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DEVELOPMENT OF ANC SECONDARY SOURCE WALL ARRAYS ASSISTING WITH NOISE BARRIERS

Youngmin Kwon[1*] **Seongmo Jung**[1] **Hyounsuk Kim**[2] **Jonggyu Kang**[2]

[1] SAMSUNG C&T, Seoul, S. Korea
[2] ARE Inc., Daejeon, S. Korea

ABSTRACT

Outdoor noise outstanding at the boundaries of residential areas are perceived disagreeably and therefore managed strictly in accordance with the national or local noise ordinances. In many cases around high density urban areas, large scale solid noise barriers along residential boundaries are to intervene to lessen noise pollution downstream of road traffic, industrial facilities, or in particular, construction sites. Noise barriers are also required for power plants whose noise sources present across a broad site of plant facilities, even though they reside in suburban or low density remote areas. This study explored active noise control (ANC) against propagation of such environmental noise pollution and a way to shorten height and/or length of or even entirely replace desired physical noise barriers. A total of 4 arrays of anti-phase signal generating secondary sources in 6 test cases atop or around a 3-meter high temporary noise barrier were designed and investigated. Up to 12 secondary sources were engaged in those arrays. Noise reduction performance of their ANC schemes was evaluated at 8 locations along a distance of 20m. Multi-row arrays either on top of or lay on the barrier was found best among others. Their performance attained up to 5.6dB reduction on average.

Keywords: *active noise control, active noise reduction, active noise barrier, active wall array, environmental noise*

[*] ***Corresponding author***: iam0min.kwon@samsung.com

1. INTRODUCTION

The outdoor noise mitigation measures typically applicable for environmental noise, which originates particularly in road traffic or construction sites, as well as for industrial noise call into question their effectiveness against noise propagation in the urban context. Such measures include noise barrier walls and temporary barrier panels. The noise barrier walls can be effective only on a massive solid scale. The temporary barrier panels that are commonly set up along the perimeter of a construction site in S. Korea are made of either galvanized iron within 1mm thick or recycled plastic. Two main purposes of those panels are 1) to reduce construction noise getting through; and 2) to screen the construction site from the view outside. However, the former is in fact not very practical due to their thin profile, causing lacking in sound insulation performance.
Noise barrier walls along the main roads and busy thoroughfares that are adjacent to a dense residential area are not unusual in S. Korea. Those barrier walls are employed profusely and erected higher than 10m oftentimes for high-rise residential buildings against roadway noise. If those barrier walls required to be higher than 10m, then their foundation structure shall be reinforced, increasing in construction cost. Such massive barrier walls whether transparent or not bring about many other issues: limited views and daylight at the lower floors of residential buildings; impeded air circulation across residential areas; and bird collisions. In some cases, tuned acoustic resonators are placed on top of the barrier walls to reduce diffraction of sound traveling around, escalating construction cost.
This study pioneered an active noise control (ANC) method to assist with such noise barrier walls or panels by attenuating sound waves traveling over and at the same time possibly weakening sound transmission passing through them. Eventually, it can be expected to scale down or replace a barrier structure entirely.

2. DEVELOPMENT OF ACTIVE WALL ARRAYS

Multi-row arrays of 8 to 12 anti-phase signal generating secondary sources (loudspeakers) were studied in close collaboration with the existing temporary barrier panels. Acoustic sample data acquisition and secondary path modeling were conducted to estimate the acoustic characteristics and behavior of outdoor sound propagation around the barrier panels. Based on this modeling, 4 arrays were designed atop or either side of the barrier panels and their active noise reduction performance was investigated.

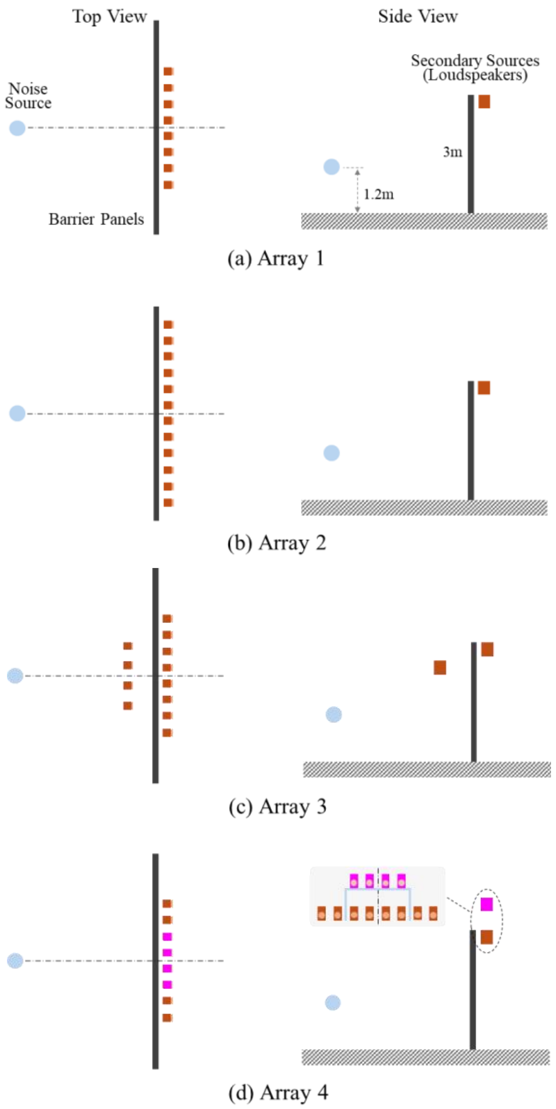

Figure 1. Active secondary source wall arrays.

