Development of a voice shutter
(Phase 1: A closed type with feed forward control)

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ABSTRACT

Telephone voice is annoying in public spaces like trains and cafés. The speaking voice was tried to be attenuated by using an active noise control technique. It is called ‘Voice Shutter’. Two types of voice shutter, which are open type and closed type, were supposed to be possible. In this paper, a closed type voice shutter with a small vent hole controlled by a feed forward active noise control method was manufactured and tested. In order to develop a small handy type of voice shutter, the distance between the reference microphone and the control speaker should be as short as about 20 mm. The causality law was satisfied by using very high sampling frequency (100kHz) and a high speed signal processor with FPGA. In order to follow the rapid change of voice, partitions with a hole was successfully installed in the voice shutter for the primary path and the secondary path not to be affected by the configuration of a mouth. As the results, the handy scale voice shutter was proved to be feasible.

Keywords: Active Noise Control, Voice Shutter, Feed Forward Control
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1. INTRODUCTION

Active noise control (ANC) has been developed and successfully applied to actual machines, such as air-conditioning ducts, engine mufflers, ear protectors, car cabins, noise barriers and so forth. Recently some unique applications have been developed such as for reducing snore noise (1), quieting infant incubators (2) and protecting human ears from MRI (Magnetic Resonance Imaging) noise (3). The author et al has been developing AAS-Window (Active Acoustic Shielding) which is an open wind without transmitting sound (4). These applications can be established only by active methods, not by passive methods. These are considered to be important application fields of the ANC techniques.

On the other hand, there is a problem that telephone voice is annoying in such public spaces as trains and cafés. This is an issue of manner. However it is convenient if we can use a mobile phone in the public space without leaking the voice in the neighborhood. If we cover our mouth perfectly with some caps, we cannot speak any more. Therefore some vent holes are necessary for speaking easily. The voice should be shielded not to leak through the holes. Any passive techniques are difficult to solve this problem because of their size and weight.

Therefore, Active Noise Control (ANC) techniques were tried to be applied to the above shielding. We call this system ‘Voice Shutter’. The concepts of voice shutter were proposed and the feasibility was proved by a trial manufacturing and some experiments in our previous work (5). However, it was too large and heavy for us to carry.

In this paper, a small and handy voice shutter was aimed to be developed, which was a closed type controlled by a feed forward method. A key issue to realize feed forward control in such a small space is how to satisfy the causality between the primary sound and the secondary sound. This issue was achieved by using very high sampling frequency (100kHz) and a high speed signal processor with FPGA (Field Programmable Gate Array). Another issue was that not only the characteristic of the primary pass but also that of the secondary pass were affected by the configuration of a mouth. Partitions with a small hole were installed to insulate those affects. As the results, a small voice

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shutter was manufactured and proved to have sufficient noise reducing performance for the leaking voice.

2. CONCEPT OF VOICE SHUTTER

Figure 1 shows the conceptual configurations of voice shutter. Type A is a closed type which is pressed against the mouth with no gap and has some vent holes with active sound shielding. Leaking voice can be controlled by either a feed forward method or a feedback method. Type B is an open type which is used apart from the mouth. Breath and voice are leaked through the gap between the voice shutter and the mouth. The leaked voice is controlled by a feedback method. In both types, the reference signal or the control signal is put into a mobile phone as communication signal. It is also mixed with receiving signal of a mobile phone and put into an ear phone to ensure the speaking voice not too loud.

The open type is our final target. However it is supposed to be difficult to be developed. Therefore, as the first step, the feasibility of the closed type with a feed forward control is examined in this paper.

