Multiphysics

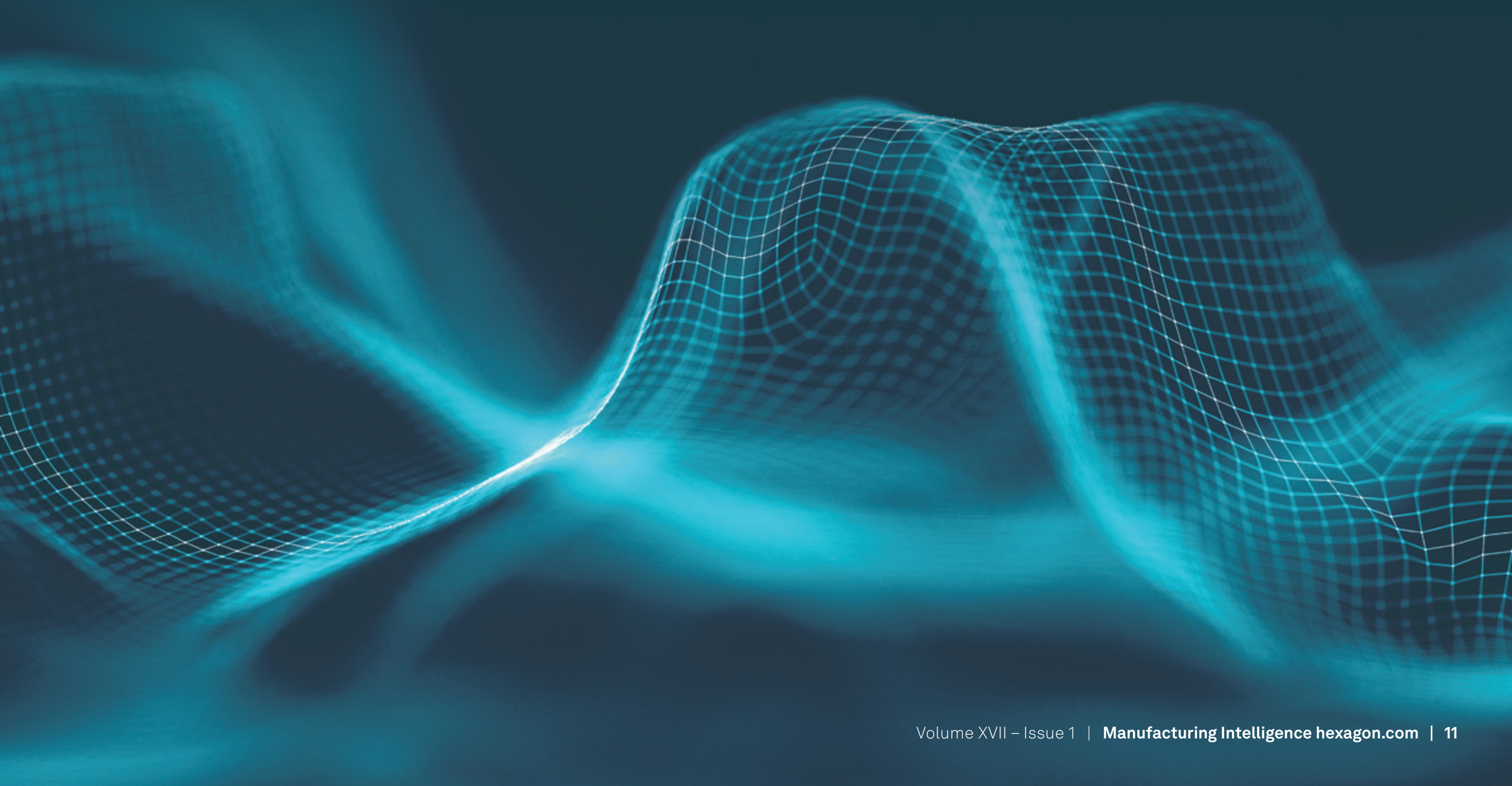
Test-based **AVAS speaker simulation**

By Wenlong Yang, Sr. Noise and Vibration Engineer, General Motors Corporation
Thanos Poulos, Product Marketing Manager, Hexagon's Manufacturing Intelligence division

General Motors utilises Actran to create a simpler AVAS speaker model that accurately represents reality

The introduction of electrification brings a new era for automobile makers, including General Motors (GM), who have millions of vehicles on the roads globally. The new powertrain architecture affects many fundamental aspects of the vehicle, and additional systems must be devised to accommodate the unique characteristics of electric vehicles.

