International Journal for Innovation Education and Research
scholarsjournal.net/index.php/ijier ISSN: 2411-2933
DOI: doi.org/10.31686/ijier.vol10.iss8.3686

Implementation of a filter for active noise cancellation in earmuffs for agricultural tractor operations

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ABSTRACT

The implementation of agricultural mechanization is of paramount importance in modern agriculture, providing the replacement of manual and animal work with the aid of modern machines, contributing to an increase in productivity in crops of increasingly larger areas. However, the use of these technologies can bring some inconvenient factors from an ergonomic point of view. Machine operators, for example, are exposed to high noise levels from tractors. Its harmful effects on health are not limited to hearing alone, but can also cause emotional, cardiovascular and fatigue disorders. There are two methods for noise attenuation: The passive method, which consists only of a physical barrier between the listener's ear canal and the external environment, and the active method, which is based on electronic equipment capable of generating a signal that the phenomenon of destructive wave interference. Agricultural operators often use passive noise mufflers which have the disadvantage of attenuating all sounds indiscriminately, thus limiting the operator's auditory perception. In this context, this work proposes an implementation of active noise cancellation that cancels only noise, allowing other ambient sounds to be heard normally. The work developed is of an experimental nature, where a noise source in an agricultural operation was analyzed, which was used as an input signal for the construction of the filter and simulation. The filter was able to perform active noise cancellation using the LMS and NLMS algorithms, but the NLMS presented better results.

Keywords: Noises; Agricultural Mechanization; Ergonomics; Security**.**

1 INTRODUCTION

The implementation of agricultural mechanization is of paramount importance in agriculture modern technology, providing the replacement of manual and animal work by the help of modern machines in activities such as soil preparation, fertilization, sowing and harvesting, contributing to an increase in productivity in crops in increasingly larger areas (SANTOS FILHO et al., 2004).

However, according to Fernandes et al. (2022), the use of these technologies can bring some inconvenient factors from an ergonomic point of view. Machine operators, for example, are subject to several risk situations, including exposure to high noise levels from tractors, which can significantly influence the productivity of tractor drivers in agricultural activities.

To analyze this exposure in noise levels, Fernandes et al. (2022) verified, using a decibel meter, the noise levels of an agricultural tractor at different speeds, where 10 readings were taken for each of the pre-established engine speeds, defined by the degree of distance, with the first measurement point being close to the tractor driver. and the other points equally spaced at a distance of 1 meter.

Through this study, the author found that the tractor driver is exposed to uncomfortable noise levels at all speeds analyzed, and at speeds above 1900 rpm, he observed the existence of an unhealthy condition, with noise levels above ninety decibels (dB) . So, the author suggests the use of noise dampers to attenuate the noise levels.

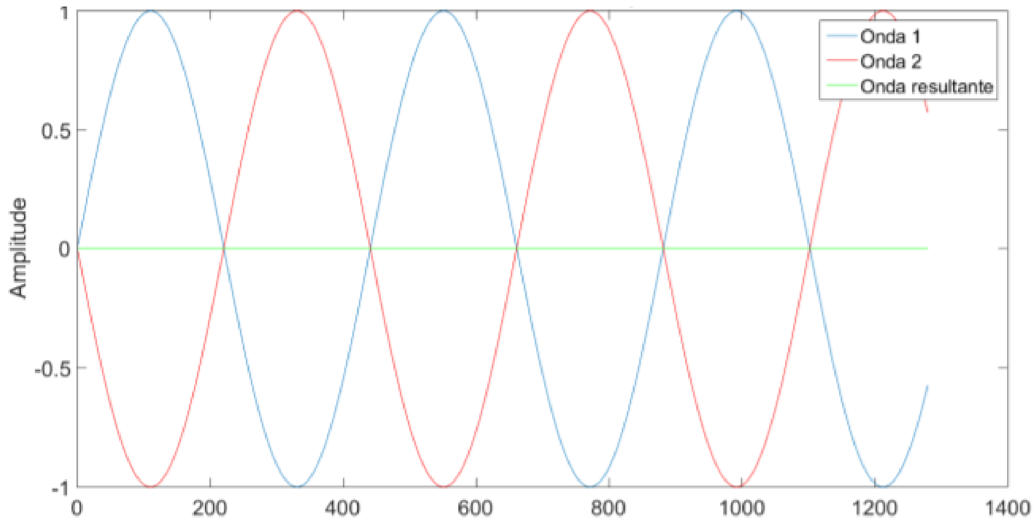
According to Seidman and Strandring (2010), noise is defined as an unwanted sound or an arrangement of sounds that have hostile effects on health, effects that can manifest in the form of psychological or physiological damage through a variety of mechanisms.

