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BASIC EXAMINATION OF NOISE MASKING IN THE HIROSHIMA PEACE MEMORIAL CEREMONY

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Abstract. *The Hiroshima Peace Memorial Ceremony is held every year in Hiroshima city. Because the demonstration procession marches inside and outside the venue, the ceremony is disturbed by the noise from the demonstrators. To address this problem, an experiment was conducted to perform noise reduction through active noise control (ANC) in 2015; however, its effect could not be confirmed accurately. Due to the influence of COVID-19 in this year, the number of participants decreased, which reduced the congestion in the ceremony, and thus, allowed the disturbance to easily reach the venue. In this study, we attempted reducing demonstrators' noise by masking their noise with some types of colored noises. Experimental results confirmed that we were able to effectively mask out the male voices of the demonstrators.*
Keywords: Noise masking, Hiroshima Peace Memorial Ceremony, Brownian noise

1. **Introduction.** On August 6 every year, the Hiroshima Peace Memorial Ceremony is held in Hiroshima, Japan to comfort the spirits of the atomic bomb victims and pray for the realization of permanent world peace. However, because various political marches are held in and around the venue, the voices of the demonstrators and sounds emitted from the megaphones could reach the venue. These disturbances tend to offend the bereaved families and participants who wish to quietly mourn the victims of the atomic bombing, which violates the purpose of the ceremony. Until now, Hiroshima city has repeatedly requested demonstrators to reduce the volume of the megaphone and change the demonstration route. However, such demands were responded with ignoration from the demonstrators, and megaphones with sound levels could still reach the venue. In 2015, Tanaka attempted to solve this through a noise reduction approach using active noise control (ANC); however, this method could not be confirmed [1] because in the year, the sound pressure level of the demonstrators' voices was lower than the ambient noise, thus making it uncontrollable. Since then, the crowds have already reduced the noise, and tents set up as sound barriers, which highly reduces the demonstration sounds heard by the ceremony attendees present in the venue. Furthermore, ANC of machinery noise including high frequencies was conducted using field programmable gate array (FPGA) [2]. However, because it is impossible to control high-frequency sounds present in such a wide space, it is difficult to implement the ANC for demonstration sounds at such events. Furthermore, due to the influence of COVID-19, the venue is uncrowded and the number of attendees this year was reduced to 1/10th, and thus, the voice of the demonstrators could easily reach the venue. Therefore, in this study, we investigated the possibility of reducing the noise caused by the demonstrators through the principle of masking. Many previous studies have confirmed that masking is effective in protecting speech privacy. For example, conversations held at dispensing pharmacies are likely to

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contain patient personal information, so Ishikawa considered using masking to protect speech privacy [3]. Based on this, we speculated that masking could prove to be effective in hiding the voices of demonstrators. This is the first attempt at the Hiroshima Peace Memorial Ceremony, and if we succeed in masking the demonstrators' noise, the purpose of the ceremony can be preserved. The rest of the paper is organized as follows: Section 2 discusses our methods, Section 3 explains the masking experiments we conducted at the Hiroshima Peace Memorial Ceremony and the results are thus obtained, and finally, Section 4 presents the conclusions of this study and future work.

2. **Methods.** In this study, the masking principle was employed to reduce the voice of the demonstrators. Specifically, masking is a phenomenon in which the auditory threshold (minimum audible value) of a certain sound rises due to the presence of another sound. The sound to be masked is a maskee, whereas that used for masking is called a masker. Here, the voices of the demonstrators and the sound of the megaphones are maskee. The masker should be a sound that is not considered as strange, even during the ceremony, and which can be played at a volume that does not bother the attendees; this is because a louder masker could also be perceived as unwanted noise. Considering this, we adopted colored noise for the masker, for which white, pink, and Brownian noise were selected as candidates [4]. The most effective masker was determined by playing these colored noises one by one simultaneously with the audio data of the ceremony, which was recorded in the previous year, and which also includes the demonstrators' voices and the loudspeaker sound. Based on the results of this observation, Brownian noise was selected as the best candidate for the masker. The frequency characteristics of the colored noise are plotted in Figure 1. It can be observed from the figure that as the frequency increases, the power density of the Brownian noise drops by 6 dB per octave. Low sounds are effective for masking high sounds. Therefore, compared to white and pink noises, Brownian noise can be expected to be less noticeable in treble even with rising volume.

