A dual adaptive filter implementation of a new active noise control structure

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Abtract

Recently, several authors have proved that the adaptive filter algorithms based on convex combinations significantly improves the overall adaptive filter performance. However, the computational cost of these approaches is significantly increased since they use two filters simultaneously. To solve this problem, we propose a new ANC structure with switching selection.

D-FxNLMS/SLMS algorithm

In this work, we present an ANC structure which exploits at the maximum the features of two algorithms, such as FxNLMS and FxSLMS, as shown in Figure 1.

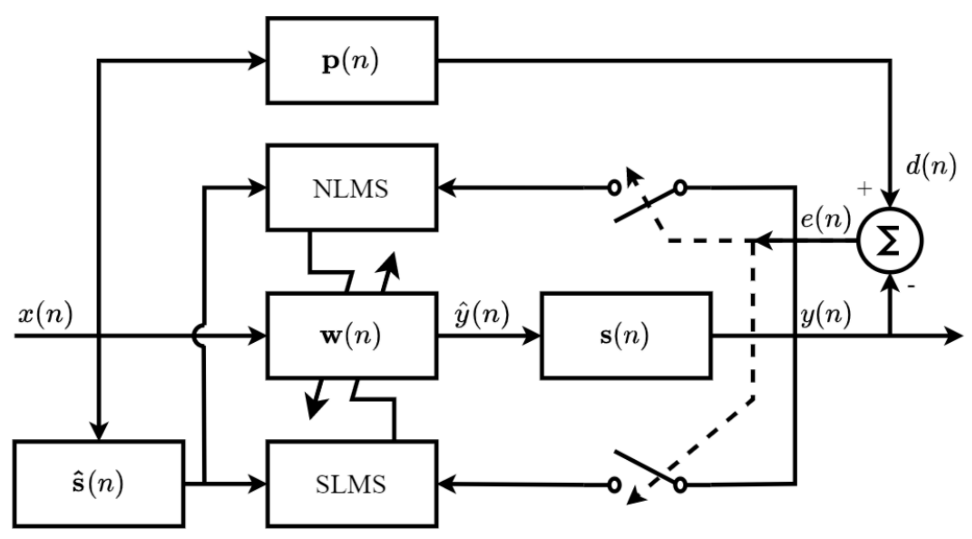


Figure 1. General structure of the proposed filtered-x ANC system.

The computation of the adaptive filter's weigths is expressed as follows:

$$\boldsymbol{w}(n) = \boldsymbol{w}(n+1) + \boldsymbol{\Delta w}(n)$$

Where $\boldsymbol{\Delta w}(n)$ indicates the direction and magnitude to reduces the error signal. In the FxNLMS algorithm, $\boldsymbol{\Delta w}(n)$ is expressed as:

$$\boldsymbol{\Delta w}(n) = \frac{\mu}{\gamma + \widehat{\boldsymbol{x}}^t(n)\widehat{\boldsymbol{x}}(n)}\widehat{\boldsymbol{x}}(n)e(n)$$

Where γ is an auxiliary value, which avoids the computation of largest values of step-sizes, specially when the product $[\widehat{\boldsymbol{x}}^t(n)\widehat{\boldsymbol{x}}(n)]$ is very small. Here, we use the FxSLMS to further reduce the cost of the ANC system. To update the adaptive filter's weights for the FxSLMS algorithm, the following expression is used:

$$\boldsymbol{\Delta w}(n) = 2\mu\widehat{\boldsymbol{x}}(n)sign[e(n)]$$

In the SLMS algorithm, the sign function is used as the error quantizer to reduce the computational complexity of the LMS algorithms.

We propose a criteria to select between these two algorithms. Hence, the proposed criteria avoids the use of both filters during the entire filtering process by comparing the instantaneous error power with the steady-state MSE , δ, of the FxNLMS algorithm.

$$\delta = \frac{\mu}{2-\mu}\sigma_x^2$$

To update the adaptive filter's weights, we use the following rule:

$$\boldsymbol{\Delta w}(n) = \mu(n)\widehat{\boldsymbol{x}}(n)e(n) \qquad if\ e^2(n) > \delta$$
$$\boldsymbol{\Delta w}(n) = 2\mu\widehat{\boldsymbol{x}}(n)sign[e(n)] \qquad otherwise$$

Where σ_x^2 denotes the variance of the signal $x(n)$.