Its harmful effects on health are not limited to hearing, but can also cause emotional, cardiovascular and fatigue disorders, and high noise levels generally impair mental concentration, compromise the ability to perform tasks that require concentration or precision, and even speed. of movements (MINETTI et al., 1998).

According to Cunha and Teodoro (2006), among the ergonomic factors that harm agricultural machine operators, noise is one of the main ones, and as a complicating factor there are few studies developed to evaluate this parameter and its implications for occupational health.

There are two methods for noise attenuation: The passive method, which is the most used and simpler to produce, as it consists only of a physical barrier between the listener's ear canal and the external environment, and the active method, which is based on electronic equipment capable of generating a signal that appropriates the phenomenon of destructive interference. of waves as shown in figure 1, which means that overlapping waves of equal magnitude and 180º out of phase cancel each other out (GARCIA, 2018).

Figure 1: Superimposed 180º lagged sine waves and the resulting wave



Source: GARCIA (2018)

In the active method, filters that can be fixed or adaptive are used. Fixed filters are programmed based on prior knowledge of the input signal and the noise source, in which both remain without sudden variations over time, while adaptive filters are self-adjusting, according to the variation of the noisy signal (PINEDA; ONOUE; TANOMARU, 2018).

Tossin, Lance and Araújo (2009), in their study on the evaluation of noise at the workplace in two agricultural tractors, concluded that the sound pressure level generated by the tractor was not influenced by the type of soil, tire inflation pressure and average speed, but by the power and rotation of the engine and by the fact that the tractor has a cabin or not.

In agricultural operations, tractor drivers usually use a nominal rotation of the tractor, which tends to be constant throughout the operation, in this way, it is possible to elaborate an active noise cancellation using fixed filters.

Among the algorithms commonly used in filtering techniques, the LMS (least mean square), NLMS (normalized LMS) and RLS (recursive least square) algorithms stand out (SAYED, 2008).

According to Lopes (2018), the LMS algorithm is a recursive procedure in which appropriate corrections are applied to the weights, in order to continuously move closer to the minimum point of the mean square error surface after each iteration.

Also according to the author, as the algorithm has a step factor dependent on the correlation characteristics of the input signal, when the energy of the system input signal is large, the algorithm may suffer from gradient noise amplification. To avoid this problem, the normalized LMS algorithm (NLMS) is used, so this algorithm can be seen as a variant of the LMS algorithm, which solves the residual error problem by normalizing the input vector.

The RLS algorithm is a parametric approximation algorithm used in adjustable filters in order to find the filter coefficients that relate to the recursive least squares production of the error signal. This technique uses the concept of estimation point instead of a base interval for the estimation and thus the estimator converges to the real value more quickly (MORAIS, 2007).

The study on active noise cancellation has been emphasized in several scientific articles in recent years and analyzing the available works on the subject, there is a lack of studies on active noise cancellation in the area of agricultural mechanization.

Agricultural operators often use passive noise mufflers and this equipment, although reasonably effective, has the disadvantage of attenuating all sounds indiscriminately, thus limiting the operator's auditory perception, impairing the identification of sounds around them, such as warning of someone close, alert sounds, animals, among others.