In terms of noise, the absence of the internal combustion engine makes electric vehicles extremely quiet, to the point that pedestrians or other road users cannot perceive their presence fast enough, with obvious safety implications. Regulation from the European Union has been implemented to mandate the use of sound systems that will alert road users to the presence of the electric vehicle.



Acoustic Vehicle Alert Systems (AVAS) need to ensure compliance with regulations by providing a minimum noise level at specific locations, which means that the system needs to provide an appropriate directivity pattern that satisfies the requirements.

AVAS systems comprise of speakers that are typically placed in the front of the vehicle. Simulation is employed to design the speakers and ensure that they will pass the homologation process adequately, as it allows for quick results without building multiple prototypes. Furthermore, it ensures fewer surprises at the time of the test as the system has been thoroughly investigated.

The speaker is typically small in size is small in size, measuring around 100 mm in diameter, and features very elaborate patterns on its grille. As a result, utilising a complex speaker model when evaluating its performance as part of the vehicle is not easily attainable as the model would require large computational resources to be solved up to very high frequencies, typically 3.5 kHz. Instead, generic sources such as monopoles are used to substitute the speaker as part of the vehicle model, producing equivalent sound radiated power to the actual speaker. On the other hand, the speaker generates a sound field with an obvious directivity pattern which cannot be accurately represented by an acoustic monopole.

Wenlong Yang, Sr. Noise and Vibration Engineer at General Motors leading the work, says, “With this project, we set out to develop a methodology to consider the acoustic directivity pattern of an AVAS speaker in a full vehicle model as well as develop a virtual speaker model that has the same sound properties as the physical speaker”.

Getting things right the first time

The proposed methodology and process can be broken down into 6 steps:

- Generating numerical results to inform decisions on the test set-up
- Testing the speaker to collect sound pressure levels on the microphones
- Extracting the simplified speaker surface vibration to integrate into the full vehicle model
- Using the test data to validate the numerical model
- Integrating the speaker onto a complete vehicle model

Generating numerical data to feed testing decisions

For the surface vibration to be extracted, the inverse pellicular analysis in Actran is used. This technique allows for identifying a vibration pattern based on the results of a number of microphones. For this vibration pattern to be accurate, the number of microphones must be sufficient to fully represent the sound pattern in the far field, especially as it becomes more complex as the frequency increases. GM virtually tested various microphone amounts, going from a minimum amount of 38 microphones up to 371 microphones.

They found that even though they could represent the radiation pattern at 1 metre away at 3 kHz with 76 microphones, the variable conditions of physical testing meant that a robustness study needed to be performed. Yang mentions, “Real testing is always affected by measurement

