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Performance Analysis of RLS and LMS, Used in Adaptive Filters for Active Noise Cancellation of an Elevator Noise

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Abstract- **Noise problems in the environment have gained attention due to the tremendous growth of technology that has led to noisy engines, heavy machinery, high speed wind buffeting and other noise sources. The problem of controlling the noise level has become the focus of a tremendous amount of research over the years. In last few years various adaptive algorithms are developed for noise cancellation. In this work we have discussed the LMS and the RLS algorithm and compared their performances for active noise cancellation of different sources of noise. We have also compared their performances for a real world noise that is cancellation of the noise collected from an elevator. MATLAB Simulink environment are used in this work for simulations.**

***Keywords* - ANC, LMS, RLS, Adaptive Filter, Gaussian Noise.**

I. INTRODUCTION

Noise is present in various form or percentage in almost all environments. Noise can cause hearing loss and may even disrupt meaningful exchange of information between persons. In industry noise can cause many physical problems. Hence noise cancellation is an important and integral part in our environment. The consequences of exposing people to noise from various sources may vary from short term effects such as sleep disturbance to long term effects such as permanent hearing loss. To reduce the noise from source reaching our year involves various methods which can be categorized into:

A. Passive Noise Control

Passive Noise control is a method in which the noise from the source is not allowed to reach the ear of the person. This is done by blocking the path of the noise using absorbing materials or by reflecting the noise in some other direction. Thermocol or polystyrene, clothes and wood are some examples of the materials which absorb the noise and reduce the adverse effects occurring from it.

B. Active Noise Control

Active Noise Control is a very effective electronic method to reduce the effect of the noise in an environment. It is basically generation of anti-noise, equal in magnitude and opposite in phase with the noise. The anti-noise and the noise are destructively interfered to remove the effects of noise from the path of the noise. While passive and active noise cancellation may be applied separately, they are often combined to attain maximum effectiveness in noise cancellation.

II. ADAPTIVE ALGORITHMS USED

A. ***Least mean square (LMS)***

The LMS algorithm is an adaptive algorithm among others which adjusts the coefficients of FIR filters iteratively. It neither requires correlation function calculation nor matrix inversions, which makes it simple and easier when compared to other algorithms.

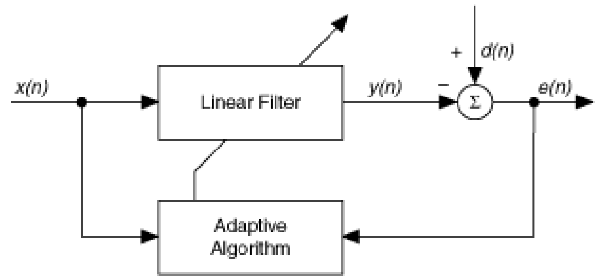

Fig. 1: Block Diagram of LMS Adaptive Filter

The filter weights update equation is given by,

$$w(n+1) = w(n) + \mu e(n)x(n)$$

where , *x(n)* is the input signal to a linear filter, *y(n)* is the corresponding output signal, *d(n)* is an additional input signal to the adaptive filter, *e(n)* is the error signal that denotes the difference between *d(n)* and *y(n).*

B. Recursive least square (RLS)

The Recursive least square adaptive filter is an algorithm which recursively finds the filter coefficients that minimize a weighted linear least squares cost function relating to the input signals.

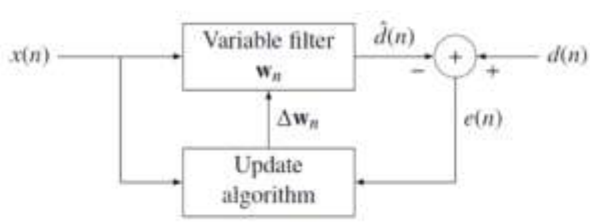

Fig. 2: Block Diagram of RLS Adaptive Filter

where ,

e(n) is the error, d(n) is the desired signal, d^(n) is the estimation.

