DOI: 10.61782/fa.2025.0723

FORUM ACUSTICUM EURONOISE 2025

RADIATION AND SPATIAL CHARACTERISTICS OF MASKING SPEAKER REPRODUCED SOUND IN RESIDENTIAL SPACES AND ITS IMPACT ON MASKING PERFORMANCE

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ABSTRACT

With growing interest in well-being, Acoustic PECS (Personalized Environmental Control System) has been introduced to enhance the indoor acoustic environment. For an active Acoustic PECS, the use of masking speakers is significant, and it is necessary to carefully examine the characteristics of the reproduced sound of the masking speaker according to spatial positions. Accordingly, field measurements were conducted in residential spaces (bedroom and living room) to assess the sound spectral characteristics of the masking speaker at different spatial positions. In the bedroom, the sound pressure level varied by up to 17.9 dB at 125 Hz band and 10.1 dB at 2000 Hz band depending on the location. Furthermore, listening tests were conducted to investigate the masking effects of residential noise based on acoustic differences in the reproduced sound of the masking speaker at different spatial positions. Subjective evaluations were conducted with and without artificial or natural sounds from the sound masking speaker, under conditions where residential noise was played through speakers. A comprehensive analysis was presented regarding the physical characteristics and masking performance of the reproduced sound of the sound masking speaker, depending on spatial positions within residential spaces.

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Keywords: Acoustics PECS, indoor acoustic environment, residential space, sound masking.

1. INTRODUCTION

With the growing interest in well-being within residential spaces [1], a variety of studies related to well-being have been conducted in the field of indoor environmental quality [2]. Among these, the concept of PECS(Personalized Environmental Control System) has recently been introduced in the context of acoustic environments [3], but related research remains limited.

In acoustic environment research, studies have progressed beyond traditional noise control approaches toward soundscape approaches that aim to promote positive outcomes [4]. Numerous studies have shown that improving the soundscape can lead to positive effects on health and well-being [5-8]. However, the soundscape of residential spaces presents significantly different characteristics from the soundscapes of outdoor environments, which have been the primary focus of previous research, particularly when viewed from various contextual factors. Recently, growing efforts have been made to understand the soundscape of indoor residential environments [9].

In residential spaces, active methods for improving the acoustic environment are often the primary approach available to occupants, especially in high-rise multi-story buildings, where the inflow of natural outdoor sounds is limited, and residents are easily exposed to household noises such as floor impact noise, prompting the consideration of sound masking via speakers as a method for improving the acoustic environment. Typically, speakers are used uniformly across various rooms without accounting for the occupant's position or alterations in the indoor sound field. However, indoor and outdoor noises heard inside are experienced differently depending on the location within the residential space [10-11], and presenting appropriate sound pressure levels at suitable frequencies plays a critical role from a sound masking perspective [12], it can be said that variations in the indoor sound radiation characteristics of speakers are of great importance in acoustic environment control.

Accordingly, this study aimed to explore the applicability of PECS to indoor acoustic environments through sound masking speaker in residential spaces. To investigate this, measurements were conducted to examine how the radiation characteristics change of sound masking speaker in residential spaces compared to an anechoic chamber, and to assess the extent to which sound pressure levels vary by spatial positions within the space. In addition, a listening experiment was also conducted to evaluate how these variations in sound pressure level influence subjective perception.

2. MEASUREMENT OF THE RADIATION CHARACTERISTICS OF THE SOUND MASKING SPEAKER

2.1 Specification of the sound masking speaker

The sound masking speaker used in this study is shown in Figure 1. It is a sound masking speaker equipped with two tweeters on the front and one woofer on the rear, designed and manufactured to provide stable output across a wide frequency range.

Figure 1. Sound masking speaker used in study

3. RADIATION CHARACTERISTICS OF THE SOUND MASKING SPEAKER

The radiation characteristics of the sound masking speaker were measured in an anechoic chamber and were then compared with those measured in an indoor residential space. Additionally, variations in sound pressure levels by frequency and spatial position within the space were analyzed.

