ISSN 2348 – 8034
Impact Factor- 3.155

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

Development and Basic Experiment of Active Noise Control System for Reduction of Road Noise

Hak-Ryong, Moon[1], You-Jin, Lim *[2], Won-Pyoung, Kang [3]
[1]Research Fellow, Korea Institute of Civil Engineering and Building Technology, Korea
[*2,3]Researcher, Korea Institute of Civil Engineering and Building Technology, Korea
*Corresponding Author

ABSTRACT

As one of the most popular methods to reduce road traffic noise, noise barrier is installed along the road, but excessive cost for installation and maintenance is pointed out as the problem and increasingly rising height has been a blot on the landscape.

Thus, it's necessary to develop core technology of electronic noise reduction method and system to enhance the performance of existing noise barrier. This study is intended to apply electronic noise reduction device to road traffic environment in a way of designing parallel core embedded processor-based signal controller and various analogue input & output and amplification module as well as implementing control algorithm in DSP (digital signal processor) so as to analyze the performance and application evaluation of noise source in open space.

This research shows the need for adjusting control algorithm and parameters depending on environment and weather at the location where active noise remover is set and when applying noise model type and optimal parameter of transfer function, reduction effect of noise source at major frequency is expected and moreover, the height of existing noise barrier would possibly be reduced.

***Keywords**:* Road Traffic Noise, Active Noise Cancelling

I. INTRODUCTION

1. 1 Background and Objective of the Study

As one of the most popular methods to reduce road traffic noise, noise barrier is installed along the road, but excessive cost for installation and maintenance is pointed out as the problem and increasingly rising height has been a blot on the landscape. Thus, it's necessary to develop core technology of electronic noise reduction method and system to enhance the performance of existing noise barrier[1]. This study is intended to apply electronic noise reduction device to road traffic environment in a way of designing parallel core embedded processor-based signal controller and various analogue input & output and amplification module as well as implementing control algorithm in DSP (digital signal processor) so as to analyze the performance and application evaluation of noise source in open space.

1. 2 Literature Review

Active noise reduction technology is intended to reduce the noise by generating counter-noise with same level and frequency after converting 180° the frequency of the noise. The study to put active noise reduction technology to practical use for automobile, airplane, train, acoustic system and noise barrier has been continued.

When it comes to active noise reduction technology, Hyundai Motor first developed active noise reduction technology in Korea and is at the stage to commercialize for deluxe car and Honda conducted the study that has reduced the noise by 10dB(A) at 100Hz. Active noise reduction technology in sound equipment has been mostly applied to headphone which has a broad market[2]. In Korea, Kim, Young-min et al (2012) conducted the study on active noise reduction for high speed railroad which showed the effect at 120Hz and 280Hz[3].

Study on applying active noise reduction technology to noise barrier has been conducted when it comes to road. Cho, Wan-Hyung et al (2011) conducted study on applying active noise reduction technology to the top of noise barrier and developed Y-type device that is installed on top of noise barrier and as a result of lab test, noise reduction, 6.4～13.8dB(A) appeared[4].

In Japan, active noise control technology was applied to noise barrier in 2004. The structure was installed on existing noise barrier as Fig 1 and noise reduction by 2～5dB(A) at 160~630Hz was demonstrated[5].

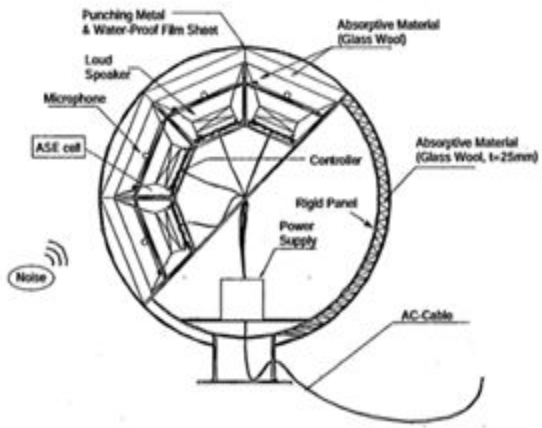
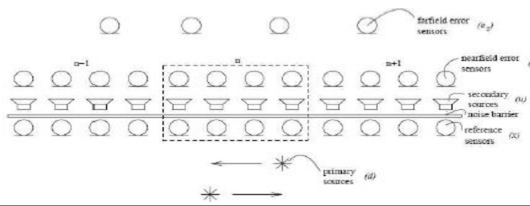


Figure 1. ANC Barrier of Japan[5]

Only case of applying active noise reduction technology to noise barrier on road was the study on reducing diffracted sound on top of noise barrier in 2005. The study to apply it to road structure stays at simulation or lab test stage.

