inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 5.2

ACTIVE REDUCTION OF AIRPORT NOISE

C. Hobbs, K. Karantonis, B. Sharp

Wyle Laboratories, 2001 Jefferson Davis Hwy Ste 701, 22202, Arlington, VA, United States Of America

Tel.: 703 415 4550 #39 / Fax: 703 415 4556 / Email: chobbs@arl.wylelabs.com

Keywords:
ACTIVE NOISE, NOISE REDUCTION, DEPARTURES, ENGINE RUN UPS

ABSTRACT
Noise from aircraft run-ups and departure operations at airports can be a continuing source of annoyance to residents living near the airport. Barriers and sound insulation modifications to houses can reduce the impact of the noise; however, the noise to the rear of a jet aircraft is predominantly low frequency, which is not well attenuated by these passive methods. Recent advancements in active noise reduction offer an alternative solution for reducing low-frequency aircraft noise by using loudspeakers to create localized areas of quiet. In this paper the authors will present results from a model which predicts the size of the noise reduction area as a function of the system parameters and configuration. These predictions are then compared with data measured during the application of an active noise reduction system outside a commercial airport.

1 - INTRODUCTION

Within an airport boundary, the noise from jet operations is spread over a wide range of frequencies. Outside the boundary, in the nearby community, the noise from aircraft run-ups and departures is typically dominated by energy below 200 Hz. This is due, in part, to ground and atmospheric absorption of higher frequency noise components. Thus, the community hears only the low-frequency noise from these types of operations, and this noise is amenable to mitigation using active noise reduction (ANR).
A simple ANR system consists of a reference microphone, some loud speakers, an electronic controller, and an error microphone. The reference microphone monitors the offending noise and passes it on to an electronic controller, that in turn generates an out-of-phase signal that is radiated by the loudspeaker. The error microphone is placed where noise reduction is required and provides feedback to the controller so the controller can use the loudspeaker to minimize the sound level at the error microphone's location. The sound power to be generated by the loudspeaker depends on the distance of the aircraft from the site where noise reduction is required − the smaller this distance, the higher the power required, and the larger the speaker assembly. Placing the loudspeakers close to the aircraft will produce a more 'global' noise reduction, but at the cost of much higher power requirements. In many cases where the noise affects a portion of the nearby community, global noise reduction is not required. There are significant trade-offs to be made between the area of reduction, the power of the noise source, and the distance between the source and the community. This paper evaluates just one possible configuration, namely, with the control source located off the airport property and adjacent to the community.
One of the most straightforward applications of active noise reduction is that of canceling a stationary noise source. Before setting up an ANR system, one needs to start with the optimal configuration of the system components for the given disturbance. In order to find this a model was created. A brief description of how the model works and the way in which it was tested follows.

2 - MODEL

Active reduction of sound using feed-forward control is performed in this model. The interaction of the actuators (loud speakers in this case), which are determined by the system configuration, plays an important role in the performance. The most important variable of the system's configuration is the location of the error sensors (microphones in this case). Noise reduction is measured as the difference in noise level with and without the ANR system operating. The performance of the ANR system is largely dependent on the distance between error sensors and actuators and the distance between the error sensors themselves. [1] There are limits to the distance between the reference sensor (here a microphone) and error sensors due to the amount of memory in the controller. The arrangement used for validation this model is shown if Fig. 1.

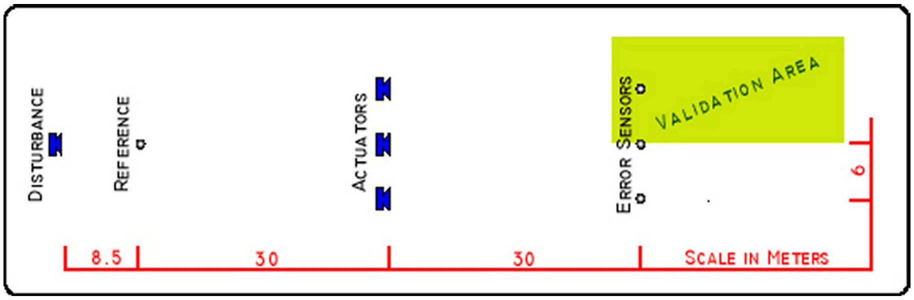

Figure 1: Components of an ANR system; distances shown are in meters.

