal transforms are limited in terms of decorrelation, which limits the performance of the TDLMS [7]. To overcome this problem, Chergui and Bouguezel proposed in [7] a new pre-whitening of the TDLMS algorithm by introducing a decorrelation filter at the input of the TDLMS filter before applying the transform. This decorrelation reinforces the decorrelation ability of the transform used in the TDLMS and improves the convergence performance of the resulting algorithm. Specifically, the authors proved that the PW-DHT$^{-\pi/6}$-LMS algorithm is better than the DCT-LMS algorithm for adaptive noise cancellation.

The performance of an adaptive filter is also limited by the noise components associated with the gradient vector, and the noise leads to an excess of the mean square error (EMSE) greater than the minimum EMSE achievable by an ideal Wiener filter [5]. In many applications such as noise cancellation and acoustic echo cancellation, the noise is colored, which again causes a higher MSE [5, 8, 9]. In this paper, we propose a solution for this problem by introducing a first-order adaptive decorrelation filter to decorrelate the error signal in the PW-DHT$^{-\pi/6}$-LMS algorithm. This allows us to further reduce the noise energy as well as the steady state reached by the EMSE.

This paper is organized as follows. Section 2 is devoted to a brief description of the PW-DHT$^{-\pi/6}$-LMS algorithm reported in [7] and the development of the proposed algorithm. Section 3 presents and discusses the simulations performed and the results obtained as well as the comparison with existing algorithms. Section 4 considers the computational complexity. Finally, section 5 gives some concluding remarks.

II. Brief Review and Proposed Algorithm

In this section, we briefly review the PW-DHT$^{-\pi/6}$-LMS algorithm and describe the performance measures