Arrays 1 and 2 aligned the secondary sources along the other topside of the barrier panels against the noise source. While Array 1 accommodated 8 secondary sources, Array 2 did 12 ones. Array 3 aligned 8 secondary sources as same as Array 1 but with 4 other ones on the barrier panels facing the noise source. Array 4 employed 2 rows with 12 secondary sources on top of the barrier panels: 8 ones at the lower row and 4 ones at the upper row. See Fig. 1.

3. TEST SETTINGS AND PROCESS

3.1 Test site

The designed active secondary source wall arrays were tested at an inactive construction site, which has been no ground breaking, under free-field conditions. The site is surrounded at its boundary by 3-meter high temporary barrier panels that are made of recycled plastic. They are two-layer sandwich panels with an air cavity in a total thickness of 35mm. Each layer is 2mm thick and their sound transmission loss is unknown. See Fig. 2 and Fig.3..

3.2 Noise source

A dodecahedron omni-directional loudspeaker was used as a single point noise source. The test signal was white noise, which is a random continuous noise type that contains broadband spectrum. The noise source was set up at 1.2m high above ground and 3.5m from the barrier panels with a sound pressure level of 100dB as measured at 1m away.

3.3 Microphone settings

A number of microphones were employed for different purposes. They were assigned as reference microphones; error microphones; and observation microphones. Error microphones were designated as physical ones and virtual ones. In due course, the former remain for good with their original purpose, whereas the latter are to be removed upon tuning of a designed active noise control scheme.
A reference microphone (RM) was placed between the noise source and the secondary sources to pick up incoming signals from the noise source. Physical error microphones (PMs) were placed at the other side of the barrier panels to pick up the residual signals and increase their correlations with those at the virtual error microphones. On the other hand, virtual error microphones (VMs) were placed away in the designated active noise controlled zone or so-called quiet zone to fine-tune the perceived signals in line with those signals at the PMs. Plus, 8 observation microphones (OMs) were placed in a row at 1.6m intervals within the farthest distance of 20m for acoustic measurements.

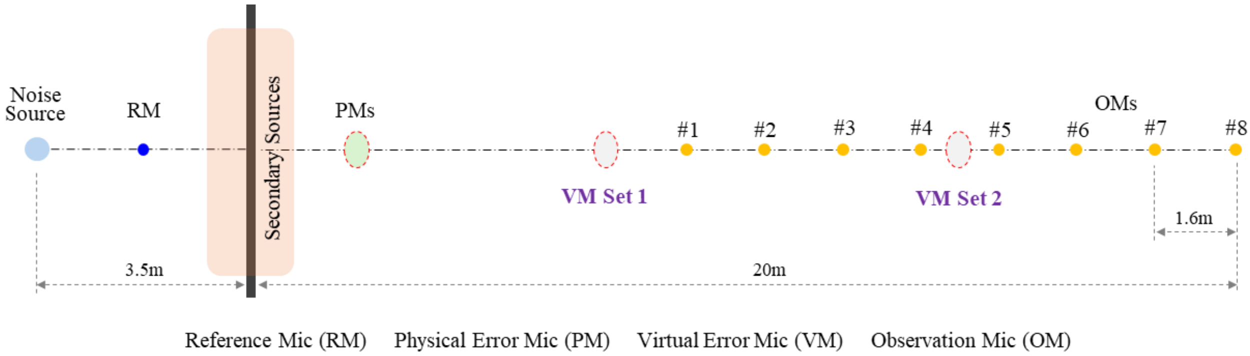

Figure 2. ANC test equipment setup plan (not to scale).

(a) At sound source side (b) At receiver side

Figure 3. ANC test setup example: Array 3.

3.4 Test method and process

A set of virtual error microphones (VMs) was placed either ahead or in the middle of the observation microphones (OMs). A total of 6 cases were tested and evaluated in combination with 4 designed active secondary source wall arrays and with those 2 locations of the VM set. Arrays 1 and 2 were evaluated only with the VM set located ahead and in the middle of the OMs respectively. Arrays 3 and 4 were done with the VM set at both locations.

Acoustic measurements of frequency-domain spectral responses up to 1kHz were carried out to evaluate noise reduction performance of the designed active secondary source wall arrays. Two measurement sets were taken for each array: one without and the other with an adaptive active noise control scheme up and running. In addition, a background noise measurement was taken for each array to review any eccentric acoustic events that might occur at the time of testing. Finally, noise reductions in dB were computed on the basis of the acoustic data obtained from the OMs.