The cases of applying active noise reduction technologies to noise barrier are as Table 1. In Netherlands, 5dB(A) was reduced and in China, White Noise was reduced by 0.2～6.0dB(A) at 200～1,250Hz and transformer noise was reduced by 0.3 ~ 4.3dB(A) at 400Hz or below. This study is aimed at reducing the noise to the extent shown in Table 1.

Table 1. Technology of ANC Barrier[6]

Country	Technology
Netherlands	- Apply to noise barrier and ANC simulation - 5dB reduction 
China	- Installs on a wooden noise barrier - Experiment with white noise - 200~1250Hz : 0.2~6.0dB reduction
	- ANC production as applied to the transformer noise by Antysound Company - 0 ~ 400Hz : 0.3~4.3dB reduction 

ISSN 2348 – 8034
Impact Factor- 3.155

II. SYSTEM DESIGN AND FABRICATION

Active noise reduction system for reducing road noise comprises signal process controller, audio input processor, audio output processor and front, and active noise controller has two mike inputs and 1 output. For the purpose of processing active noise signal, controller comprising of TMS320C6748 DSP processor, ARM dual core product OMAP-L138, 128MB RAM and 8MB flash memory was designed.

Active noise controller comprises, as shown in figure 2, power supply system that feeds phantom power, OMAP-L138 and analogue power and input system including free amp that amplifies mike input and ADC that converts analogue signal to digital signal, and DAC that produces counter noise generated by algorithm, free amp and power amp. Phantom power was designed to use 24V or 48V and interface with external system through UART. And for set value of controller and parameter setting, it's designed to use User Interface menu on front board as figure 2.

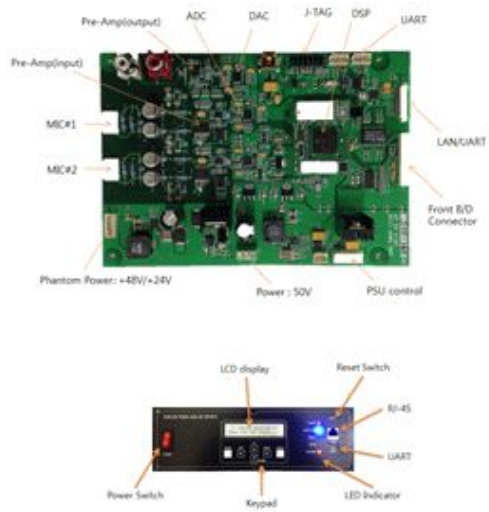


Figure 2. Active Noise Remover H/W and Front

III. SIGNAL PROCESS SOFTWARE

To review noise reduction effect obtained by active noise control, Fx-LMS was used as control algorithm which is implemented in DSP to speed up the calculation and a driver to directly control audio input & output by DSP at device initialization stage was designed and applied.

For reviewing active noise control, Fx-LMS was used as control algorithm and was expressed as Equation (1)[7].

(1)

Where, μ is step size that determines stability and convergence of algorithm and h(n) is impulse response of H(z) Input vector x(n) is filtered by H(z) and is the value before updated by weight vector. But H(z) is unknown and modeling by filter C(z) is necessary and thus,

(2)

And

(3)

Where,

(4)

And, is calculated by filtered vector of reference input x'(n) as follows.

(5)

ISSN 2348 – 8034
Impact Factor- 3.155

And coefficient vector of second path C(z) is as follows.