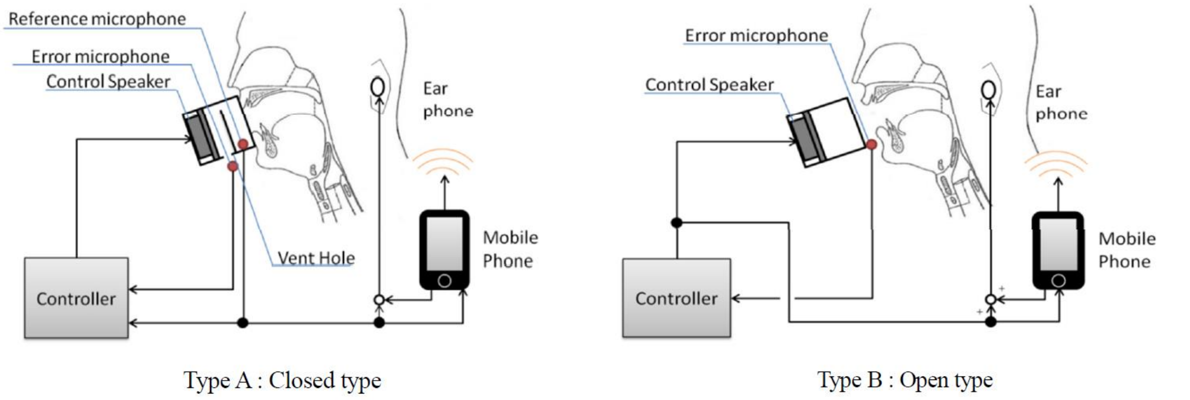


Figure 1 – Conceptual configurations of voice shutter

3. TRIAL MANUFACTURING OF VOICE SHUTTER

3.1 Prototype Voice Shutter

Small closed type voice shutters were designed and manufactured for the trial experiments. Figure 2 shows a schematic drawing of the feed forward type. The configuration is a shape of cylindrical cup having a control speaker at the end. In order to reduce the change of the sound field inside the voice shutter induced by the variation of the configuration of a mouth when we speak, two partition plates with a vent hole of 10mm ϕ are installed in the voice shutter. A reference microphone is installed near the vent hole of the partition plate. An error microphone is located at the exit vent hole. This active noise control system operates not to leak the speaking voice through this vent hole.

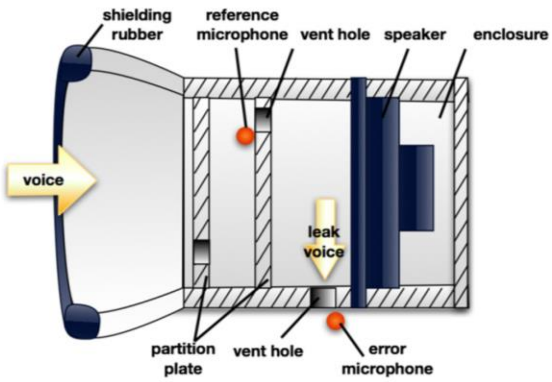


Figure 2– Schematic drawing of the feed forward type voice shutter

We performed two kinds of experiments. One was using speaker voices as the primary source, which were recorded voices radiated from a speaker, and another was using real voices radiated from a human mouth. The former experiment was performed to ensure whether the Filtered-X-LMS algorithm is effective for this type of voice shutter or not. The latter experiment was carried out to make clear the influence of the variation of mouth configuration and to prove the final performance and issues for human use.

Figure 3 shows photos of the prototype voice shutter for reducing speaker voices. The total size is about 75mm and it is enough small to be carried by one hand as seen in the photo. The control speaker is S57C25-1 made by Toyo Cone Paper MFG. Co., Ltd.. The microphone is WM-61A made by Panasonic Co. Ltd..

