Abstimmung auditiver Anzeigen für Fahrerassistenzsystme – Adjustment of Auditory Displays for Driver Assistance Systems

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ABSTRACT

During the last decade the application of driver assistance systems has become an important part in passenger cars. The goal is to provide the car driver with an optimal amount of information, which can be reached by using multimodal interfaces. During the development process of such a new assistance application with acoustic feedback, it is necessary to accurately prove for correct leveling and sound tuning to achieve an appropriate, stable and qualitatively outstanding auditory display.

Many in-vehicle information systems (IVIS) and advanced driver assistance systems (ADAS) use pure tones to present auditory information. In practice, the acoustics of small rooms hold a couple of challenges. Especially measuring sound pressure levels of pure tones above the Schroeder frequency in enclosed spaces, e.g. inside car cabins, is an arduous task because single-point microphone measurements do not provide enough spatial stability to conclude a corresponding average sound pressure level.

In this paper, we propose how to accurately measure corresponding sound pressure levels of arbitrary in-vehicle auditory presentations using a multichannel microphone setup. Listening tests were conducted inside car cabins to validate the derived methods.

INTRODUCTION

It has been proven useful for many car manufacturers to take advantage of the cars entertainment system to present auditory information for in-vehicle information systems (IVIS) and advanced driver assistance systems (ADAS).

With the use of the entertainment systems the auditory information can be integrated in more complex concepts of concurrent presentation and mixing of different audio sources is achieved while guaranteeing high quality overall sound reproduction. For every car model and entertainment system configuration, the sound levels of such auditory information needs to be adjusted due to differences in the general loudspeaker setup as well as in the functionality of the head-unit and sound amplifiers, respectively.

Sound engineers at BMWs research & development facilities employ and confirm subjective adjustments of sound levels for the various auditory stimuli in each and every new car model and entertainment system for a multiplicity of scenarios during the development process. Recently, the range of car models has expanded and the configuration options for entertainment systems have increased to accommodate for individual customization making objective microphone measurements inevitable.

Car Interior Acoustics

It is important to keep in mind some aspects regarding the acoustics of small rooms. In a small enclosed space, e.g. inside a car, the Schroeder frequency [1] is about 150-200 Hz and depends on the reverberation time T_{60} as well as on the volume V. For pure tones above the Schroeder frequency more and more room modes are excited. The result of many virtually random modes being added will be a Gaussian distribution in both the real and the imaginary parts (phase and amplitude of sound pressure level) and imply that the statistical properties of all rooms above the Schroeder frequency are basically identical and resulting in a Rayleigh distribution of sound pressure levels [2]. This accounts for the much higher likelihood of measuring a sound pressure value that is too low than too high [3].

Ear Ellipsoid

The ear ellipsoid defines the 99th percentile area where the listeners head and thus the ears inside the car cabin will be (figure 1) positioned. This volume can easily be calculated using digital car construction data from computer aided design in conjunction with software tools normally used for ergonomic simulations [4].

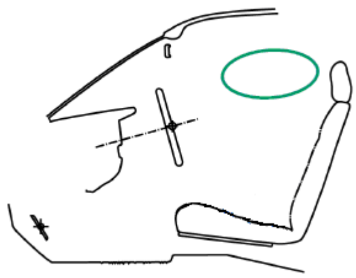

Figure 1: Sectional view of possible positions of the ear represented by the ear ellipsoid (green line) inside a car (driver’s seat).

MEASUREMENT-BASED APPROACH

The aim is to get an objective measure for already adjusted sound levels of auditory information from IVIS/ADAS inside the car. Therefore we propose an approach by recording (A-weighted) sound pressure levels at a sufficient number of discrete points inside the ear ellipsoid which was also suggested in [2]. In practice this can only be managed effectively in terms of time consumption and practicability by using a specially designed setup as described below [5].

Construction and Setup

The basis of the derived system is a lightweight construction made up of aluminum profiles to hold eight omni-directional measurement microphones. The setup is attached to the headrest of the driver's seat. This concept allows for rapid (de)mounting inside the car. We also ensure that all measurement points are at least 15 cm away from adjacent walls and windows to avoid that the microphones indicate a pressure level which is higher by up to 3 dB [6].

We use an eight microphone spatial average at three defined positions of the driver's seat spaced 15 cm apart (ear ellipsoid) resulting in a total number of 24 measurement points to quantify the steady state sound field inside the car. For measurement points to be spatially uncorrelated with each other they need to be separated by at least a half-wavelength of the analyzed frequency [3]. A distance between the microphones of at least 12 cm is implemented as shown in figure 2.

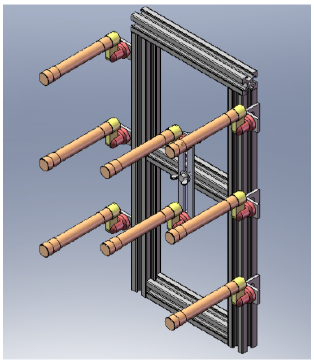

Figure 2: The setup consisting of eight omni-directional measurement microphones that are attached to the headrest inside the car to quantify the steady state sound field.

Measurements

The analysis task results in a spread of sound pressure levels of approximately 15 dB for pure tones between the 24 aforementioned measurement points (excitation with 1 and 1,5 kHz representing existing auditory information). This demonstrates that single point measurements are not stable. The arithmetic mean of all 24 measured sound pressure levels can be used as a first estimate of an average sound pressure level for the volume of the ear ellipsoid. The linear relationship between the calculated average and different excitation levels (increments) is illustrated in figure 3.

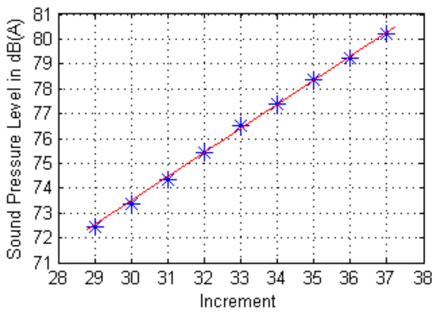

Figure 3: The linear relationship between the calculated weighted sound pressure level from 24 measurement points and the system excitation level (increments).

VALIDATION

Subjective listening tests were carried out to validate the proposed methods. The audio systems of two different cars were adjusted by using the measurement described within this paper, thus enabling the playback of auditory information with predefined deviations in average sound pressure levels of 0, 2 or 4 dB (1,5 kHz signal). A random test set of 10 items was prepared and 4 subjects were asked to compare the sound level inside the cars with possible answers being identical, different or widely different. In a set of two the subjects were able to detect 38 and 39 out of 40 test cases. The well trained subjects (sound engineers) where able to continuously detect the 0 dB difference in all test cases thus allowing the conclusion, that an exact and stable measurement can be achieved with this setup.

In the example given here we need to draw comparisons between identical and well defined and simple source signals only (single-frequency sinusoids). Therefore, it is valid to use A-weighted sound pressure levels in the analysis. Note that for a comparison of different and possibly unknown signals one would need to apply more complex psychoacoustic models.

CONCLUSIONS

In this paper we have presented a multichannel microphone setup for fast, stable and reproducible average sound pressure level measurements of pure tones above the Schroeder frequency in small enclosed spaces like car cabins.

As a result of the listening tests in cars, the correct and stable functionality of the applied methods has been shown. Besides acoustical purposes the system can also offer decisive advantages to production-related quality control. The overall consistency of average sound pressure levels of auditory information in different car cabins, e.g. car models, can significantly be increased.

References

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