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VEHICLE EXTERIOR NOISE SIMULATION

Georg Eisele*, Norbert Alt and Fabienne Pichot

FEV Motorentechnik GmbH, Vehicle Physics Acoustics Department,
Neuenhofstraße 181, 52078, Germany
eisele@fev.com

Abstract

Currently, the exterior pass-by noise level during acceleration is the only legal limit in vehicle acoustics. In an effort to further reduce noise emissions, a tightening of limit values and/or procedures is to be expected. Pass-by noise simulation can support the design activities of car manufactures in this field. It is based on the measurement of the individual noise sources and the corresponding airborne noise transfer functions. Important noise sources include for instance the engine, the intake orifice, the exhaust orifice as well as the tires. The transfer functions depend on the position of the vehicle and are measured reciprocal. In the simulation, the individual excitations are synchronized and filtered by applying the transfer functions. Thus, the total noise can be assigend to the individual noise paths and the individual noise paths can be analyzed with regard to excitation, transfer behavior and frequency content. Thus, development efforts can be focused on the dominant noise sources and the weak points of the vehicle and the engine.

INTRODUCTION

Especially in densely populated areas, environmental pollution due to exhaust gas and noise emissions caused by road traffic poses a serious problem. In the past few decades, exhaust gas pollutants have been considerably reduced, incited by – among other reasons – legislative measures. This process, however, is approaching its natural limitations. It can be assumed that in the future the reduction of noise emissions due to vehicles will grow in importance. One sign for this development is, for instance, the planned tightening of the legal guidelines for the pass-by noise measurement procedure.

The automotive industry's efforts to build quieter vehicles can be supported by the Vehicle Exterior Noise Simulation (VENS). With this procedure, the exterior noise of a vehicle can be calculated and the noise components due to the individual sources can be analyzed at an early stage of the development process. This facilitates

the evaluation of modifications to individual vehicle components regarding exterior noise. We will demonstrate this in the following by the example of the pass-by measurement according to ISO 362.

PASS-BY NOISE MEASUREMENT AND THE PRINCIPLE OF NOISE SIMULATION

In the pass-by noise measurement according to ISO 362, the vehicle noise is acquired by a microphone on every side of the vehicle [1] (Fig. 1). The vehicle drives into a standardized testing route with a speed of 50 km/h. At 10 m from the microphone position, it starts accelerating until the end of the vehicle has left the testing route of 20°m.

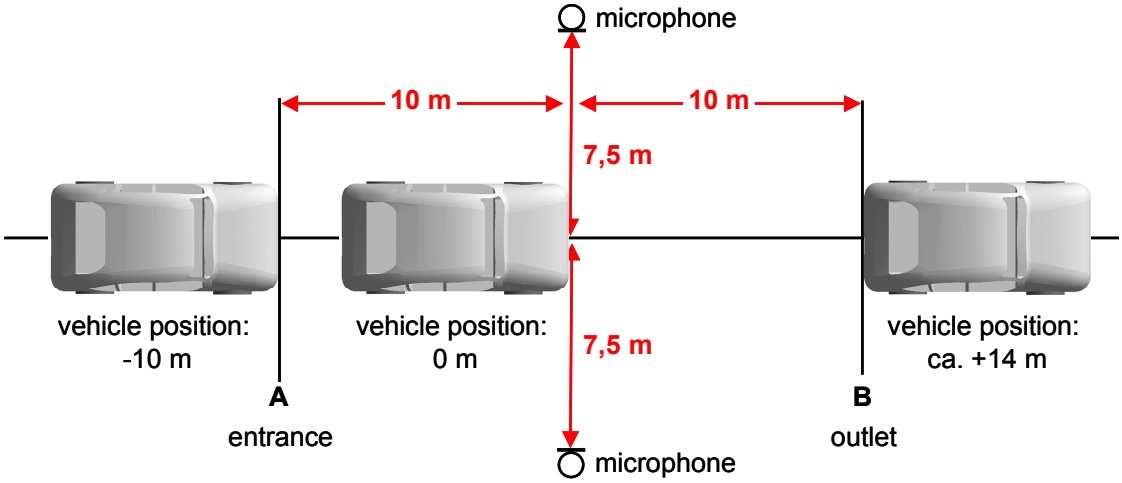

Figure 1:Pass-by Noise Measurement According to ISO 362 – Schematic Setup

The required input parameters for the simulation of the pass-by noise (VENS: Vehicle Exterior Noise Simulation, Fig. 2) are measured or calculated data on the vehicle behavior (vehicle position, vehicle speed, engine speed), the noise sources (tires, engine, intake noise, exhaust noise) and the corresponding transfer functions (engine compartment attenuation, sound propagation). The components due to the individual noise sources in the pass-by noise are determined by a calculation program based on Matlab. With this procedure, the individual noise sources are synchronized and filtered by the transfer functions which depend on the vehicle position. The summation of the noise components yields the total pass-by noise.

