INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 3, Issue 6)
Available online at www.ijariit.com

Comparison of FxLMS and NFxLMS Algorithms in MATLAB Using Active Vibration Control

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***Abstract:** The paper presents simulation results of the performance of adaptive filtering algorithms such as Filtered –x Least Mean Square (FxLMS) and the Normalized Filtered-x Least Mean Square (NFxLMS) algorithm using the concept of active vibration control. The FxLMS and NFxLMS algorithms are most popular in adaptive filtering feed-forward control methods. The FxLMS and the NFxLMS are used in order to overcome the disadvantages of conventional Least Mean Square (LMS) algorithm. The MATLAB implementations for both the algorithms are carried out and the parameters such as convergence rate, efficiency, and step size results are compared using the principle of Active Vibration Control.*

***Keywords:** Active Vibration Control, Filtered-x Least Mean Square (FxLMS), Normalized Filtered-x Least Mean Square (NFxLMS), Feed-forward control, Convergence Rate.*

I. INTRODUCTION

"Vibration is a mechanical ponder whereby movements occur around a balance point. Vibration is proficient by bringing a driving capacity into a structure, more often than not with some kind of shaker. On the other hand, a DUT (Device under Test) is appended to the table of a shaker. Vibration testing is performed to look at the reaction of a device under test (DUT) to a characterized vibration condition. The deliberate reaction might be weakness life, thunderous frequencies or squeak and shake sound yield [1]. So these vibrations can be controlled in an active manner. The term filtering in signal processing refers to the linear process designed to alter the spectral content of an input signal in a specified manner. Filters are classified into fixed and adaptive types. Adaptive filters can be implemented in a variety of ways, allowing solutions to practical problems. The input signal is filtered to produce an output which is typically passed on for succeeding processing. FxLMS filter is a versatile channel which is utilized for system identification. The channel delivers an error signal which decreases gradually. The error signal is the difference between the desired signal and the yield of the output signal in the FxLMS channel. The NFxLMS algorithm is the improved model of the FxLMS algorithm. The concept of Active Vibration Control is used in MATLAB. In Active Vibration Control, the random vibration signal is taken as the input signal and the incoming signal is transposed with a cancellation signal and the net result is approximated to zero. In MATLAB it is observed that the resulting error signal is approximated to zero.

II. ACTIVE VIBRATION CONTROL

Active vibration control (AVC) is the dynamic use of force in an equal and opposite frame to the force compelled by the external vibration. Dynamic vibration control depends on standards of superposition and disturbance. It is accomplished by utilization of similar forces yet precisely inverse in phase to the original vibration.

This principle was first connected to vibration reduction systems, particularly in air channels which acts as waveguides, where the acoustic field is easy to lessen the acoustic level in structures with a more complicated geometry or free-field noise, it was endeavored to lessen the noise at the source, by adjusting the vibration conduct of the structures where the noise begins. Figure 1 shows the incoming vibration and cancellation signal transposed, the zero net effect [2].

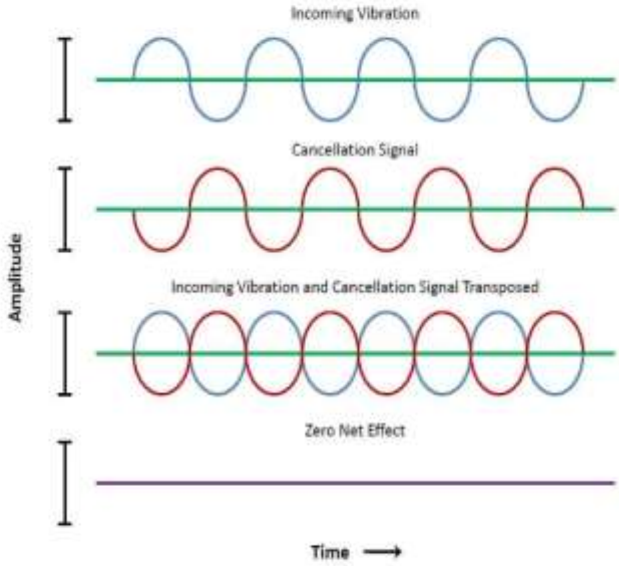

Fig.1 Incoming and Cancellation Signal in Active Vibration Control

Here once more, dynamic arrangements supplement to passive ones, particularly in the low frequency domain as the passive ones are not suitable. This is known as dynamic vibro-acoustic control. At the point when connected to a structure, rather than making an anti-noise wave, the principle comprises of locating vibration sensors on the structure or in the outside space and actuators prepared to make vibrations in the structure to accomplish the minimization objective.

