Loudspeaker array for the directional generation of acoustic warning signals of electric vehicles

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Introduction

Due to their relatively low radiated sound pressure, hybrid or electric vehicles (HEVs) represent a significantly higher danger for vulnerable road users (VRUs) such as pedestrians and cyclists. The danger of an accident involving a pedestrian was found to be twice as high in the case of an electrical car as for a vehicle with internal combustion engine (ICE) [1].
In the last years, the NHTSA has issued the recommendation [2] that HEV produce a minimum sound level to increase their detectability and thus ensure the safety of VRUs. On the other hand, the permanent and omnidirectional generation of sound signals reduces the progress that electrical vehicles represent for the quietness of city centers.

eVADER

eVADER (Electrical Vehicle Alert for Detection and Emergency Response) is a project funded by the European Commission (EC) involving leading research institutions and OEMs in Europe [3, 4]. It aims at developing the prototype of an onboard pedestrian detection and response system that will warn both pedestrian and driver of a potential accident. The main goal of the project is to combine the security of the VRUs and the low sound radiation of HEVs (see Figure 1).

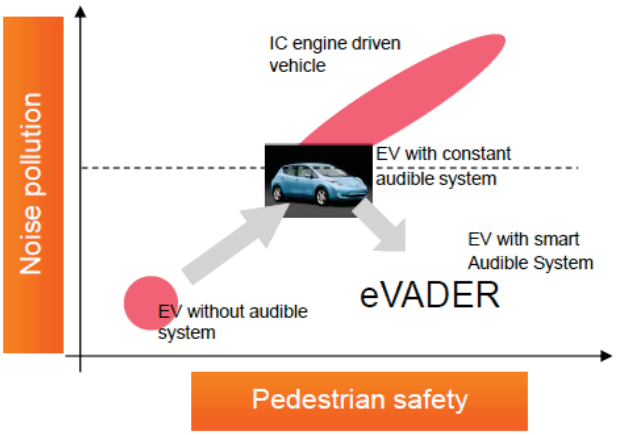

Figure 1: The objective of eVADER is a noise pollution/ pedestrian safety compromise. An intelligent warning system is investigated to maximize the safety of vulnerable road users while contributing to minimize the noise pollution (source: consortium partner Applus IDIADA).

This can be achieved, when a directional source placed in the front part of an electric car generates a sound towards a pedestrian detected and considered in danger of collision with the car. In an earlier part of eVADER, appropriate warning sounds for pedestrians were developed based on psychoacoustic experiments [5] and measurements of sound pressure levels in several representative cities of Europe [6]. The detection system is based on a stereo camera developed by Continental for their Advanced Driver Assistance System (ADAS).

Loudspeaker array

In the framework of this project, an array of loudspeakers was mounted in the bumper of a Nissan LEAF (see Figure 2).

Figure 2: Demonstration of the warning system prototype mounted on a Nissan LEAF at the eVADER workshop in Barcelona on Nov. 21st, 2013 (source: consortium partner Nissan)

Such an array of loudspeakers is, of course, subjected to projection of solid particles and water and must be appropriately protected. To achieve a sufficient protection, GORE® Acoustic Vents GAW113 were selected. This membrane material developed by Gore-Tex provides a protection grade IP65 with an acoustic transmission loss of less than 2 dB [7]. The placement of the speakers behind the bumper is shown in Figure 3. Their positions were determined by the consortium partners LMS and TNO using finite element calculations.

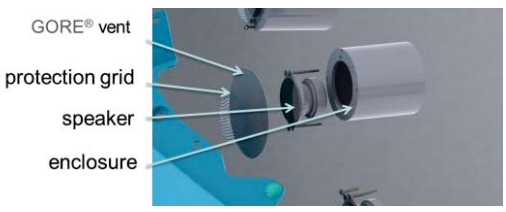

Figure 3: Schematics of an array speaker with protection against particles and water. The loudspeakers are placed at appropriate positions on the bumper and protected against solid particles and water projection by GORE® Acoustic Vents and grids.

Measurement results

The attenuation of the sound radiation of a loudspeaker caused by a GORE® Acoustic Vent GAW113 is shown in Figure 4. In an anechoic chamber, the sound radiation of an array loudspeaker was measured without and with an acoustic vent to determine the transmission loss. The transmission loss amounts to less than 2 dB in the range between 300 Hz and 2 kHz, which corresponds very well to the specifications of Gore-Tex.

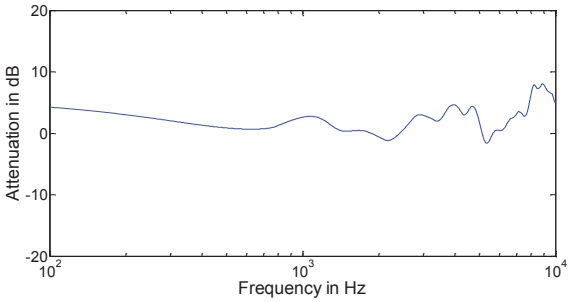

Figure 4: Attenuation of sound radiation through GORE® Acoustic Vents GAW113, measured in an anechoic chamber.

Figure 5 shows the measurement of the difference of sound pressure level radiated by the speakers of the array. The bumper with mounted sound sources was placed in a semi-anechoic chamber, and the sound radiation in response to a white noise signal was measured with a microphone 46AE from G.R.A.S. One of the most central loudspeakers (speaker 3) was used as reference, and the SPLs radiated by the other speakers were subtracted from the signal measured from speaker 3.

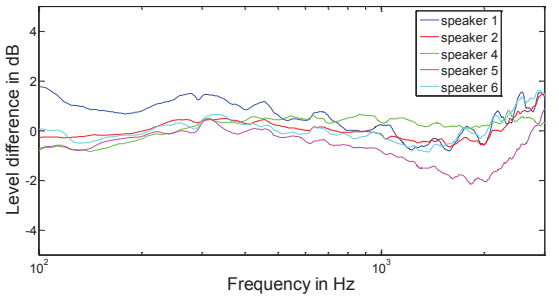

Figure 5: Difference of the responses of the loudspeakers used in the acoustic warning device designed in the framework of eVADER. Reference is speaker 3.

As can be seen in Figure 5, the difference of the SPLs radiated by the speakers amounts to less than 2 dB. Measurements of the directionality of the array were conducted at Nissan's facility in Cranfield, UK, and will be presented at the FISITA in Maastricht in June 2014 [8].

Conclusion

In the framework of eVADER, a directional sound source was mounted on the bumper of an electric car LEAF from Nissan, and its acoustic properties were tested. Combined with an appropriate pedestrian detection system, it will be made possible to selectively warn VRUs of the presence of an approaching electric car without significantly increasing the overall sound radiated by the vehicle. Thus, the benefit of the quietness of HEVs regarding noise pollution in cities will be combined with an increased safety of pedestrian and bicyclists.

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