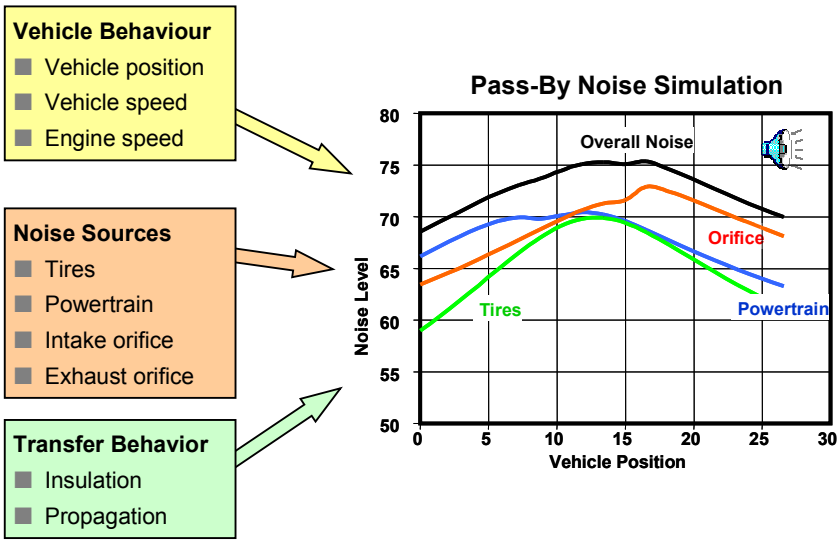

Figure 2: Input Parameters for the Simulation of the Pass-by Noise

The calculation is performed in a similar manner as the vehicle interior noise simulation (VINS) which is in use as a standard method for some time already [2], [3]. However, there are some noteworthy differences. In VENS there is no structure-borne noise, the airborne noise transfer functions depend on the position of the vehilce and the Doppler effect must be considered.

NOISE SOURCES

The noise sources can be determined independently from the real conditions of the pass-by noise measurement (Fig. 3).

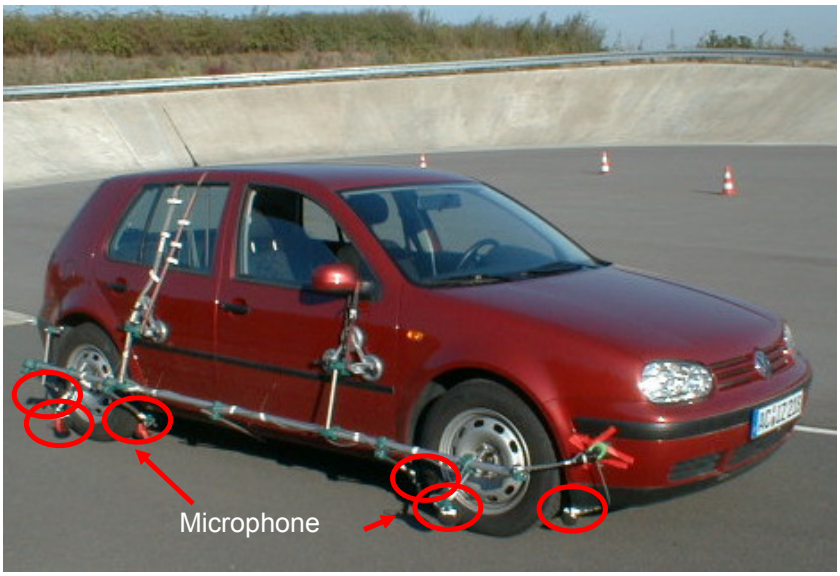

Figure 3: Measurement of Tire Noise on the Road or on the Test Bench

As a rule, the measurement of engine airborne noise is performed on the engine test bench, the orifice noise of the intake and the exhaust system are measured on the vehicle test bench or are determined by 1-D-CFD calculations, and the tire noise is measured in a vehicle test on the road or on the test bench.

