PRELIMINARY INVESTIGATION OF ACTIVE CONTROL OF DIPOLE NOISE SOURCES

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1. INTRODUCTION

Most studies of active noise control (ANC) in open space have concentrated on reducing the primary field generated by a monopole sound source. Although many practical noise sources may be represented by a monopole source at low frequencies, more complex noise sources, such as aircraft propellers, are better represented by multipole sources (e.g. dipole, quadrupole, etc.). Unlike the sound field produced by a monopole source, multipole sound fields are orientation dependent and do not display cylindrical symmetry [1].

This research was divided into two main components: creating a sound source with dipole directivity; and investigating the effectiveness of a multi-channel control system on the dipole source.

During the experiments, the primary source was located on the central axis of the control system, and the control sources and error microphones were placed in parallel arrays, as shown in Fig. 1. The distances between adjacent control sources and error microphones were kept equal, such that $r_{ss}=r_{ee}$ for all test cases. Using the local control method, the quiet zone achieved by the control system in the area surrounding the error microphones was studied.

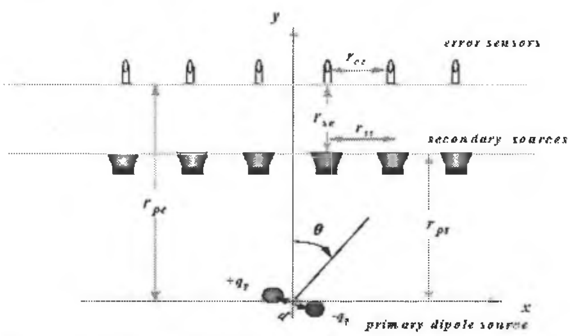

Fig. 1. Multi-channel ANC system for a dipole noise source.

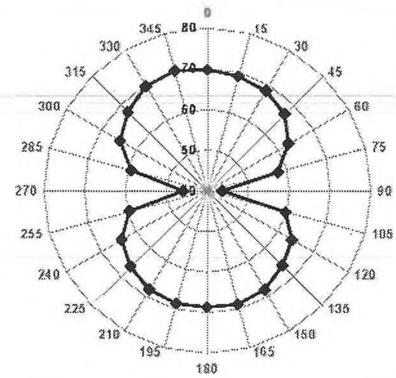

Fig. 2. Directivity at 200 Hz of a speaker placed at the center of an enclosure.

2. CREATION OF A DIPOLE SOURCE

The first sound source that was used was an enclosed loudspeaker with its back cover removed. The directivity pattern had the general shape of a dipole, but was asymmetrical. The radiation from the front of the speaker was about 5 dB stronger than to the back, and the radiation to the sides of the speaker was only 8 to 10 dB lower than to the front and back. In order to improve the symmetry of the radiation pattern, a four-sided enclosure was built that allowed the speaker position to be adjusted. Pushing the speaker back into the box compensates for the stronger directivity to the front, and improves the nulls to the sides of the source. The directivity of the source at 200 Hz is shown in Fig. 2. The pattern is now symmetric, with a drop of about 25 dB to the sides. This sound source is thus a good approximation of a dipole at low frequencies.

3. ANC EXPERIMENTS

ANC experiments were performed in an anechoic chamber at the University of British Columbia. The dimensions of the chamber are 4.7x4.2x2.2 m^3. The primary source was located 0.5 m from the back wall of the chamber at a height of 1.25 m. The control speaker array consisted of three enclosed loudspeaker (monopoles), spaced at equal distances from each other. The error-sensor array of three equally-spaced microphones was placed in front of the control speakers. The distances between the control speaker array and primary source, and between the control source and error microphone array, were kept constant at 1.0 m. The commercially available multi-channel EZ-ANC was used as the ANC controller. The test signal was a pure tone of 200 Hz, which is above the cut-off frequency of the anechoic chamber. The primary source was driven by a signal generator, which also provided a reference signal to the controller. The noise measurements were carried out in a plane at the height of the control system at 0.5 m intervals, yielding 45 measurements.

The noise attenuation was measured for three orientations of the dipole: θ=0, 45, and 90°. As shown in Fig. 1, θ=0° corresponds to when the lobes of the dipole are aligned along the x-axis, such that the null of the dipole is directed towards the control system. The separations of adjacent control channels were determined from simulations, as discussed in [2].

Fig. 3 shows the attenuation for the dipole oriented at 0°. The quiet zone created by the control system is very small, though the sound increase in other areas is also very small. The attenuation achieved in most areas was only about 5 dB.

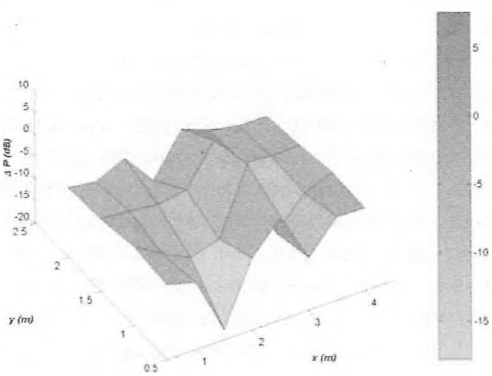

Fig. 3. Measured noise attenuation of a 3-channel control system for a dipole source oriented at 0° (null pointing towards the control system) with r_{ss} = 0.67m (0.4λ).

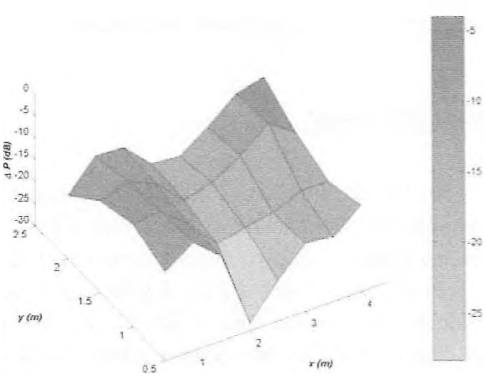

Fig. 4. Measured noise attenuation of a 3-channel control system for a dipole source oriented at 45° with r_{ss} = 1.07m (0.64λ).

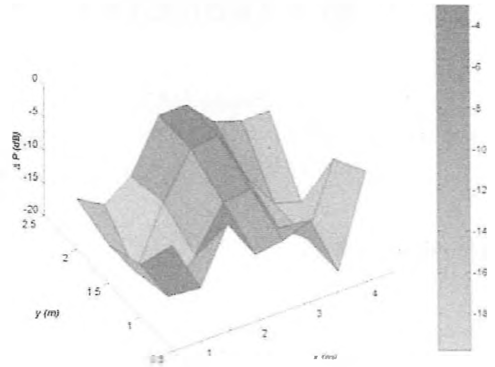

Fig. 5. Measured noise attenuation of a 3-channel control system for a dipole source oriented at 90° with r_{ss} = 1.25m (0.75λ).

The size of the quiet zone increases when the dipole orientation is changed to 45°, as shown in Fig. 4. Attenuation was achieved at all of the measurement positions.

The maximum noise attenuation and largest quiet zone were measured when the dipole was oriented at 90°, as shown in Fig. 5. Attenuation was again achieved at all measurement positions, and the quiet zone is symmetrical.

4. CONCLUSIONS

This preliminary investigation of the effectiveness of a control system on a directional dipole noise source demonstrates that a primary source with non-cylindrical radiation directivity does affect the performance of the control system. The control system works more effectively when it is used to create quiet zones in the area with the strongest primary-radiation directivity. It has also been shown that the quiet zone shifts slightly in the direction with the strongest radiation directivity.

REFERENCES

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