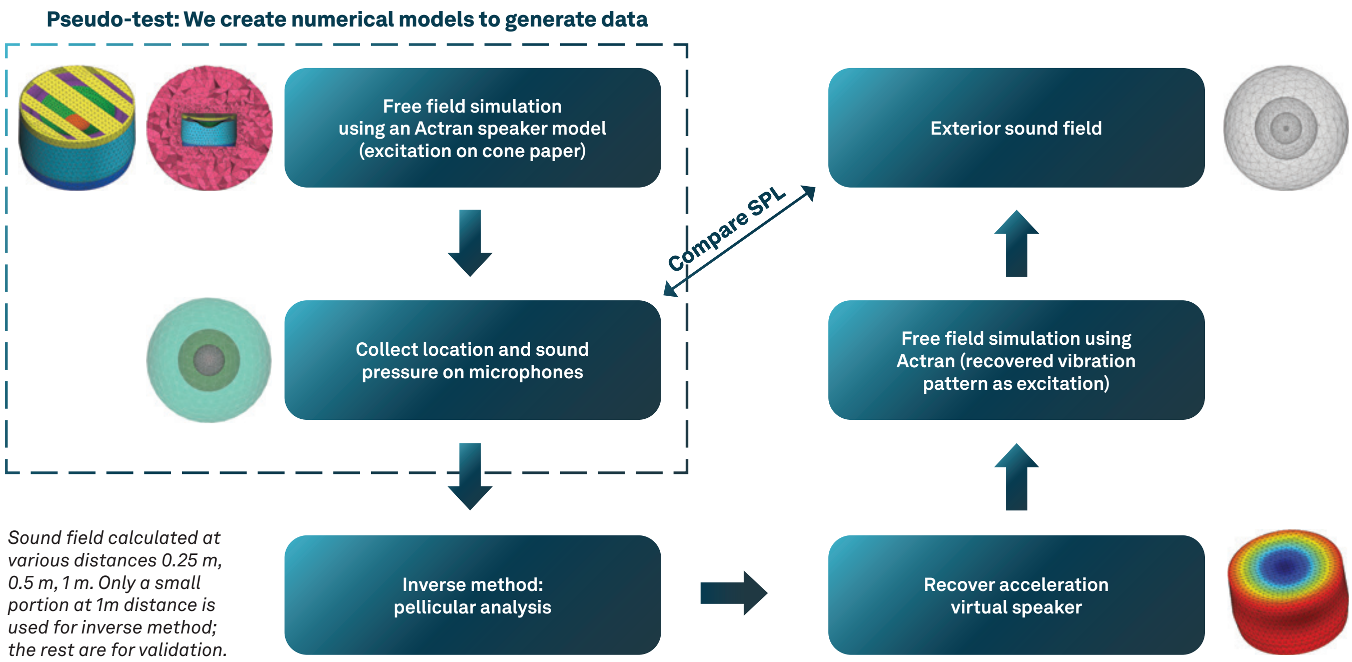


Figure 1. Flowchart of the proposed process.

