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Technical note

Effect of active noise control and masking sound on speech intelligibility

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ABSTRACT

Passengers sitting in the back seats of cars while talking on their phones can easily have the privacy of their speech invaded by the driver. One way of protecting speech privacy is to utilize masking sounds, which may also lower speech intelligibility- masking sound may be so loud that it annoys both drivers and speakers. Here, we evaluate the feasibility of utilizing active noise control (ANC), which aims to reduce the level of speech targeted toward the driver, thus lowering the needed level of masking sounds while still protecting speech privacy. Evaluation of speech intelligibility has been completed both objectively and subjectively using Speech Intelligibility Index (SII) and Speech Reception Threshold (SRT), respectively. SII value calculation has shown that ANC is not effective at lowering the level of masking sounds and speech intelligibility. On the other hand, SRT measurement has shown that ANC, which reduces the speech level to around 10 dB below 1000 Hz, is able to lower the level of masking sounds by about 5 dB.

1. Introduction

Passengers in the back seats of cars talking on their phones often want the privacy of their speech to not to be intruded upon by drivers. Although delivering a masking sound toward the driver can achieve the protection of speech privacy, it is not ideal since the masking sound may be so loud that it distracts drivers and speakers from safe driving and conversations. In this paper, we have investigated the feasibility of utilizing ANC for lowering the level of masking sounds by reducing the level of speech directed toward the drivers position.

Speech intelligibility is highly related to how much the listener can understand or rewrite a given sentence with his/her own words. Throughout this paper, speech intelligibility is used as a measure of determining whether speech privacy is protected. To measure the speech intelligibility of a given sentence, we selected two measurements called the Speech Intelligibility Index (SII) and Speech Reception Threshold (SRT), which are objective and subjective measurements, respectively.

SII is a method for computing a physical measure that is highly correlated with the intelligibility of speech as evaluated by speech perception tests given a group of talkers and listeners [1]. Since first being suggested in 1997, the SII value calculation has been used in research under the purpose of estimating speech intelligibility. In 2005, Rhebergen et al. predicted the speech reception threshold for sentences in noise using SII values [9]. Kates and Arehart used the SII concept for estimating intelligibility to include broadband peak-clipping and center-clipping distortion [7].

SRT is also a method for measuring how much the listener perceives the intelligibility of given speeches under specific circumstances [10]. The SRT measurement procedure is well described by Steeneken [5].

There have been many efforts to develop and utilize the SRT method. In 1992, Bronkhorst and Plomp investigated the effect of multiple speechlike maskers on binaural speech recognition in normal and impaired hearing using SRT measurement [2]. Versfeld proposed a method for selecting sentence materials for efficient SRT measurement in 2000 [8]. And, as proposed by Hagerman in 1984, the SRT measurement has also been used for clinical purposes [3]. Sentences used during the SRT measurements in this paper were chosen from the Korean-Standard-Sentence-List-for-Adults (KS-SL-A) [6]. These sentences satisfy conditions required for speeches to be used as sentences for SRT measurement. Sentences should (a) represent conversational speech, (b) be short enough to be easy to repeat, and (c) be neither too redundant nor too difficult or confusing [10]. All participants had normal hearing and were between 21 and 29 years old. Participants were asked to wear headphones with equal input signals on both ears.

The main purpose of this research is to investigate the possibility of implementing ANC to lower the level of a masking sound, which can protect the speech privacy of a passenger in the back seat of a car. This study also seeks to: (1) measure the possibility of implementing an active noise control system upon the human voice in a given vehicle, via a simple active noise control experiment in a vehicle; and (2) see the effect of ANC on speech intelligi-

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bility and masking sound level, by considering sentences before and after applying active noise control during SII and SRT measurements. The effect of active noise control is investigated via simulation while conducting SII and SRT measurements.

2.1. SII value calculation without ANC

The SII value calculation result is given in this section. The calculation is from the case without the application of ANC technology.

