Cancellation and its simulation using Matlab according to active noise control case study of automotive noise silencer

Alfisyahrin¹, I Isranuri²

¹Department of Electrical Engineering, University of Syiah Kuala Darussalam, Banda Aceh, Indonesia
²Department of Mechanical Engineering, University of Sumatera Utara. Jalan Almamater, Kampus USU, Padang Bulan, Medan 20155, Indonesia.

*E-mail: isranuri@yahoo.com

Abstract. Active Noise Control is a technique to overcome noisy with noise or sound countered with sound in scientific terminology i.e signal countered with signals. This technique can be used to dampen relevant noise in accordance with the wishes of the engineering task and reducing automotive muffler noise to a minimum. Objective of this study is to develop a Active Noise Control which should cancel the noise of automotive Exhaust (Silencer) through Signal Processing Simulation methods. Noise generator of Active Noise Control is to make the opponent signal amplitude and frequency of the automotive noise. The steps are: Firstly, the noise of automotive silencer was measured to characterize the automotive noise that its amplitude and frequency which intended to be expressed. The opposed sound which having similar character with the signal source should be generated by signal function. A comparison between the data which has been completed with simulation calculations Fourier transform field data is data that has been captured on the muffler (noise silencer) Toyota Kijang Capsule assembly 2009. MATLAB is used to simulate how the signal processing noise generated by exhaust (silencer) using FFT. This opponent is inverted phase signal from the signal source 180º conducted by Instruments of Signal Noise Generators. The process of noise cancelation examined through simulation using computer software simulation. The result is obtained that attenuation of sound (noise cancellation) has a difference of 33.7%. This value is obtained from the comparison of the value of the signal source and the signal value of the opponent. So it can be concluded that the noisy signal can be attenuated by 33.7%.

1. Introduction

Noise in this century is already a big enough problem to the whole society forward. Where the noise factor is increasing almost complete in various sectors, such as environmental and industrial sites. The cause of all this is a technological advancement that has increased since the start of the Industrial Revolution in the 17th century creation of industrial machines are on average almost cause noise.

Therefore, to overcome the noise of it needs to be studied and researched more about the noise factor by science or acoustic sound to a more developed science noise control. This science originated from the physical sciences Acoustics which later evolved to the various disciplines such as Mechanical Engineering, Architecture, Electrical, even chemistry. However, the discussion in this paper covers the scope of the Electrical and Mechanical Engineering is the science Active Noise Control.

We can look at some reference point of the research that has been studied by many people on Active Noise Control, such as research on noise cancellation using Active Noise Control System. Signals on the single channel Active Noise Control has reduced its best when low frequency noise at -
10.72 dB. This system is unstable when part of the signal is constantly changing. This section varies the displacement of an object in the room. Active Noise Control less than the maximum signal from the zone generated is also very relative silence to generate a large test area. We can see the set-up tool as follows [11].

![Figure 1. Hardware configuration on Active Noise Control](image1)

![Figure 2. The two signal propagation](image2)

In the study of the Active Noise Control against the best vacuum cleaner in achieving the objectives of the Active Noise Control on signal generated simulation optimal under 6 dB. Radiation noise on the vacuum cleaner is direct. This makes it difficult to study the setting up mikropone to obtain a good correlation with the noise signal [8].
Figure 3. Active ear protectors of the second source

Figure 4. Block Diagram of the System channel Active Noise Control.

Research emphasis on low frequency noise or vibration passive has many disadvantages, largely because of concerns the volume silencer. With the use of signal processing becomes possible to use the Active Control. Noise secondary (artificial) should be produced, which weakens the noise that the primary (original) propagating in microphone] positioned [13].

Figure 5. System Active Noise Control [2].
Modeling and controller design procedures for an FB-ANC for the sound system. Acoustic sound wave controlled modeled as a short. A feedback controller is designed then to attenuate the noise level around, involving a sensor fault with H8 control theory based on IIR models. The effectiveness of the proposed design procedure performed by test experiments. A sound field has been assumed in this study. A controller and systematic modeling procedures designed to examine a field of acoustic echo cancellation will become a staple further studies [12].