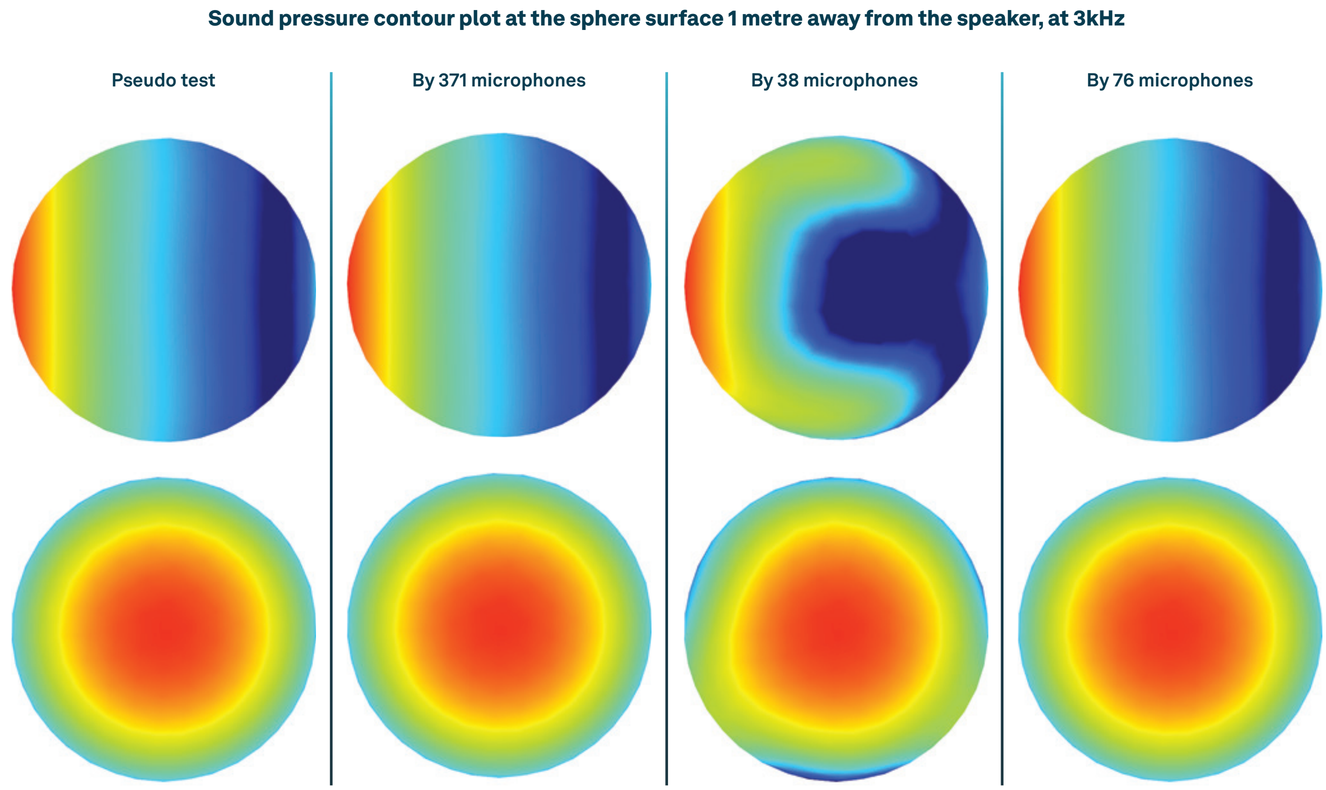


Figure 2. Sound field generated by utilising different numbers of microphones.

errors. We can have inaccuracies in the measurement of microphone locations as well as in the sound pressure measurement at each microphone, including the magnitude and phase. So, we wanted to check how those errors occur and to do this, we added artificial perturbations to the input data". This was easily done via simulation.

Three factors of influence were evaluated: the microphone location, the sound pressure magnitude and the sound pressure phase. They found that, even though with 76 microphones they could get a good representation of the pattern at a specific location and under specific conditions, they were not enough to ensure the necessary robustness required for translating the process to physical testing. Approximately 300 microphones would be required for the next phase: physical testing.

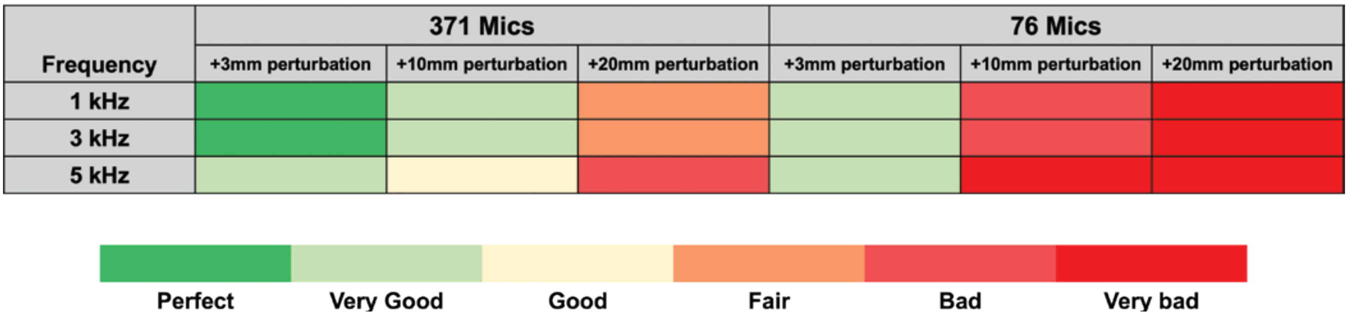


Figure 3. Robust analysis regarding different measurement error factors.

