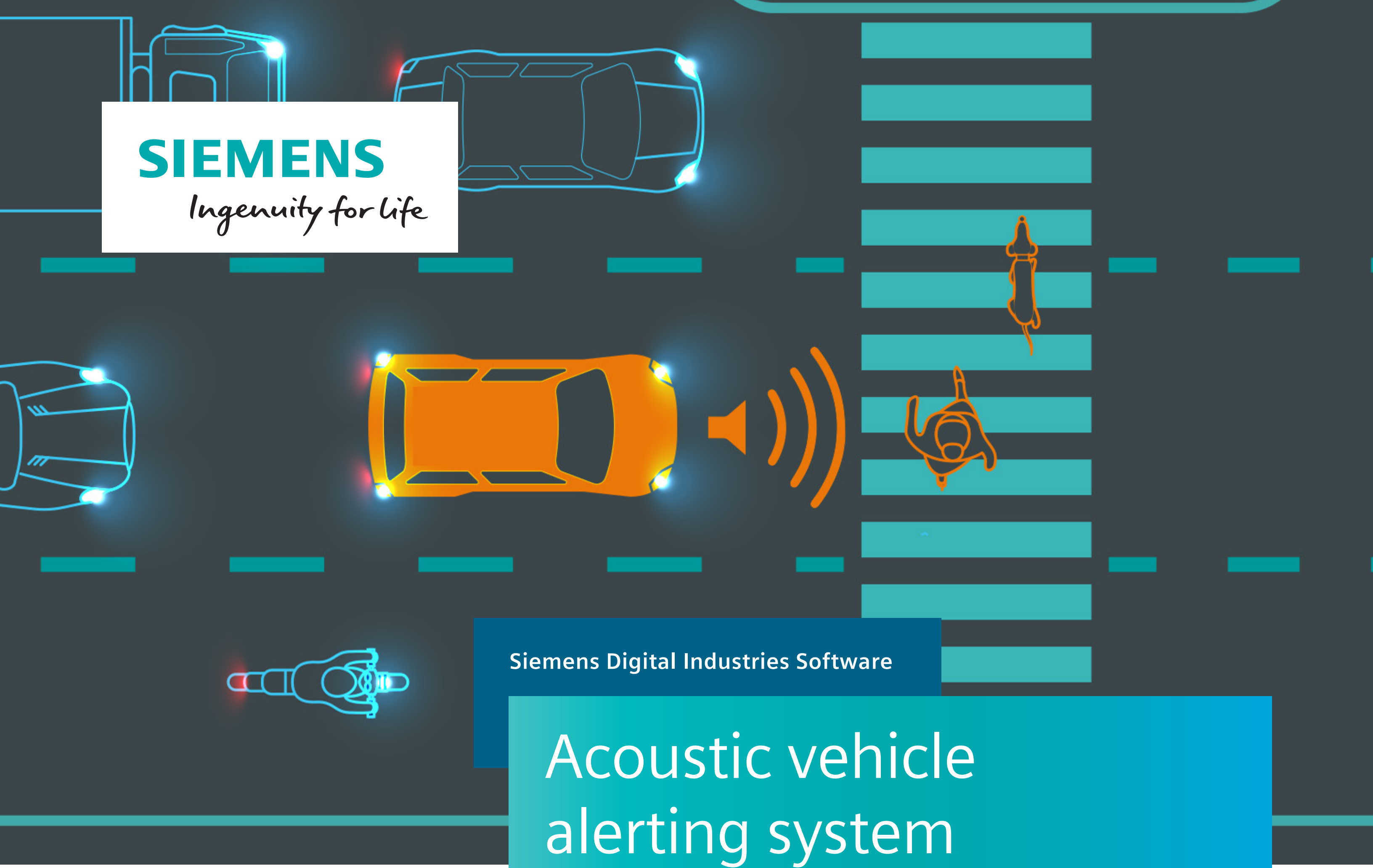

SIEMENS

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Siemens Digital Industries Software

Acoustic vehicle alerting system

Designing the right exterior sound and assessing its performance by integrating simulation and testing

Executive summary

The absence of exterior sound in hybrid and electrical vehicles is a concern for both automotive manufacturers and regulators, especially at low speed. In terms of pedestrian safety, this is particularly important for those with visual impairments. As a consequence, legislation all over the world has moved toward making an acoustic vehicle alerting system (AVAS) mandatory for electric vehicles[1,2] and imposing a minimum noise level.[3,8] For instance, in Europe hybrid and electric vehicles already are required to be equipped with AVAS since September 2019 and the US will follow mid 2020.[1]

Contents

Abstract

Adding sound at low vehicle speed improves the detectability of the vehicle and hence the safety for those in the vicinity. But how loud should it be, and more importantly, what would people like to hear? Are we only aiming to fulfill the requirement for an AVAS or can we use the same loudspeaker to produce a characteristic brand sound at the same time? And should that sound come through in all directions surrounding the car? Would equal sound illumination in all 360 degrees be the way to go or would inserting the required amount of sound in a directed way toward the concerned pedestrian or cyclist receiver locations be preferred?

Questions such as the above can be answered by designing the right sounds for your vehicle, followed by experimenting with those sounds, loudspeaker systems, their positions and controls. This paper illustrates how different sounds can be designed and evaluated by jurors.

Next, we have a look at how this AVAS system can be tested and implemented on the development vehicle, including how to test compliance with regulations. To further accelerate and improve this process, this paper also explains how different experiments can be carried out (at least partially) in the virtual world, using simulation solutions for optimizing both geometrical-acoustical and control aspects.

Making noise about increasing safety

When electric and hybrid vehicles operate in full electric mode, the absence of any perceived engine noise and hence of any recognizable vehicle proximity warning can endanger vulnerable road users (VRUs) such as cyclists, pedestrians and the visually impaired. This is particularly important at vehicle speed below 30 kilometers per hour (km/h) before tire or wind noise becomes audible.

As legislation on minimum noise levels is now more common than ever before, automotive manufacturers are encouraged to study how exterior warning signals for quiet vehicles can increase the safety of other road users.