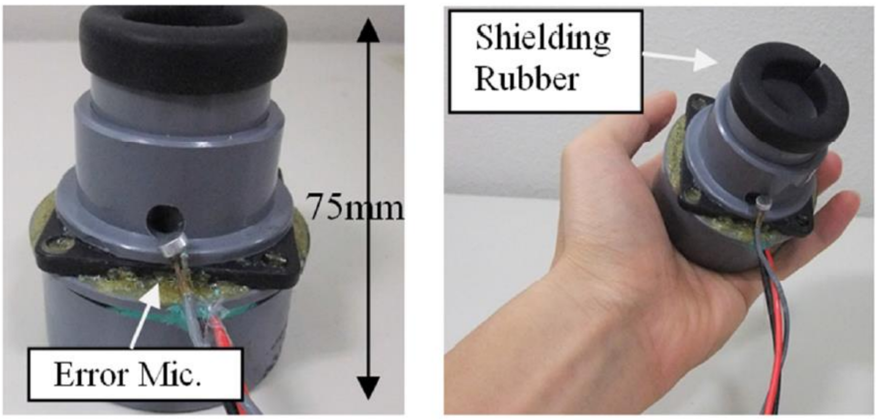


Figure 3– Photo of the prototype voice shutter for reducing speaker voice

Figure 4 shows photos of the prototype voice shutter for reducing real voice. This was improved by designing the size and shape to fit a human face. When we examined the contribution of leaking voice from a human body, leaking voice from a nose was found to be most dominant except from a mouth. Therefore, this voice shutter has a vent hole at the throat side, because it is not affected by the leaking voice from a nose. It also has a conical cover with a shieling rubber at the contact part to a face to increase fitness and to make easy to speak. A telephone microphone and an earphone are also installed in the voice shutter. The total size can be within about 75mm as same as that for speaker voice, by improving the design of the speaker enclosure.

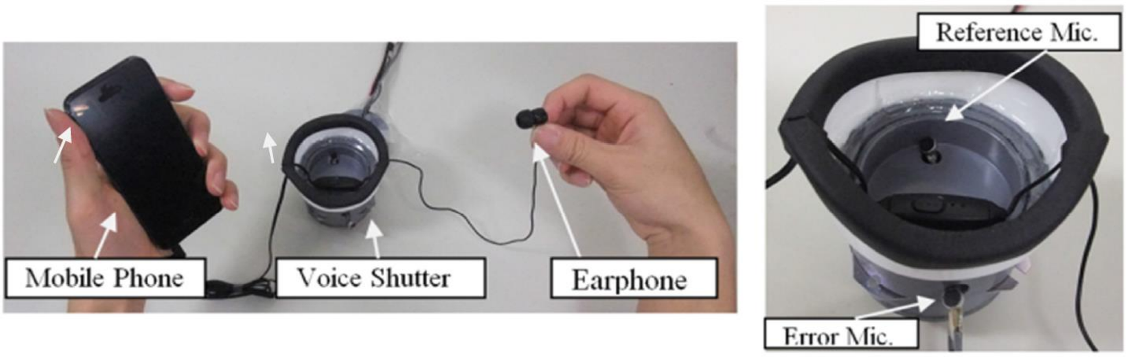
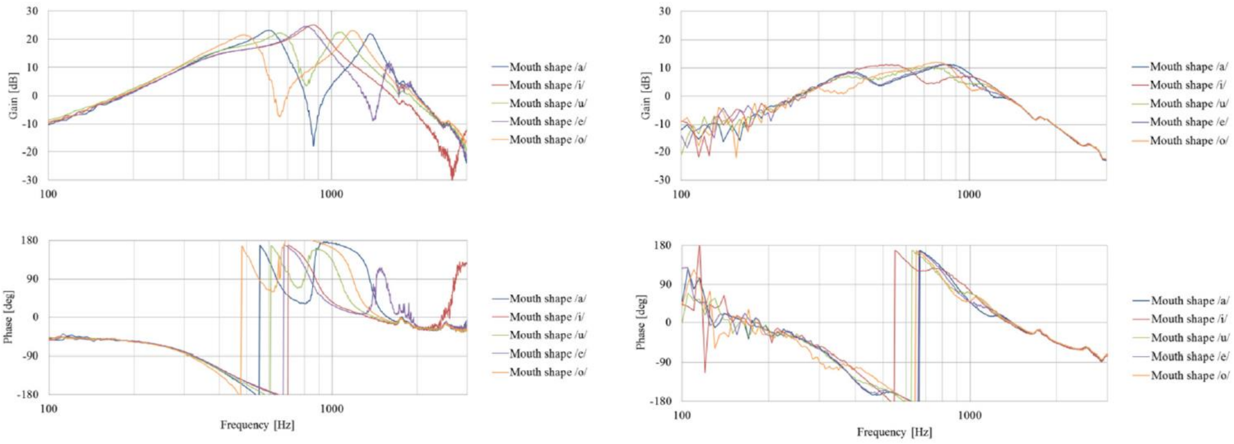