Dynamic vibration control systems, additionally called dynamic vibration cancellation or isolation systems are separate systems that progressively respond to approaching vibrations. That is, they sense approaching vibrations and respond to them, instead of passively decreasing their impact by the excellence of their mechanical structure. There are two general sorts of dynamic vibration cancelation systems: feed forward and feedback systems. Feed forward systems are particularly customized to adjust for periodic vibrations. Feedback systems sense and respond to approaching vibrations. Some feedback systems have a detecting component which detects approaching vibrations and an actuator which responds to these vibrations, either by tuning an isolator to lessen the approaching vibrations or making a signal which cancels them. Some of the advantages of Active Vibration Control are there is no low recurrence reverberation, segregation in the low frequencies, inside feedback loop damps every single mechanical reverberation.

III. FxLMS and NFxLMS ALGORITHMS

In the class of utilization managing with identification, a versatile channel is utilized to give a linear model that speaks to the best fit (in some sense) to an unknown system. The adaptive filter and the unknown system are driven by similar information or it has the same input. The unknown system generates the desired response for the adaptive filter [3]. Conventional (LMS) calculations can't adjust for the impact of the secondary path. For those applications, the adaptive filter channels are made [4]. The main advantage of using FxLMS algorithm is that it is computationally simple like the most commonly used LMS algorithm. The FxLMS algorithm generates the known filter coefficients and the filtered input signal. The secondary path response is generated and the step size is updated. The block diagram for the FxLMS algorithm is shown below in figure 2. The secondary path estimation is made more precise and accurate for FxLMS algorithm [5].

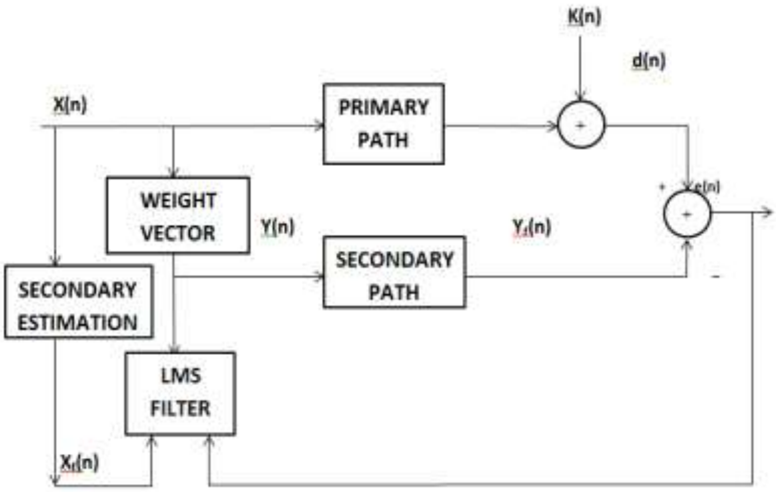

Fig.2: FxLMS Algorithm Block Diagram

The filter updating co-efficient formula for FxLMS algorithm is given by equation,

$w(n+1)=w(n)-mu*e(n)*X_f(n)$
$e(n)=d(n)-y(n)$
Where,

$X(n)$ is the input signal to the primary path

$X_f(n)$ is the filtered input signal

mu is the step size

$w(n)$ is the adaptive filter weight vector

$d(n)$ is the desired signal from the primary path to the adaptive filter

$e(n)$ is the error signal which is the superposition of $d(n)$ and $Y_f(n)$

$Y(n)$ is the system's output

$Y_f(n)$ is the filtered output from the secondary path.