There are some models of electronic dampers on the market, but they are intended for shooters and hunters, which cannot be used by tractor drivers because of the type of noise. In this context, this work proposes an implementation of a filter for active noise cancellation in dampers for operations with agricultural tractors, which cancels only the noise, allowing other ambient sounds to be heard normally, seeking comfort and at the same time safety for the tractor driver.

2 METHODOLOGY

The experimental work was carried out at the Professor Hamilton de Abreu Navarro farm, belonging to the Federal University of Minas Gerais, Montes Claros/MG campus.

The methodology was divided into two stages, according to the following topics:

2.1 Noise source analysis

The first step of the methodology consisted of analyzing the noise source of an agricultural tractor in a soil preparation operation using the nominal work rotation, where this noise source was used as an input signal for the construction of the filter.

For the operation, an agricultural tractor without cabin, Massey Ferguson, model MF 291, 4x2 TDA, rated power of 73.6 kW (100 hp) at 2200 rpm was used.

The implements used were a 14 disc offset harrow 1.8 m wide baldan and offset crushing grid with 28 Super Tatu discs with 2.37m wide.

To capture the noise during the agricultural operation, a microphone from the brand STMicroelectronics, model MP23AB02B, was used close to the operator's ear.

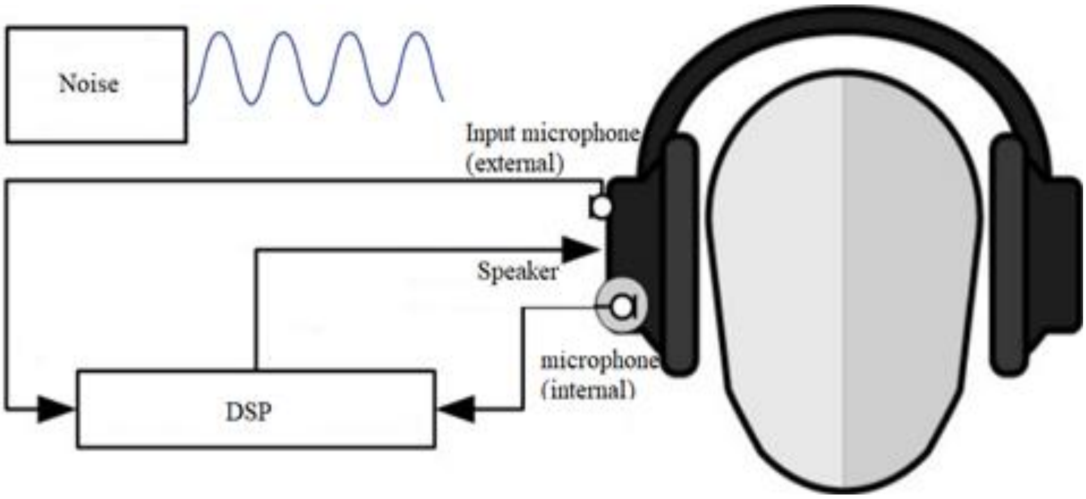
2.2 Filter construction

After analyzing the noise source, a filter was implemented and a subsequent simulation was carried out using the MatLab software, version R2019b on a Samsung book X45 notebook with an Intel Core i5-10210U processor 1.60 GHz up to 4.20 GHz with 8 GB of RAM in the Windows 10 64-bit operating system.

The LMS, NLMS and RLS algorithms were used and the one with the highest efficiency was used to perform the simulation. To evaluate the efficiency of the algorithms, the noise attenuation and later the mean square error were verified.

The proposed model is represented in Figure 2, which illustrates an example of active noise cancellation by means of an ear protector.