Figure 4– Photo of the prototype voice shutter for real voice

3.2 Influence of Mouth Configuration

If the transfer function of the error path varies according to the configuration of a mouth, feed forward control by Filtered–X-LMS algorithm without online system identification of the error path is difficult to be applied. Because the configuration of a mouth varies very rapidly, we tried to insulate its influence by using partition plates with a vent hole. The effect of those plates was examined by the following experiment. The transfer function of the error path was measured by radiating white noise from the control speaker in the condition of mouth shape /a,/i,/u,/e,/o/, when we put on the voice shutter. The experiment was conducted in two cases, with and without partition plates.

Figure 5(a) and (b) shows measured transfer functions in the cases with and without partition plates respectively. It is found that the transfer functions are quite different from each other in the case without the partition plates. However, the partition plates well reduce the differences.



(a) Without partition plates (b) With partition plates

Figure 5– Measured transfer functions of the secondary path

3.3 Control System

Control system is shown in Figure 6. Normal Filtered-X-LMS algorithm with the howling canceller was used. The distance between the reference microphone and the control speaker is very short around 20mm. Therefore, very rapid signal processing is needed to satisfy the causality law. We adopted very high sampling frequency, 100kHz, to shorten the delay by the anti-aliasing filter. However, in this case, an adaptive control filter W, an error path filter $\hat{C}$ and a howling canceling filter $\hat{F}$ must have large number of taps, 4000taps. We used FPGA (Field Programmable Gate Array) for this signal processing which can calculate in parallel like an analog circuit (6).

Even if using this high speed signal processor, an adaptive control was worried to be difficult. Therefore, after converging the adaptive control filter by using white noise generated by a speaker, we fixed the filter and performed the speaker voice experiments.

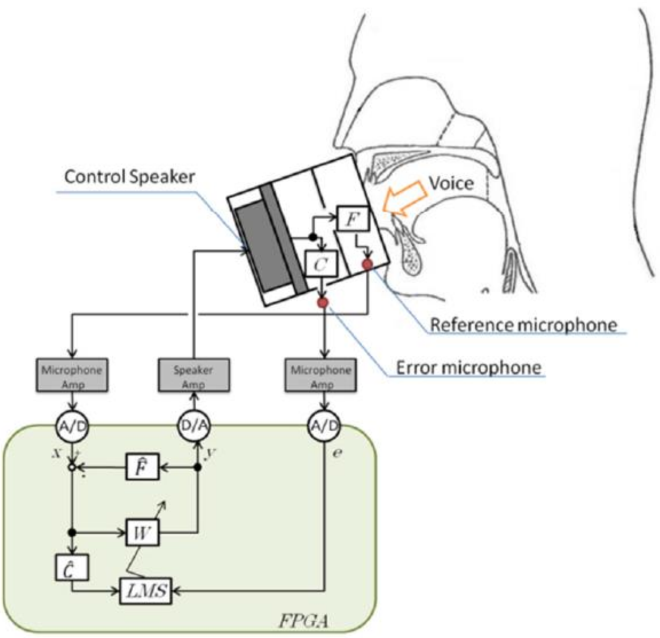


Figure 6– Control system

4. ANC EXPERIMENTS FOR SPEAKER VOICES

4.1 Experimental Procedure

Figure 7 shows the experimental set up for speaker voices. Recorded sounds were radiated from a primary speaker and attenuated by the voice shutter. The voice shutter was stuck fast to the primary speaker during experiments. Noise reduction was evaluated at the control point and a monitor point 0.5m apart from the voice shutter.

Three kinds of sound were examined as the recorded sounds. The first is white noise. The second is male slow voice speaking vowel sounds, /a/i/u/e/o/. The third is female voice speaking a Japanese sentence /sou ookuno hitonomeni fureru sassi dewa naiga/ from the voice data base SRV-DB. This sentence has a frictional sound /s/ and an explosive sound /k/.