The Normalized Filtered-x Least Mean Square algorithm is modified form of FxLMS algorithm. The normalized filtered-x LMS combines the filtered-x and normalized LMS values [6]. The filter updating co-efficient formula for NFxLMS algorithm is given by
$w(n+1)=w(n)-mu*e(n)*X_f(n)/||X_f(n)||^2$
$mu(n)=mu/||X_f(n)||^2$
Where,
$mu(n)$=Variable step size.

IV. MATLAB IMPLEMENTATION

At the first the input signal must be generated where the sample rates and the number of samples are considered. The boundaries of the input signal are found by taking the length of the sample rate. The filter coefficients for FxLMS and NFxLMS filter is generated. The secondary path response plays an important factor as it may reduce the delay in time. The step size and the adaptive filter coefficients are considered to be different for both the algorithms. As in the concept of active vibration control the inverse form of the vibration signal is taken i.e. the anti- vibration signal. So the inverse of the input signal for a random signal is formed in MATLAB. If the inverse order is equal to the input signal then the error signal and the adaptive filter coefficients are achieved else the known coefficients are to be considered again. Therefore by knowing these parameters the error signal is approximated to zero.

V. RESULTS AND DISCUSSIONS

The study of convergence rate, step size and efficiency are done in MATLAB and the simulation results for the FxLMS and NFxLMS algorithms for these parameters are accomplished. In numerical techniques, the rate at which the speed achieves its terminal point is called the rate of convergence. Here when the adaptive filter converges together then it is observed that the error signal approaches zero. When the error approaches zero, the step size varies excessively [7]. The comparison study of the adaptive algorithms is shown in table 1.

TABLE I: Comparison Study of Adaptive Algorithms for Active Vibration Control

PARAMETERS	FxLMS	NFxLMS
Step Size	Fixed	Variable
Convergence Rate	4000	1500
Efficiency	60%	85%

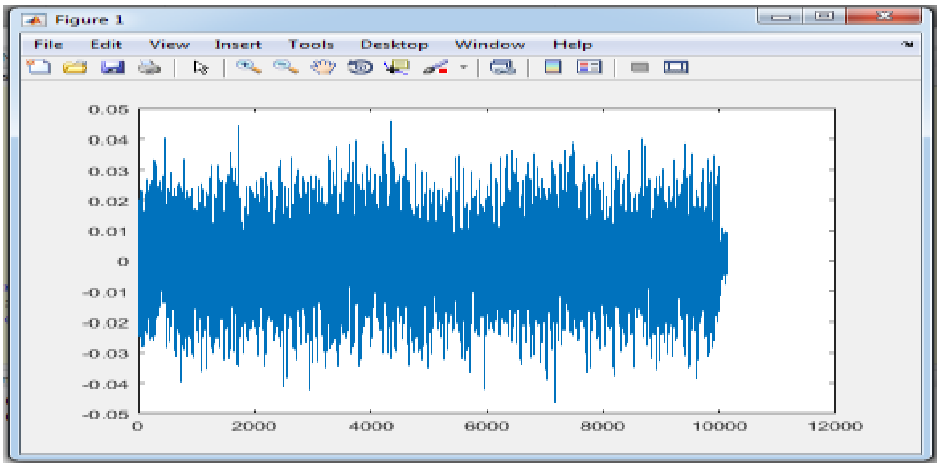

Fig.3: The Input Signal of both FxLMS and NFxLMS Algorithms

The above graph represents the input signal of the filtered-x least mean square and normalized filtered x-least mean square algorithm which is of 10000 numbers of samples. Its amplitude varies from +0.05 to -0.05v.