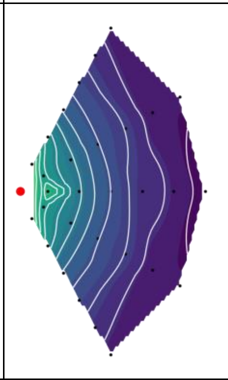
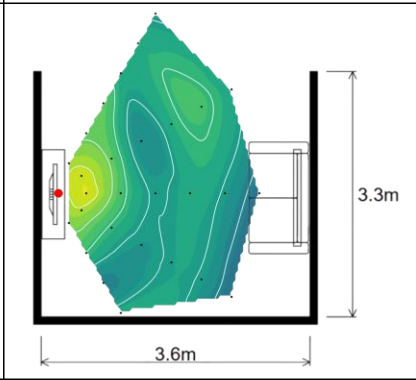
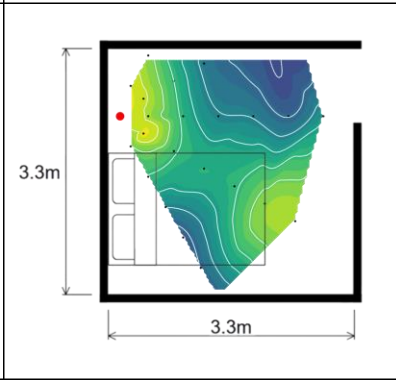
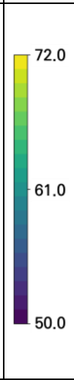
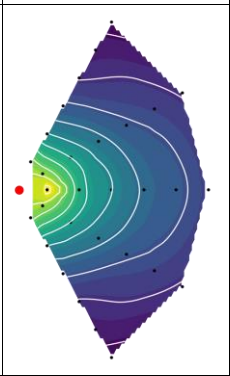
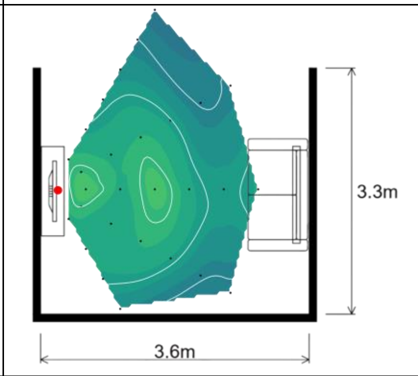
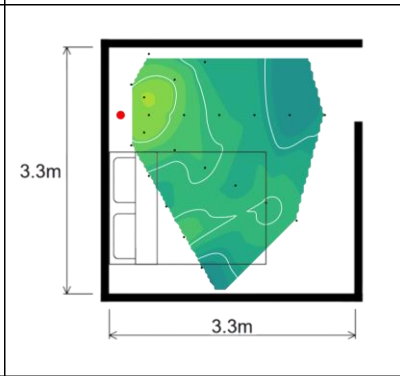
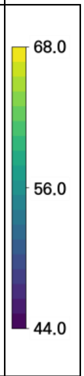
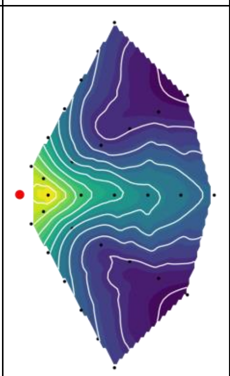
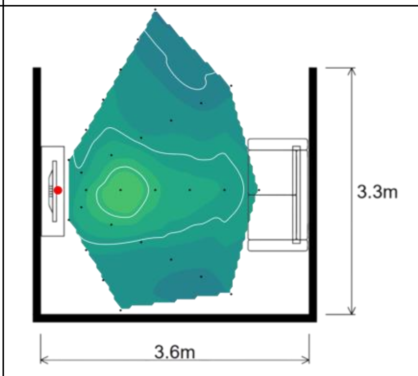
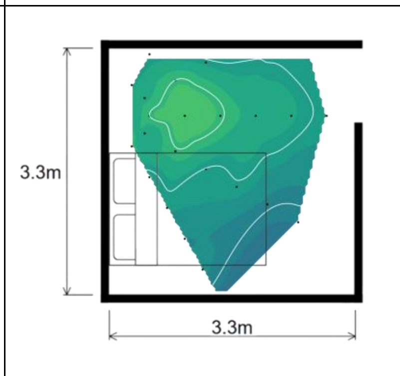
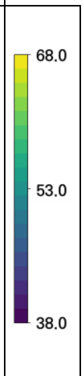
In a residential space with a floor area of 59 m², sound pressure levels were compared between measurement points located at the same radial distance from the speaker in both the anechoic chamber and the residential space. The results showed that levels in the 63, 125, and 250 Hz bands were consistently higher in the residential space, regardless of distance or room type. In the living room, the 250 Hz band exhibited a 17.7 dB higher, while the 2000 Hz band showed a 11.1 dB lower. In the bedroom, the 250 Hz band was 19.3 dB higher, whereas the 4000 Hz band was up to 10.8 dB lower.