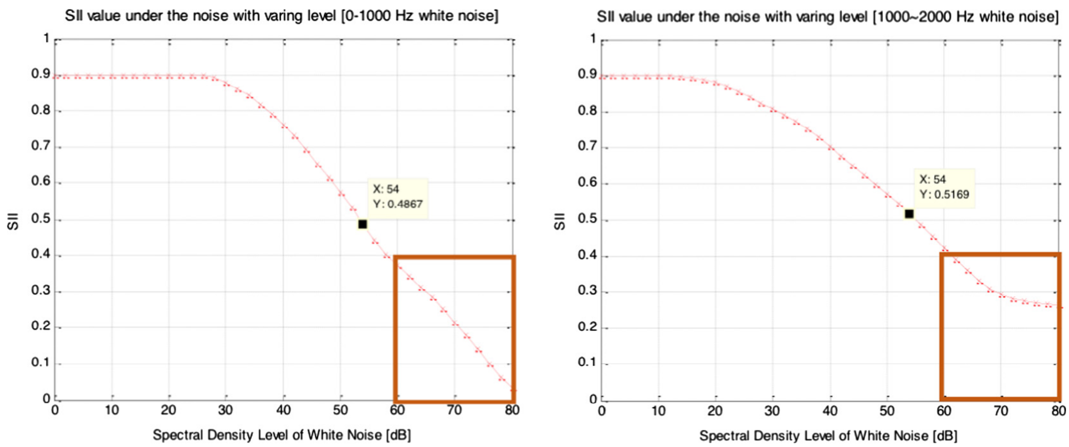

Fig. 1. SII value calculation without ANC. Masking sound type 1 [left]; masking sound type 2 [right].

2. Speech intelligibility without active noise control

In this section, the results of SII value calculation and SRT measurement before applying ANC are covered. All sentences used for SII and SRT are chosen from the KS-SL-A, designed for the purpose of speech intelligibility test using Korean sentences. 11 people, both male and female, with normal-hearing participated in the SRT measurement, and their ages ranged between 21 and 29. For SII and SRT measurement, every sentence is set to be 70 dB level.

Before applying ANC to speeches, we briefly investigated which frequency range of masking sound is effective for lowering speech intelligibility. We have chosen two types of masking sounds based on the distribution of speech energy and the ANC effective frequency range. Since both the frequency ranges containing most speech energy and the ANC effective frequency range are below 1000 Hz, the frequency ranges of (1) 20–1000 Hz and (2) 1000–2000 Hz have been used. Throughout this section, the speech intelligibility measurement results from two different masking sounds are compared. The masking sound with a frequency range between 20 and 1000 Hz is called masking sound type 1 and the one between 1000 and 2000 Hz is called masking sound type 2.

The SII value for maintaining speech privacy should be below 0.3 or 0.2, as indicated in Fig. 1. Fig. 1 suggests that masking sound type 1 shows better efficiency in lowering the SII value than masking sound type 2. For example, with a masking sound level of 70 dB, masking sound type 1 results in a 0.2 SII value, whereas masking sound type 2 results in an SII value of 0.3. As the masking sound level increased over 70 dB, we observed that, with the type 1 masking sound, the SII value decreased linearly; with the type 2 masking sound, the SII value stopped decreasing at a saturation level of approximately 0.25. In conclusion, the masking sound of which the frequency range coincides with the range of speech energy distribution and the ANC effective range is better for lowering the speech intelligibility than the other one with higher frequency range components. (See Figs. 2–6).

2.2. SRT measurement without ANC

In this section, we compare two types of masking sounds, type 1 and type 2, and, via SRT measurements with 11 participants, we determine which one is better at lowering speech intelligibility. As mentioned earlier, all participants had normal-hearing and were asked to wear headphones during measurements.

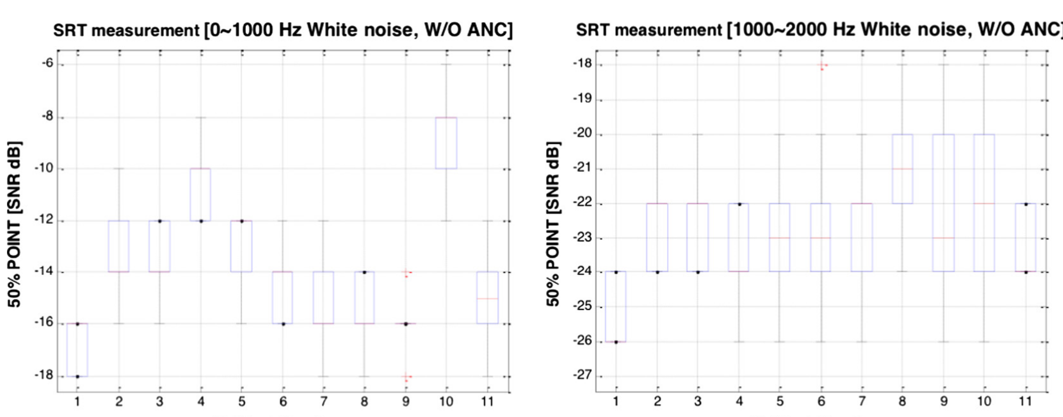

Fig. 2. SRT measurement without ANC. Masking sound type 1 [left]; masking sound type 2 [right].