The Federal Motor Vehicle Safety Standard (FMVSS) 141 legally requires all new hybrid and electric vehicles in the United States to emit an audible proximity warning sound whenever traveling under 31 km/h (18.6 miles per hour). This is not required at higher speeds as other noises, such as tire and wind noise, provide adequate audible warnings to pedestrians and cyclists. For Europe and other United Nations Economic Commission for Europe (UNECE) member countries, UNECE Regulation 138 applies.

Apart from the detectability of the presence, direction and location of quiet vehicles, the sound must allow VRUs to distinguish critical operating scenarios such as constant speed, accelerating and decelerating.

Adding sound to the vehicle poses carmakers with an important challenge: If their car is “forced” to create noise in a suburban area, it better create a great sound that links to the brand value of the vehicle. In that sense, AVAS is both a threat as well as an opportunity for carmakers. Doing this the right way could turn the AVAS sound into a competitive advantage. Not surprisingly, carmakers increasingly realize this is a strategic aspect that needs the proper level of attention in the vehicle development process.

Adding sound to quiet vehicles

Many automakers have already fitted warning sounds to their vehicles, but current and future regulations are likely to set increasingly stringent controls for sound levels and types in order to harmonize the safety of electric and hybrid vehicles on a global basis.

For designing a warning sound system (figure 1), manufacturers need to consider the following development aspects:

- First of all, different possible sound models need to be designed. In this phase, it's important to have tools that enable the sound design specialist to be creative and allow him/her to step away from the more conventional sound models. With the right methodologies, innovative new sound models can be generated that not only meet regulations, but also represent unique brand values
- Designing those sounds and the sound models is not sufficient. In the end these models will need to run on the vehicle and be generated by an AVAS speaker system (figure 2). First, it requires the user to look at the impact of the vehicle on the sound radiation, for example by testing the created sound models on the vehicle prototype or a mule. It could also require analysis of the right position(s) for integrating the AVAS speaker system into the vehicle. Although most vehicles today are equipped with one speaker on the front bumper and optionally one in the back, to enable sound creation with directivity, multiple speaker configurations with control would be preferred. This requires assessing the right location of those speakers in order to effectively create the required directivity. It can also be important to look at the interaction with the environment and validate how the developed sounds balance the warning effect with ambient annoyance . Last, it can also be important to look at the impact of the AVAS sound on the interior sound in the car.
- Although these evaluations can be done on prototypes, it is possible to evaluate these aspects earlier on by using simulation tools. Using a combination of acoustic simulations and design of the controls (active AVAS)

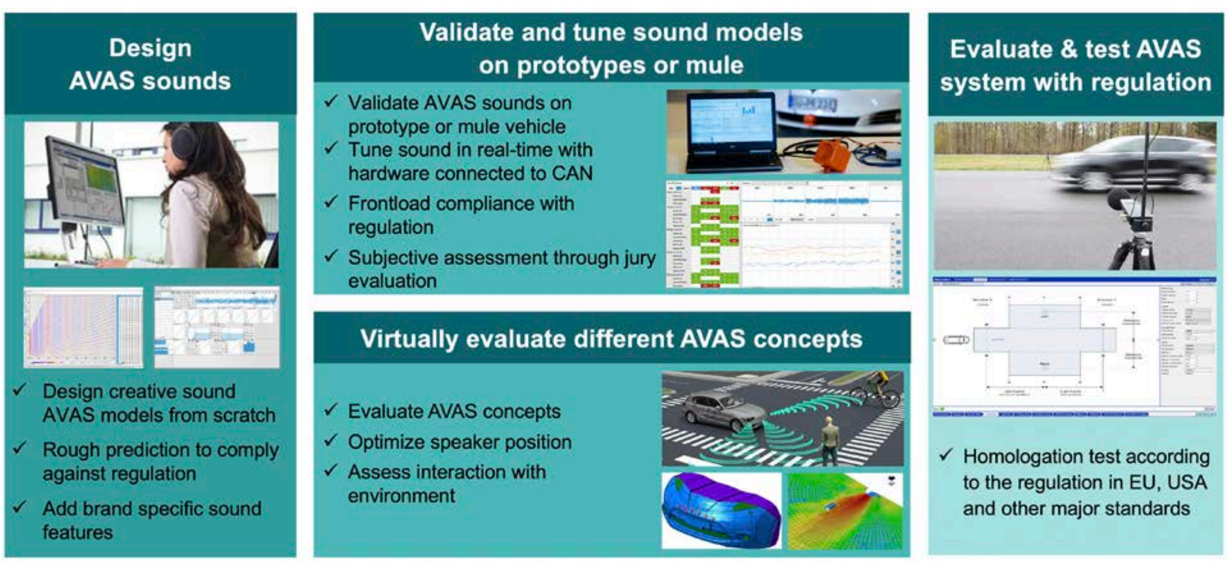


Figure 1: Overview of the development steps for AVAS system.

allows car manufacturers to assess the performance and robustness of their warning system

- The different sound models will need to be tested on the vehicle to check if they properly interact with their environment and if they create the right brand sounds for pedestrians. It is crucial to have the right hardware available to evaluate these models, while interacting with vehicle parameters such as vehicle speed.
- Automotive original equipment manufacturers (OEMs) can also decide to implement a branding sound that is both a warning sound and complies to the standards. Either of these sounds can be added together to be broadcast by the same loudspeakers, or several groups of loudspeakers can transmit warning and branding sounds separately. For instance, some loudspeakers in the motor compartment under the hood could take care of a branding sound and transmit a rather omni-directional sound radiation at all vehicle speeds. Other loudspeakers could be put in array formation at the front bumper. In this case, beam-forming techniques could be used to direct the sound to a camera-detected VRU and act only at lower vehicle speed.