When comparing measurement points within the same room, as shown in Figure 2, the maximum variation in sound pressure level in the living room was 12.9 dB at 125 Hz, 7.5 dB at 500 Hz, and 9.3 dB at 2000 Hz, depending on the spatial position. In the bedroom, the maximum variation in sound pressure level reached 17.9 dB at 125 Hz, 8.8 dB at 500 Hz, and 10.1 dB at 2000 Hz, showing greater differences than those measured in the living room.

4. LABORATORY LISTENING TEST ON SOUND MASKING EFFECTS BASED ON MEASURED DATA

Based on the measured distribution of sound pressure levels, specific spatial points exhibiting distinct frequency-dependent variations were identified. To understand how these differences in sound pressure levels at various locations affect people’s subjective perception of the indoor soundscape, a listening test was conducted.

The listening test was conducted in a laboratory setting that simulated an indoor residential environment, where background noise(outdoor road noise, indoor floor impact noise) was reproduced through speakers to create a realistic acoustic condition. Under the noise condition, natural sounds(water sound, birdsong) were played through a sound masking speaker, and an effective evaluation was conducted to assess the participants’ responses. The sound sources used in the experiment were adjusted through equalization based on the actual frequency-specific variations in sound pressure levels measured in the indoor residential space.

	Anechoic chamber	Living room	Bed room	
125 Hz				
ΔSPL_{125} * [dB]	16.4	12.9	17.9	
SD_{125}* [dB]	4.6	3.3	5.3	
500 Hz				
ΔSPL_{500} [dB]	24.0	7.5	8.8	
SD_{500} [dB]	6.6	2.1	2.5	
2,000 Hz				
ΔSPL_{2000} [dB]	29.4	9.3	10.1	
SD_{2000} [dB]	8.4	2.1	2.5	

*ΔSPL: SPLmax – SPLmin
*SD: Standard deviation of SPL at Each Measurement Point

Figure 2. Radiation characteristics of the sound masking speaker by space (1/1 octave band)

5. SUMMARY

This study was conducted to explore the potential application of PECS in the field of acoustic environments. The study examined the extent of frequency-dependent variations in sound pressure levels at different locations within an indoor residential environment and confirmed perceptible differences of sound presented from masking speaker in the different locations.
In future research, it will be necessary to collect data by measuring the radiation characteristics of speakers in various types of residential spaces and comparing them with simulation results. Based on this measurement-driven big data, further studies from various Acoustic PECS perspectives are required, such as quantifying the effects of sound masking according to spatial position. These efforts are expected to contribute to more effective improvements in the indoor residential soundscape.

6. ACKNOWLEDGMENTS

This work is supported by the Korea Agency for Infrastructure Technology Advancement (KAIA) under a grant funded by the Ministry of Land , Infrastructure and Transport (RS-2022- 00144050), the Ministry of Trade , Industry & Energy (MOTIE, Korea) under the Industrial Technology Innovation Program (No.20023556), and the National Research Foundation of Korea (NRF) grant funded by the Korea government (RS-2024-00455815).

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