Results

- **Computational cost**

To demonstrate the performance of the proposed D-FxNLMS/SLMS adaptive filter, we perform a comparison between the proposed scheme and existing convex combination schemes, such as C-FxLMS/F and MC-FxLMS/F algorithms. The comparison was made in terms of the number of multiplications per each iteration for single-channel simulation, as shown in Figure 2.

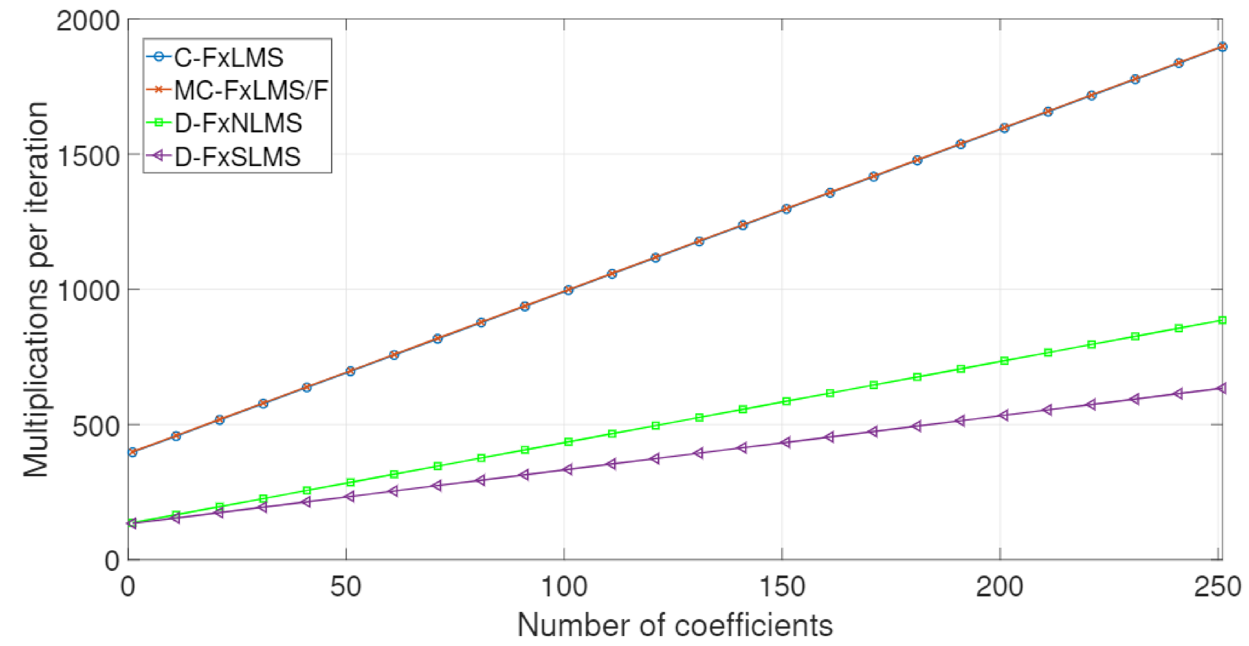


Figure 2. Number of multiplications for a single-channel ANC systems by considering a range (N = 1-250) and M = 128.

- **Implementation**

In this work, we carry out 1:1:1 ANC experiments in a medium-density fiberboard (MDF) duct. Specifically, the measurements of the duct were defined as L=121cm, W=11cm and H=12cm, as shown in Figure 3.

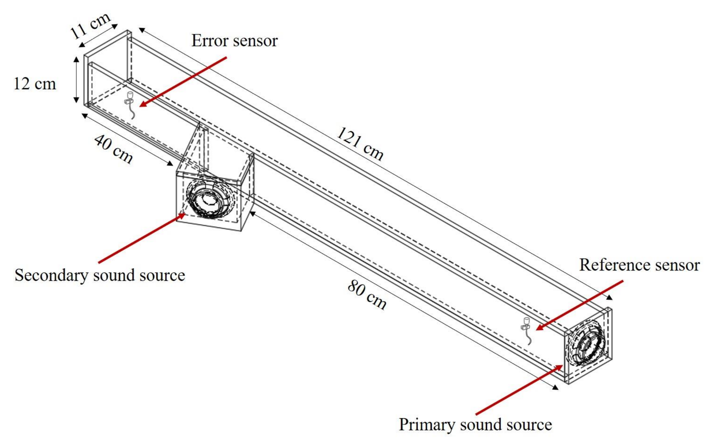


Figure 3. Experimental duct model.