In the model, the user inputs the atmospheric conditions, ground impedance, and system geometry. The model predicts the sound the disturbance will make at the error microphones. Knowing the characteristics of the loud speakers, the model can predict the noise from the speakers at the error microphones; thus the solution is found by determining what noise from the loud speakers will reduce the disturbance noise at the error microphones. With that solution, the model can predict the sound levels over any area for which it is programmed. Plotting the difference of the predicted sound levels with only the disturbance operating and the predicted sound levels with both the disturbance and ANR system operating will show the area of reduction. By changing the location of the ANR system's components, the user can find which configuration creates the largest area of noise reduction.

3 - VALIDATION

In order to validate the model, a set of low frequency speakers was used to generate broadband noise from $30 - 130$ Hz. This frequency range is where commercial jets emit their highest sound levels during takeoff when measured behind and to the side of the aircraft. The prime concern in validating the model was whether the model correctly predicts the border location of the quiet zone. The quiet zone here is defined as the area which experiences any noise level reduction. Figure 1 shows the set up used to validate the model.

Figure 2 shows spectra taken from recordings from a roving microphone that was used to measure the noise levels before and after operating the ANR system. This microphone was moved on a grid so that the measured levels could be used to generate contours. Its signal was pass-band filtered from 30 Hz to 130 Hz. The spectra in Fig. 2 were from recordings made at a point 3 m behind the center error microphone on the edge of the validation area shown in Fig. 1. At each point on the grid a recording was made with and without the ANR system operating to cancel noise from the disturbance.

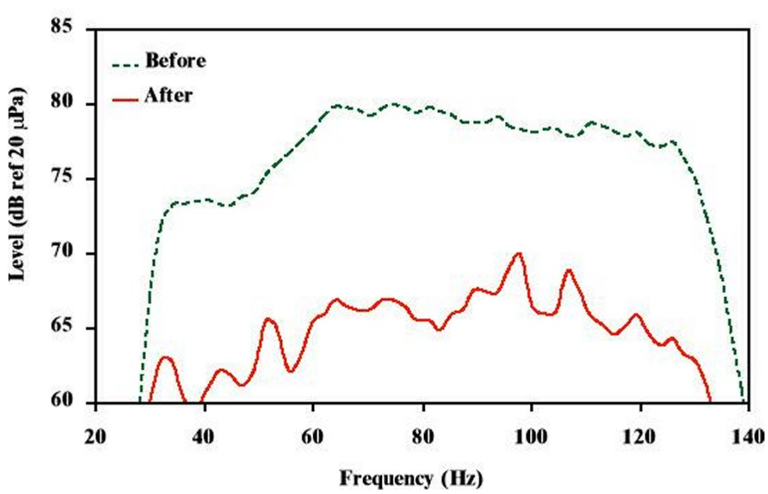

Figure 2: Spectra used in the validation of the ANR model.

For the 3 ×3 system (3 error microphones and 3 cancellation speakers) shown in Fig. 1, the ANR system performance can be seen in the contours of Fig. 3. The model using the configuration shown in Fig. 1 generated these contours. The area for which output was desired is shown by the rectangle in Fig. 1. The roving microphones (there were actually 3) were moved every 3 m. The rectangle is approximately 30 m by 15 m. Due to symmetry, the contours in Fig. 3 were made only for an area beginning at the ANR system's centerline. The noise reduction on the other side of the system's centerline is a mirror image.

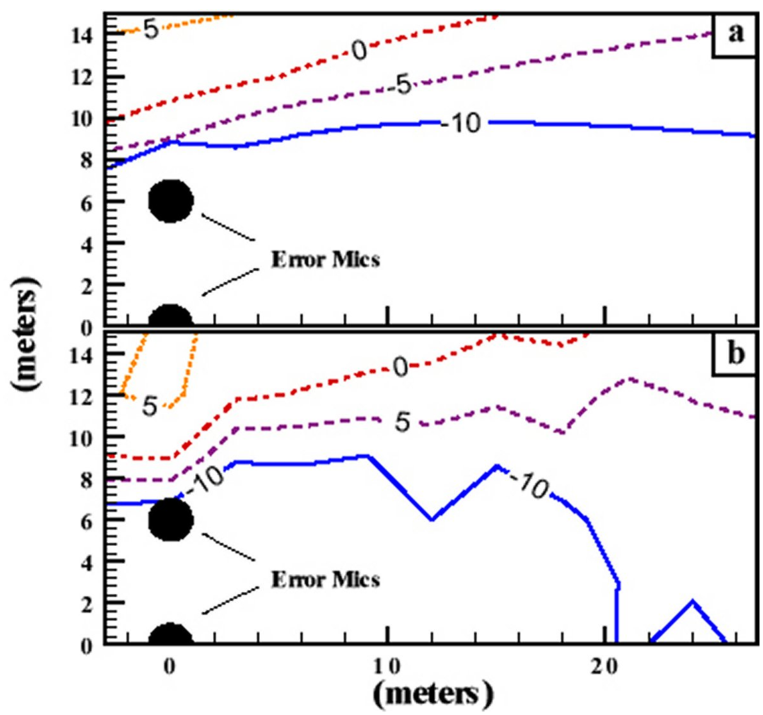

Figure 3: (a) Model and (b) data contours for a 3 ×3 ANR system.

