Acoustic Ground Tests in a Cross-Section of a Long-Range Airliner for Validation of the Inverse Finite Element Method

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Introduction

Identification of noise sources in aircraft cabins proves to be difficult particularly at low frequencies. A new approach, based on the Inverse Finite Element Method (IFEM), reconstructs the spatial distribution of sound pressure and particle velocity at the interior wall. If all sound sources are located on the boundary, the equation system resulting from a matching FE model can be resorted in such a way that computation of the unknown boundary impedance is possible, see [1, 2]. This procedure requires measurements in the cavity first.
The paper presents the set up and first results of an acoustic ground test that was performed to prepare a validation of this noise source localization technique.

Experimental set up

In this study, the approach was validated under realistic conditions. Therefore a test bed, the cross section a long-range airliner (see Figure 1), was used. It is located at the Technologiezentrum Hamburg Finkenwerder.

Figure 1: Test bed for acoustic ground tests (cross section of a long-range airliner)

During the measuring campaign the cavity was fully equipped with lining, luggage bins (so called hat racks or overhead storage compartments) and five rows of seats. In Figure 2 you can see this interior and part of the measuring array. The mock up is terminated at the cut faces with sound absorbing foam wedges to attenuate sound propagation in flight direction.

Figure 2: Cavity of mock up with interior and part of measuring array

Correct mapping of the sound field needs sufficient density of measurement points. In FEM models with linear shape functions, there are commonly 6 points per wavelength used for discretization. This means, with an upper frequency limit of 330Hz and a consequential wavelength of round about one meter, a maximal grid distance of 0.173m should be used - we chose 0.170m.
For high accuracy, we used Brüel&Kjaer (B&K) front ends (Type 3560 B and D) and B&K ¼" array microphones (Type 4935 and 4958).
In Figure 3 you can see a cross section of the cavity containing the microphone positions of the custom built array as coloured dots. The different colours represent all in all five sub arrays used one after the other. One X-Y-plane contains 152 points. With 22 array positions along flight direction Z, one mapping consists of 3344 points.

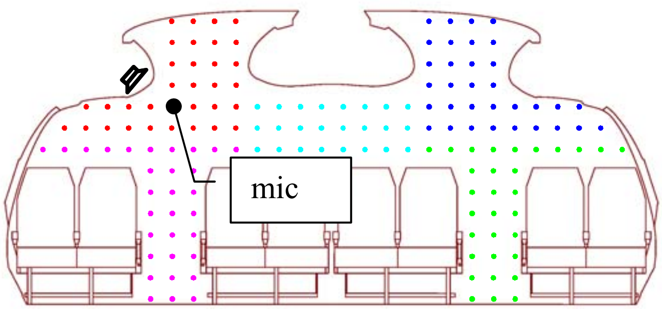

Figure 3: Cross section of cavity with measuring grid, position of internal sound sources and of a microphone close to this sources.

The cavity was excited by both interior and exterior noise sources for broadband disturbances with a total SPL of at least 80dB at microphone "mic" in the near of the internal

sound source. The overall background noise level was measured with less then 50dB.
SPL and frequency response functions were measured up to 800Hz and with a frequency resolution of 1 Hz. The averaging was performed over 100 time records with overlap, leading to duration of about 10 seconds for each measurement.
For post processing and visualization, the data was exported as text file and reorganised with Mathworks MATLAB to get a 4-D matrice (X-position, Y-position, Z-position, value at frequency) for each sound excitation set up. Then 2-D slices were mapped with filled isoplanes (MATLAB function “contourf”) and saved as emf-images or assembled to create an avi movie file.

Noise excited by a volume velocity source

To validate the IFEM computations, a known sound excitation is useful. In a first set up, this was established by using a volume velocity source (VVS, B&K OmniSource Type 4295 with velocity measurement adaptor and extension hose). The VVS was mounted into the hat rack with its orifice at the position of a hat rack opening grip, see Figure 4.

Figure 4: View into hat rack with mounted velocity measurement adaptor and extension hose of a volume velocity source.

In the following, the frequency response functions (FRF) between the mapping microphones and one of the VVS microphones are presented. The computed volume velocity was already used for validation, but not presented at this point. Figure 5 shows the FRF magnitude in 2 dB-steps at 120Hz, measured at a horizontal plane just above the back rests. The vertical position of the VVS orifice, about 0.5 meters above the plane, is marked, too.

