

ACTIVE NOISE CONTROL IN ENCLOSURE WITH VIRTUAL MICROPHONE

Stéphane Renault, Franck Rymeyko, Alain Berry

GAUS, Université de Sherbrooke, J1H 2R1, Quebec, e-mail: Stephane.Renault@gaus.gme.usherb.ca

INTRODUCTION

This study concerns local active noise control (ANC) in confined spaces [Ne92]. In cases where an active zone of quiet is intended in an enclosure, it is not always practical to place error microphones in this zone. Error microphones placed on the enclosure walls would sometimes be a more convenient solution. This article discusses the concept of a "virtual" microphone, which consists to generate a quiet zone distant from the error microphone used during control. Two virtual microphone algorithms are presented and experimentally tested. Such a virtual microphone technique has been implemented in the past for essentially fixed primary sources with respect to the enclosure (e.g. active control of propeller-induced aircraft cabin noise). The virtual microphone technique is especially examined here in the context of a moving primary source with respect to the enclosure (such as road traffic noise).

VIRTUAL MICROPHONE CONCEPT

The principle is shown on figure 1. Because of the extreme difficulty to achieve global active noise control in enclosures, most successful applications of active noise control are based on a local approach. Indeed, in many cases (in automobile interiors for example), there is no need to reduce noise at all locations, but only around the passengers' head. Such systems use one or several microphones (called error microphones) located in the area where the noise must be reduced. The control algorithm minimizes the signals given by the error microphones to produce a "quiet zone" in the neighborhood of the microphones. The size of the quiet zone around one microphone is closely related to the frequency of the disturbance (it is approximately proportional to the wavelength).

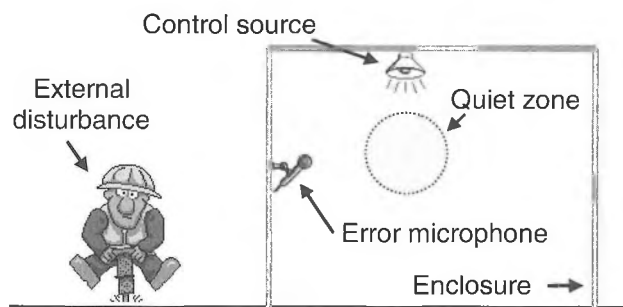


Figure 1 : The principle of virtual microphone

The dimension of the quiet zone can be from a few centimeters to approximately one meter for very low frequencies. However, in many cases, it is not practical to place microphones in the area where the noise must be controlled. Additionally, if the error microphones are located outside of the desired zone, the reduction should be acceptable for low frequency, because the quiet zone is rather large, but not for higher frequencies.

Several algorithms, called "virtual microphone arrangement (VMA)" [Ga97] or "remote microphone technique (RMT)" [Ro99], have been proposed to locate the error microphone outside of the

intended zone of quiet. In both algorithms a preliminary identification step is required, with an extra microphone (the "virtual" microphone) located inside the zone of quiet. During this step, the RMT algorithm estimates three transfer functions : - first, between the control source and the virtual microphone (inside the zone of quiet), - second, between the control source and the error microphone (outside the zone of quiet), - and third, the difference between the disturbance signal at the error microphone and the disturbance signal at the virtual microphone. Consequently, if the frequency or the location of the disturbance source vary, this third transfer function may vary and the control performance is degraded. The RMT algorithm is thus based on the assumption that the disturbance source is stationary in space and time, or more strictly that the disturbance signals at the two microphone locations do not change in time. The VMA algorithm is a simplified version that additionally assumes that the disturbance signals at the two microphone locations are identical.

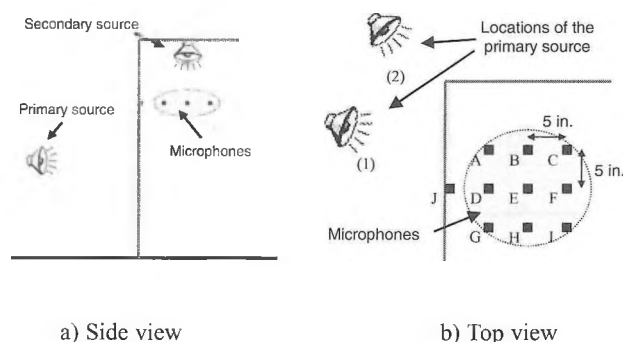


Figure 2 : Experimental setup

EXPERIMENTAL SETUP

The two virtual microphone algorithms (VMA and RMT) and the classical feedforward control approach (filtered-X LMS) have been experimentally compared. The primary source is a loudspeaker placed about 1 meter outside of the enclosure (figures 2a and 2b), that produced a white noise in the 50-300 Hz range. For the RMT algorithm, two different locations of the source (indexed (1) and (2) in figure 2b) were tested. The grey area on the figures depicts the intended quiet zone. Nine monitoring microphones (indexed A to I in figure 2b) were placed in this area to measure the sound attenuation obtained. For the RMT and VMA algorithms, the central microphone (E) is used during the identification stage as the virtual microphone. The error microphone used by the controllers is placed on the wall (J). The control source, also called secondary source, is fixed to the ceiling of the enclosure, and is about 50 cm from the microphones. The reference signal, which is necessary for these algorithms, is directly obtained from the white noise generator connected to the primary source.