Alternatively, excitation data from existing data banks can be used. The tire noise, for instance, does not depend very much on the vehicle and thus needs not to be measured for every vehicle. Further noise sources such as for example surface noise radiation of exhaust system components can also be considered.

TRANSFER PATHS

The airborne noise measurement is performed reciprocally with maximum sequence excitation (Fig. 4).

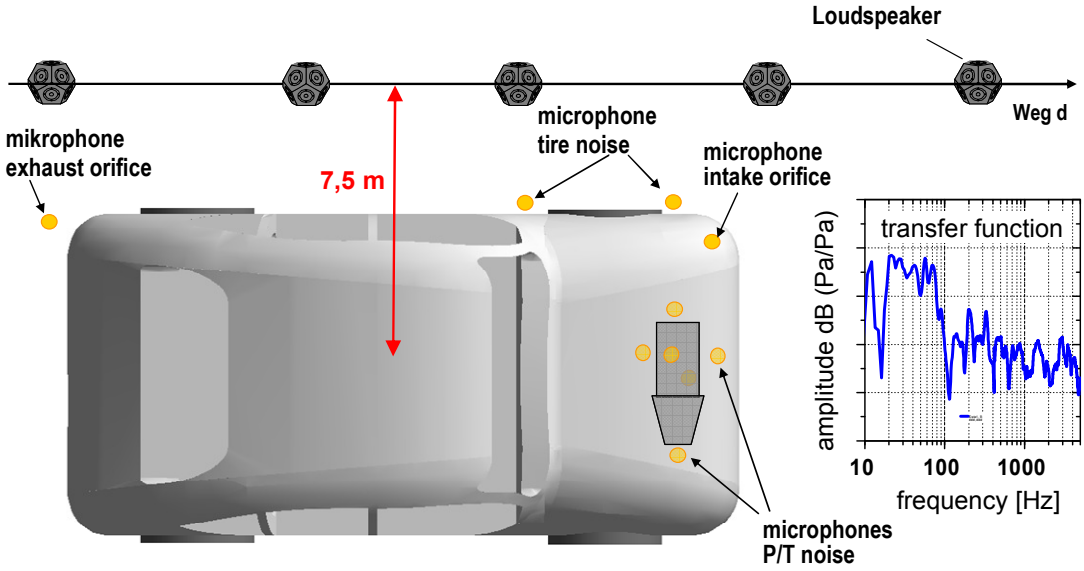

Figure 4: Reciprocal Measurement of the Transfer Functions for the Individual Sources and Vehicle Positions

For the reciprocal measurement the loudspeaker is in the position that corresponds to the position of the microphone during pass-by. The microphones are in the locations of the examined sources: 6 sides of the engine, intake orifice, exhaust orifice, 4 tires. The loudspeaker position is varied in several steps according to the pass-by situation. Figure 5 shows as an example the change of the transfer function versus the vehicle position. Regarding the sources intake and exhaust orifice, which are depicted here, the covering effects are clearly noticeable.

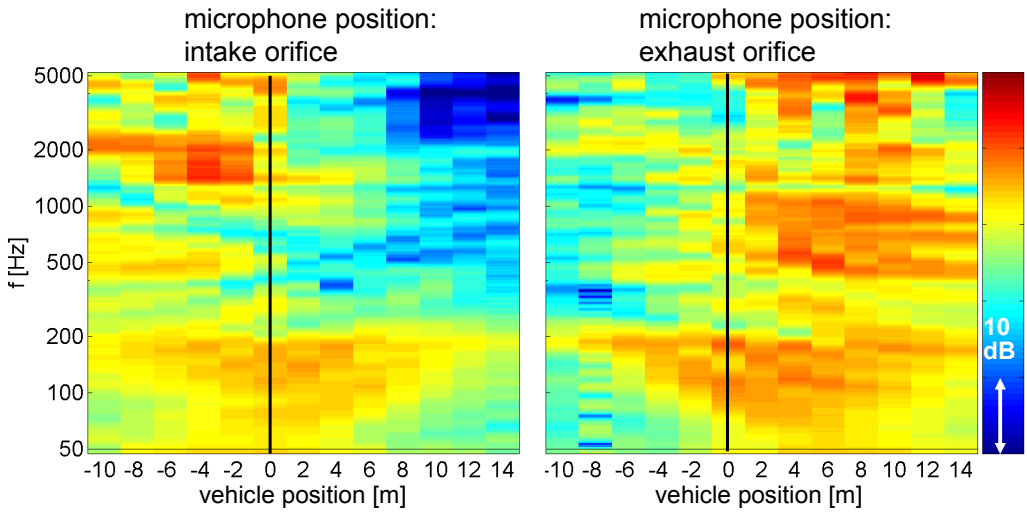

Figure 5: The Transfer Functions of the Orifice Noise Are Strongly Influenced by Vehicle Covering Effects