Figure 2: Proposed model



Source: Adapted from Garcia (2018)

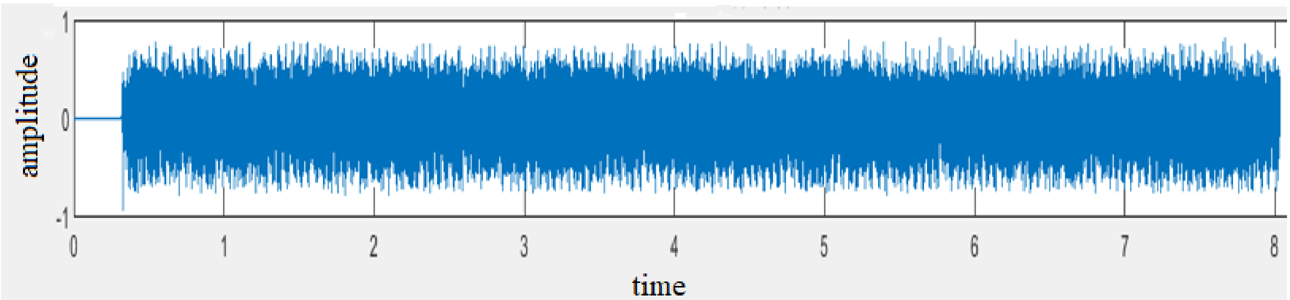
The source of ambient noise and sound is measured with an input microphone (external), and the signal present at the system output is monitored with an error microphone (internal).

The digital signal processor (DSP) exemplifies a programmable electronic circuit to generate the anti-noise sound wave through the loudspeaker with a polarity opposite to the sound wave caused by the noise produced by the previously known tractor, which tends to be equal to the noise that arrives at the input microphone, so noise is canceled and only ambient sound passes through. In the DSP contains the algorithm for filtering.

3 RESULTS AND DISCUSSIONS

With the analysis of the noise source, it was possible to observe, as shown in Figure 3, the noise signal that was used to construct the filter.

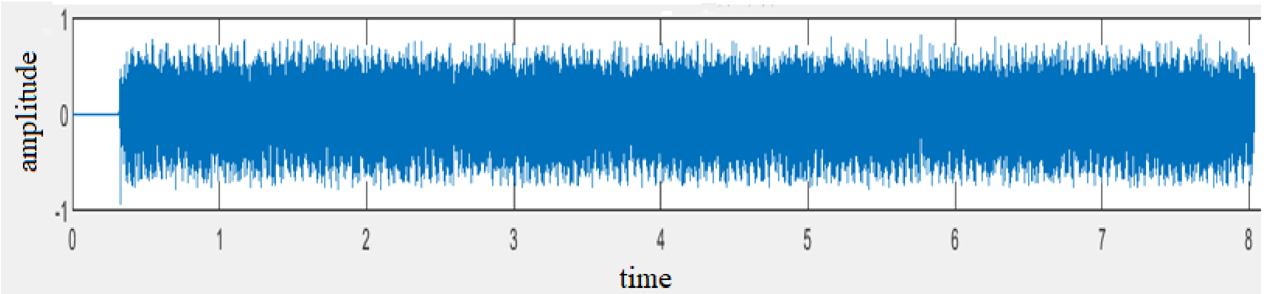
Figure 3: Noise source signal



Source: Prepared by the authors (2022)

To carry out the tests with the filter, the noise signal plus the ambient sound was used, as shown in Figure 4, in order for the filter to remove the noise source, leaving only the ambient sound.