Figure 6. ISOSE configuration FF- Active Noise Control System.

Active Control of Noise Using FXLMS

Figure 7. Active Noise Control at the ear is placed on the primary path and the forward path.

In practical applications, methods of Active Noise Control saling mempengaruhi with nonlinear. Nonlinear controller based on Volterra filter to apply in the form of multichannel filtering and useful data can be utilized on the environment. One of the aspects of the complex is the origin of efficient adaptation algorithms. In general, the so-called filtered-X LMS or NLMS algorithm. In this study we propose the use of affine projection technique, and we obtain in detail the so-called Filtered-X AP algorithm for homogeneous quadratic filter. According to the multichannel approach, the origin of this can be easily extended to general Volterra filter. Our extensive experiments to confirm the AP report compared to the classic technique LMS and NLMS algorithms with a limited increase concerns the computational complexity compared with the Active Noise Control acoustic. One application for the Active Noise Control is the active control of noise and vibration in a lathe. In the adaptive control of vibration at a fixed point behind this FXLMS control the display accordingly. It is also interesting for further describes the digital and analog [18].
Signal processing

![Block diagram of Active Noise Control](image)

**Figure 8.** Synchronization signal processing block diagram of the Active Noise Control.

2. General

2.1 The concept of Active Noise Control

Active Noise Control sound plain language is countered by voice or a signal method that we get we must seek anti signal that is similar to the start signal but the opposite phase.

We can see an example in the description of Figure 9 which are described erect low amplitude signal with no sound condition.

![Low Upright stationary wave amplitude](image)

**Figure 9.** Low Upright stationary wave amplitude [7].

![High Upright wave amplitude](image)

**Figure 10.** High Upright wave amplitude [7].

From the comparison Figure 8 and 9 can be seen that the amplitude at rest with the state of low and high amplitude. And looks at the low amplitude sound does not have to sound a loud high amplitude.
Figure 11. Upright waves on the phase shift [7].

Figure 12. Two standing waves with a phase difference of 180° mutually exclusive [7].

Table 1. Data Sound Pressure Level (dB)

| No | Sound sources                                      | Intensity (dB) | Intensity (W/m²) |
|----|----------------------------------------------------|----------------|-----------------|
| 1  | Jet Plane at 30 m                                  | 140            | 100             |
| 2  | Pain threshold                                     | 120            | 1               |
| 3  | Strength of Rock concert in the open air.          | 120            | 1               |
| 4  | Siren at 30 m                                      | 100            | 1x10⁻²           |
| 5  | Auto Interior, moving at 90 km / h                  | 75             | 3x10⁻⁵           |
| 6  | Busyness / road congestion                         | 70             | 1x10⁻⁵           |
| 7  | Casual conversations at 50 cm                      | 65             | 3x10⁻⁶           |
| 8  | Radio calm                                         | 40             | 1x10⁻⁸           |
| 9  | Whisper                                            | 20             | 1x10⁻¹⁰          |
| 10 | Desir leaves                                       | 10             | 1x10⁻¹¹          |
| 11 | Threshold of Hearing                               | 0              | 1x10⁻¹²          |

Source: Giancolli, Douglas. Physiscs Third Edition. New Jersey: Prentice Hall, Englewood Cliffs

In the Figure 12 is shown a signal source or signal 1 in an Active Noise Control system. Then the equation shown are:

\[ y_1 = A \sin \omega t \]  \hspace{1cm} (1)
Figure 13. The source signals or signal 1

Figure 13 is shown opposing signals or signal 2 of an Active Noise Control system. The equation shown are:

\[ y_2 = -A \sin \sigma t \]  \hspace{1cm} (2)

Figure 14. Opponents signal or signal 2

In the figure 14 is an active signal, wherein the signal 1 and signal 2 are members of the opposite phase signal 180° and cancel each other out.

Then the equation of incorporation Signals Start / Signal 1 to Signal Opponent / Signal 2 is:

\[ Y_{\text{active noise}} = y_1 + y_2 \]

\[ Y_{\text{active noise}} = A \sin \sigma t - A \sin \sigma t \]

\[ = 0 \]

ANC Sinyal

Figure 15. Active Noise Control Signal
In this study, Active Noise Control is used to detect the signal attenuation in the muffler (silencer) car. Noisy signal to be generated is reduced to a minimum cultivated for comfort noise.