SIMULATION RESULTS

Figure 6 shows a good correlation between the simulated and the measured pass-by noise. The strongest noise source is the powertrain and in this example it is situated approximately 2 to 3 dB above the tire noise level. As could be expected, the orifice noise makes a signficant contribution especially in the first part of the measurement route, whereas the same can be said for the exhaust orifice during the vehicle's exit.

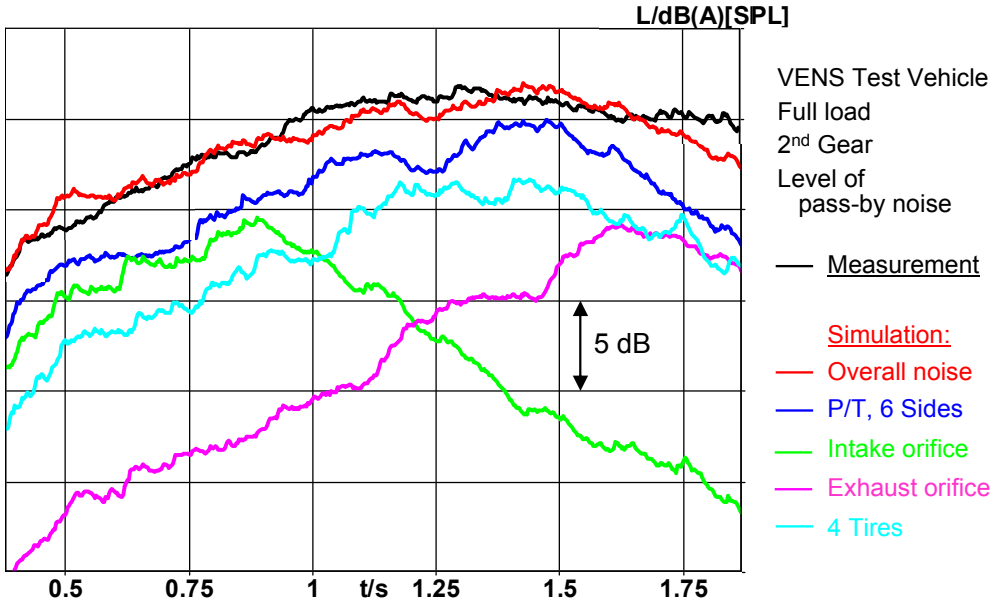

Figure 6: Comparision of Measured and Simulated Pass-by Noise

SUMMARY

Currently the exterior noise level of the accelerated pass-by measurement is the only legal limit for vehicle acoustics. Within the scope of further noise emission reduction efforts, a tightening of limits and/or of the procedure can be expected.

Pass-by noise simulation can support the development activities of car manufactures in this field. It is based on the measurment of the individual noise source components, such as engine, intake orifice, exhaust orifice and tires. The transfer functions depend on the position of the vehicle and are measured reciprocally.

In the simulation, the individual excitations are synchronized and filtered by the transfer functions. Thus, the total noise can be traced back to the individual transfer paths and the individual transfer paths can be analyzed with regard to excitation, transfer behavior and frequency content.

Thus development work can focus on the dominant components and the weak points of the vehicle and the engine.

REFERENCES

[1] ISO 362: Acoustics - Measurement of noise emitted by accelerating road vehicles - Engineering method, International Organization for Standardization

[2] Alt, N., Wiehagen N., Schlitzer M. W., “Interior Noise Simulation for Improved Vehicle Sound”, SAE-Paper 2001-01-1539

[3] Georg Eisele, Klaus Wolff, Norbert Alt, Michel Hüser, „Application of Vehicle Interior Noise Simulation (VINS) for NVH Analysis of a Passenger Car”, SAE-Paper 2005-01-2514