Figure 4: Noise signal plus ambient sound

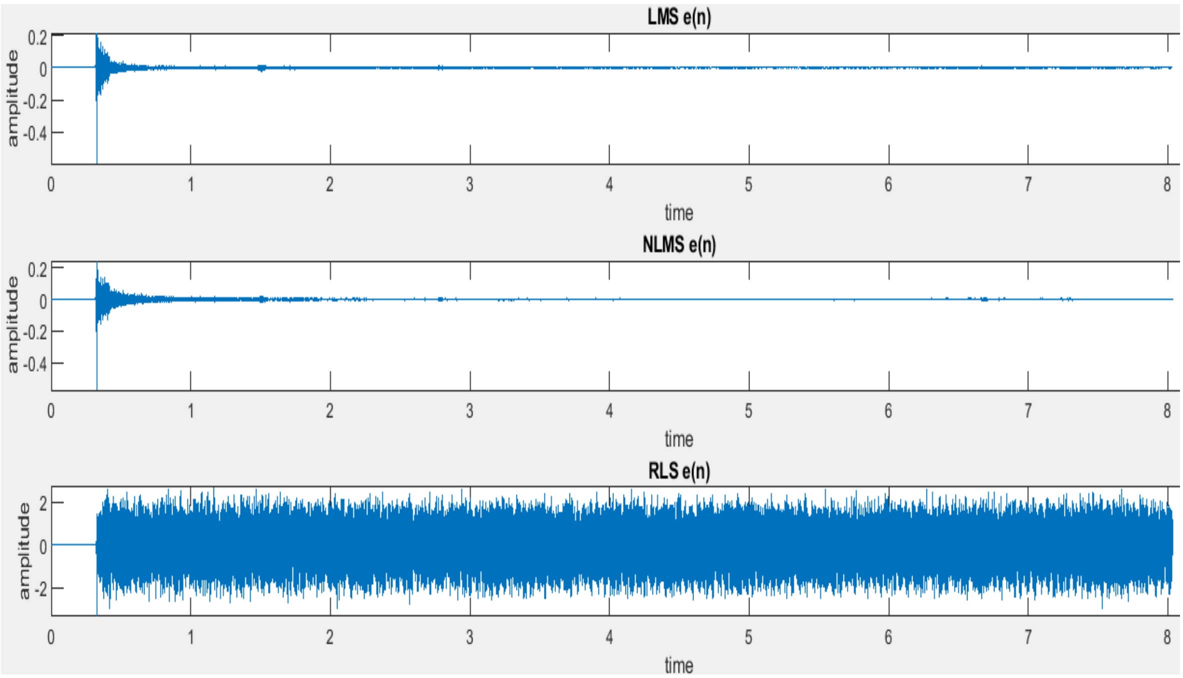


Source: Prepared by the authors (2022)

Note that the noise source signal overlaps the ambient sound, resulting in a graph similar to the previous one.

After applying the filter, it was possible to perform active noise cancellation using the LMS and NLMS algorithms as shown in Figure 5, a fact that was not observed when using the RLS algorithm.