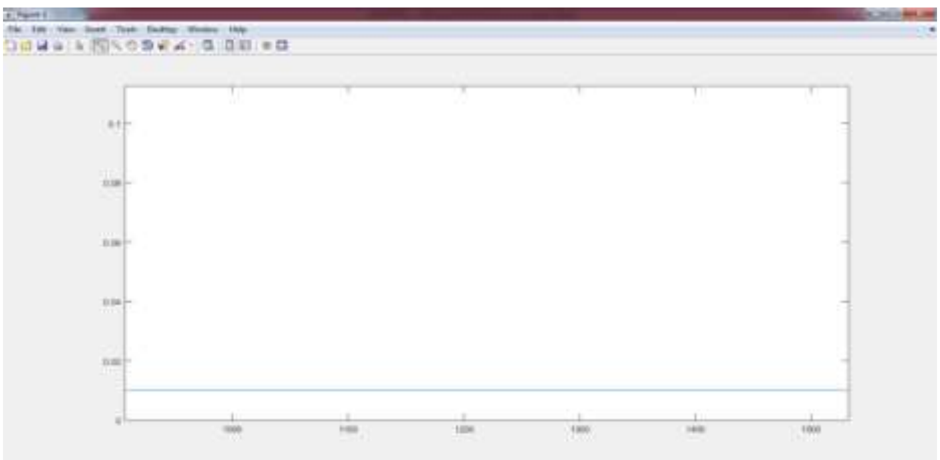

Fig. 4: The Step Size of the FxLMS Algorithm

In the above graph of the FxLMS algorithm, the step size is constant. The step size amplitude is of 0.01V.

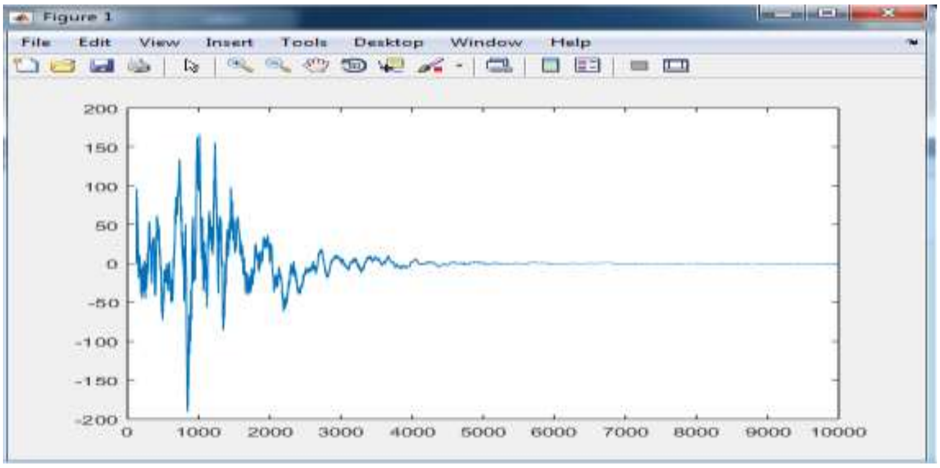

Fig.5: The Error Signal for FxLMS

In the error signal graph initially error signal is large; as the time (t) increases the adaptive filter update its filter co-efficient. Hence the error decreases and reaches approximately to zero as shown in figure 5.

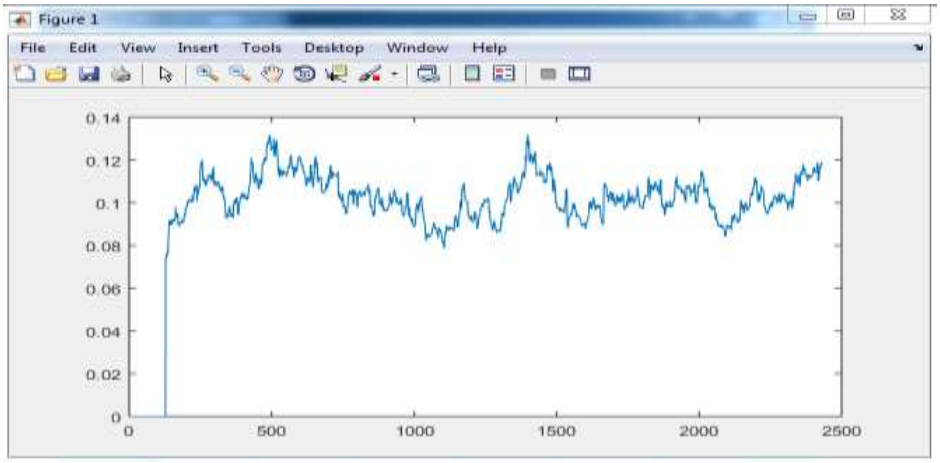

Fig.6: The Step Size of the NFxLMS Algorithm

The above chart represents the step size of the normalized filtered least mean square algorithm. This proposes a variable step-size NFxLMS algorithm to improve the performance of the adaptive algorithm.