Figure 17. Exhaust (noise silencer) Cars

Figure 16 is a set of data collection to measure the noise that exist in the exhaust (noise silencer) then this setting is used to perform Active Noise Control Engineering is made thereof or signal virtual opponent is Noisy Signal Generators.

2.2 Noise Signal Generators
Noise generator is generating noise which serves to produce opposing signals, this signal can be regarded as a virtual signal from the signal source. The goal is the frequency and amplitude that are emitted by Instruments Signal Generators has similar characteristics to the signal source so as Active Noise Control can be realized. In making the character of many noise generator circuit configuration that can be applied to one of them is to use oscillator IC 555 is figure 17.

Figure 18. Oscillator IC 555.

IC 555 as a timer which is also a formula for the oscillator has a frequency and duty cycle:

\[ f_r = \frac{1.44}{(R_1 + 2R_2)C_{\text{ext}}} \]  \hspace{1cm} (4)
And for the duty cycle is:

\[
\text{Duty cycle} = \left( \frac{R_1 + R_2}{R_1 + 2R_2} \right) \times 100\% \quad (5)
\]

Before moving to the signal generator needs to know the value of the voltage to be generated by the IC 555 Oscillator. It needs to be taken into account for the voltage divider out of the value generated by a voltage source which is then inserted into the Oscillator. The voltage divider circuit as in Figure 18.

![Figure 19. The voltage divider circuit](image)

This voltage divider calculation:

\[
V_{out\ (unloaded)} = \left( \frac{R_2}{R_1 + R_2} \right) V_s = \left( \frac{10K}{30K + 10K} \right) 9V
\]

\[
= \left( \frac{10K}{40K} \right) 9V = 2.25 V \quad (6)
\]

### 2.3 Phase Shifter

Phase shifter is a tool for moving phase on the signal. This technique is used for the purpose of reversing the phase 180° the goal is to make the opponent signal (anti signal) at this research, to get the results of signal processing Active Noise Control.

Theory of the phase shifter by the input on transistors which then issued on foot of collector and emitter with a certain resistance so that the output signal can be adjusted phase shift can be seen in figure 19.

![Figure 20. Process input and output of the phase shift.](image)

180° collector signal is turned on and the input signal to the emitter signal. This analysis derived from Low Frequency Response amplifier can be seen in figure 20.
The input current is the basis:

\[ \text{where } R_C = R_C \parallel R_L \]

Circuit input  RC

\[
V_{\text{base}} = \left( \frac{R_{\text{in}}}{\sqrt{R_{\text{in}}^2 + X_{\text{C1}}^2}} \right) V_{\text{in}} \tag{7}
\]

This condition occurs in the input RC circuit when \( R_{C1} = R_{\text{in}} \)

\[
V_{\text{base}} = \left( \frac{R_{\text{in}}}{\sqrt{R_{\text{in}}^2 + R_{\text{in}}^2}} \right) V_{\text{in}} = \left( \frac{R_{\text{in}}}{\sqrt{2R_{\text{in}}^2}} \right) V_{\text{in}} = 0.707V_{\text{in}} \tag{8}
\]

low frequency can be calculated:

\[
X_{C1} = \frac{1}{2\pi f_c} = R_{\text{in}} \tag{9}
\]

\[
f_c = \frac{1}{2\pi \sqrt{C_{1}}} \tag{10}
\]

then input source can be calculated:

\[
f_c = \frac{1}{2\pi (R_s + R_{\text{in}})C_{1}} \tag{11}
\]

The process of achieving the 180º phase shift can be seen in figure 21.
Figure 22. Input to the RC circuit is due to precede the base voltage of the input voltage at an angle below the intermediate frequency phase [18].

Figure 23. Block Diagram Noise Generator

Figure 24. Block Diagram Phase Shifter.

Figure 25. Setting Noise Signal Generators Instruments and Phase Shifter.