The filter weights update equation is given by, w(n+1)=w(n)+ e(n)k(n)

Table. I. Adaptive algorithm comparison table

Algorithm	Output signal [y(n)]	Estimate error [e(n)]	Update weights [w(n+1)]
LMS	y(n)=w(n)x(n)	e(n)=d(n)-y(n)	ω(n+1)=ω(n)+ 2μx(n)e(n)
RLS	y(n)=w(n)x(n)	e(n)=d(n)-y(n)	ω(n+1)=ω(n)+ e(n)k(n)

III. Simulation Results

In this section, we have used Simulink in MATLAB for realizing our objective of noise cancellation. Noise Cancellation done using LMS and RLS algorithm for Gaussian noise, Band limited noise and Uniform random noise

A. Simulation Results for the LMS filter algorithm

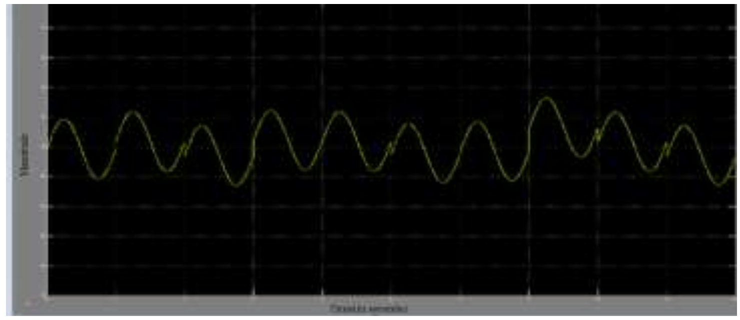

Fig. 3: Noise signal before ANC for Gaussian Noise

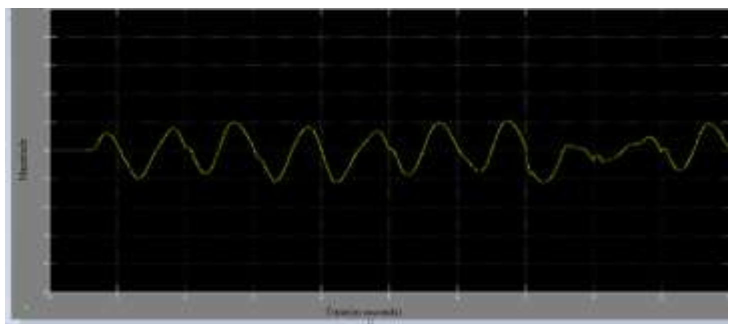

Fig. 4: Noise signal after ANC for Gaussian Noise

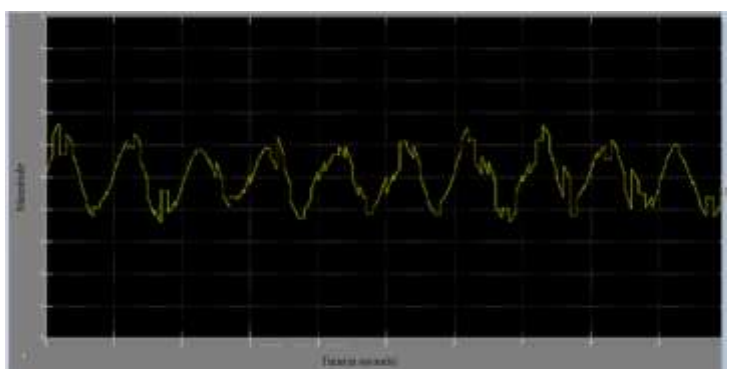

Fig. 5: Noise signal before ANC for Band Limited noise

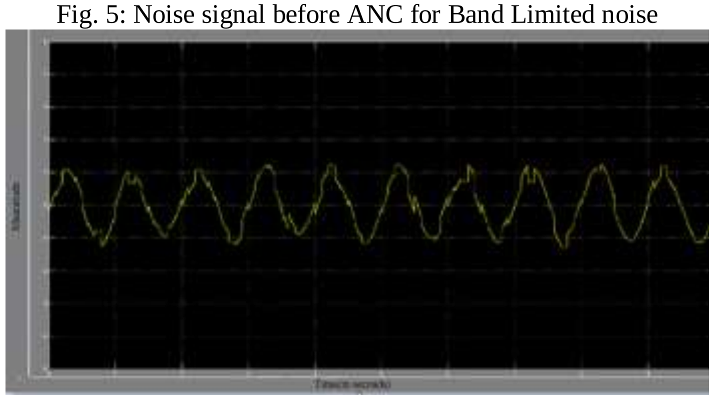

Fig. 6: Noise signal after ANC for Band Limited noise

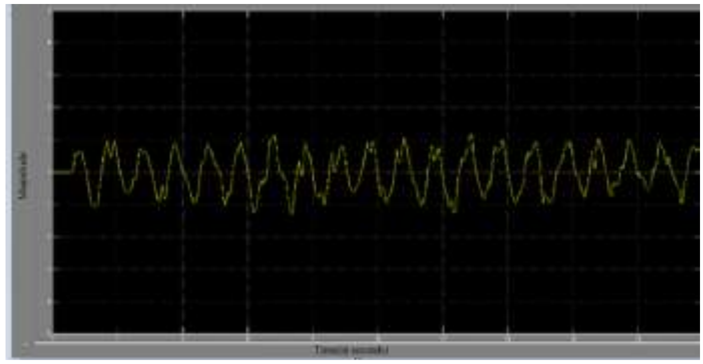

Fig. 7: Noise signal before ANC for uniform random noise.