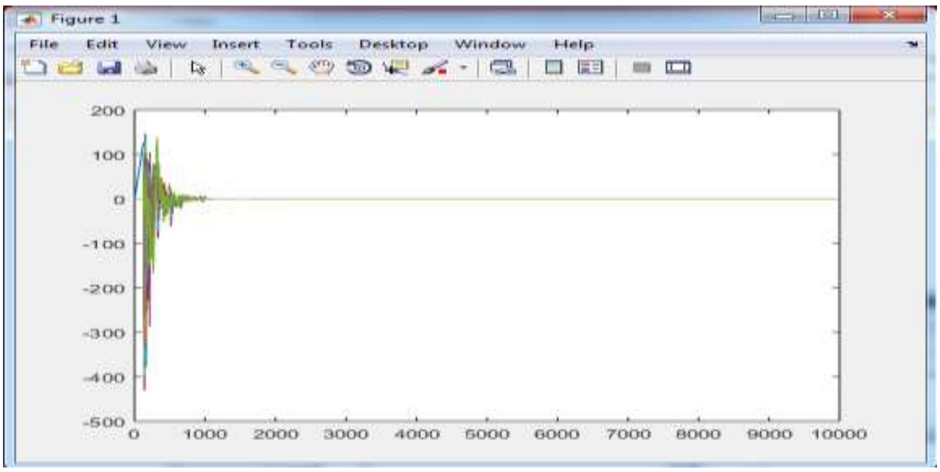

Fig.7: The Error signal for NFxLMS

Figure 7 represents the error plot for the NFxLMS algorithm. The time taken to reduce the error is shown in the above figure.

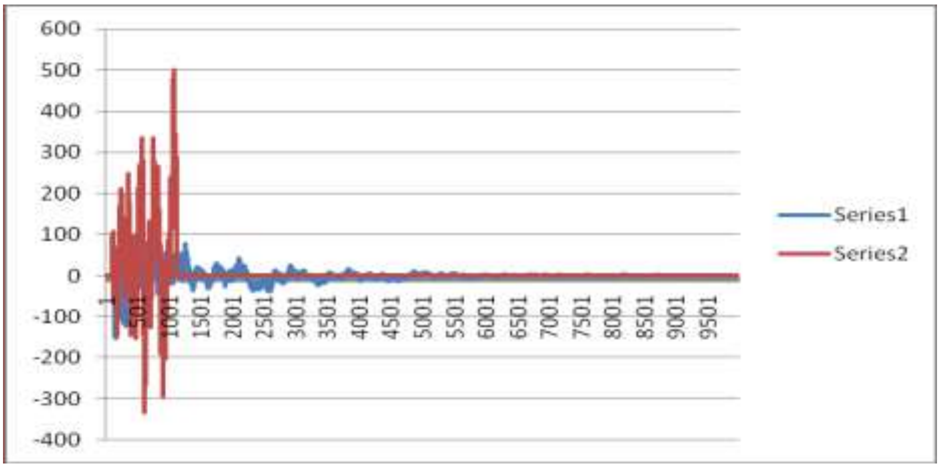

Fig.8: Comparison of FxLMS and NFxLMS Algorithms

In above graph, the comparison of the error signal for FxLMS and NFxLMS algorithm are shown.The series1 graph is the NFxLMS error graph and series2 is the FxLMS error graph.

IV.CONCLUSIONS

We can now conclude by this calculation that the efficiency of NFxLMS is higher compared to the FxLMS algorithm. Because the convergence rate of FxLMS is greater than NFxLMS. Therefore the performance of NFxLMS is better than a FxLMS algorithm. The step size is constant for the FxLMS algorithm. Hence it is known that FxLMS is more stable than NFxLMS algorithm.

ACKNOWLEDGEMENT

The authors would like to thank the Director, Mr. Jitendra J. Jadhav CSIR-National Aerospace Laboratories for his persistence to carry out the work and Dr. Satish Chandra, Head Structural Technologies Division (STTD) for providing all the facilities for completing this work. My Special thanks to Ms. Sowmia Devi, Structural Technologies Division (STTD), CSIR-National Aerospace Laboratories, for their help.

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