The shallowness of the − 10 dB contour from the data compared to the model prediction may be explained by a lack of power from the disturbance at positions farther from the error microphones. If the disturbance did not exceed the background noise by 10 dB, then the amount of reduction achievable would be limited to less than 10 dB.

It is important to note that the width of the quiet zone changes with frequency [2]. This agrees with theory because the spacing of the control speakers becomes greater relative to the wavelength as frequency increases. Compared with simulation, there is good agreement as to where the 0 dB reduction boundary occurs. Using the model, one can optimize the spacing of speakers for a particular application.

4 - APPLICATIONS

Figure 4 shows the spectra of a jet engine before and after ANR. The engine was on a portable test stand 90 m from the ANR system. The rest of the configuration was identical to that shown in Fig. 1. Like the spectra in Fig. 2, the signals used for the spectra in Fig. 4 were pass-band filtered from 30 Hz to 130 Hz. The signals for Fig. 4 were measured in the vicinity of the center error microphone.

Clearly, with both speakers and jet engines the ANR system achieved similar magnitudes of reduction. Figure 5 shows the output of the model for the configuration of the jet engine on the test stand.

As can be seen from Fig. 5, an ANR system can reduce the noise levels from an engine run up by 10 dB. It is important to note that the configuration used for this test could be changed and the system expanded in order to reduce the low-frequency noise coming from the engine for the entire area around it; this, in effect, would be global reduction.

Lastly, the application of an ANR system to the noise created from departing jet aircraft. The rumble created behind (and to the side) of a departing jet is a well-known phenomenon. Figure 6 is an aerial photograph of the space behind runway 28R at Baltimore Washington International Airport. The inset shows where an ANR system was placed in order to measure its effectiveness for reducing the noise behind departing aircraft.

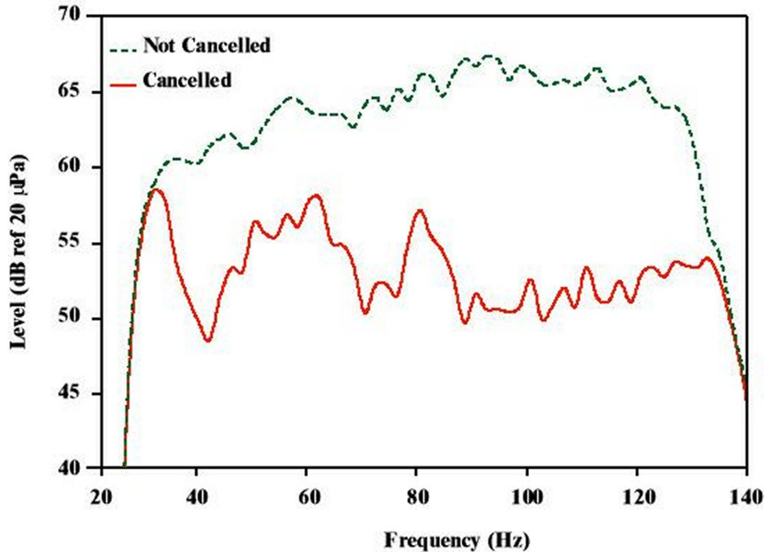

Figure 4: ANR applied to the noise from a jet engine on a test stand.