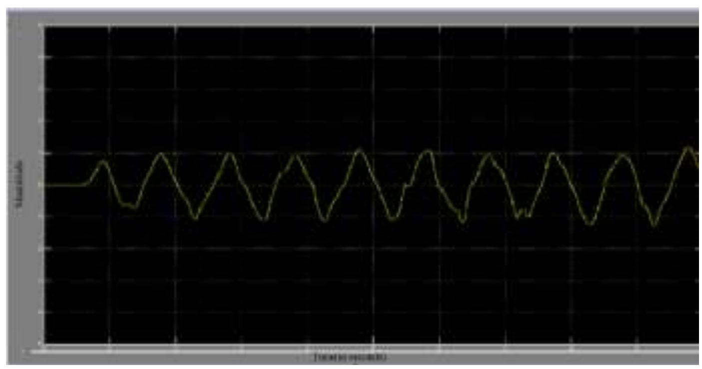

Fig. 8: Noise signal after ANC for uniform random noise.

B. Simulation Results for the RLS filter algorithm

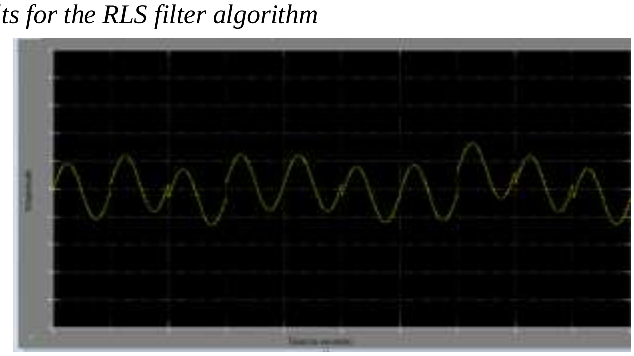

Fig. 9: Noise signal before ANC for Gaussian Noise

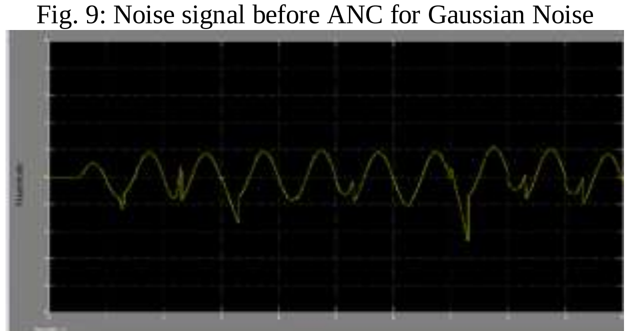

Fig. 10: Noise signal after ANC for Gaussian Noise

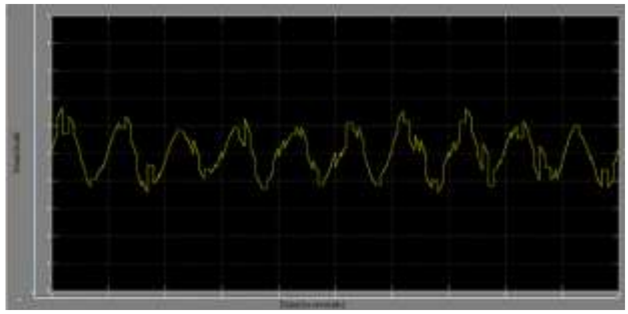

Fig. 11: Noise signal before ANC for Band Limited Noise

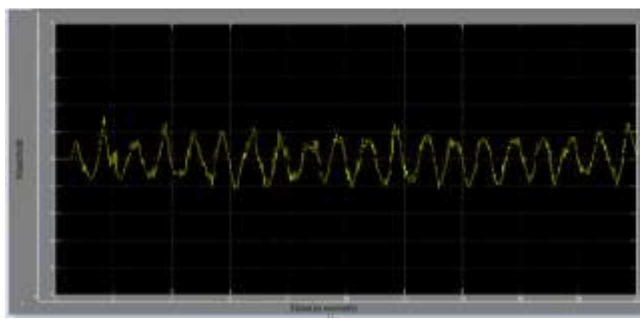

Fig. 12: Noise signal after ANC for Band Limited Noise

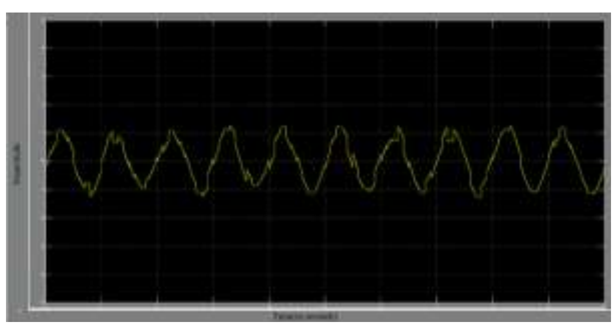

Fig. 13: Noise signal before ANC for uniform random Noise

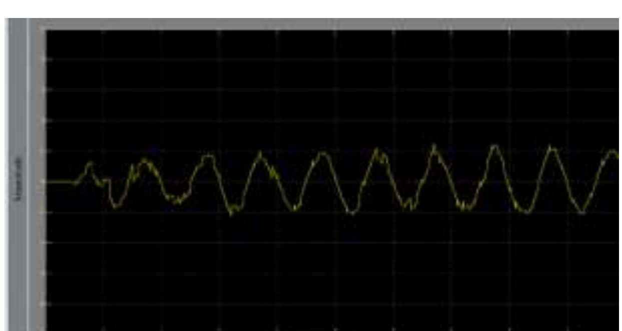

Fig. 14: Noise signal after ANC for uniform random Noise

IV. EXPERIMENTAL RESULTS