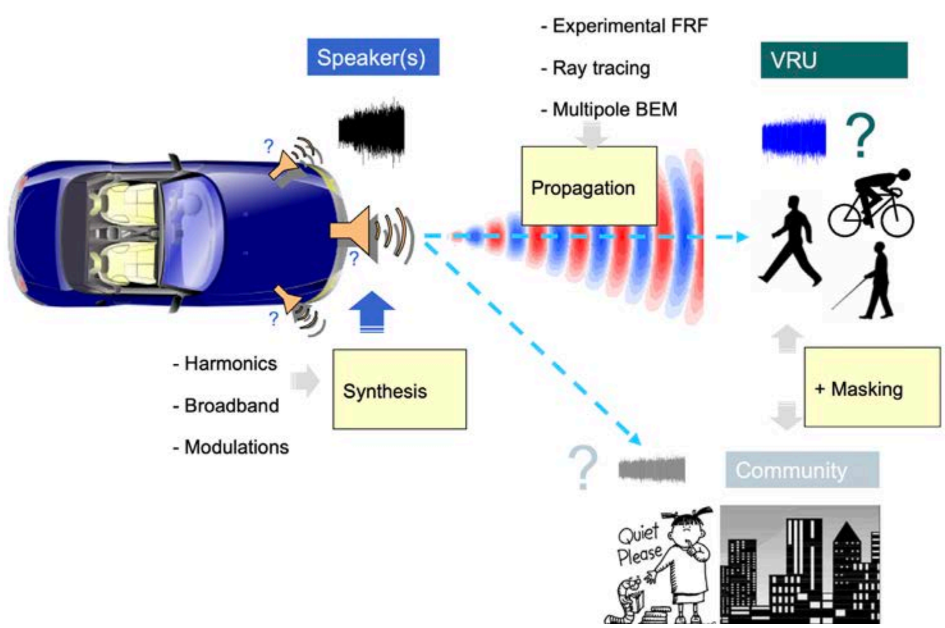


Figure 2: Warning signal design showing the importance of sound content (synthesis) and directivity (propagation).

Designing the sound of the AVAS system

Like the internal combustion engine (ICE) sound, the sound of an electric motor (EM) is impacted by certain mechanical constraints. For ICEs, the number of cylinders is decisive in shaping the color of the sound. On the other hand, for an EM the number of poles and stator slots of the electric motor results in highly pitched tonal noises. Apart from a few dominant tones, the EM noise is rather low. Hence, there is a need for an effective warning sound system. If the additional sound is broadcast through a loudspeaker, no mechanical constraints apply.

OEMs are free to design the sound they want within certain legal boundaries. For instance,[1] the warning sound signature or the content of the sound should be indicative of vehicle behavior, pitch and level increase with speed, and should be comparable to the sound of a vehicle of the same category equipped with an internal combustion engine. This still leaves a lot of freedom in shaping the warning sound.

An electric vehicle's warning sound is a branding opportunity and can therefore be brand- or even model-defining. A vehicle brand should have a general theme that conveys the image of the company. This general branding theme should be intrinsic to each aspect of the product sound and marketing material. Each model should have a warning sound that is tuned to the type of vehicle and target audience (sport, luxury or city car for young, high end or families), but still belongs to the branding sound. As a consequence, decisions for sound design require specifications for the vehicle's branding. For example, should the electric vehicle sound signature hint at a combustion engine containing orders, providing a familiar sound, or a more complex and musical sound that would clearly identify the vehicle as an electric car?

Let's look at the noise signature of the Nissan Leaf public dataset. Figure 3 shows that two signal contributions clearly stand out. The first contribution component consists of broadband low-frequency content with a peak at 600 hertz (Hz) and an important contribution up to 1,000 Hz. An additional broadband group is found in the range between 2,800 and 3,500 Hz. The second contribution features a purely harmonic content with speed-dependent frequencies. Two groups are found: a first dominant group with two nominal frequencies at 2,000 to 2,200 Hz, and a secondary group with three nominal frequencies at 1,100 Hz, 1,350 Hz and 1,600 Hz, active particularly in the first part of the measurement window. In order to further validate the various signal constituents, a modulation study was performed to extract broadband and narrow tonal noise components. The result is shown in figure 4.[4]

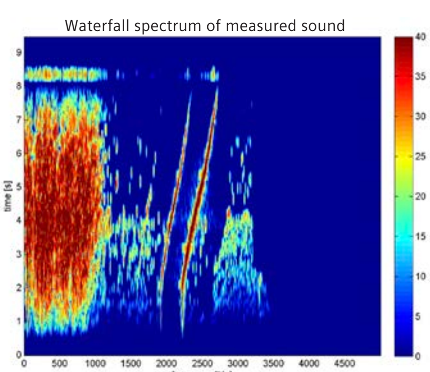


Figure 3: Electric vehicle warning sound spectrum (0 to 20 km/h).

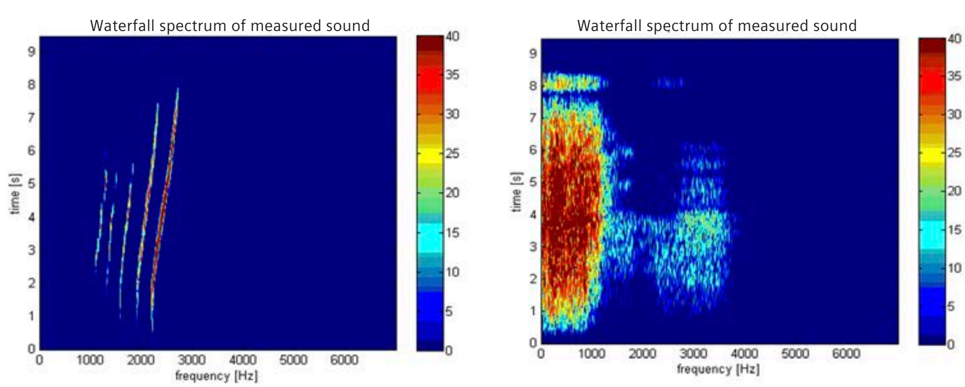


Figure 4: Tonal and broadband components of warning sound spectrum.

When speaking of sound perception, it is important to distinguish between objective measurements and subjective experience. Hearing is a powerful human sense and can link a product to a perception; reliable, safe, luxurious, etc. Sound has become a dominant commercial criterion and is included in the standard product design process. At Siemens, sound engineers help design the desired sound based on targets and match it to the vehicle's brand identity.

The sound as generated in the previous example is still quite a conventional sound model. To develop truly innovative brand sound models, Simcenter Testlab™ Sound Designer software can be used. Simcenter Testlab Sound Designer gives the design engineer access to two main approaches for designing the AVAS sound as shown in figure 5.

