EXTERIOR ACOUSTIC ARRAY MEASUREMENTS ON THE BOMBARDIER GLOBAL EXPRESS

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1. INTRODUCTION

Because of the increase of aircraft traffic and population around airports, governments are putting pressure on international ruling agencies to become more stringent on community noise certification limits. Some airports have also taken the liberty of imposing on the airliners landing fees that vary according to the noise emitted by their aircraft. As a result, and in line with its constant efforts to offer its customers aircraft with minimized operating costs, Bombardier has funded research and development projects over the last few years to study and reduce the noise from its aircraft.

The microphone array project exposed in this article served to identify and measure noise coming from individual aircraft components such as landing gears, flaps, slats, engine, etc (see Fig. 1). In collaboration with the Transportation division of Bombardier in Sweden, which had already performed sound source localization on high-speed trains and possessed the necessary hardware, a methodology and in-house software were developed. The first measurements with microphone array at the Aerospace division of Bombardier were done in November 2005 on a Global Express, an ultra-long range business jet.

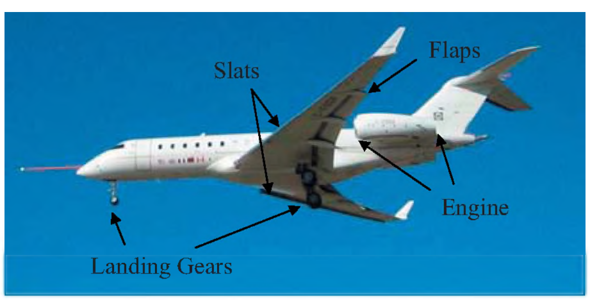

Fig. 1. Major noisy components of a Bombardier Global Express on approach

2. METHOD

The method consists in using a large number of microphones (microphone array) to focus on sound coming from a specific direction. Based on similar work done in the past to localize sound sources on moving vehicles [1], a temporal delay-and-sum beamforming technique was developed at Bombardier to process the phased array data. In this method, the sensor outputs are delayed by appropriate amounts and added together reinforce the signal emanating from a specific region in space. It can be described as an acoustic camera, where the focus can be electronically shifted in space by manipulating the phases of the signals, similarly to how a parabolic antenna is mechanically aimed (see Fig. 2).

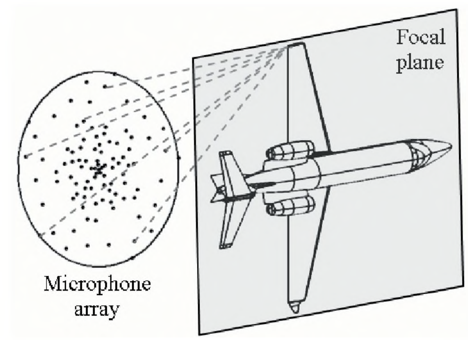

Fig. 2 - Principle of the acoustic camera, ability to focus on a specified region

3. FLIGHT TESTS

A site was selected with very low aircraft traffic and the array was placed on the extended runway centerline (see Fig. 3). The phased microphone array composed of 95 transducers was used to record aircraft noise during a series of flyovers at an altitude of 30 meters. A compromise was found to distribute the microphones semi-randomly in an 8.5-meter diameter circle (see array represented in Fig. 2) to sample the acoustic field with an optimized resolution. The electret microphones were installed on plastic plates nailed to the ground. The space between the edges of the plates and the ground was filled with sand to reduce acoustic scattering. Their membranes were assumed to be located in the reflection plane resulting in a doubling of the sound pressure [2].

Information collected by a Differential-GPS (DGPS) and an Inertial Reference System allowed aircraft tracking with high precision, 5 times per second. Flush-mounted piezoelectric noise generators producing tonal sources were attached below the aircraft wing tips to help for the method calibration. A time-synchronization was done between the flight data recorded onboard and the acoustic data recorded on the ground via an event-tone transmitted over VHF.