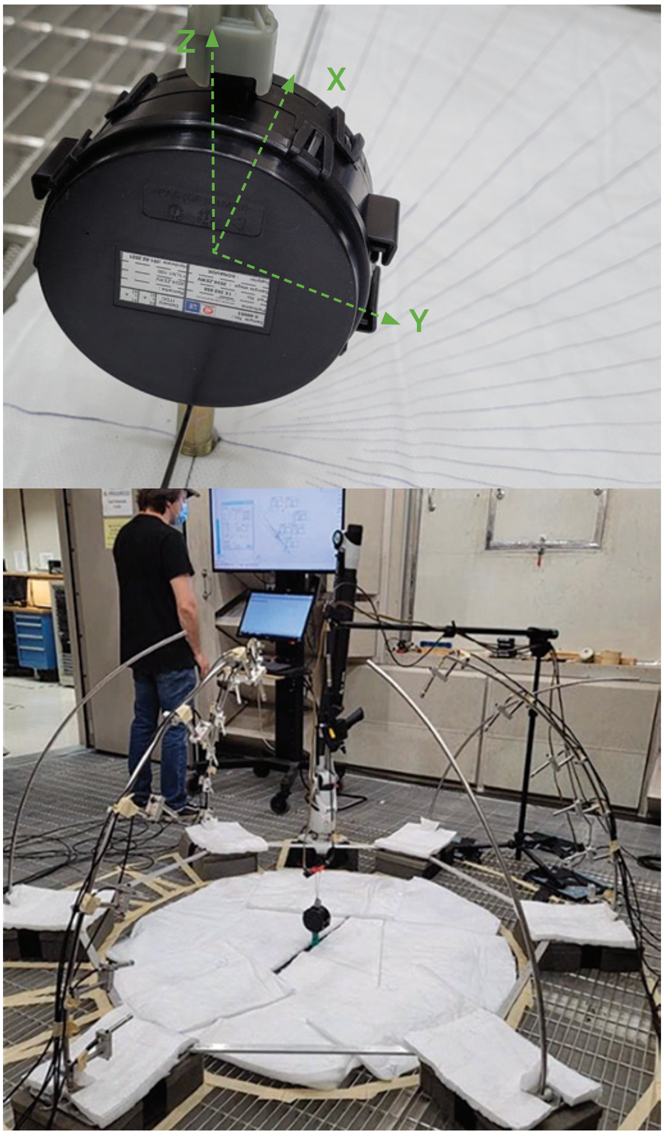


Figure 4. Acoustic testing for the physical speaker.

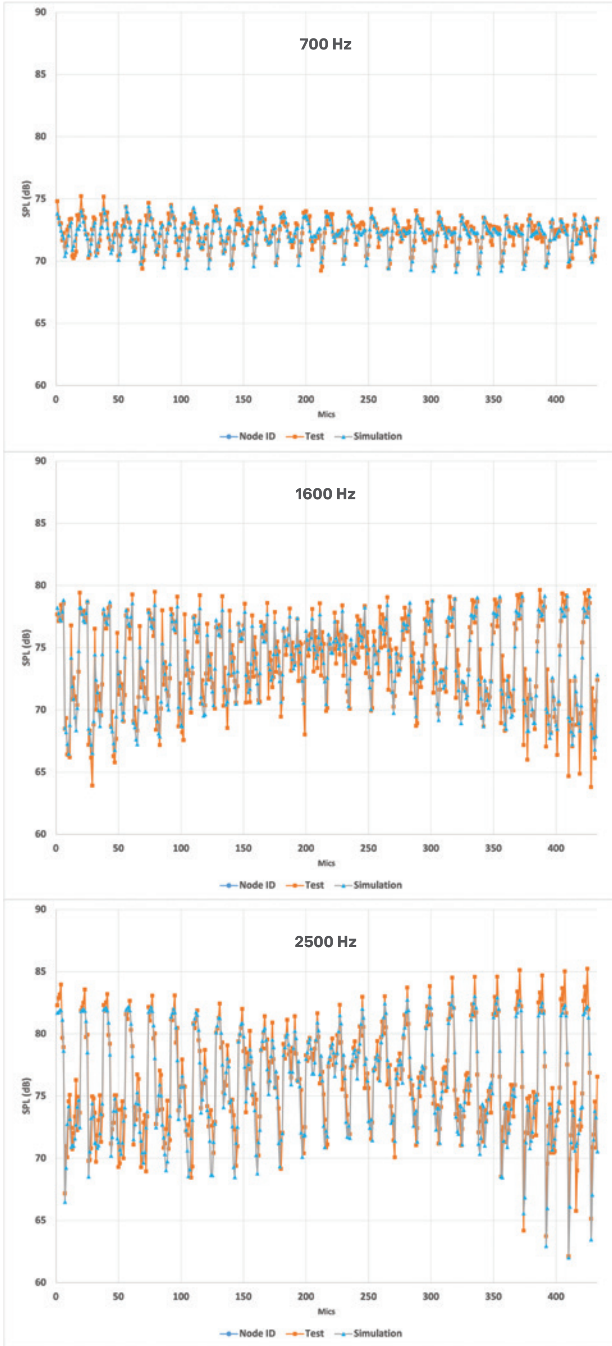


Figure 5. SPL for the microphones at three frequencies.