A first approach is order-based sound synthesis, which is less commonly applied for AVAS sounds, but very popular when designing the sounds for interior sound enhancement. As the name indicates, in this case the AVAS sound is generated based on a combination of orders. The level and shape of the orders of the sound model can easily be tuned interactively while immediately assessing the impact on the sound model. The resulting sound will mimic the natural behavior of a combustion engine, which is usually not preferred for an AVAS sounds that by definition is functioning at a moment of absence of combustion engine noise.

A second approach, named granular synthesis, is mostly used for AVAS sounds. It enables you to create completely new sound concepts that deviate from the sound generated by combustion engine-driven vehicles. With this approach, the sound design engineer synthesizes sounds that are constructed from different variable parts from an audio file (so-called "grains") of the sample, which are replayed for a certain duration, one after the other, and changed in pitch with vehicle speed. This gives a rich and robust broadband sound in which the listener will not hear the same sample replayed. This is the state of the art method mostly applied for AVAS sound development. The entire synthesis is done as a function of speed. The Simcenter Testlab Sound Designer solution is very powerful for interior sound enhancements too. In those cases, it is a lot more common to apply the order synthesis approach.

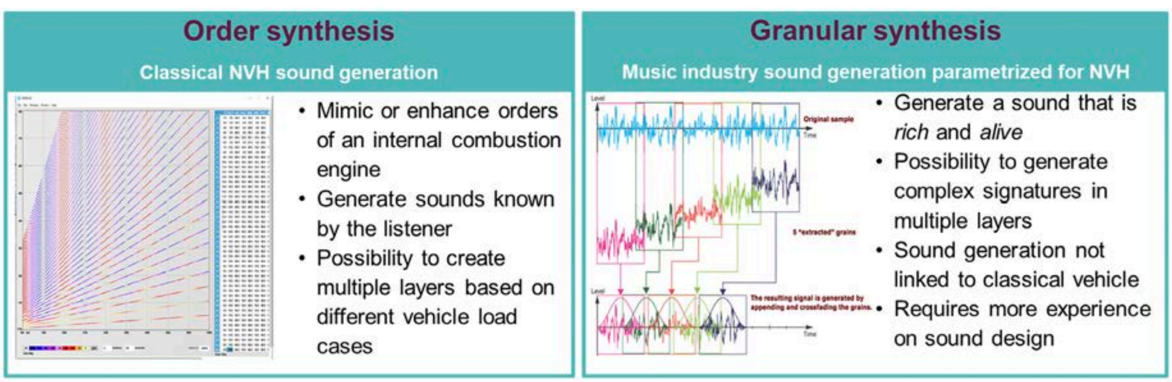


Figure 5: Two main sound design approaches of Simcenter Testlab Sound Designer

It's not sufficient to just develop sound models. In the end, the AVAS system will need to comply with regulations. Simcenter Testlab Sound Designer allows you to frontload compliancy of the generated sound model with regulations by simulating the levels and frequencies generated at the pedestrian target. To do this, the user only needs to enter the transfer function from the AVAS speaker toward the pedestrian target. This transfer function is used to convolute the designed sounds and predict the end sound at the target. This resulting sound is processed according to different standards from which a first report is created (as shown in figure 6). The conditions that aren't met are indicated in red in the report, which allows the user to exclude them from the AVAS model and avoid surprises late in the development process. This method can be applied at early stage already, by assuming a certain transfer function from a previous vehicle for instance, or once the prototype is available by using a physically measured transfer function.

Sound is subjective. As such, Asian customers might favor a frequency or tune that is perceived as annoying by European customers and vice versa. To understand the target customers' preference, it can be appropriate to conduct a jury evaluation. With Simcenter Testlab Jury Testing software, experts subjectively evaluate the product sound design and correlate it with objective metrics.

By asking a defined audience to listen to designed sounds and mark their preference, essential feedback from target customers can be collected. As shown in figure 7, a group of jurors participate in an A-B comparison evaluation of automotive sounds. Their answers will be used to identify a relationship between subjective preference and objectively measured component characteristics.

Figure 7: Jury testing in action.

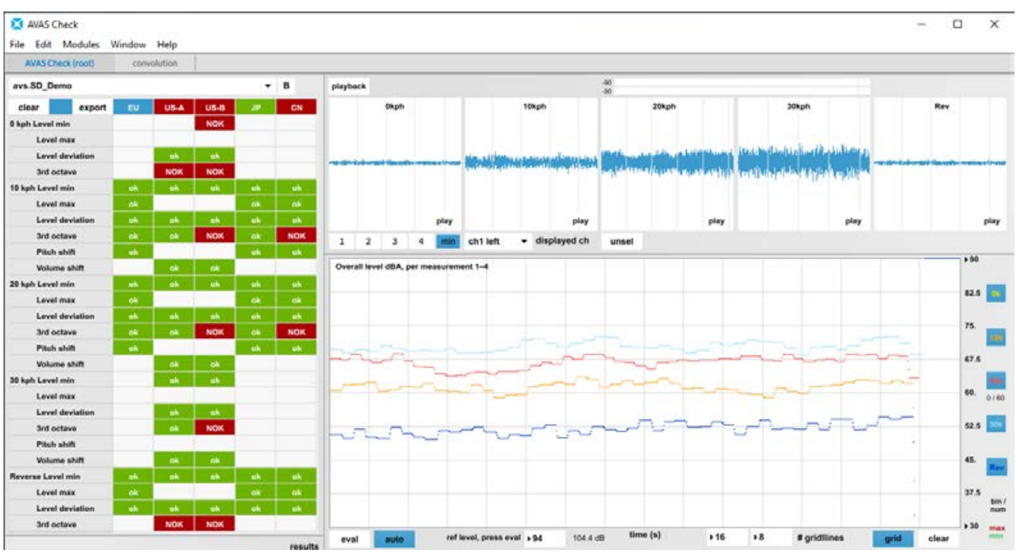


Figure 6: First assessment to check if the created sound model complies with AVAS within Simcenter Testlab Sound Designer.