Figure 5: Active noise cancellation with LMS, NLMS and RLS algorithms

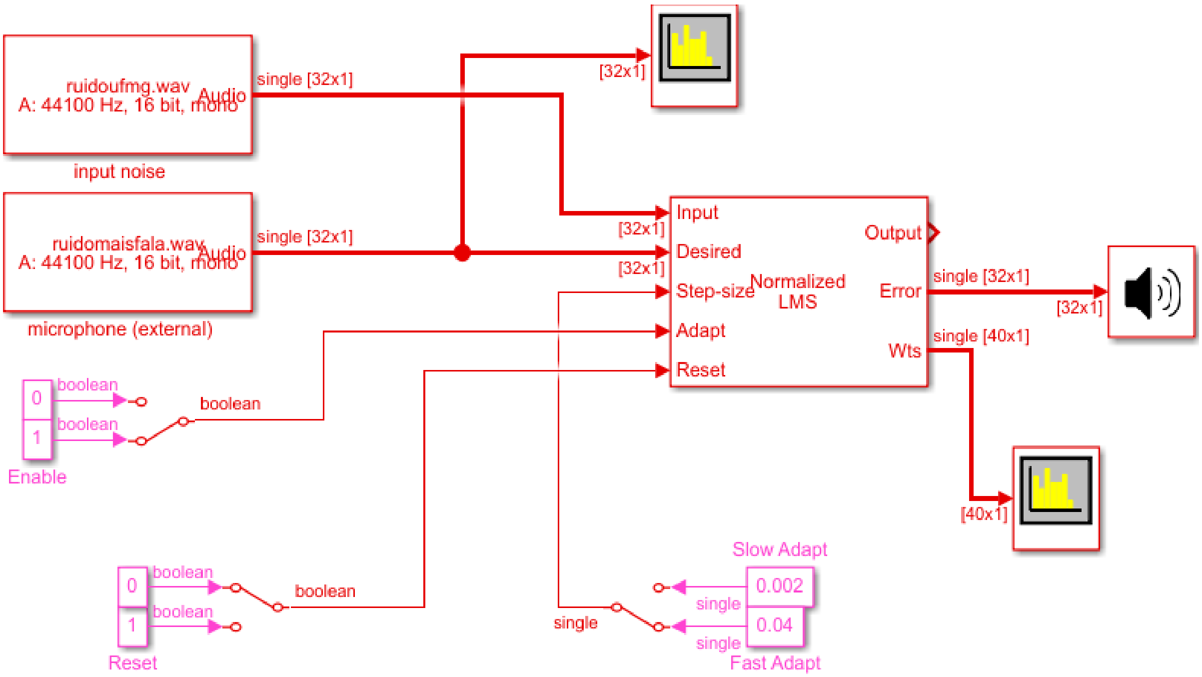


Source: Prepared by the authors (2022)

The mean square error of the noise canceling algorithms: LMS and NLMS, were $5.90 x 10^{-3}$ and $3.46 x 10^{-3}$, respectively.

With the best result presented, the NLMS algorithm was used to simulate the system through the Simulink environment of the MATLAB software, shown in Figure 6.

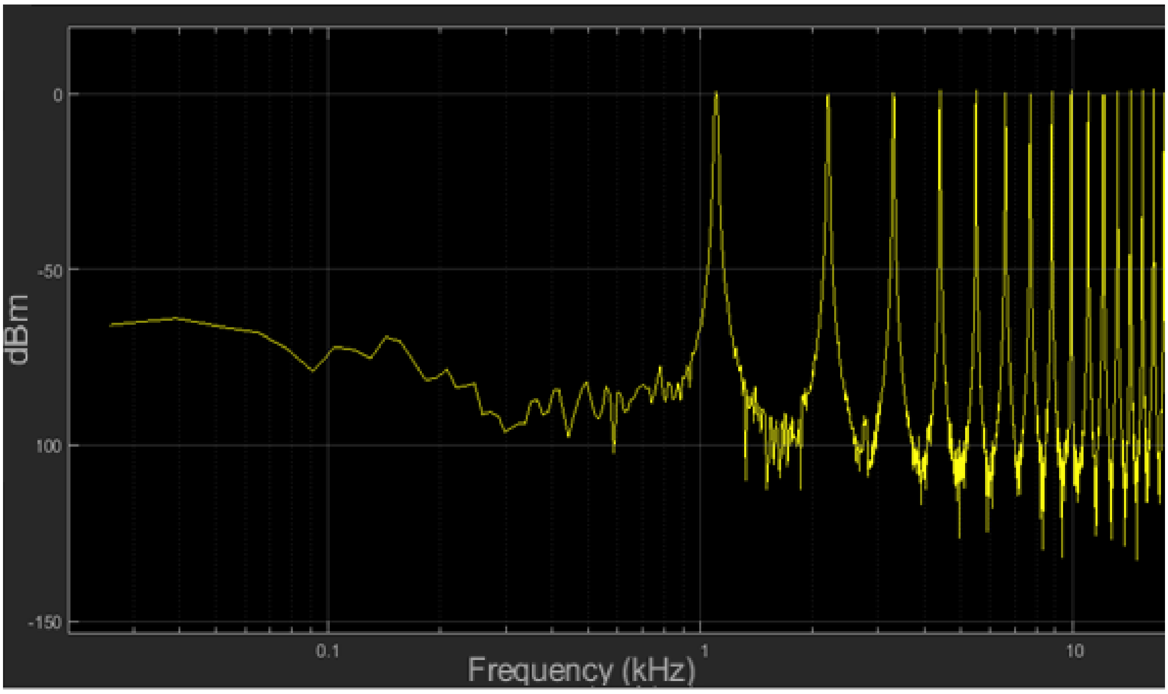
Figure 6: System simulation



Source: Prepared by the authors (2022)

It was possible to observe the noise source signal in the frequency domain, in decibel values (dB), as shown in Figure 7.

