DLR is Germany’s national research centre for aeronautics and space. Their Experimental Methods department set out to investigate noise transmission and propagation on the Airbus A320 family of aircraft. Brüel & Kjær’s multi-field microphone measured the uncertain sound field inside the aircraft cabin, and between the fuselage and the lining.

**CHALLENGE**
Investigate noise transmission and propagation on the Airbus A320 family of commercial aircraft, while improving the methodology of flight tests

**SOLUTION**
Relating external vibration and pressure to interior noise, using multi-field microphones to measure the uncertain sound field inside the aircraft cabin, and in the small areas between the fuselage and lining

**RESULTS**
- Link established between coherent fluctuations in the turbulent boundary layer and the noise experienced in the cabin
- Improved test methodology
we don’t know if the sound-field is diffuse or something else,” says Dr Spehr. “We also put microphones between the aircraft structure and the lining. And what are the conditions like there? We don’t know, so we use the multi-field microphone,” says Dr Spehr.

SOLUTION

Multi-field microphones were placed along the longitudinal section of the aircraft, facing upwards in the positions taken by the passengers, in an F-frame array that covered a cross-section of the aircraft.

DLR also developed their own arrays of multi-field microphones for closed test sections. “The area is small, so we couldn’t use a normal preamplifier,” says Dr Spehr. “Because they are smaller than ½”microphones, multi-field microphones are easy to use in such a confined space.”
DLR measured the transfer paths with accelerometers, and the turbulent boundary layer with pressure sensors placed in three dummy windows. "If you measure aerodynamic flow distributions then you want a high spatial resolution, which means you want to have a really small surface. We measured the flow in the turbulent boundary layer with a pressure sensor recessed behind a hole of 0.3 mm. These pressure sensors have a low dynamic range, but you can measure even high pressure, and they are very small," explains Dr Spehr.

In all, the testing used 65 multi-field microphones, 154 accelerometers and 30 pressure sensors.

**Multi-field microphone**

There were no problems setting up the multi-field microphones. As Dr Spehr says, "They use a standard CCLD input, so you know that there are no problems. Sensitivity is usually an issue, as normally ¼" microphones are not so sensitive, so it was really nice to have small microphones with the same sensitivity as ½" microphones."

"Aircraft are reverberant, and not the same in different directions, where there are different dimensions, but we didn’t have to think about that. We knew we would make an error in every direction, so to minimise this error it is best to have an omni-directional microphone that doesn’t care about that."

"When doing these kinds of tests, there are also sometimes issues with electromagnetic interference, but with the titanium build, we didn’t have any problems at all, even on the inside of an aircraft where there is a 400 Hz electrical field – which is a quite strong – we didn’t have to even think about it."

**RESULTS**

By combining sound measurement results with those from pressure sensors and accelerometers, the tests established the link between coherent fluctuations in the turbulent boundary layer and the noise experienced in the cabin.

"WE ALSO PUT MICROPHONES BETWEEN THE AIRCRAFT STRUCTURE AND THE LINING. AND WHAT ARE THE CONDITIONS LIKE THERE? WE DON’T KNOW, SO WE USE THE MULTI-FIELD MICROPHONE."

Dr Carsten Spehr, Institute of Aerodynamics and Flow Technology
In the aerodynamic part of the measurement — the turbulent boundary layer — the coherence in acoustic waves is quite large, which as Dr Spehr explains, is significant. "If you have coherent fluctuations, then they can excite the fuselage, and that can create noise you can really hear."

"At four different speeds at the same flight level in cruise conditions, you would expect 1 mm of aluminium to have the same transmission. However, this is not the case. There is a 3 dB difference with just a 10 percent speed increase," says Dr Spehr.

CONCLUSION

“If you consider this in the airframe design stage, you can adapt the modal distribution of your fuselage to the turbulent boundary layer and ensure that you don’t have this coincidence. So if you know that this is your normal speed, then you can adapt your fuselage and make sure that it is not in coincidence with the hydrodynamic coincidence outside. So the interesting point from this is that even without adding mass or anything else, you can really change the behaviour,” explains Dr Spehr.

“It was a nice flight test, and the analysis is still ongoing,” says Dr Spehr. “I have had some more requests because it was such a success.”

Convincing stakeholders to buy equipment is an issue, so when DLR was procuring their multi-field microphones it was important that stakeholders were convinced of the advantages, and of their high quality. As Dr Spehr says, “It doesn’t make sense to have cheap microphones in a flight test that costs millions of Euros, so the multi-field microphones are good value.”

The multi-field microphones were an optimal solution for DLR: “The only possible alternative to a multi-field microphone would be to use ½ microphones, where we would then have to consider whether it was a free-field condition or any unknown condition. So it was perfect that at the same time that we made the technical requirements for the flight test, Brüel & Kjær came out with the multi-field microphone, so we didn’t have to search long before our answer came along. For cabin noise the multi-field microphone is perfect.”

"We have different types of mikes,” says Dr Spehr. “Mostly ¼ mikes from Brüel & Kjær, including a special version designed for measuring in a cryogenic environment (100 Kelvin). This has been used in a great research project. A colleague of mine developed a new measurement technique in that, so it is a great success story.”

DLR’s wind tunnel is transonic, meaning up to 1.5 Mach, which is fast and loud. They need microphones with a high dynamic range that can operate at 176-180 dB.

“NORMALLY ¼” MICROPHONES ARE NOT SO SENSITIVE, SO IT WAS REALLY NICE TO HAVE SMALL MICROPHONES WITH THE SAME SENSITIVITY AS ½” MICROPHONES. WE DIDN’T HAVE TO SEARCH LONG BEFORE OUR ANSWER CAME ALONG. FOR CABIN NOISE THE MULTI-FIELD MICROPHONE IS PERFECT.”

Dr Carsten Spehr, Institute of Aerodynamics and Flow Technology