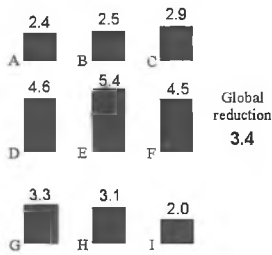


Figure 3 : LMS algorithm with the error microphone inside the control area (E) *

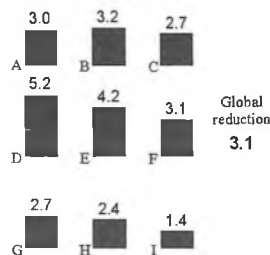


Figure 4 : LMS algorithm with the error microphone on the wall (J) *

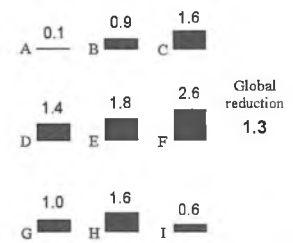


Figure 5 : VMA algorithm *

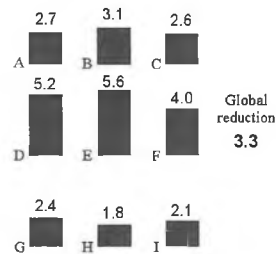


Figure 6 : RMT algorithm *

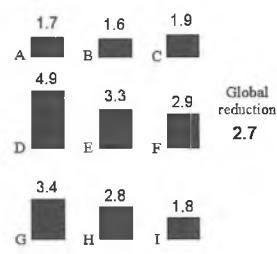


Figure 7 : RMT algorithm after displacement of the disturbance source *

* Each value corresponds to the noise reduction at each microphone in the quiet zone. The number on the top of each column is the value of the sound reduction in decibels. To the right of each figure is given the mean value of the reduction for the nine monitoring microphones.

RESULTS

A classical feedforward approach (filtered-X LMS) was first tested, with the error microphone (E) in the center of the desired quiet zone (figure 3). The classical filtered-X LMS corresponds to the case where the virtual microphone and error microphone are collocated. This first test experiment thus gives the achievable reduction if the error microphone is placed inside the quiet zone. The classical filtered-X LMS is then tested, but with the error microphone placed on the wall (J) (figure 4). The quiet zone is obviously shifted to the left, near the error microphone. Since the acoustic wavelength remains fairly large compared to the distance between microphones E and J (25cm), the average sound attenuation at the 9 monitoring microphones is almost the same. The VMA algorithm was then tested (figure 5), with microphone E as the virtual microphone in the identification step, and microphone J as error microphone during control. The reduction obtained with this algorithm (1.3 dB) is considerably less than the reduction obtained with the filtered-X LMS (3.4 and 3.1 dB). This is due to the fact that the primary disturbance at the physical (J) and at the virtual (E) microphone locations are not identical in this particular case. Finally, the RMT algorithm was tested, with microphone E as the virtual microphone in the identification step, and microphone J as error microphone during control. As expected, the reduction obtained with the RMT algorithm (3.3 dB) is close to the optimal reduction (3.4 dB). If this experiment is repeated after moving the primary disturbance source between the identification step and the control step (figure 7), a significant control degradation is observed (2.7 dB instead of 3.3 dB), as a result of the transfer function variation between the primary sources and the virtual and error micro-

phones.

CONCLUSION

For low frequency sound in enclosures, it is possible to obtain a large quiet zone, with only one error microphone using a classical filtered-X LMS algorithm. It implies that if the error microphone cannot be placed inside the desired quiet zone, acceptable - if not optimal sound reduction can be obtained with the filtered-X LMS. However, a virtual microphone technique can provide a significant improvement of the control in this case. The VMA algorithm (that assumes no variation of the primary sound between virtual and error microphones), and the more general RMT algorithm were tested. While the VMA algorithm did not perform well in our case, the results obtained with the RMT algorithm are encouraging. Despite the predictable fact that when the primary disturbance source is not fixed in space, the control performance is degraded, this solution will certainly be interesting in the case of a disturbance source moving in a limited area. Further work is needed to more precisely quantify the effect of the displacement of the disturbance source during the experiment.

REFERENCES

- [Ne92] P.A. Nelson, S.J. Elliott, "Active control of sound", Academic Press, New York, 1992.
- [Ga97] J. Garcia_Bonito, S. J. Elliot, and C. C. Boucher, "Generation of zones of quiet using a virtual microphone arrangement", J. Acoust. Soc. Am., **101** (6), 3498-3516 (1997).
- [Ro99] Alain Roure, Anne Albarrazin, "The remote microphone technique for active noise control", ACTIVE 99, pp1233-1244.