Physical testing and validation

The testing phase was performed at GM's testing facility. The speaker was placed at the centre of a microphone array, and the results of the measurements were compared with the simulation at various microphone locations as well as in terms of sound radiated power.

Overall, a very good correlation is achieved between the measurements and the simulation for all microphones, with very small differences at lower frequencies that become slightly larger at higher frequencies without compromising the overall quality of the simulation. An example of the sound pressure level at a specific microphone can be found in Fig. 6.

After validation, surface vibrations can be extracted using inverse pellicular analysis based on the physical measurements. This can then be integrated into the full vehicle model simulation, replacing the speaker model with this equivalent boundary condition.

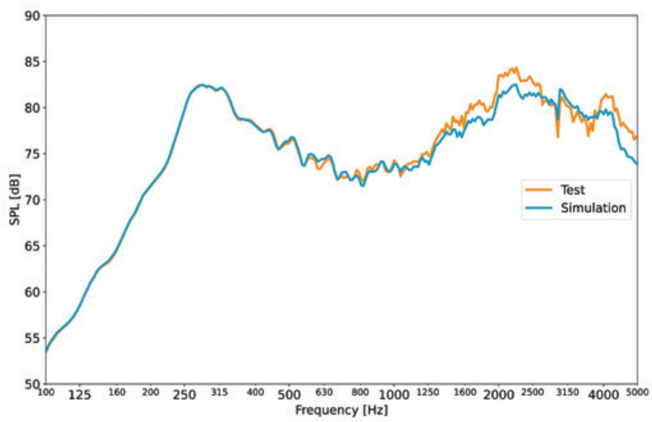


Figure 6. SPL at a specific microphone.

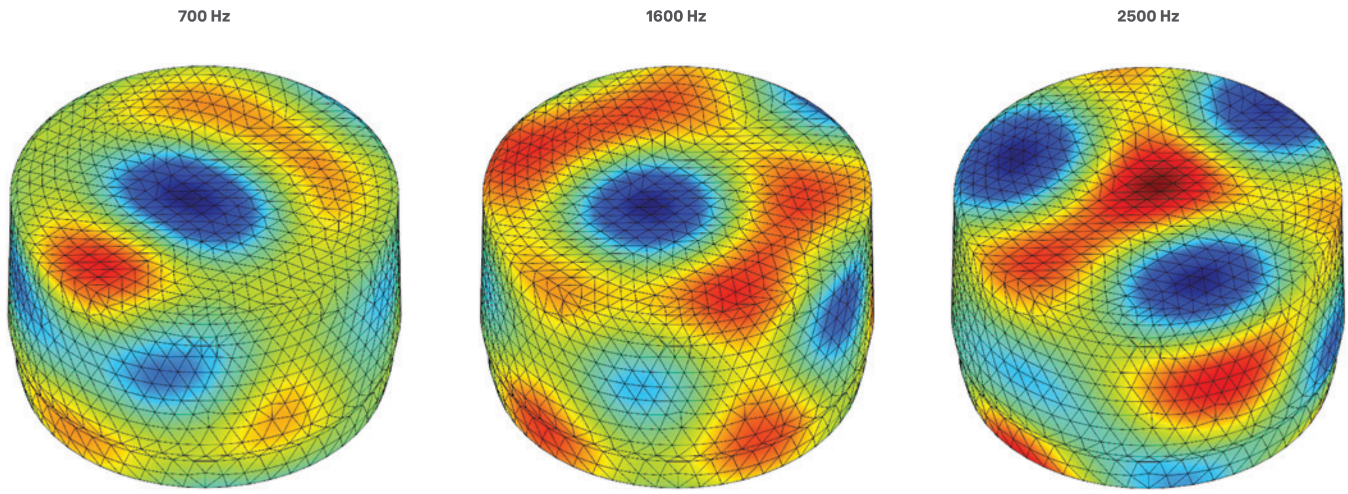


Figure 7. Surface vibration patterns of virtual speaker.