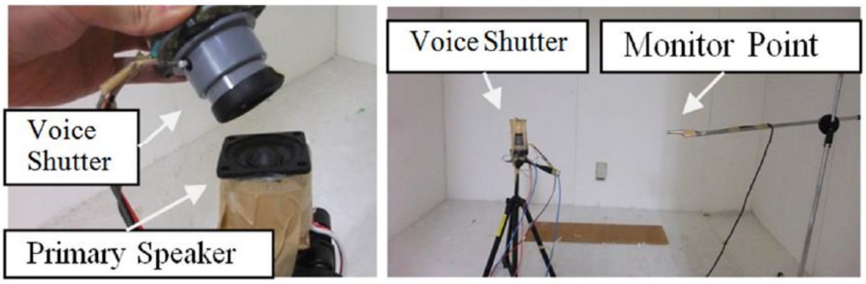


Figure 7– Experimental set up for speaker voices

4.2 Experimental Results for White Noise

Figure 8(a) and (b) show the sound spectra measured at the control point and the monitor point respectively; in the case that white noise is radiated from the primary speaker. Red lines, green lines and blue lines stand for the case without the voice shutter, with the voice shutter (ANC off) and with the voice shutter (ANC on) respectively. Passive effect of the voice shutter can be seen only in higher frequency region above 800Hz at the monitor point. ANC can effectively reduce sound spectrum amplified by the resonance inside the voice shutter as shown in Figure 8(a). ANC also reduces the sound spectrum at the monitor point. The blue sound spectrum in Figure 8(b) is buried with the back ground noise.

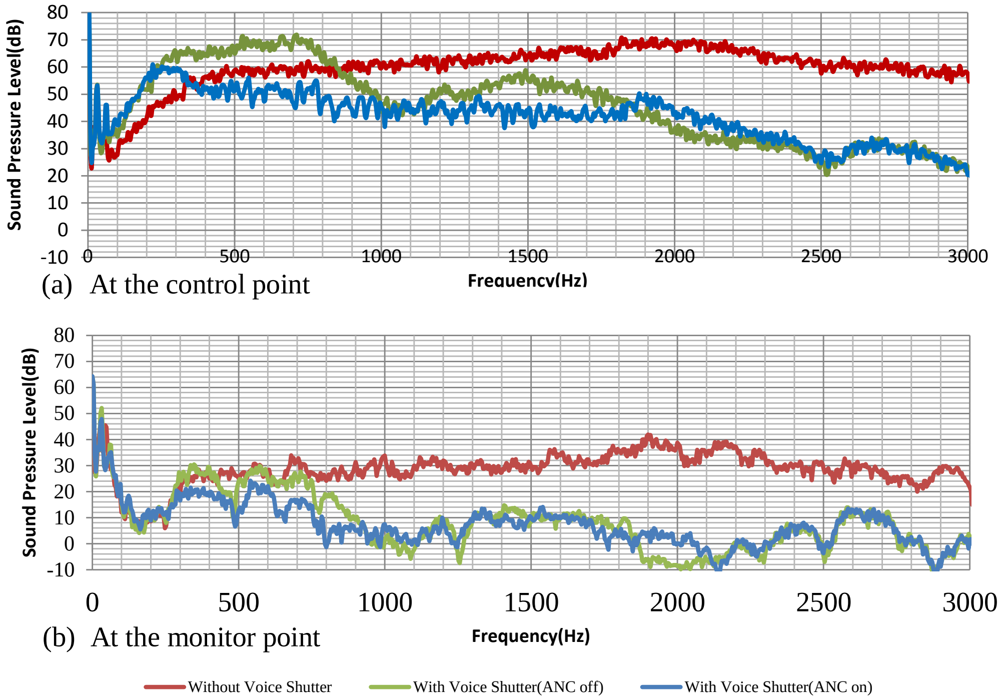


Figure 8–Noise reducing performance of the voice shutter for white noise

4.3 Experimental Results for Recorded Voices

The ANC effects for recorded voices are shown in Figure 9 and 10, with sound pressure wave forms and sound spectrograms measured at the control point. Figure 9 shows the results for male voice, speaking /a/i/u/e/o/. The voice shutter without ANC can make the voice a little mumbling, but we can distinguish the words. However, ANC can reduce the voice remarkably. We cannot distinguish the words any more.