Virtually evaluate different AVAS concepts

Assessing sound propagation and directivity

The sound observed by a VRU largely depends on the design of the warning sound. However, this sound, emitted at the source location, can still get amplified or attenuated by its environment. For instance, for loudspeakers located under the hood of the car, some frequencies of the designed sound may get muffled away while others pass through. This way, the final sound is a function not only of source content but also of the loudspeaker and receiver location. Consequently, a pedestrian standing beside the vehicle may perceive a different sound than someone walking in front of the car.

The frequency-dependent ratio between perceived sound and unit sound source strength is referred to as a frequency response function (FRF). Although it only depends on the propagation environment, it could become adaptive by means of control strategies. For instance, the transfer functions can be made dependent on the target location of a receiver. This can be done by use of beamforming techniques applied to loudspeaker arrays. With this technique, the same signal is fed to all loudspeakers with a short time delay (we consider this modification a part of the transfer function). This results in a directive sound beam aimed at the receiver location. Figure 8 indicates how the AVAS system can be seen as a transfer path analysis (TPA) system, in which each source represents a path contributing to the response by source strength and FRF strength.

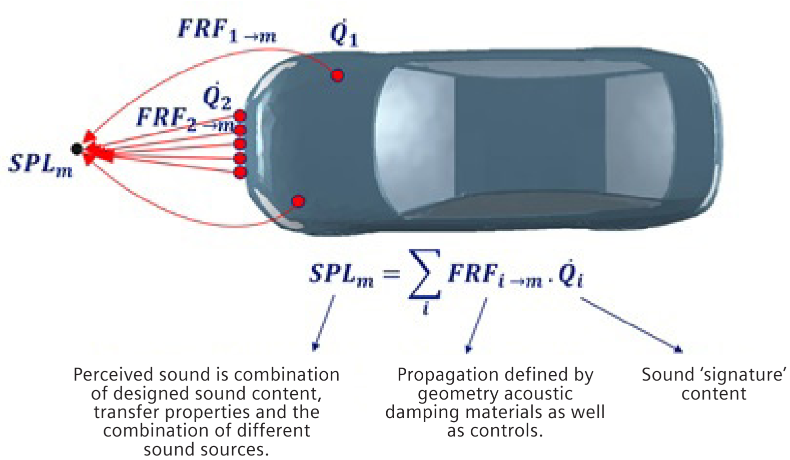


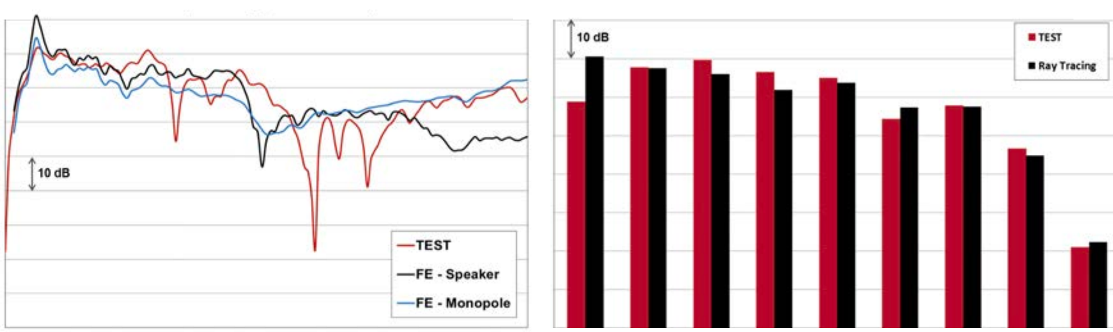
Figure 8: AVAS warning system, transfer path analysis representation.

Passive directivity: optimizing the speaker location

As a large number of possibilities exist for loudspeaker locations, signal controls and sound content, it makes sense to run a set of experiments in order to select the best design afterwards using quantitative and qualitative evaluation. In order to do this, fast, high-end simulation techniques can be used that quickly provide results for a number of combinations.

Simcenter 3D software contains acoustic simulation technologies such as finite element method (FEM) acoustics, boundary element method (BEM) acoustics and ray tracing methods. Each of them allows you to model the fluid surroundings of a car as well as the fluid inside of the motor compartments by either volume elements (FEM) or boundary (shell-like) elements (BEM and ray acoustics). All of the above account for absorption on the car's surfaces and capture the use of absorption material in the motor compartment.

For the low- and mid-frequency regime, FEM and BEM are reference methods in industry. Siemens' Simcenter FEM-based acoustic solutions incorporate specific technologies such as automatically matched layer (AML) and FEM adaptive order (FEM AO). Both techniques allow for much faster computations compared to conventional FEM methods,[5] which means they allow for virtual experiments. Despite these powerful FEM technologies, at high frequencies FEM and BEM methods become too slow and are not suited for running many virtual experiments. Here ray acoustics can be used, which is based on geometrical scattering techniques and is typically much faster compared to FEM and BEM techniques. As ray acoustics are only valid at a sufficiently high frequency regime, it nicely complements the FEM and BEM approaches. Figure 9 shows a comparison between tested and simulated warning sounds for a specific loudspeaker location and response point in front of a car.[6] The Simcenter Engineering and Consulting services team explored different approaches for source representation, from a simple monopole to a more complex vibrating loudspeaker membrane. Although details on the location of the sound source as well as on the scaling of the frequency and amplitude axis were omitted for the sake of confidentiality, the figure clearly shows a correlation. This is of course required in order to trust the simulation results and can be seen as a calibration of this virtual measurement method prior to exploring additional AVAS candidate designs.



FEM for low frequency

Ray acoustics for high frequency

Figure 9: Comparing tested and simulated FRF using an FEM-based approach for lower frequencies (left) and ray tracing-based approach for higher frequencies (right).

Adaptive directivity: beam forming with speaker arrays

When a fixed set of speaker locations and motor compartment design is selected, this depicts frequency-dependent directivity, as stated earlier. There will be zones with higher noise content; for example, typically in front of the car and zones with lower content. In case the aim is to restrict the emitted AVAS sound to specific VRUs locations, an adaptive system is needed as VRUs can move around the car in real traffic situations. Such an adaptive system also avoids polluting the environment with too much with noise.

