Computation of speech clarity indicators in a car accounting for background Noise

Arnaud Caillet[1], Joseph Venor[2], Simon Martin[2], Massimiliano Calloni[3], Oussama Fatmi[1]
[1]Engineering System International GmbH, E-mail: arnaud.caillet@esi-group.com
[2]*ESI UK Ltd*
[3]*ESI Group*

Abstract

In the context of the increase of customer requirements for the quality of the audio system in cars and the new regulation regarding emergency calls, evaluating the speech clarity in vehicles has become more important. The background noise around the vehicle is playing an important role to evaluate this parameter. This paper will present a workflow to evaluate the speech clarity indicators using ray tracing method with a realistic background noise computed in a previous step using Statistical Energy Analysis (SEA). On a first step a car SEA model will be excited with realistic loads from powertrain, rolling noise and windnoise to evaluate the sound pressure level in the vehicle. On a second step, a ray-tracing model based on the SEA model geometry of the interior of the vehicle is created to evaluate the speech clarity indicators. The influence of the background noise on the speech clarity will be demonstrated. The influence of a design change in the vehicle sound package will be investigated.

Introduction

With the emergence of new mobility concepts, the vibro-acoustics comfort focus is changing. In the past and still today, the comfort and experience perspective was focused on the drive experience of the driver. In the future with vehicles autonomously driven and electric, the perspective is shifted to the passenger who would like not to be disturbed by the car driving but enjoying a moment for interacting with the other occupants of the vehicle or resting. Because of that, it becomes important to optimize the vibro-acoustics experience of the passenger by providing a high level of quality for the entertainment system. For example, optimizing the position, the directivity and the number of the loudspeakers. This paper will present a process which can predict the effect of the background noise on the prediction of the speech clarity in a vehicle.

Using SEA and Ray-Tracing to predict speech clarity

A two-step process is used to predict the speech clarity in the vehicle. First using a validated SEA model, the background noise inside the vehicle is assessed. Then the background noise levels are used in a Ray-Tracing model representing the interior of the vehicle to predict the speech clarity in the influence of several parameters. The full simulation process is done using ESI Group VA One software [1]. **Figure 1** shows the simulation process proposed.

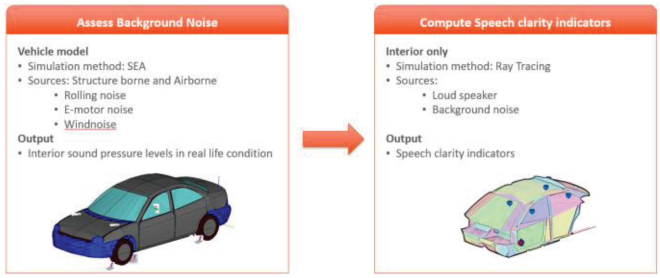

Figure 1: Simulation process to assess the effect of background noise on speech clarity. From SEA to Ray-Tracing model.

Predicting background noise using SEA

A typical vehicle SEA model is used to predict the background noise. The model is built to assess the vibro-acoustics performances of the vehicle for structure-borne and airborne noise sources. Real life or normalized excitations can be considered. The model used for the analysis presented here is built with the same rules as presented in the following papers [1],[2]. For this paper, the analysis is done using a model simulating a typical electric car with 2 electric motors (**Figure *2***).

Figure 2: Typical SEA car model

The load case considered for the analysis is a real-life excitation at constant speed. It accounts for rolling noise, engine noise and windnoise. The structure-borne and airborne noise contributions are considered. **Figure *3*** shows the sound pressure level predicted by the model for this load case at the driver's head space (black line). The results must be considered above 250Hz. It shows also the contribution of the different sources to the sound pressure level. Below 800Hz, the engine structure-borne noise contribution is dominating the response. After, the airborne rolling noise and engine noise are dominating. A maximum of the contribution due to the engine airborne noise is observed at 1600Hz. This is due to the constant rotation regime of the electric engine which is generating a tonal noise at this frequency. The SEA model could be also used to optimize the vehicle (sound package, damping pads, panel materials and leakage) to reduce the sound perceived by the passengers.