Figure 10 shows the results for female voice, speaking /sou ookuno hitonomeni fureru sassi dewa naiga/. In this case, the voice shutter with ANC can also reduce the voice remarkably, but we can barely distinguish the sentence.

The telephone voice transmitted to a receiver while ANC operates is listened as nearly same as that without ANC. The sentence can be distinguished.

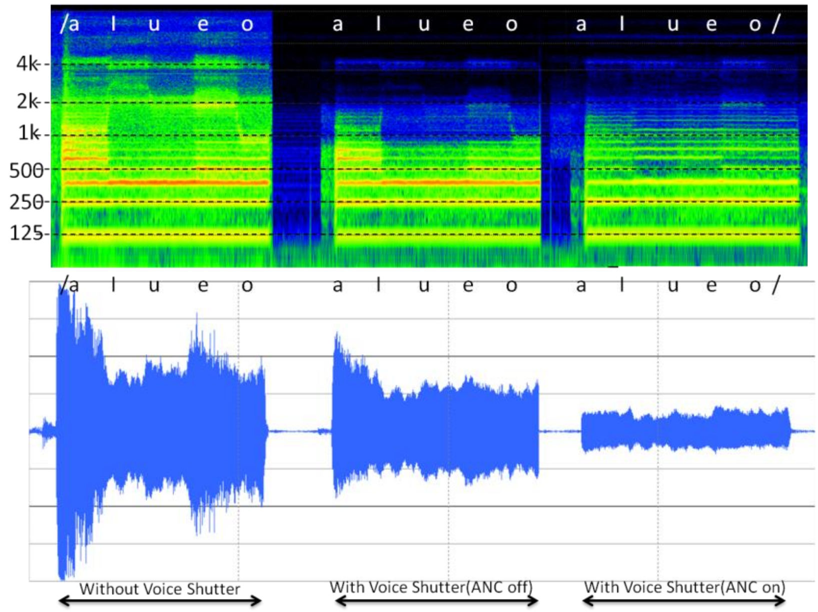


Figure 9–Noise reducing performance of the voice shutter for recorded male voice at the control point (/a/i/u/e/o/)

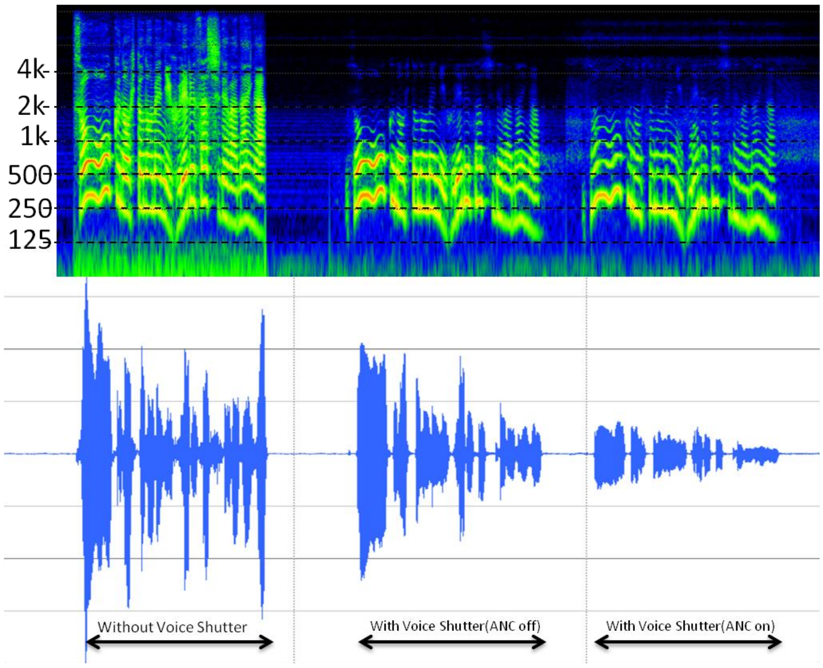


Figure 10–Noise reducing performance of the voice shutter for recorded female voice at the control point (sentence /sou ookuno hitonomeni fureru sassi dewa naiga/)