Adaptive systems typically use a beam-forming technique that requires an array of loudspeakers in the front bumper and some control algorithms that regulate the delay between the audio signals going to the different speakers of the array. The signals obtained as such are further multiplied with the FRFs corresponding this time only to the transfer of the sound in the environment (the delay part here is assumed to be already included in the sources). In order to accurately consider the shape of the bumper in such FRFs, FEM and ray acoustics, techniques can be used with acoustic models that include the prototypes for the car bumper geometry. These FRFs can also be evaluated for multiple scenarios: changes in bumper geometry and loudspeaker array positioning, presence of other cars, presence of buildings, weather conditions, etc.

Siemens Digital Industries Software participated in eVADER, a European project to address the road safety concerns for VRU. In this context, Simcenter experts studied three basic acoustic elements for the sound system devices: detectability, annoyance and brand sound. Figure 10 illustrates the layout of the full eVADER warning sound system as well as the steps in the device design. It shows how the eVADER system aims to adapt sound toward detected VRUs. The detection is camera-based and also involves risk estimation to decide on the sound steering actions. Once the decision to emit a warning sound to a specific location has been made, beam-forming algorithms are used to accomplish a directive sound beam.

FEM-based methods were used to predict the FRFs for a bumper mounted loudspeaker system.[7] A picture of the model creation is shown in figure 11. As can be seen on the right side, the Simcenter acoustics FEM methods require the modeling of only a small layer of air: surrounding the front of the car and reaching up to the floor. Thanks to the AML technology, such an FEM model can be used to predict the sound inside the FEM mesh as well as outside the FEM, as required in AVAS applications. After the FRFs are obtained, they can in turn be used in a beam-forming algorithm that sets the delays between the loudspeakers so the sound is directed properly.

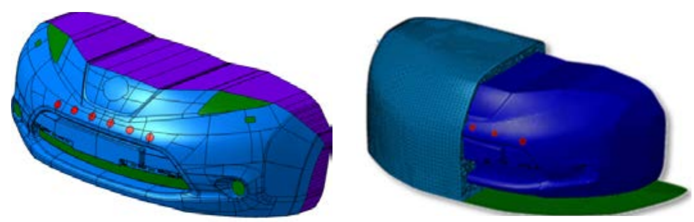


Figure 11: Left: CAD geometry of the front bumper.
Right: FEM AML acoustic model with loudspeaker positions.

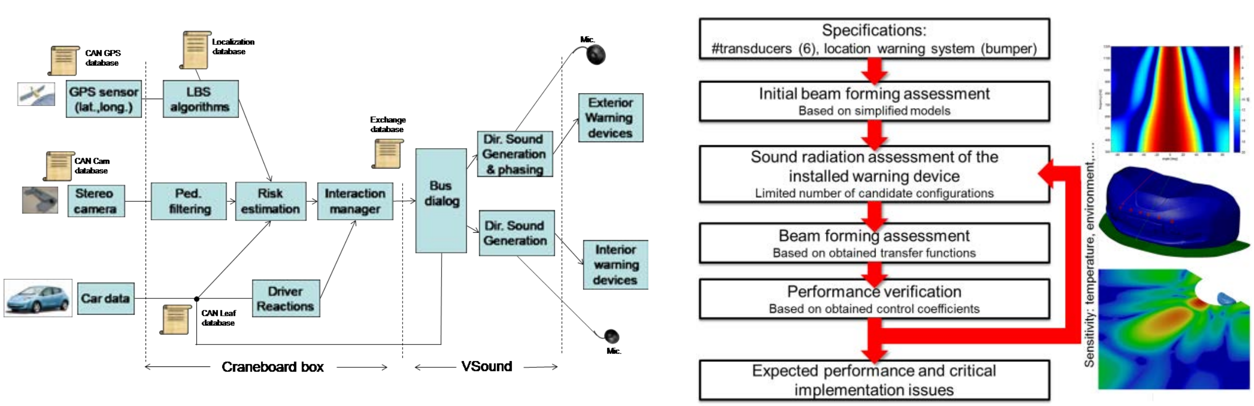
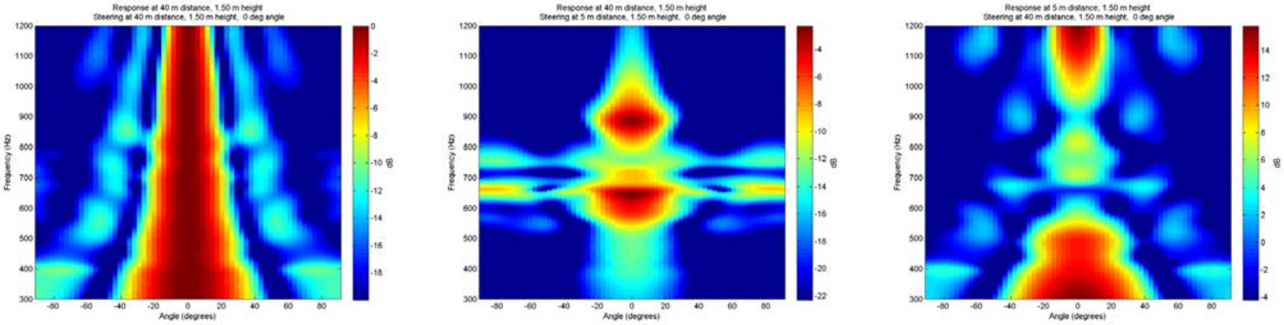


Figure 10: Overall eVADER warning system layout (left) and exterior warning device design strategy (right)



Beam optimization at 40 m distance, evaluation at 40 m

Beam optimization at 5 m distance, evaluation at 40 m

Beam optimization at 40 m distance, evaluation at 5 m

Figure 12: Frequency-dependent beam directivity is influenced by differences between target and evaluation range.

Figure 12 gives an example of how beam forming allows the user to direct sound. The direction to point at in this case is simply straight ahead. Note how a rather narrow beam is obtained. The directivity is prominent between -40 and 40 degrees at low frequencies and the beam is trapped in a -15/+15 degrees arc above 1 kilohertz (kHz). However, distance also plays a significant role. When tuning the signal delays for a target at 40 meters and evaluating the sound at 40 meters, we get the desired beam-forming result. In case the listener location differs from the distance for which the delays were optimized, we can see how the beam forming is effective only at specific frequencies. A detection device that captures range and direction allows the user to optimize for both variables.