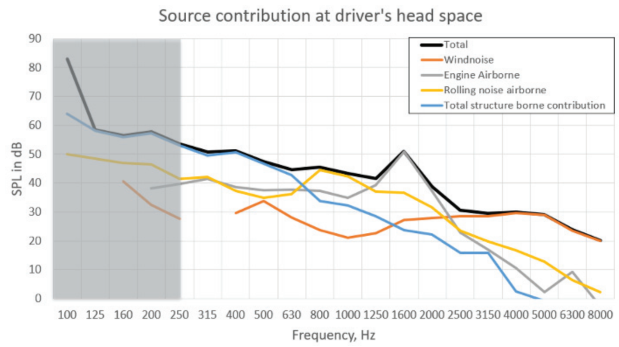

Figure 3: Source contribution analysis for the driver's head space

As all typical SEA models, the interior volume of the car is divided into several cavities (***Figure 4***). For each cavity, the sound pressure level is collected and will be used later as an input for the Ray-Tracing model to account for the background noise. The background noise levels are displayed on ***Figure 5***.

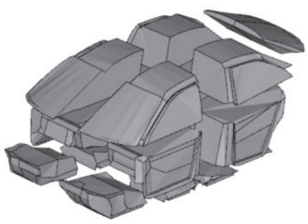

Figure 4: Interior SEA cavity split

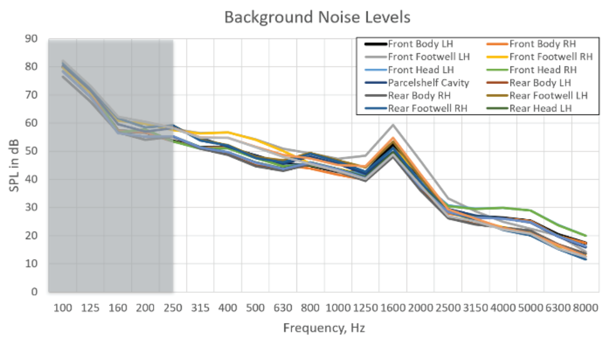

Figure 5: Background noise levels at the different SEA cavities

Speech-clarity prediction using Ray-Tracing

Based on the geometry of the SEA model, a Ray-Tracing model of the interior of the vehicle is built. This model accounts for the shape of the vehicle, the sound package (using Biot parameter and the transfer matrix method). The Ray-Tracing model is shown on **Figure 6**. A compact acoustic source is located at the position of a door loudspeaker (purple dot). The directivity and the amplitude of the loudspeaker can be defined by the user. The input for the directivity can be assessed for example by a first BEM detailed simulation of the loudspeaker or from a database file shared by the loudspeaker manufacturer as a .clf file **[5]**. The speech clarity indices will be recovered at the blue dots on the figure representing the heads of the passengers. The STI, RASTI, D50, T30, TS and impulse response can be recovered. They are all automatically calculated by VA One according to the norm ICE 20268-16 from the International Electrotechnical Commission **[6]**

Figure 6: Ray-Tracing interior model

To support the user for the choice of the number of rays, reflections and size of sensors to be used for the model, a utility is available in VA One which runs a pre-convergence analysis. The parameters given by the utility are used further in the model.

Speech-clarity results and design changes analysis

This section will present the results of the analysis done using the Ray-Tracing model and the influence of design changes.

Influence of the background noise:

Figure *7* shows the influence of the background noise on the STI ,an indicator about the deterioration of the speech signal, after being subjected to reverberation and background noise. It also means, the deterioration of the direct field and the early reflections over time. For all the positions, the STI is lowered by activating the background noise. Especially for the rear microphones positions where the reflections are playing a higher role on the perception of the sound in the vehicle. For those points, there is no direct path between the source and the receiver. Moreover , the source to noise ratio ($r_{SN} = \frac{\mathrm{I}_{\mathrm{signal}}}{I_{\mathrm{signal}}+I_{\mathrm{noise}}}$) which is the basic concept in the speech clarity is lower at the rear microphone, hence the STI decreases more compared to the front microphone where the background noise intensity is still negligible compared to source intensity. However, for all positions the STI is between 0.9 and 1 which is a very good value and shows that the passengers can have a very good perception of the sound radiated by the loudspeaker.