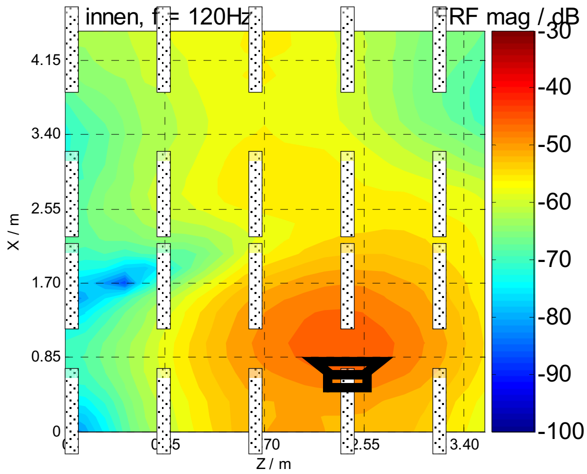

Figure 5: FRF magnitude with VVS, mapped at a horizontal plane above back rests

Noise excited by internal loudspeaker

Another set up with a custom built loudspeaker inside the hat rack was established. For referencing the FRF, a miniature accelerometer (B&K Type 4517) was mounted on the centre of the loudspeaker membrane, see Figure 6.

Figure 6: View into hat rack with custom built loudspeaker as sound sorce.

Figure 7 shows the same plane as Figure 5, with FRF magnitude in dB Pa/(m/s²).

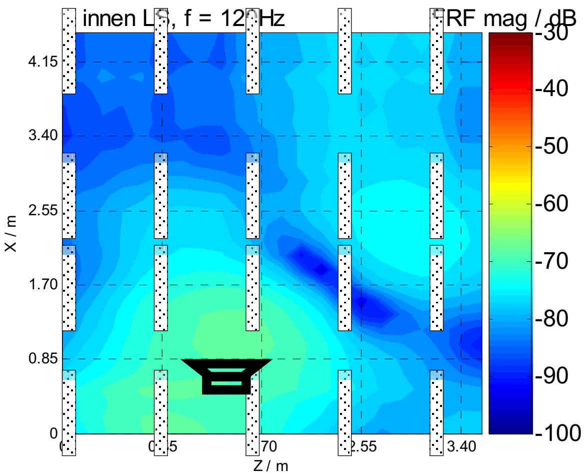

Figure 7: FRF magnitude with internal loudspeaker, mapped at a horizontal plane above back rests

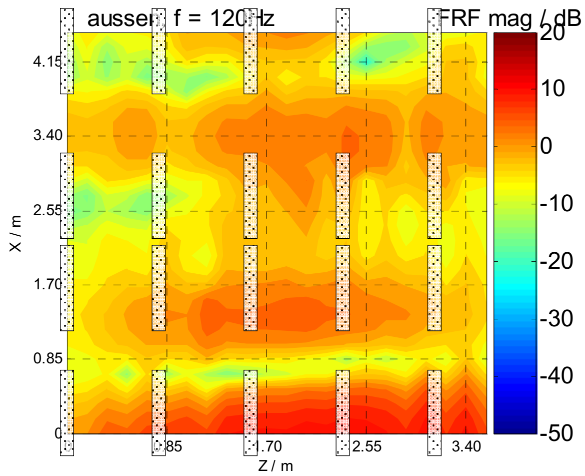

Figure 9: FRF magnitude with outside sound excitation, mapped at a horizontal plane above back rests

Noise excited with external PA loudspeakers

For realistic environmental conditions, PA loudspeakers outside of the cavity were used. These were placed symmetrically on both sides of the mock up in a distance of 6 meters. Figure 8 shows the set up, the position of the reference microphone “Ref” at a window is marked, too.

Figure 8: Set up for sound excitation with PA loudspeakers from the outside of the mock up.

In Figure 9 you can see the FRF magnitude in dB Pa/(m/s²).

Summary and outlook

An export of the data from PULSE LabShop to MATLAB was possible. The quality of the measured data is good and the grid distance proofs to be sufficient. The positions of the inside sound sources can be found in the mappings and both sound fields are quiet similar. With external PA loudspeakers, no obvious sources could be found inside the cavity and with this excitation, the sound field mainly has its peak and nodal lines parallel to flight direction, showing the influence of the absorbing foam wedges.

The next steps in post processing the data contain a closer look at the measured volume velocity and the approach to compute surface impedances. Then, this information will be validated by measurements with a Microflown USP and a B&K Intensity probe, which were used during the campaign, too.

References

[1] M. Weber, T. Kletschkowski, D. Sachau, „Identifikation von Schallquellen mittels inverser FEM mit realen Messdaten“, DAGA’08, Dresden

[2] M. Weber, T. Kletschkowski, D. Sachau, “Noise Source Identification in a Cross-Section of a Long-Range Airliner by Means of the Inverse Finite Element Method”, NAG/DAGA’09, Rotterdam