Especially for scenarios that include other vehicles in the vicinity, BEM approaches or ray tracing present an attractive alternative. This is due to the reduced model size compared to FEM for such scenarios. The BEM model encompasses the geometries, including reflective properties, of all other vehicles and the road surface, and can also include noise sources introduced by the other vehicles, such as tailpipe noise, ICE noise or another warning signal. Figure 13 shows the scenario in which two vehicles are parked on the side of the road five meters (m) in front of the approaching demonstrator vehicle. In this example an advanced solver was chosen for the BEM equations: the H-Matrix BEM solver, which is available in Simcenter acoustics simulation products.

This simulation allows engineers to predict how loud the warning signal will sound to a pedestrian standing in between the parked vehicles. As shown in figure 13, the presence of the two vehicles shields the area where the pedestrian is located, creating increased risk. Thanks to advanced numerical methods used for the acoustic simulations, such a performance assessment can be carried out quickly, and many designs can be evaluated up-front for any physical prototype, thus reducing the total development cost.

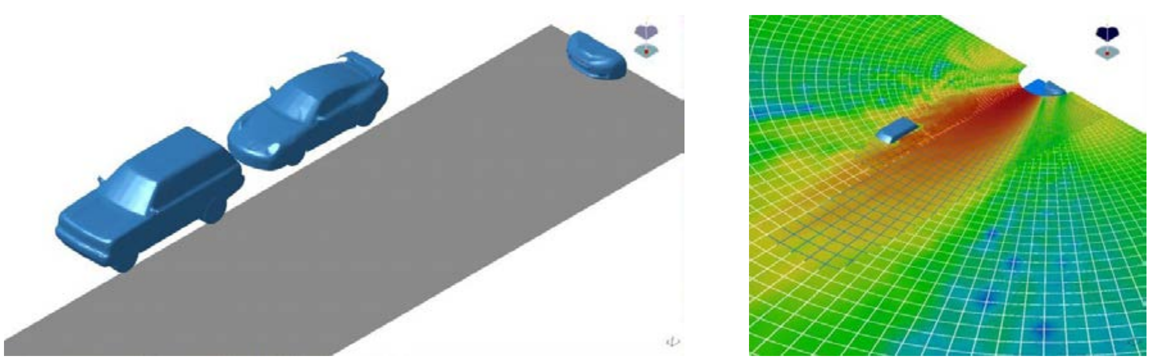


Figure 13: Impact of road surface impedance and nearby scattering objects on beam-forming performance. Left: H-matrix BEM model discretization. Right: Spatial distribution of the acoustic pressure field at 600 Hz.

Validate and tune sound models on prototypes or mule

Whatever sounds great in the sound studio, needs to be validated in the car. Physical testing of the sound quality of the AVAS system on the vehicle prototype is an important aspect. In this step, the designed AVAS sound model is tested for different vehicle driving scenarios. To test this, the sound model needs to interact with the vehicle can bus to get all relevant vehicle parameters, such as vehicle speed and torque. In many cases, different sound model variants need to be tested and evaluated. It can even be of interest to still further tune the sound models. This is also an important step for validating possible interior active sounds.

Simcenter Testlab Sound Designer offers the required hardware component in support of this process. To evaluate the AVAS sound models, a dedicated production model AVAS speaker is available on which one or more designed model can be loaded. The speaker connects through the vehicle can bus and can be attached on one or more different locations of the prototype vehicle to evaluate the model. Alternatively, when the AVAS sound is played over a passive speaker and synthesized on the on-board audio DSP or head unit, then a dedicated development vehicle unit can be used. This unit is also popular when testing designed sound for interior sound enhancement.

Both hardware components are shown in figure 14.

Figure 14: Simcenter Testlab Sound Designer hardware. Left: AVAS speaker for AVAS sound model validation. Right: interior sound enhancement validation system.

Complying with the regulation

Finally, AVAS systems have to be certified according to a pass-by noise (PBN) testing standard. The most well-known PBN tests is UNECE Regulation 51.3., which imposes a maximum noise level on vehicles passing by in an urban environment. As AVAS systems add sound to (H)EVs, new standards are created to certify a minimum noise level for VRUs: UNECE Regulation 138 (R138) is applied worldwide with the exception of the United States. AVAS has been mandatory for type-tested cars since July 2019. The same will be true for all newly registered electrified passenger cars starting on July 1, 2021, according to EU and UNECE regulations. The National Highway Traffic Safety Administration (NHTSA) test FMVSS 141 applied in the United States starting in September 2020.

A typical setup of R138 is shown in figure 15. Two microphones are positioned only 2 m from the center of the vehicle. R138 tests the AVAS system for:

- Forward constant speed driving at 10 and 20 km/h, as well as reverse driving at 6km/h. These tests require a minimum noise level in at least two third-octave bands, of which one band shall be below 1,600Hz
- A frequency shift test where increasing pitch of a particular tone at different speeds allows VRUs to identify if an HEV is accelerating, and, if it is, how fast is it going

The U.S. regulation FMVSS 141 adds 30km/h constant speed, and requires a more complex assessment, in which several nonadjacent third-octave bands have to comply. Both regulations can be calculated with the same datasets, making testing efforts more efficient. A typical report can be seen in figure 16.

For R138, automotive OEMs have a choice to test these conditions on the outdoor PBN test track or in indoor facilities. Some tests allow the user to choose whether to physically test the vehicle in motion, or to simulate this condition; for example, by applying the required operational conditions through a digital bus system so the AVAS system operates as if the vehicle was driving. FMVVS 141 has to be tested outside exclusively.