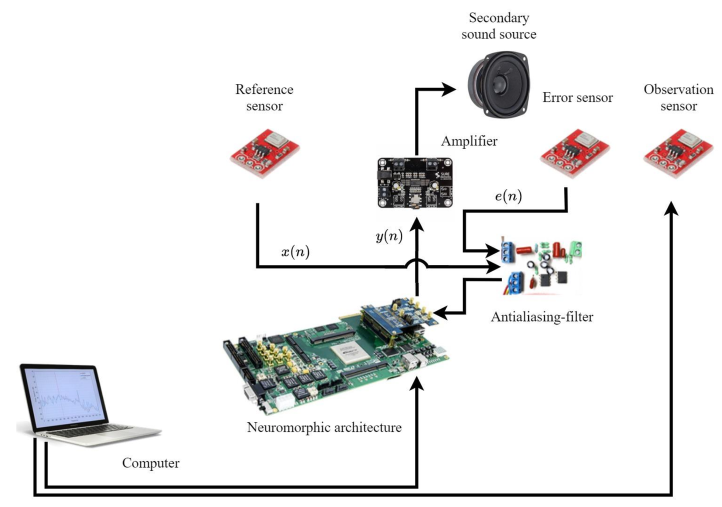
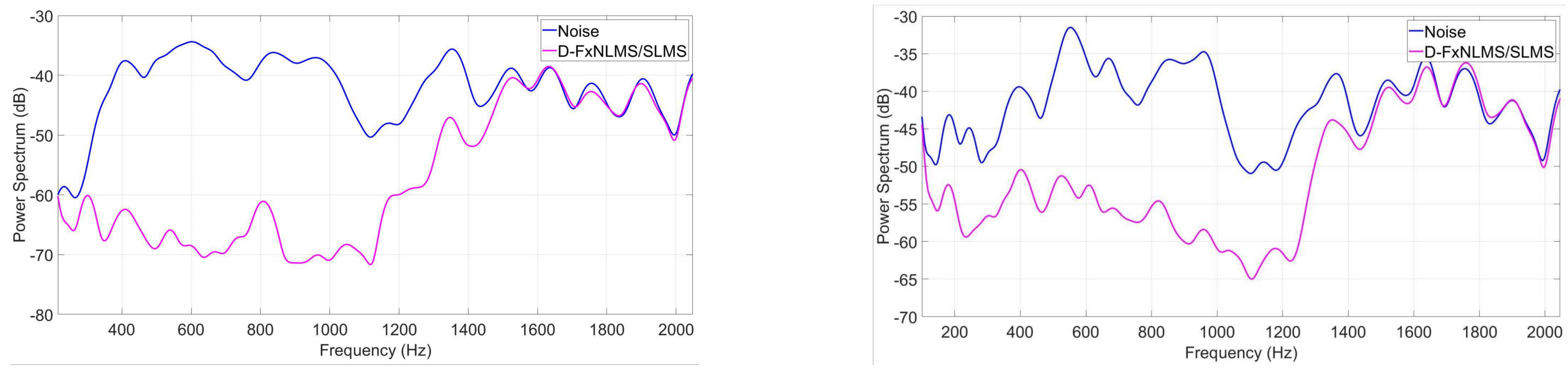


Figure 4. Components of the ANC system.

As can be observed from Figure 4, the single-channel ANC system is composed of anti-aliasing filters, a reference microphone, an error microphone, an amplifier, an anti-noise source, an observation microphone and DSP as controller.



a) b)

Figure 5. Power spectrum of the error signal at observation microphone by considering: a) AR(1) process as a reference signal. b) Aircraft interior noise as a reference signal.

Here, we estimated the secondary path off-line by means of LMS algorithm with 128 coefficients. In this way, we can easily get the acoustic characteristics between the reference microphone and error microphone.

Conclusions

The proposed ANC structure exhibits similar convergence properties when compared with existing convex combination approaches. However, the proposed ANC structure expends lower number of multiplications and additions. Therefore, the implementation of this algorithm in embedded devices was feasible and it can be applied in real-time ANC applications.

Acknowledgments

IPN- SIP projects 20200013 and 20202029, IPN-BEIFI program and Mexico-CONACYT scholarships.