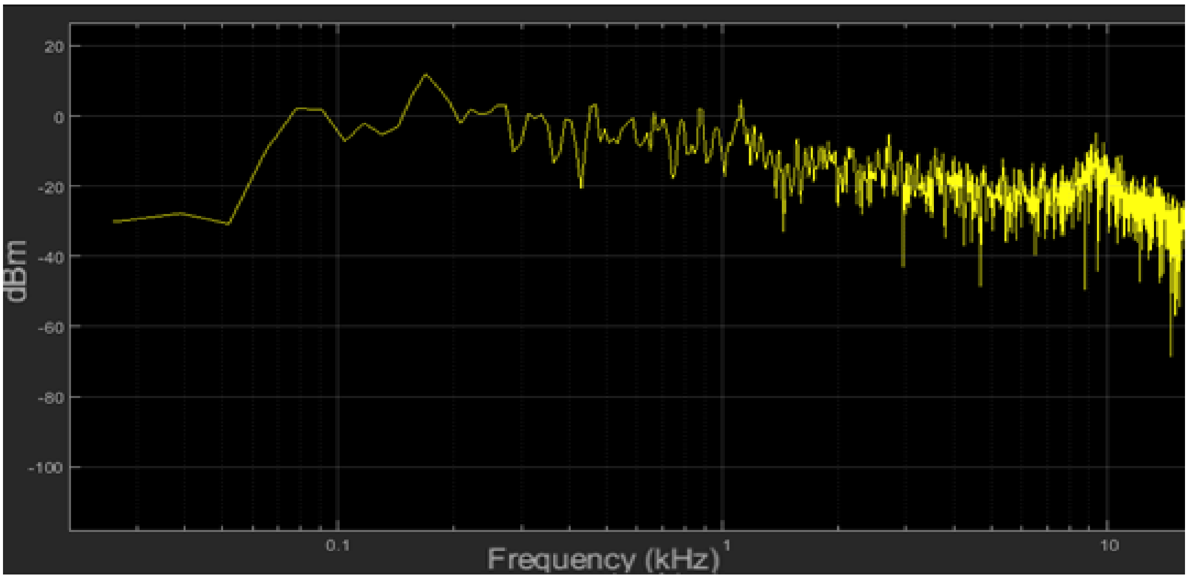
Figure 7: Signal noise plus ambient sound in dB



Source: Prepared by the authors (2022)

After the simulation in the Simulink environment, it was possible to perform active noise cancellation using the NLMS algorithm, as shown in Figure 8, where the filtered signal (no noise, only with ambient sound) can be observed with values in dB.

Figure 8: Filtered signal



Source: Prepared by the authors (2022)

It is then verified that it was possible to remove the signal from the noise source, leaving only the ambient sound.

4 CONCLUSION

Active noise cancellation has been successfully performed for use in mufflers for use in agricultural operations, being possible to cancel only the noise, allowing other ambient sounds to be heard normally, improving comfort and at the same time the safety of the tractor driver.

The LMS and NLMS algorithms obtained similar results. However, the NLMS algorithm presented a certain advantage in relation to the LMS algorithm, since it obtained a lower mean square error.

It was not possible to perform active noise cancellation using the RLS algorithm, possibly because this algorithm is more appropriate for adjustable filters using parametric approximation.

For future work, practical implementation of active noise cancellation in dampers for use in agricultural operations is suggested.

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