(6)

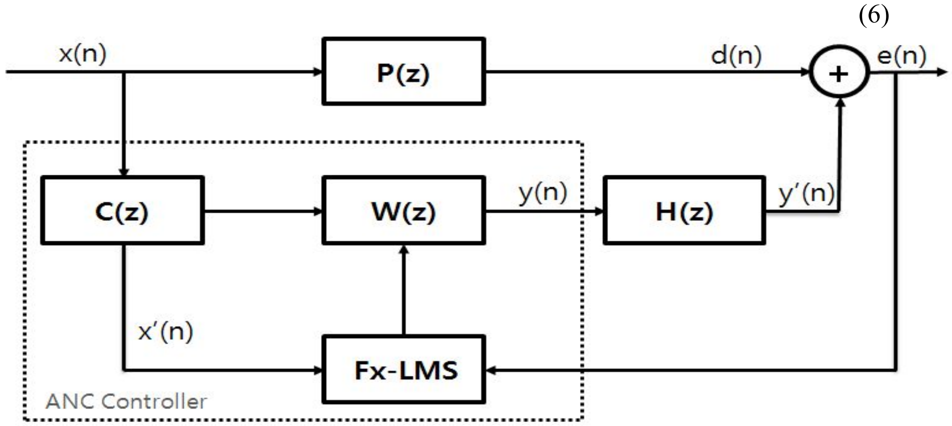


Figure 3. Fx LMS Algorithm Block for ANC[7]

IV. EXPERIMENT AND REVIEW

4. 1 Experiment Condition on Road Environment

The experiment was conducted on a 2-way road with 4 lanes and microphone for measuring and collecting road noise was set 6.25m away from the center of a 2-lane road as shown in figure 4 and figure 5 and noise reduction effect by active noise controller was measured while changing the position of speaker generating counter wave and error microphone.

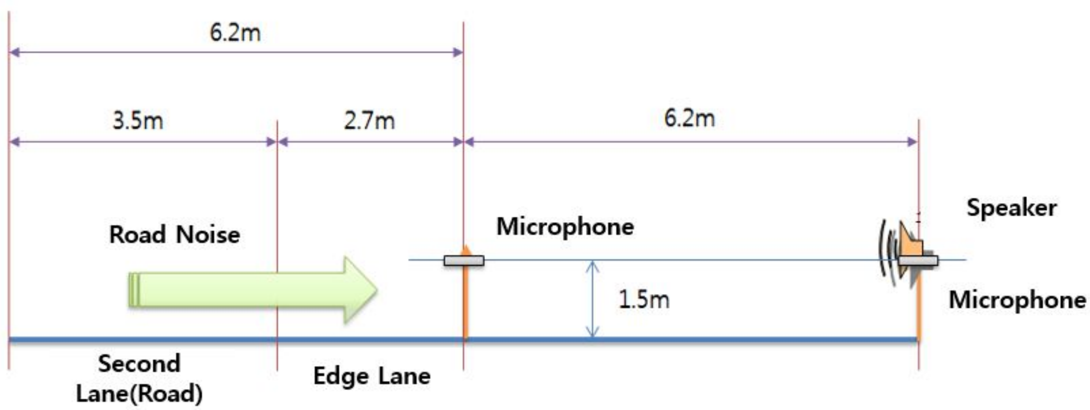


Figure 4. Test Layout

Figure 5. Test Site

Noise reduction effect was analyzed using active noise reduction device designed for the road with line source characteristics as shown in figure 6.

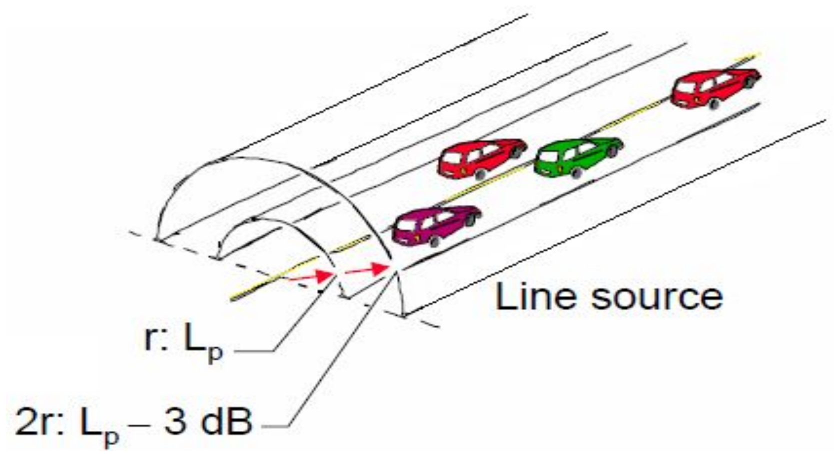


Figure 6. Line Source of Noise

To analyze the road noise, 1/3 octave band analysis program and 5 microphones were set and the noise varying dependent on vehicle type and speed was analyzed at frequency band 200Hz～1,250Hz.