In this section we have experimented two algorithms as to how they would perform in reducing noise in case of a real world noise signal. For this we have considered a noise collected from an elevator for total time duration of 10 seconds and applied the two algorithms on it turn by turn. Then the results are analyzed and compared.

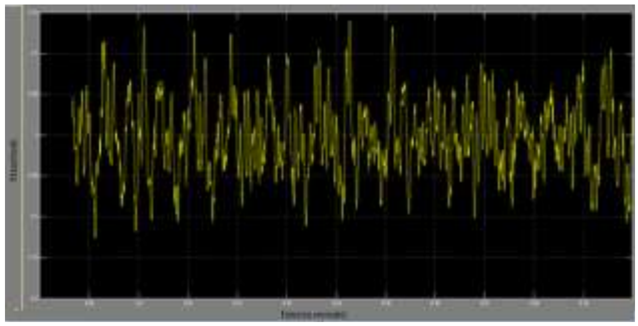

Fig. 15: Noise signal collected from an elevator

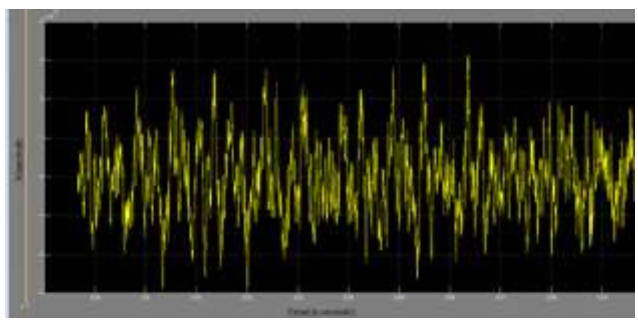

Fig. 16.: Elevator Noise signal after ANC using LMS algorithm

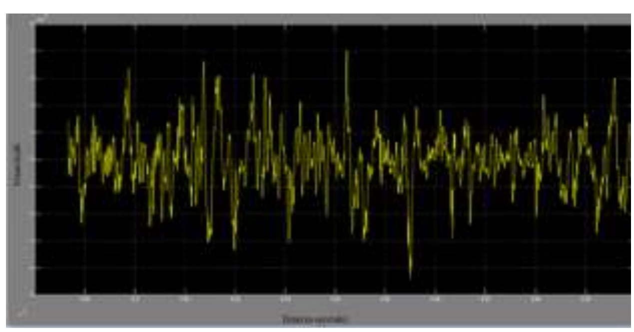

Fig. 17: Elevator Noise signal after ANC using RLS algorithm

V. POWER SPECTRAL DENSITY ANALYSIS OF THE NOISE SIGNAL

Up until now, we have been dealing with signals in the time domain. In this section we move on towards the frequency domain analysis. The power spectrum of a signal represents the contribution of every frequency of the spectrum to the power of the overall signal.