Incorporating the virtual speaker into full vehicle

The extracted surface vibration was introduced to the full vehicle model as an acceleration boundary condition to allow GM to evaluate the performance of the speaker as part of the complete system. Results were assessed at the positions of three regulatory microphones where the acoustic transfer function was calculated. The acoustic transfer function is defined as the free field source power minus the sound pressure level at the microphone.

The transfer functions for this new methodology were compared to the previous methodology based on monopole sources, and the results look more realistic than before. Yang concludes, "Even though the sound power level is the same with both approaches, we can see that in specific frequencies and locations, there are differences up to 4 dB. This further proves that we must properly consider sound directivity during the AVAS speaker design process in our vehicle development".

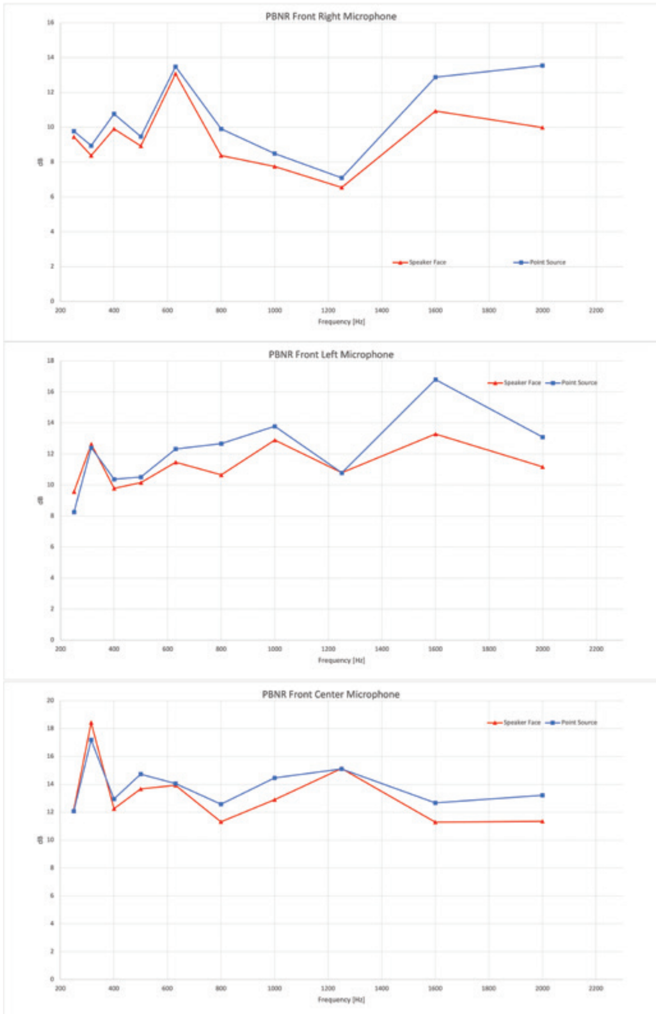


Figure 8. Acoustic transfer functions from speaker to vehicle exterior locations.

Conclusions and future work

With the help of simulation, Yang and the GM team managed to develop a methodology that considers the acoustic directivity pattern of an AVAS speaker, investigating the robustness of their physical testing setup as part of the process.

This led to an appropriate testing rig developed that helped them create a virtual speaker with much simpler geometry but with all the essential sound characteristics of the actual one. The virtual speaker was validated independently and as part of a full-vehicle model.

For the future, GM will be looking at applying all the knowledge gained here to apply the virtual speaker for interior noise as well as the effect of the speaker on the sound package of the vehicle.

They will be expanding this concept to encompass other vehicle components that exhibit distinct acoustic directivity patterns and that prove to have surface vibration that is difficult to measure with precision.