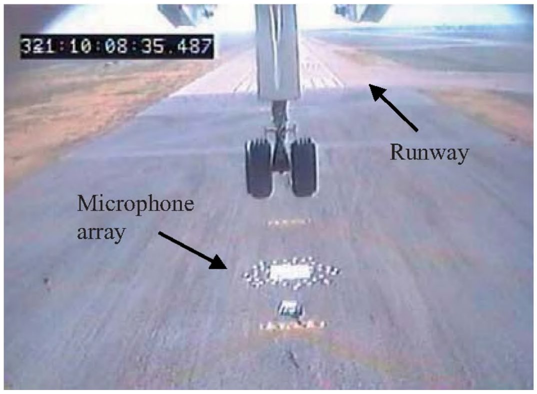

Fig. 3 - Picture from aircraft camera during flight test

4. RESULTS

Fig. 4 shows a typical source localization map of the Global Express in an approach flight condition, with landing gears down and high-lift devices (slats/flaps) deployed. The colors correspond to the sound pressure levels of mid-frequency sources in dB(A), relative to the maximum level in the map. The A-weighting was chosen because the low frequencies are dominating the noise emission seen by the array. The 10 dB scale on the graph means that no source could be detected 10 dB below the maximum level found in that 1/3 octave band. The observation angle is 90° relative to the flight direction, which means that the aircraft was overhead when this acoustic map was computed. All sources are studied under this angle, which means that the nose landing gear is studied at an earlier time in the flyover than the main landing gear.

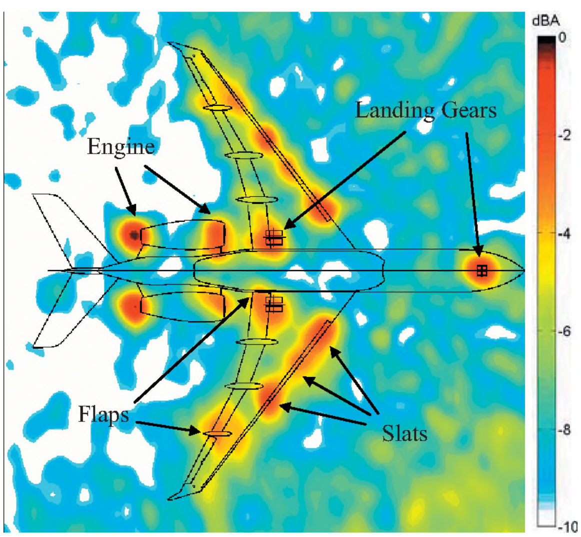

Fig. 4 - Localization of mid-frequency sources on the Global Express during a normal landing configuration; observation angle 90° (overhead); aircraft seen from below

In Fig. 4, the noise of the nose landing gear is clearly visible. Other sources are localized all along the slats and at the engine entrances. The loudest noise sources shown in black are located near the exhaust, near the slat edges and near the landing gears. Noise sources can also be localized at the outboard flap side edges of the wings. The slat edge noise generated at the slat junction with the fuselage can also be seen as a dominant source. This source was already detected as being an important noise contributor in previous wind tunnel measurements with a 7 %-scaled CRJ700 model [3].

5. CONCLUSION

At Bombardier, the phased microphone array has been shown to be a powerful tool for localizing the sound sources on a flying aircraft. The main sources of noise that could be found were due to turbulence and vortices created by the airflow around high-lift devices, landing gears, and flow excited acoustic resonators. The acoustic data collected on the Global Express aircraft in landing configuration revealed important information for future designs of Bombardier aircraft. Thanks to the reference sources, to the low flyover altitude chosen during the tests and to the accurate tracking system, a good definition of noise sources was found. Both detection of the loudest sound sources on the aircraft and evaluation of precision and performance of the method were achieved. An extension of this work would be a quantification of absolute source levels in order to relate microphone array results to the overall aircraft noise.

REFERENCES

[1] A. Nordborg, J. Wedemann and L. Willenbrink, “Optimum Array Configuration”, 29th International Congress Inter-Noise, Nice, France, 27-30 August 2000

[2] J. F. Piet, U. Michel and P. Böhning, “Localization of the Acoustic Sources of the A340 with a Large Phased Microphone Array during Flight Tests”, AIAA 2002-2506, Onera and DLR, 2002

[3] P. Soderman, F. Kafyeke, N. Burnside, R. Chandrasekharan, S. Jaeger, J. Boudreau, “Airframe Noise Study of a CRJ-700 Aircraft Model in the NASA Ames 7- by 10- Foot Wind Tunnnel No. 1”, AIAA-2002-2406, 8th AIAA/CEAS Aeroacoustics Conference and Exhibit, Breckenridge, Colorado, June 17-19, 2002

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