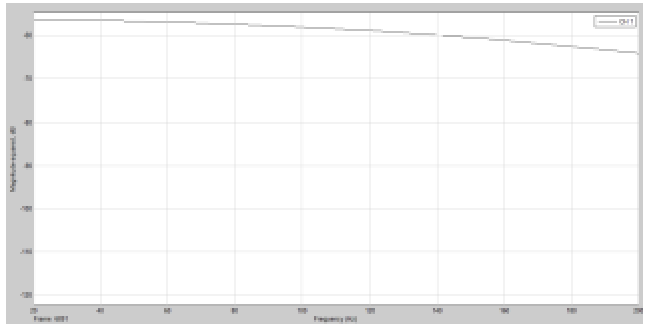

Fig. 18: Power spectral of the elevator noise signal without ANC

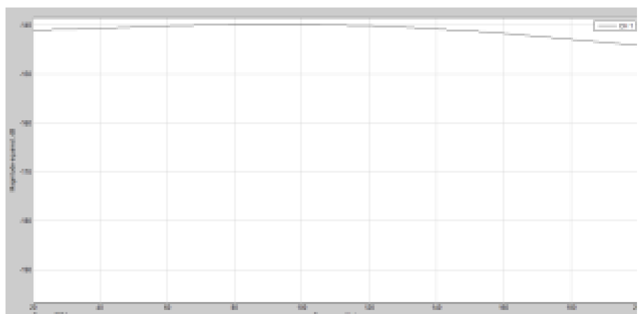

Fig. 19: Power spectral of the elevator noise signal with ANC using LMS.

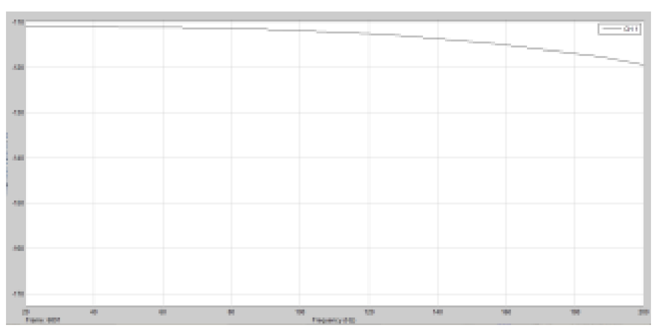

Fig. 20: Power spectral of the elevator noise signal with ANC using RLS

The approximate analysis of the frequency spectrum or the power spectral density analysis in a tablature form is given below

Table. II: Power spectral Comparison

SL NO	Filter Algorithm	Magnitude of the Noise Signal (in dB)			
		AT 20Hz	AT 60Hz	AT 100Hz	AT 140Hz
1	Original noise signal (without any filter algorithm)	-54	-55	-56	-60
2	With the LMS filter algorithm	-141	-140	-140	-142

3	With the RLS filter algorithm	-111	-113	-114	-115

VI. CONCLUSIONS

LMS & RLS algorithms for Active Noise Cancellation have been studied and compared. The implementation and simulation of Adaptive FIR filter using LMS and RLS algorithm have been done using MATLAB Simulink environment and their responses have been studied and compared in various waveforms as given both in the simulation & experimental results. The comparison for different sources of noise shows that RLS is better than LMS. But while we use real time noise we found that LMS shows slightly better result than RLS. The Adaptive FIR filter using LMS algorithm shows relatively good filtering result, having short filter length, simple structure and simple operation, and it is easy to realize hardware.

VII. FUTURE SCOPE

The ANC systems using different adaptive algorithms used for noise control in an elevator, despite of its effectiveness in attenuating low frequency noise, have several limitations. To overcome such limitations, soft computing techniques like genetic algorithm, Particle swarm optimization etc. can be used. Soft computing techniques may be applied to active noise control (ANC) systems in two quite different ways. First, it may be used to adapt the weights of the digital filters which generate the signals to drive the control sources that cancel the noise. Second, it may be used to optimise the locations of the control sources. The genetic algorithm can be used to adapt the weights of the FIR filter. Also a mathematical modelling of the elevator cabin can be done and then different optimisation techniques can be applied to get the optimum solution.

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