5. ANC EXPERIMENTS FOR REAL VOICES

5.1 Experimental Procedure

Noise reducing performance of the voice shutter was examined for real human voice. A person wears the voice shutter as shown in Figure 11 and speaks three types of voice. The first is long continuous voice /a/, the second is slow voices /a/i/u/e/o/ and the third is a Japanese sentence /sou ookuno hitonomeni fureru sassi dewa naiga/. In this case, the control filter W was adaptively converged during the experiments. It was difficult to speak in constant loudness. We adjusted the loudness carefully by watching an oscilloscope.

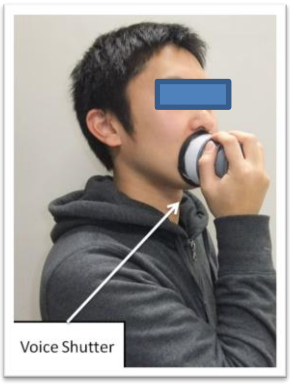


Figure 11–Photo of a person using the voice shutter

5.2 Experimental Results

Figure 12 shows sound pressure spectra, sound spectrogram and sound pressure wave form measured at the control point for the long continuous voice /a/. ANC can attenuate the voice remarkably especially in the frequency region above 400Hz and it becomes almost inaudible.

Figure 13 and 14 shows sound spectrograms and sound pressure wave forms measured at the control point for the slow voices /a/i/u/e/o/ and the sentence /sou ookuno hitonomeni fureru sassi dewa naiga/ respectively. ANC can attenuate the slow voice not to be distinguished. However, ANC cannot attenuate the sentence so much. It is supposed to be because the controller cannot follow the rapid voice change.

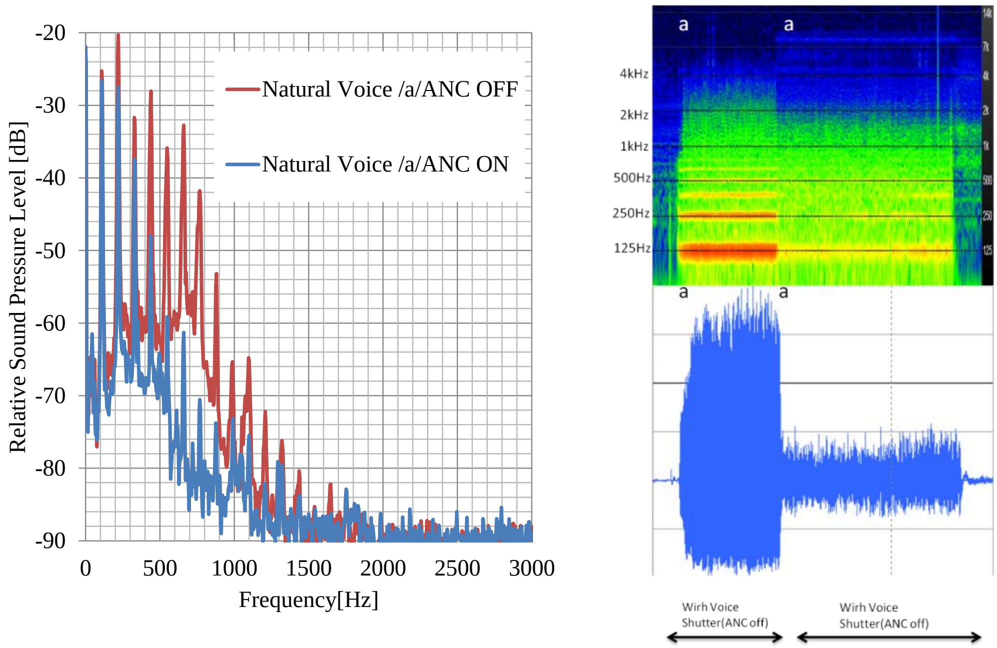


Figure 12–Noise reducing performance of the voice shutter for real voice at the control point (long continuous /a/)