2.4 Fourier Transform

Theories about the Fourier transform signal that will be used equation is as follows:

$$X(\omega) = \int_{-\infty}^{\infty} x(t) e^{-j\omega t} dt$$  \hspace{1cm} (12)
The function \( f(x) \) is a periodic function if the function is repeated at a certain time with a single variable. This is a repetition of a certain time period in a vibration on the image can be seen in figure 25.

**Figure 26.** The function of a signal with a period of \([22]\).

It is obvious that \( y = \sin nx \) is a periodic function, where the distance value \( x \) increases from 0º to 360º. The period of 360º is said to 2\( \pi \) radians and maximum amplitude shift of position backrest, see figure 26.

**Figure 27.** Amplitude \([22]\).

Definition of Fourier series: The function \( f(x) \) which can be determined at the interval \((-L, L)\) and outside interval and outside the specified interval pleh \( f(x + 2L) \), which is considered to be that \( f(x) \) has a period of \( 2L \). Fourier series or Fourier expansion with respect to \( f(x) \) was defined as:

\[
\frac{a_0}{2} + \sum_{n=1}^{\infty} \left( a_n \cos \frac{n\pi x}{L} + b_n \sin \frac{n\pi x}{L} \right)
\]  

(13)

With prices Fourier coefficients \( a_n \) and \( b_n \) is determined by:

\[
a_n = \frac{1}{L} \int_{-L}^{L} f(x) \cos \frac{n\pi x}{L} \, dx
\]

\[
b_n = \frac{1}{L} \int_{-L}^{L} f(x) \sin \frac{n\pi x}{L} \, dx \quad n = 0, 1, 2, \ldots
\]

(14)

With prices Fourier coefficients \( a_n \) and \( b_n \) is determined by:

Every periodic function \( f(\omega t) \) can be decomposed into an infinite trigonometric series and is called Fourier series. So that can be decomposed into a Fourier series, the function must meet the following conditions. That function is a periodic function and meet relation \( f(\omega t) = f(\omega t + 2\pi) \) the period \( 2\pi \).

Take a periodic function \( f(\omega t) \) then the Fourier series for the function in the formula:

\[
f(\omega t) = A_0 + \sum_{n=1}^{\infty} [A_n \cos(n\omega t) + B_n \sin(n\omega t)]
\]

(15)

\( A_0, A_n, \) and \( B_n \) is called the Fourier coefficients and are determined by formula:
where, \( n = 1, 2, 3, \ldots \)

To simplify the calculation of Fourier series, is to use a Fourier transform tables. Table Fourier Transformation is a variety of forms, but the researchers took the simplest form of the signal to be processed.

Waveform is still a sinusoidal shape, by cutting in parts of randomness signals are very complicated.

| Table 2. Fourier transformation. |
|----------------------------------|
| \[ f(x) = \left( \frac{1}{2\pi} \right) \int_{-\infty}^{\infty} F(y) e^{-i\omega x} dy = FT^{-1}\{ F(x) \} \] |
| \[ f(y) = \left( \frac{1}{2\pi} \right) \int_{-\infty}^{\infty} F(x) e^{i\omega y} dx = FT\{ F(y) \} \] |

Source: Champeney, D.C. Fourier Transform and Their Physical Application: Academic Press, Inc

In this study, the use of Fourier calculations are Fourier transform using the above table is the equation of table 2.
Which we then use the equation calculates the signal for are:

\[ f(x) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(y) e^{-i\omega x} dy = FT^{-1}\{ F(y) \} \]  \hspace{1cm} (16)

\[ A \exp(-a^2 x^2) \]  \hspace{1cm} (17)

Where,
- \( A \) = Amplitude
- \( a \) = Real constant
- \( x \) = Function value

2.5 MatLab

MatLab is a software that is maximal for the execution and solution on methods and techniques of Noise Control. The software can provide solutions with signal processing methods using FFT (Fast Fourier Transform). the goal is to get Noise Control analysis, especially in this research is the Noise Control focused on exhaust (silencer).
Figure 28. Menu on MATLAB in solving signal issues.