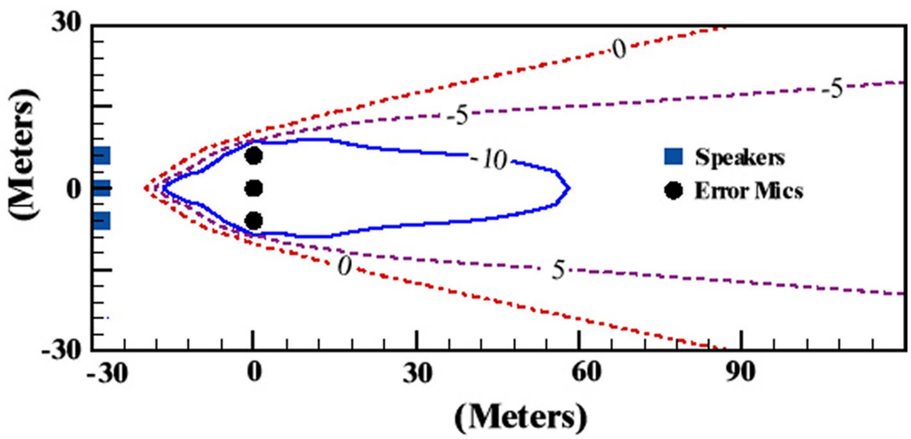

Figure 5: Model output at 100 Hz for the jet engine at coordinates (-300,0).

Because of the proximity of the reference microphone to the speakers, another microphone was placed outside the influence of the ANR system so that its signal could be used for comparison with a microphone in the area of noise reduction. Figure 7 shows the spectra from a departing jet as measured at G1 and G3.

Finally, in Fig. 7 one can see the spectra measured at microphones G1 and G3. The difference in overall levels is 7 dB (from $30 - 130$ Hz). The spectrum measured at G3 is denoted 'not canceled'.

5 - CONCLUSIONS

It has been shown that ANR can provide local areas of noise reduction by as much as 10 dB around run-ups and to the rear of departing aircraft. Active noise reduction is most efficient for a frequency range of $30 - 130$ Hz. As passive methods of noise reduction are generally less effective for lower frequencies, the two methods of noise reduction, active and passive, are complementary.

REFERENCES

1. **J. Guo and Jie Pan**, Actively created quiet zones for broadband noise using multiple control sources and error microphones, *JASA*, Vol. 105, pp. 2294-2303, 1999

2. **J. Guo and Jie Pan**, Actively created quiet zones by multiple control sources in free space, *JASA*, Vol. 101, pp. 1492-1501, 1997

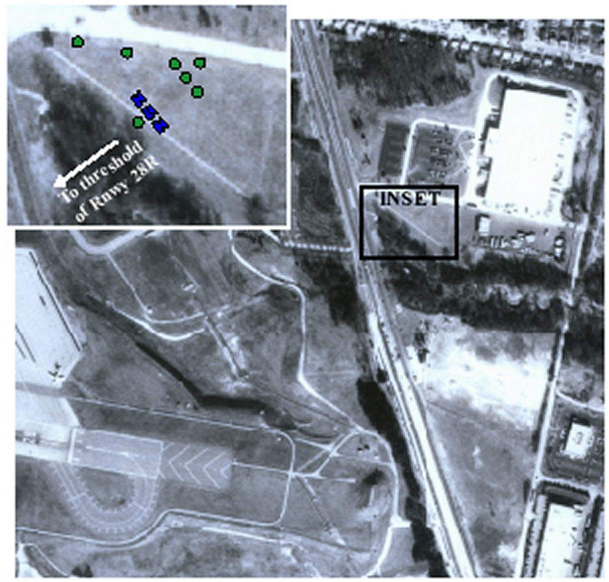

Figure 6: Aerial photograph of runway 28R at BWI; the inset denotes the ANR configuration used to reduce noise created from aircraft departures.

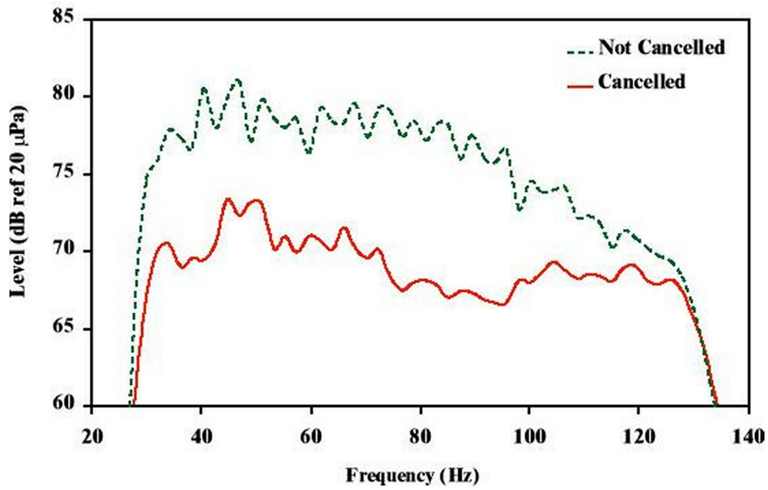

Figure 7: Effects of an ANR system on the noise behind a departing aircraft.