Acoustic Echo Cancellation

Himavanth Reddy, ESD15I014

Indian Institute of Information Technology,
Design and Manufacturing, Kancheepuram

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Introduction

Acoustic echo:
It occurs when an audio source and sink operate in full duplex mode. The signal interference caused by acoustic echo is distracting to both users and causes a reduction in the quality of the communication.

Adaptive filters:
Filters that alter their parameters in order to minimize a function of the difference between a desired target output and their output. In the case of acoustic echo in telecommunications, the optimal output is an echoed signal that accurately emulates the unwanted echo signal. This is then used to negate the echo in the return signal. The better the adaptive filter emulates this echo, the more successful the cancellation will be.

Block Diagram

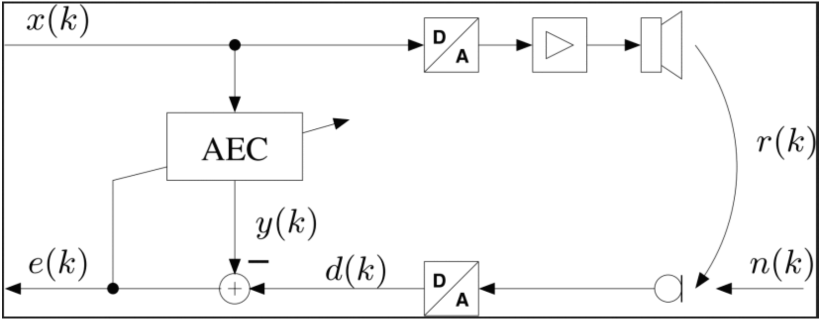


Figure 1: Block Diagram of an Acoustic Echo Cancellation System

Adaptive Algorithms

The algorithms that we will be discussing today for Acoustic Echo Cancellation are:

1. Least Means Square (LMS)
2. Frequency Domain Adaptive Filtering (FDAF)

LMS Algorithm

Given:

- The (correlated) input signal samples $u(1), u(2), u(3), ...,$ generated randomly
- The desired signal samples $d(1), d(2), d(3), ...$ correlated with $u(1), u(2), u(3), ...$

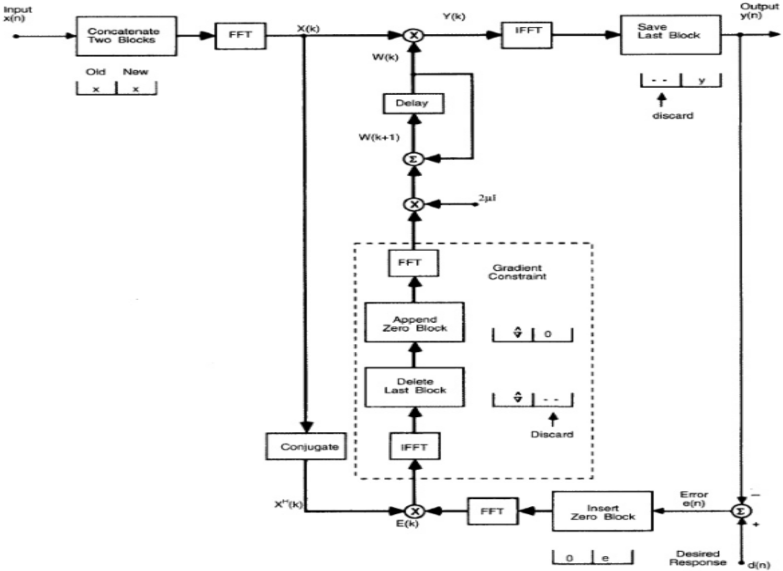
1. Initialize the algorithm with an arbitrary parameter vector $w(0)$, for example $w(0) = 0$.
2. Iterate for $n = 0, 1, 2, 3, ..., n_{max}$
   1. Read /generate a new data pair, $(u(n), d(n))$
   2. (Filter output) $y(n) = w(n)^T u(n) = \sum_{i=0}^{M-1} w_i(n)u(n-i)$
   3. (Output error) $e(n) = d(n) - y(n)$
   4. (Parameter adaptation) $w(n+1) = w(n) + \mu u(n)e(n)$

FDAF Algorithm

For each block of M data samples do the following:

1. Compute the output of the filter for the block $kM, ..., kM + M - 1$
$$\begin{bmatrix} \underline{C} \\ \underline{y} \end{bmatrix} = IFFT\left(FFT(\begin{bmatrix} \underline{w}(k) \\ \underline{0} \end{bmatrix}) * FFT([\underline{u}])\right)$$
2. Compute the correlation vector
$$\begin{bmatrix} \underline{\phi} \\ \underline{D} \end{bmatrix} = IFFT\left(FFT(\begin{bmatrix} \underline{0} \\ \underline{e} \end{bmatrix}) * \overline{FFT([\underline{u}])}\right)$$
3. Update the parameters of the filter
$$FFT\begin{bmatrix} \underline{w}(k+1) \\ \underline{0} \end{bmatrix} = FFT\begin{bmatrix} \underline{w}(k) \\ \underline{0} \end{bmatrix} + \mu FFT\begin{bmatrix} \underline{\phi} \\ \underline{0} \end{bmatrix}$$