**Figure 29.** The signal processed by FFT.
3. Outline
The method in this study is a comparison between the results of simulation Noise Control derived from field data or data measuring muffler (silencer) Toyota Kijang Capsule assembled in 2009 with the data Instruments Signal Generators Noise with the results obtained from the simulation Noise Control signal processing using MatLab.

Comparison of results from research using data simulation calculations with the Noise Control Simulation Noise Control software that uses MatLab. Whether the results of calculations with the Signal Processing using Fourier better Transforms its reduction compared to simulations using MatLab.

Conclusion:
- Comparing the results of its initial research Signal Processing Simulation Active Noise Control muffler (silencer), which uses Fourier Transform calculations simulated with software simulation results using MatLab.

Figure 30. Framework concept

Figure 31. Block diagram of Active Noise Control on the exhaust (silencer).
Figure 32. Instruments Noise Signal Generators Circuit

Table 3. Data Instrument Noise Signal Generators.

| No | Frek | dB X- | dB Z+ | dBZ- |
|----|------|-------|-------|------|
| 1  | 31.5 | 29.33 | 30.23 | 31.55 |
| 2  | 40   | 30.34 | 29.78 | 29.33 |
| 3  | 50   | 31.25 | 30.76 | 31.55 |
| 4  | 63   | 31.22 | 33.34 | 32.76 |
| 5  | 70   | 33.34 | 34.44 | 33.34 |
| 6  | 80   | 26.22 | 25.34 | 27.22 |
| 7  | 100  | 32.35 | 35.55 | 33.55 |
| 8  | 125  | 30.35 | 31.35 | 30.55 |
| 9  | 160  | 36.6  | 37.23 | 36.23 |

3.1 Results graph of the data Instrument Noise Signal Generators

Figure 33. Value of Data Noise Signal Generator on the X-axis.
3.2 Measurement Method and Data Collection noisy

**Figure 36.** Measurement conditions Half Spherical.
Figure 37. The process of data retrieval noisy muffler (silencer) Toyota Kijang Capsule assembly, 2009.

Table 4. Measurement data table muffler (silencer) Toyota Kijang Capsule assembly in 2009

| No | 1/3 Octave (Hz) | X- | Z+ | Z- |
|----|----------------|----|----|----|
| 1  | 31.5           | 26 | 25.9 | 26.3 |
| 2  | 40             | 26.7 | 27.8 | 26.7 |
| 3  | 50             | 35.7 | 35.5 | 35.5 |
| 4  | 63             | 26.8 | 26.9 | 26.3 |
| 5  | 70             | 27.2 | 26.3 | 26.5 |
| 6  | 80             | 28.3 | 28 | 27.9 |
| 7  | 100            | 35.2 | 35.2 | 34.9 |
| 8  | 125            | 27.3 | 27.4 | 27 |
| 9  | 160            | 25.6 | 26 | 26 |

3.3 The result of the measurement data graph muffler (silencer) Toyota Kijang Capsule assembly in 2009.

Figure 38. Value of Data Noise Signal Generator on the X- axis
Figure 39. Value of Data Noise Signal Generator on the Z+ axis

Figure 40. Value of Data Noise Signal Generator on the Z+ axis.

Discussion on the study is to conduct a simulation test signals processing from the exhaust (Silencer) using MatLab. The simulation results are then carried out the process of Noise Control signal after signal given opponents of the results of the data Noise Signal Generators. Then the results of this simulation compared with the results of previous research.

Figure 41. Graphic of data noise generator result on the X- axis.

Figure 42. Graphic FFT of data noise generator result on the X- axis.
4. Conclusion
Based on the conclusion of the study, the comparison of results of noise data in the can, a significant difference between the results obtained from data capture directly on the exhaust (silencer), compared with the results obtained from simulation using MatLab. By comparing the simulation results of Active Noise Control in the exhaust (silencer):
1. With Active Noise Control based simulation using MatLab pretty much closer to achievement. Spl produced quite closer to the data that has been obtained from the data field. So that the resulting error is in the range of 40% - 33.7% with 66.7% of phase shift.
2. While the achievements based on field data (measurements directly on the exhaust/ silencer). Active Noise Control Solutions achievements have 33.7% error by shifting the phase 66.7%.
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