4. 2 Result of Road Environment Test

For the noise generated on road, test of noise reduction was conducted by active noise controller using Fx-LMS algorithm. In order to enhance the reliability of noise measured, road noise was measured when active noise controller was inactive. Two tests were conducted using active noise controller depending on layout of microphone and speaker.

4. 2. 1 Road Environment Test - Case 1

Case 1 was conducted with microphone layout as shown in figure 7. 2 anti-noise speakers and 6 microphones were set in parallel with the road and error mike was set between measuring mike and counter wave speaker to measure the noise reduction effect. In this study, #4 mike was set within the influence of ANC and in Case 1, error mike was 2m away from #4 microphone.

ISSN 2348 – 8034
Impact Factor- 3.155

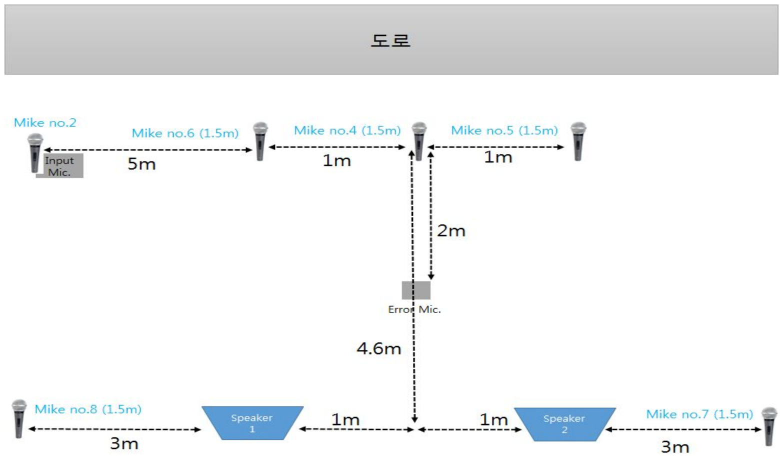


Figure 7. Case 1 Layout

Noise on road is considered linear as the car runs linearly, which was quantified and in case of 2r to distance r, noise reduction by 3dB(A) appeared. As a result of substituting by measured value, the result obtained is as shown in table 2.

Table 2. Test Result of Case 1

Frequency	Noise source		ANC ON	Effect
	Original	Distance		
200Hz	67.2	64.2	60.8	3.3
250Hz	65.9	62.9	59.2	3.7
315Hz	67.5	64.5	62.7	1.8
400Hz	68.5	65.5	63.9	1.6
500Hz	69.4	66.4	65.8	0.6
630Hz	72.5	69.5	68.2	1.3
800Hz	75.3	72.3	71.1	1.2
1000Hz	77.0	74.0	73.1	0.9
1250Hz	76.2	73.2	71.8	1.4

When indicating 1/3 octave band value to the data calculated, the result is as shown in figure 8. 0.6dB was reduced at 500Hz and 1.6 ~ 3.7dB at less than 500Hz.