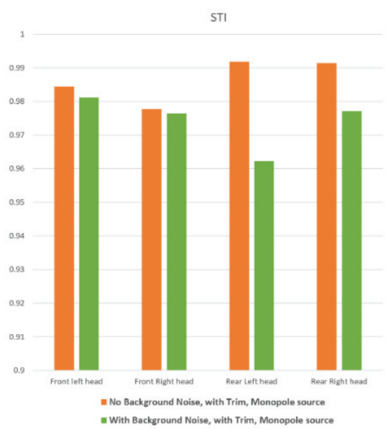

Figure 7: Influence of background noise at microphone position on STI

Influence of the sound package (Trim):

Figure *8* shows the influence of removing the sound package (Trim) of the vehicle on the STI. When the trims are removed, the absorption levels are reduced, and the reverberation level is high which reduce the speech intelligibility.

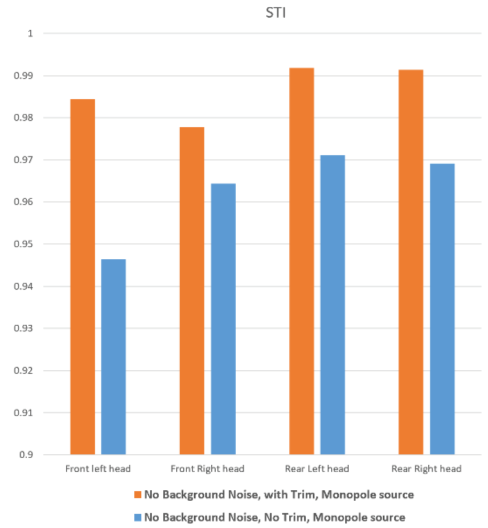

Figure 8: Influence of the sound package on STI

Influence of the source's directivity

The effect of the directivity is particularly visible for the front left head. The directivity pattern of the source can explain it. The directive source is mostly radiating noise (***Figure 9***) toward the normal direction of the door panel (X axis). But the Front left head microphone is in a region where less energy is radiated. This can explain the lower STI levels observed at this specific microphone (**Figure *10***)

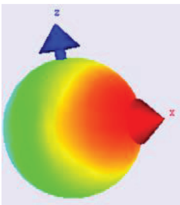

Figure 9: Source directivity pattern used in the model

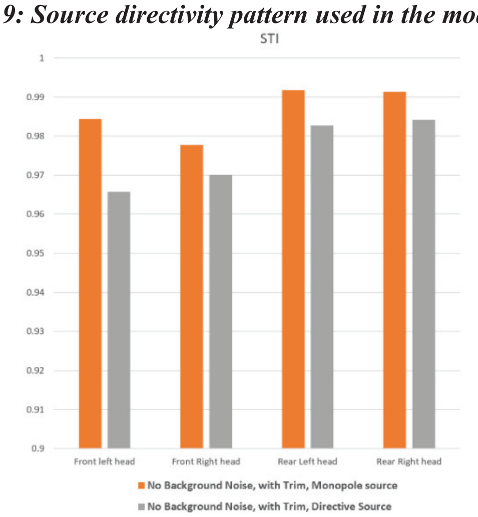

Figure 10: Influence of source directivity pattern on STI

Conclusion and Perspectives

This paper presented a simulation process to predict the speech transmission quality at the passenger's head in a vehicle. Several methods are used to support this simulation process. From the SEA and the transfer matrix method to compute the background noise and the effect of the sound package to the ray tracing method to account for the geometry and the source-receiver transfer path. The impact of the design or environmental changes (like background noise) can be observed during the simulation and used to support decisions during the design process. As a perspective, the impulse response in time domain which is also provided by the method could be convolved with the speaker spectrum to hear the quality of the sound at passenger's hears positions.

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