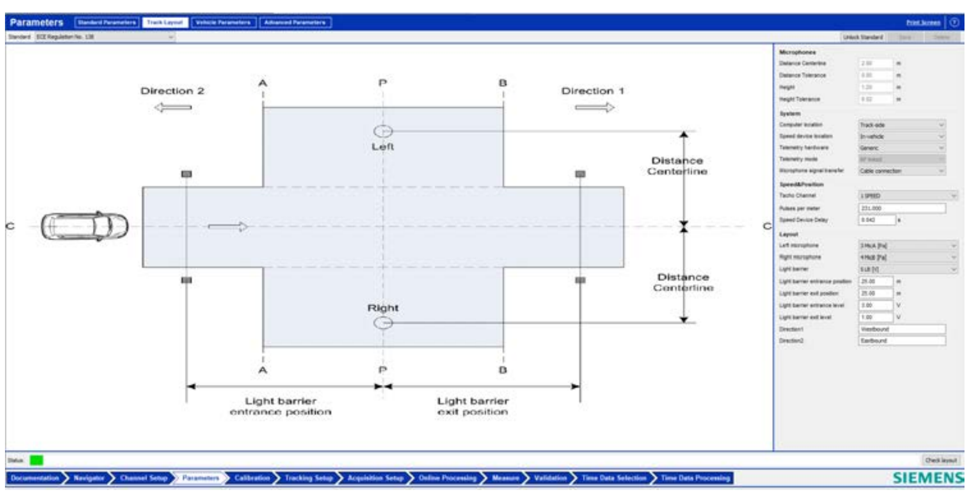


Figure 15: Siemens' Simcenter Testlab application with typical test track layout for UNECE Regulation 138.

NHTSA

Minimum Sound Requirements for Hybrid and Electric Vehicles IAW 49 CFR § 571.141
Quiet Vehicle Compliance Tool - Summary Log

Testing Data		Operating Conditions	4 Band (S5.1)		2 Band (S5.2)		Test Result	Relative Volume Change (S5.4)	Low Side Location	Relevant Signal Files			
Vehicle Information			# of Passing Band Combinations	Result	# of Passing Band Combinations	Result	Best Result of 4 OR 2 Band Columns						
Year	2020	1. Stationary	0	Fail	1	Pass	Pass		Passenger	ProvingGround_20200129_0001_Make_Model_2020_EV_Stationary_002.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_Stationary_003.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_Stationary_004.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_Stationary_005.wav
Make	MyVehicle	ᴸ Directivity	0	Fail	2	Pass	Pass		Front	ProvingGround_20200129_0001_Make_Model_2020_EV_Stationary_002.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_Stationary_003.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_Stationary_004.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_Stationary_005.wav
Model	Model1	2. Reverse	0	Fail	1	Pass	Pass		Passenger	ProvingGround_20200129_0001_Make_Model_2020_EV_Reverse_001.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_Reverse_002.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_Reverse_003.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_Reverse_004.wav
NHTSA No.	-	3. 11 km/h +/- 1	0	Fail	2	Pass	Pass	Pass	Driver	ProvingGround_20200129_0001_Make_Model_2020_EV_10Passby_002.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_10Passby_003.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_10Passby_004.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_10Passby_005.wav
VIN	-	4. 21 km/h +/- 1	0	Fail	10	Pass	Pass	Pass	Passenger	ProvingGround_20200129_0001_Make_Model_2020_EV_20Passby_002.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_20Passby_003.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_20Passby_005.wav	ProvingGround_20200129_0001_Make_Model_2020_EV_20Passby_007.wav
		5. 31 km/h +/- 1	0	Fail	10	Pass	Pass	Pass	Passenger	ProvingGround_	ProvingGround_	ProvingGround_	ProvingGround_
User Comments		*Optional Tests*											
-		*6. Between 10-20 km/h*											
		7. Between 20-30 km/h											
					OVERALL RESULT		Pass						

Quiet Vehicle Compliance Tool Version: Beta 1

Figure 16: Typical report for R138 and FMVSS 141: a single measurement campaign can be analyzed for both regulations.

Conclusion

An acoustic vehicle alerting system will be mandatory for all newly registered electrified passenger cars starting in July 2021. As complying with AVAS regulations becomes the standard, manufacturers will leverage AVAS and design for a brand sound.

This paper has shown how integrating simulation and testing delivers the best results for designing the right exterior sound and assessing its performance. To consolidate the AVAS system into the vehicle and properly evaluate alternatives, the AVAS system was tested and implemented on the development vehicle, while virtual validation was carried out for optimizing both geometrical, acoustical and control aspects. The scope of AVAS designs can cover changes in sound content as well as parameters that affect the sound propagation or sound transfer.

With regards to sound propagation or sound transfer, this white paper has illustrated how acoustic simulations allow you to assess the effects of multiple designs in a quick and effective manner. Using advanced FEM, BEM and ray tracing approaches, several designs can be virtually evaluated and combined with beam forming methods to achieve a performing AVAS.

With ever more electric vehicles being produced, AVAS and active sound design will continue to define and shape the sound landscape of urban areas in the next decades.

References

1. European regulation for Acoustic Vehicle Alerting System: https://ec.europa.eu/transparency/regdoc/rep/3/2017/EN/C-2017-4296-F1-EN-ANNEX-1-PART-1.PDF
2. Critical Pedestrian Safety Legislation Moves to White House for President's Signature: https://www.prnewswire.com/news-releases/critical-pedestrian-safety-legislation-moves-to-white-house-for-presidents-signature-112016879.html
3. Minimum Sound Requirements for Hybrid and Electric Vehicles: https://www.nhtsa.gov/staticfiles/rulemaking/pdf/QuietCar_FinalRule_11142016.pdf
4. Van der Auweraer H., Janssens K., Sabbatini D., Sana E., "Electric Vehicle Exterior Sound and Sound Source Design for Increased Safety," Internoise 2011, Sept 4-7, 2011, Osaka, Japan.
5. Vansant K., Bériot H., Bertolini C., Miccoli G., "An Update and Comparative Study of Acoustic Modeling and Solver Technologies in View of Pass-By Noise Simulation," SAE paper at the ISNVH conference 2014, Graz, Austria.
6. Bosmans I., Tocarciuc A., Rissler K., Brombach A., "Acoustic simulation for evaluating loudspeaker location for pedestrian warning systems in EV/HEV," ISMA 2014, Leuven, Belgium.
7. Van Genechten B., Vansant K., Berkhoff A., "Simulation-based design of a steerable acoustic warning device to increase (H)EV detectability while reducing urban noise pollution," Transport Research Arena (TRA) 2014, Paris, France.
8. UN ECE Regulation 138 Rev 1. Uniform provisions concerning the approval of Quiet Road Transport Vehicles with regard to their reduced audibility: https://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/2017/R138r1e.pdf

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