FDAF Block Diagram



Performance Parameters

The performance parameter which is used here for the performance evaluation of different AEC Algorithms is known as

Echo Return Loss Enhancement (ERLE)

What is ERLE?
It is the measure of the amount (in dB) that the echo has been attenuated. It is mathematically defined as

$$\text{ERLE(dB)} = 10log_{10}\frac{d^2(n)}{e^2(n)}$$

Where,
$d(n)$ is the far-end echoed signal
$e(n)$ is the residual echo after cancellation

Results

LMS Algorithm

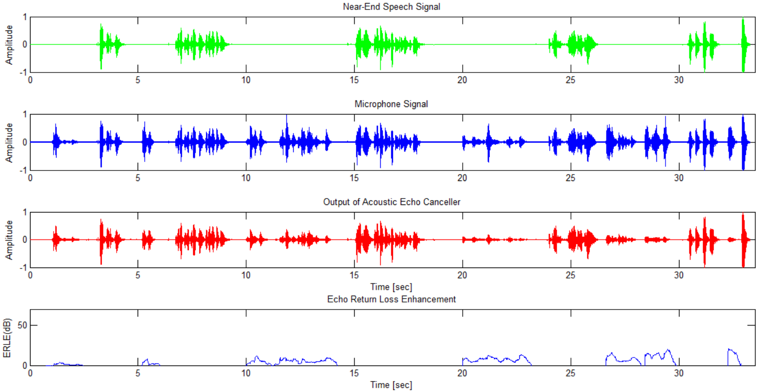


Figure 3: Results with LMS algorithm, Step size = 0.05

LMS Algorithm

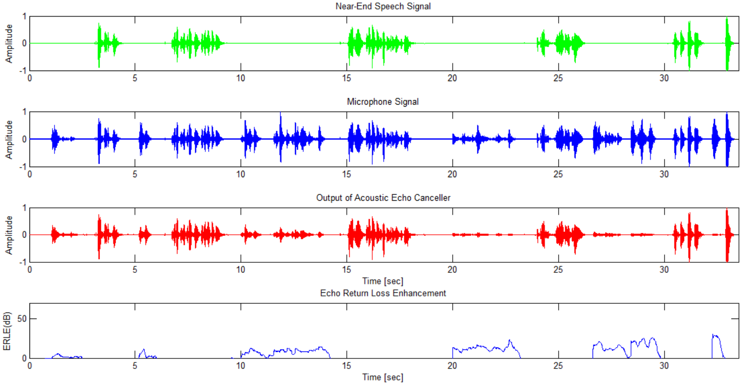


Figure 4: Results with LMS algorithm, Step size = 0.13

FDAF Algorithm

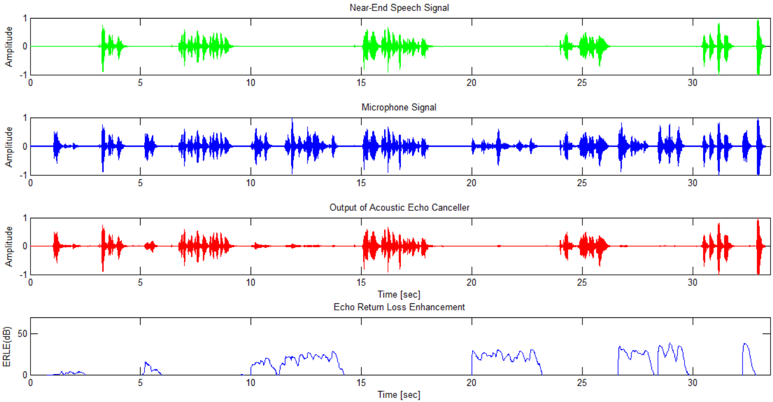


Figure 5: Results with FDAF algorithm, Step size = 0.025

FDAF Algorithm

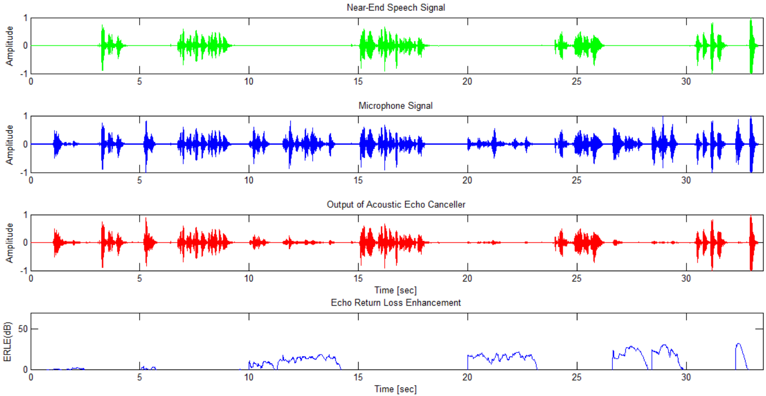


Figure 6: Results with FDAF algorithm, Step size = 0.05

Bibliography

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