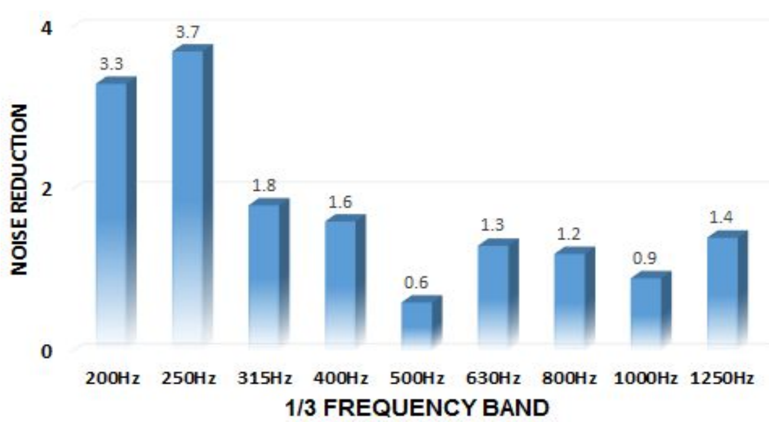


Figure 8. Noise Reduction of Case 1

ISSN 2348 – 8034
Impact Factor- 3.155

4. 2. 2 Road Environment Test - Case 2

Microphones are set vertically as shown in figure 9. And, #4 microphone and error microphone were set at same position.

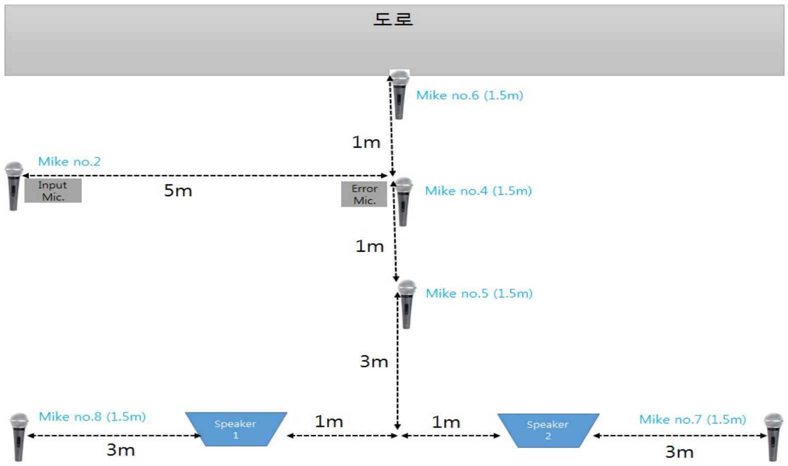


Figure 9. Case 2 Layout

As measuring mike was at the zone influenced by counter wave and #4, #5 and #6 mike were vertically set, -3dB could be applied in case of 2r to distance r when applying line source to #8 mike same as horizontal layout and the result obtained is as shown in table 3.

Table 3. Test Result of Case 2

Frequency	Noise source		ANC ON	Effect
	Original	Distance		
200Hz	61.8	58.8	54.7	4.0
250Hz	63.2	60.2	58.0	2.2
315Hz	64.3	61.3	58.1	3.3
400Hz	65.8	62.8	61.4	1.4
500Hz	68.9	65.9	64.3	1.6
630Hz	71.5	68.5	67.3	1.2
800Hz	75.4	72.4	71.3	1.1
1000Hz	77.9	74.9	73.8	1.1
1250Hz	76.7	73.7	72.6	1.0

Figure 10 shows the data calculated in 1/3 octave band graph. Noise reduction by 1.5dM at 500Hz or below and 4.0dB 200Hz.

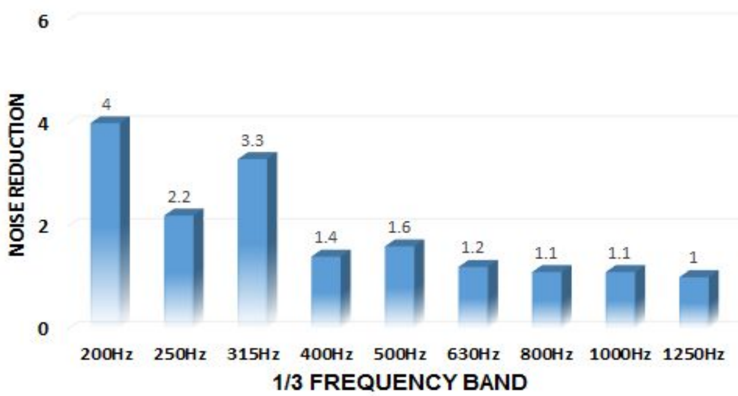


Figure 10. Noise Reduction of Case 2

4. 2. 3 Analysis of Noise Reduction Effect

Field test was conducted twice in this study and noise reduction effect was compared with the effect suggested in bibliography. In simulation for road noise worldwide, noise reduction was 2~5dB(A) and in the test for transformer noise, noise reduction was 4.3dB(A) at 400Hz or less. And reduction effect for transformer noise obtained in this study was compared and as a result, the effect reached to 93% of suggested effect 4.3dB(A) in bibliography.