4. TEST RESULTS

Spectral analyses were carried out across the frequency range of 30Hz through 500Hz where ANC filtering was applied. Noise reductions were computed from these analyses on the acoustic data obtained at each of the OMs and their performance by distance was examined within the designated active noise controlled zone. In addition, noise reductions of both all of 8 OMs and the last 3 OMs were tabulated on average and compared with each other. See Tab. 1.

Table 1. Summary of noise reductions on average.

Arrays	Test Cases	VM Locations		Average Reductions (dB)	
		Set 1	Set 2	Overall	End 3 OMs
1	1	●		3.0	1.6
2	2		●	4.8	5.1
3	3-1	●		4.2	3.0
	3-2		●	5.3	5.3
4	4-1	●		5.3	3.4
	4-2		●	5.6	4.6

Among the frequency range of interest, noise reduction performance was beginning to take effect from about 130Hz and it was effective up to 500Hz. Note that the designed ANC scheme performed ably between 200Hz and 450Hz but did not perform well at the lower frequencies than 130Hz. See Fig. 4. This noise reduction performance was observed broadly from most of the test cases coupled with those active secondary source wall arrays.

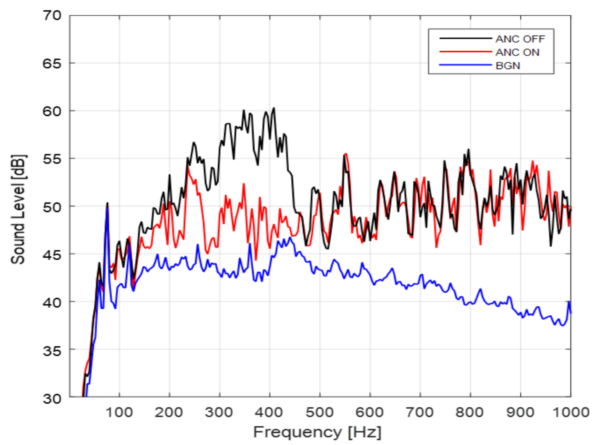

Figure 4. Spectral responses measured at the OM #6 from Test Case 3-2 with Array 3.

According to the test results of noise reduction by the active secondary source wall arrays, it is obvious that the more secondary sources are employed, the better noise reduction performance is achieved. The noise reductions of Arrays 2 through 4 which were with 12 secondary sources were 2 or 3dB higher than that of Array 1 which was with 8 ones. It appears that diffraction effect of sound decreases as the coverage by secondary sources widens either vertically or horizontally.

Next, it was found that the noise reduction performance improves as the virtual error microphones are set farther back in the active noise controlled zone. Among Arrays 3 and 4, Test Cases 3-2 and 4-2 that employed the VM Set 2 made 1 to 2dB or even more reductions than Test Cases 3-1 and 4-1 that employed the VM Set 1 except for the OMs at #1 and #2, which were the closest to VM Set 1. See Fig. 5

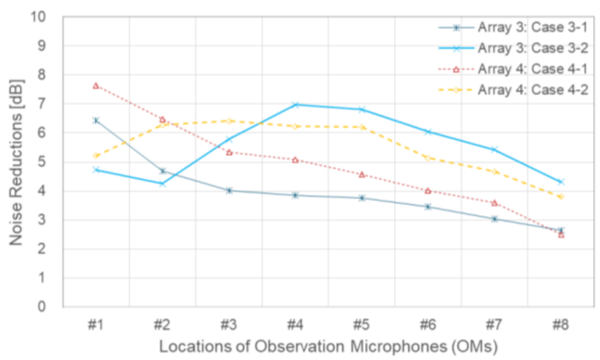

Figure 5. Noise reductions of Arrays 3 and 4 across the OMs by distance

Lastly, the noise reduction performance of Array 3 was comparable to that of either Array 2 or Array 4. Although the number of secondary sources was rather small, those residing at the sound source side of the barrier panels would come into play as the first line of active noise control directly on sound propagation from the noise source.

To summarize, for the cases of Arrays 2 through 4 tested with the VM Set 2, the overall noise reductions averaged from all of 8 OMs were 4.8, 5.3 and 5.6dB respectively and the noise reductions averaged from the last 3 OMs were 5.1, 5.3 and 4.6dB respectively.

5. CONCLUSION

The average noise reductions made by each of the active secondary source wall arrays, Arrays 2 through 4, that were equally with 12 secondary sources and tested with the VM Set 2 were shown comparable to each other in this study. Based on the overall noise reductions resulted from all of 8 measurement locations, the noise reduction performance of Array 4 appeared to be only marginally better than others. On the other hand, that of Array 3 was slightly higher if only the last 3 measurement locations were taken into account. However, it should not be suggested that Array 2 is to be considered least.

It is obvious that noise reduction performance becomes more effective as the virtual error microphones are placed as farther away from the noise source or the barrier panels back in the designated active noise controlled zone where the actual receivers reside to perceive the resulted sound. In addition, it should be noted that a set of the secondary sources accommodated near to the sound source can be of an initial role in noise reduction performance.

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