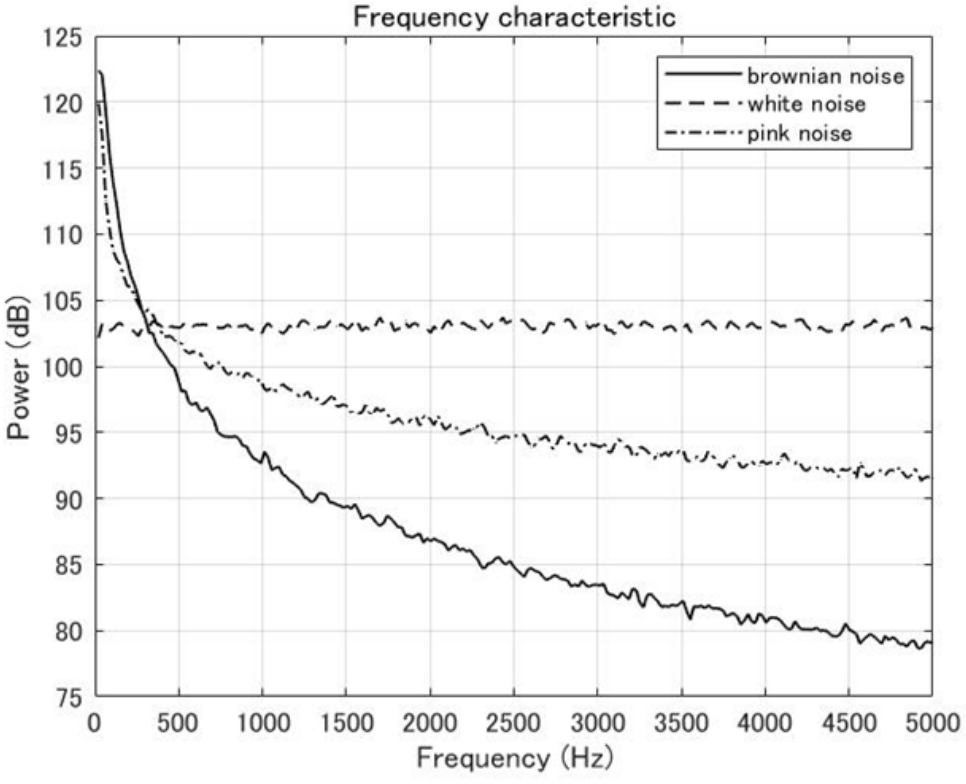

FIGURE 1. Comparison of the frequency characteristics of white, pink, and Brownian noise

3. **Masking Experiment at the Hiroshima Peace Memorial Ceremony.** An on-site masking experiment was conducted at the venue on the ceremony day. An experimental tent was set up behind the attendees' tent, where we investigated whether the demonstration sound could be masked out by adjusting the masker volume. During the ceremony, the environmental sound was recorded binaurally using binaural microphones with and without masking. The wiring diagram of the equipment used in the masking experiment is illustrated in Figure 2, while the photograph showing the experiment site is presented in Figure 3. The masker was played from the masker speakers via a PC. The