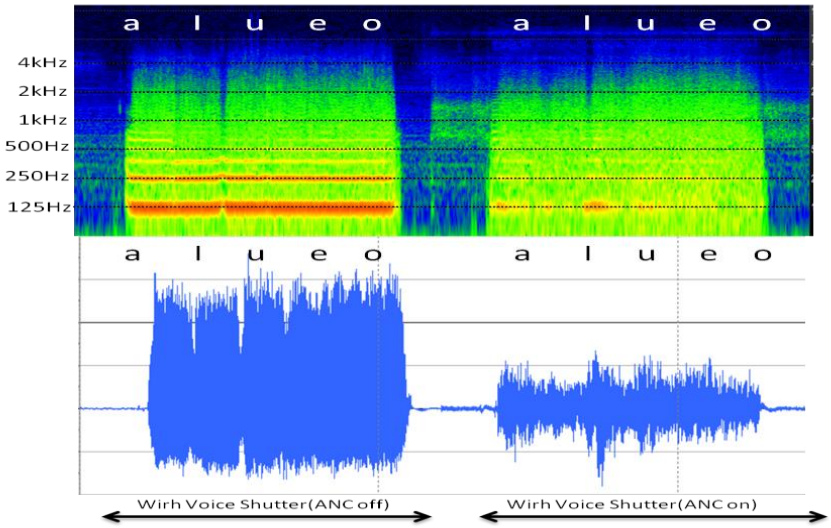


Figure 13–Noise reducing performance of the voice shutter for real voice at the control point (/a/i/u/e/o/)

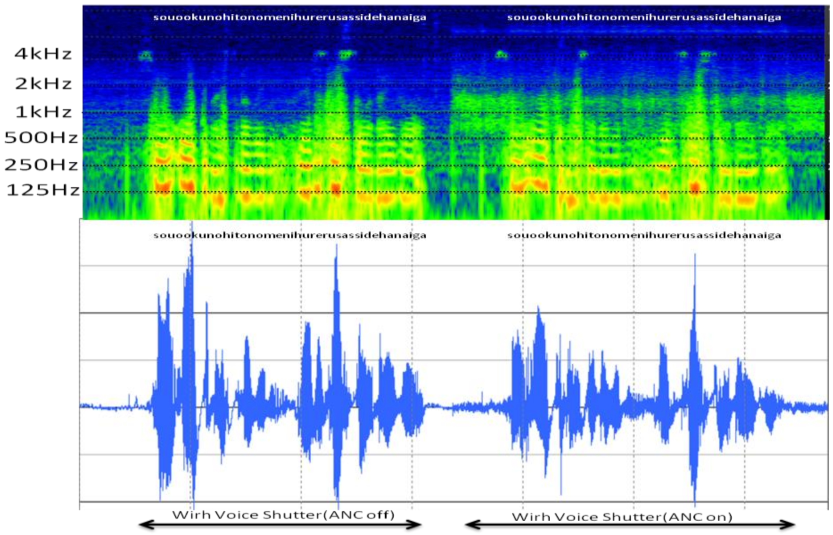


Figure 14–Noise reducing performance of the voice shutter for real voice at the control point (sentence /sou ookuno hitonomeni fureru sassi dewa naiga/)

6. CONCLUSIONS

A voice shutter was proposed and developed to attenuate the leaking voice in the neighborhood when we call a telephone in public spaces. In this paper, a closed type voice shutter with a small vent hole controlled by a feed forward active noise control method was manufactured and tested. Obtained conclusions are as follows.

(1) A small handy voice shutter with a feed forward ANC was realized by using very high sampling frequency (100kHz) and a high speed signal processor with FPGA.

(2) Partition with a vent hole could reduce the influence of the configuration of mouth to the transfer functions of the primary path and the secondary path and made the voice shutter easy to be controlled.

(3) The voice shutter could reduce the leaking voice to be undistinguishable in the case of recorded voice.

(4) It was also effective for real voices. However, it was difficult to adjust the loudness of voices.

Based on the above results, a small and handy voice shutter with a feed forward control was proved to be feasible. However, such future works will be necessary as auto level control according to voice loudness, use of masking noise and so on.

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