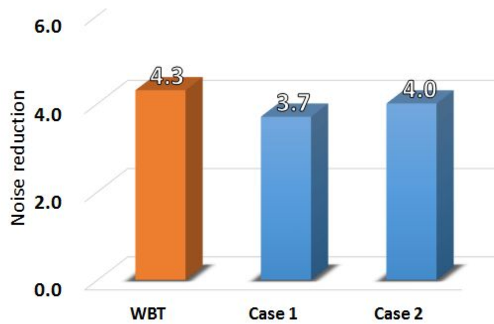


Figure 11. Effect Comparison of World and This Research

Viewing the result, performance has almost reached world's top level but further study to enhance the stability at low frequency and controller needs to be implemented before applying to the real road environment.

V. CONCLUSION

This experiment was conducted at real road environment using active noise reduction controller designed to reduce road noise and Fx-LMS algorithm implemented in DSP processor and noise reduction effect was analyzed at various environment conditions including type of vehicle, temperature, wind velocity/ direction.

In order to analyze the noise reduction, mike position was arranged to calculate it mathematically considering the road noise with the characteristics of line source and to enhance the reliability of the data, noise data when active noise controller is inactive was collected.

In order to identify the noise reduction effect, test was conducted while changing the input like and error mike position as well as output speaker as Case 1 and Case 2.

The test shows the need for adjusting control algorithm and parameters depending on environment and weather at the location where active noise remover is set and when applying noise model type and optimal parameter of transfer function, reduction effect of noise source at major frequency is expected and moreover, the height of existing noise barrier would possibly be reduced. Thus, road traffic noise in open space would also be reduced when modeling appropriate to road environment is developed based on this signal process controller is developed and applying improved active noise control algorithm is implemented.

ISSN 2348 – 8034
Impact Factor- 3.155

VI. ACKNOWLEDGEMENTS

This research was supported by a grant from a Strategic Research Project (Development of Electronic Road Traffic Noise Reduction Technology) funded by the Korea Institute of Civil Engineering and Building Technology.

REFERENCES

1. *Korea Institute of Civil Engineering and Building Technology, Technology Development of Noise and Dust Reduction for Road Environmental Improvement – Development of Electronic Road Traffic Noise Reduction Technology, Annual Report 2012 KICT 2012-106, 2012.*
2. *W. P. Kang, H. R. Moon and Y. J. Lim, "Analysis on Technical Trends of Active Noise Cancellation for Reducing Road Traffic Noise", Journal of Emerging Trends in Computing and Information Sciences, Vol. 5, No. 4, 2014, pp. 286-291.*
3. *Kim. Y. M. and Lee. K. S., "A Study on the Modeling for Reducing High-Speed Train KTX's Interior Noise using Active Noise Control Technique" The Transactions of the Korean Institute of Electrical Engineers, Vol.61 No.11, 2012, pp.1725-1731.*
4. *W. H. Cho, D. W. Kim, J. K. Park, K. J. Kim, T. H. Jung, and S. W. Nam, "Multichannel ANC System for Electronic noise Barriers in the Roadside, the conference of Korean society of road engineers, 2011, pp.193-196.*
5. *P. A. Morgan, Review of Japanese Noise Barrier Research, 2004, p.33.*
6. *Korea Institute of Civil Engineering and Building Technology, Technology Development of Noise and Dust Reduction for Road Environmental Improvement – Development of Electronic Road Traffic Noise Reduction Technology, Annual Report 2014, 2014.*
7. *Sen M. Kuo, Issa Panahi, Kai M. Chung, Tom Horner, Mark Nadeski and Jason Chyan, Design of Active Noise control system with the TMS320 family, Texas Instruments, 1996.*
8. *Bruël & Kjær, Basic Concept of Sound, 1998.*