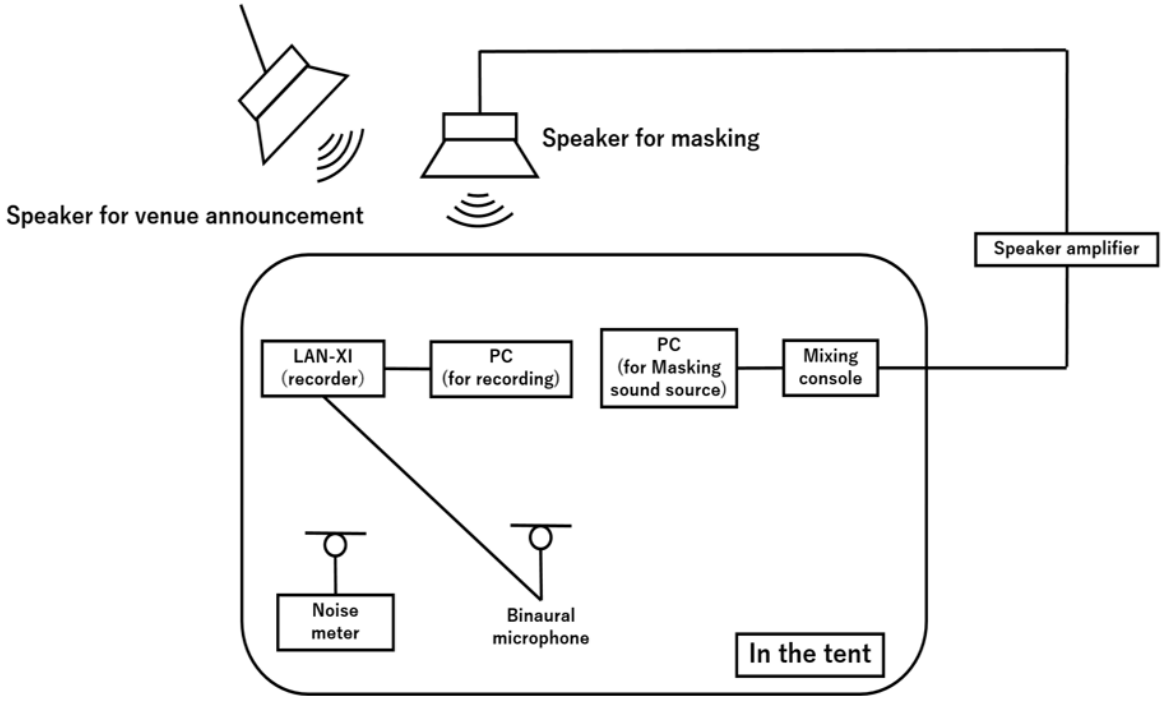

FIGURE 2. Wiring diagram of the equipment used in the masking experiment

FIGURE 3. Photograph depicting the experiment site

sound pressure level of the masker was adjusted using the mixing console. Moreover, the sound during the experiment was recorded using a LAN-XI recorder.

The first half of the ceremony was quiet because demonstration voices were absent. However, as the prime minister's greetings began, the voices of the demonstrators and the sound of megaphones gradually started to become audible. The demonstrators started marching from a place approximately 200 m to the east (in the direction of the Atomic Bomb Dome) of the ceremony venue. The difference in frequency characteristics between the male and female voices of the demonstrators was recorded at a sampling frequency of 65536 Hz and is plotted in Figure 4.

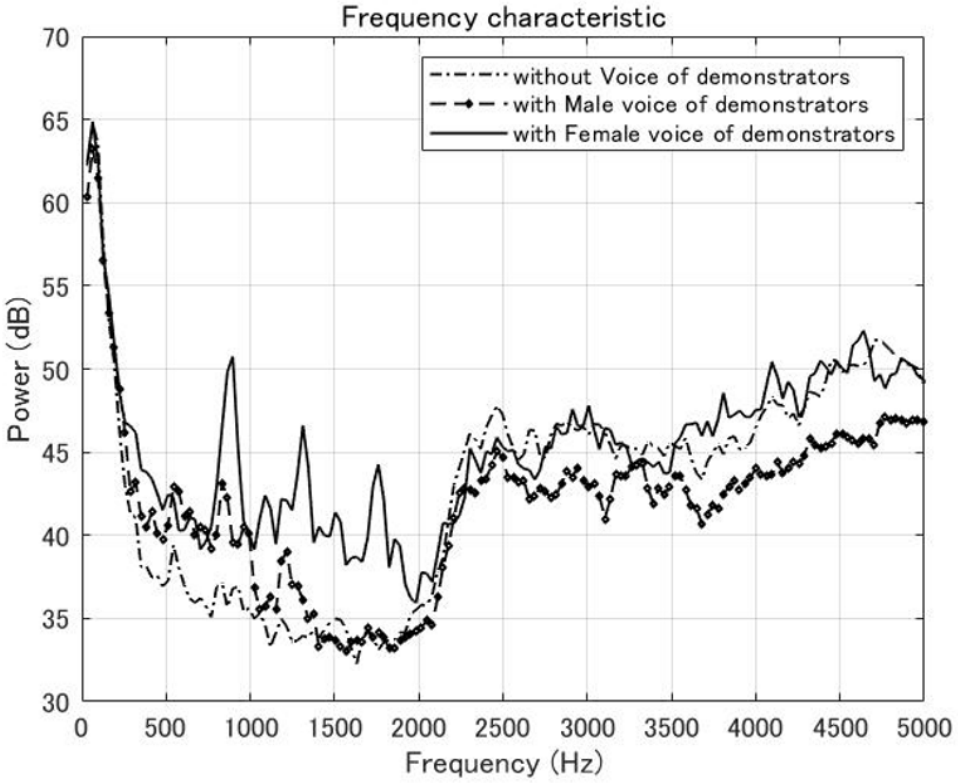

FIGURE 4. Difference between the frequency characteristics of male and female demonstrators' voices

As shown in Figure 4, there exist large peaks at 640 Hz and 1216 Hz for male voices and at 896 Hz, 1312 Hz, and 1760 Hz for female voices. This reveals that examining the volume and frequency characteristics of the masker is crucial to mask out both male and female voices. The women were using megaphones during the demonstrations this year, due to which the volume of female voices was louder, and thus, the peak of the fundamental frequency of female voices appeared to be higher, as shown in Figure 4.

Next, the frequency characteristics of the recorded data when the male voice was masked out by the Brownian noise with a non-bothering volume are demonstrated in Figure 5.

As shown in Figure 5, when the male voice of the demonstrators was masked out, the power was stronger in the frequency range of 100 Hz to 2 kHz than the original data. During the experiment, the sound pressure level was monitored with a noise meter and was found to be 60-65 dB without the masker and 66-70 dB with the masker. Consequently, there was no significant difference in sound pressure level with or without masking, and the Brownian noise was not perceived as noisy. Therefore, we believe that the masking of the male demonstration voices was successful.

However, the female voice of the demonstrators was not masked out successfully. As mentioned above, women were using megaphones; hence, the attendees of the ceremony could hear the female demonstration voices louder than the male voices. When the

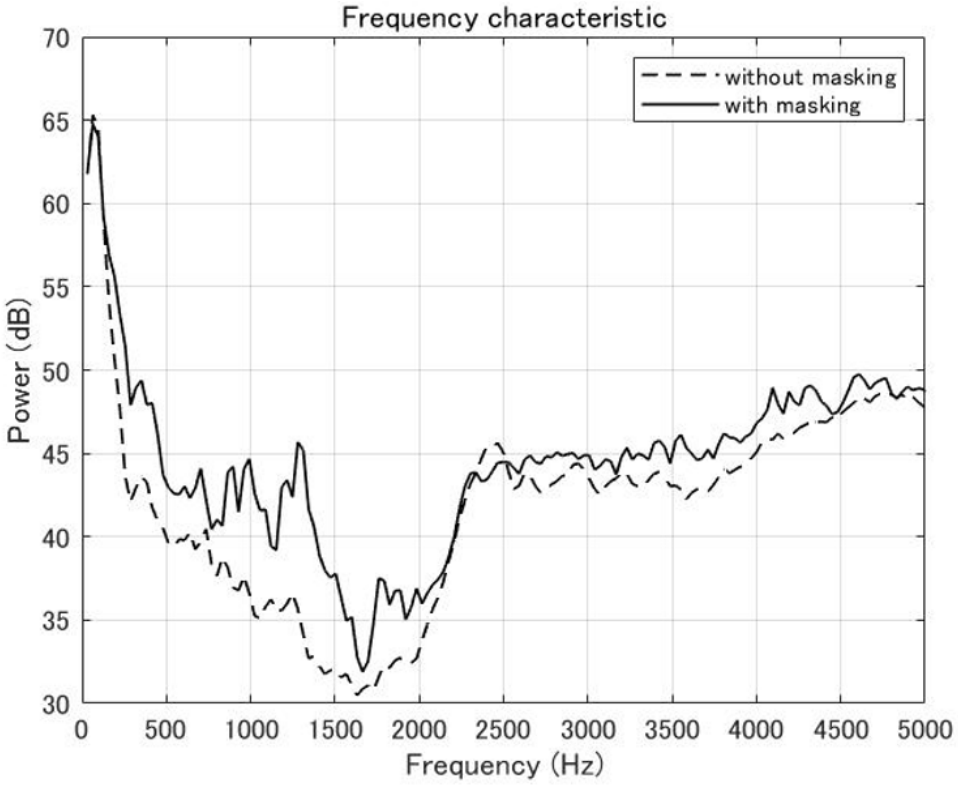

FIGURE 5. Frequency characteristics when masking out the male voice of the demonstrators

Brownian noise was played at a sufficiently high volume to mask out the female voice, it became noticeable and noisy. Meanwhile, although pink noise was also played to mask out the female voice, its treble range became conspicuous, making it difficult to be played during the ceremony. Therefore, to efficiently mask out both male and female voices, it is necessary to consider the masker type to be used and its corresponding volume in further detail.

4. **Conclusions and Future Work.** In this study, we investigated the possibility of masking out the noise caused by the demonstrators' voices and the megaphone sounds during the Hiroshima Peace Memorial Ceremony. The outcomes and findings can be described as follows:

- Masking is an effective approach to make the voices of demonstrators and megaphones inaudible and ensure quiet at the Peace Memorial Ceremony;
- The male voice of the demonstrators was masked out successfully by Brownian noise with a volume that did not feel noisy;
- As the female demonstrators used megaphones, their voices were heard louder than the males, and thus, the attempt to mask them out using Brownian noise was unsuccessful.

In future work, we plan to investigate different masker types and volumes to successfully mask both male and female voices while considering the use of megaphones.

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