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Measurement and Possible Solutions of the Non-uniform Sound Field in the Automotive Industry

Ladislav Zuzjak[1]; Oldrich Turecek[2]

[1,2] University of West Bohemia, Faculty of Electrical Engineering, Regional Innovation Centre for Electrical Engineering (RICE), Plzen, Czech Republic

ABSTRACT

A high-quality car sound system is important for comfortable listening. At the present, the sound systems in the automotive are realized using multiway loudspeaker systems positioned at different distances of the listening positions. This different placement of the loudspeakers causes strong non-uniform frequency distribution of the sound field. The possibility of the placement of the loudspeakers into the optimal position in the car is limited and very often it is not possible. Thus, it is necessary to solve the consequences of the inappropriate position of the loudspeakers on the sound field using sophisticated digital signal processing.
In this paper, we focus on the measurement of the distribution of the sound field in various listening positions in the car. Attention is also paid to the compensation of the non-uniform sound field. Primarily, these compensations can be performed using the frequency and dynamical corrections. Another option is to change the delay of the signal for each loudspeaker separately.
This topic is very complex because the listening positions are placed in the near field of the multiway loudspeaker systems, where the distances between the loudspeakers are often close to or larger than the distance between the listening position and the loudspeaker.

Keywords: Sound, Localization, Transmission, Array I-INCE Classification of Subjects Number(s): 74.6

1. INTRODUCTION

At present there is an evident increasing trend in the requirements on the quality of the multimedia reproduction in car cabins. This trend is primarily due to the large amounts of multimedia features that are now commonly available in the cars.

The construction of the loudspeakers used in cars is typically electrodynamic. These loudspeakers are modificated for the automotive industry. The modifications of the loudspeakers are most commonly based on the different material of the membrane (enhanced humidity resistance), special magnetic circuits made of NdFeB alloy (in the case of requirement of the low mass) and plastic material baskets made of PP, PC + GF, ABS or similar.

In the car cabins the position of the loudspeakers is strongly affected by limited space, safety requirements and by the design of the interior as well. Limited possibility of the placement of the loudspeakers is determined primarily by the effort of the constructors to maximize the usage of the space of the car cabin for the comfort of the crew. In terms of the safety it is very important to design the baskets of the loudspeakers in such way, that the magnetic circuit of the loudspeaker shouldn´t separate during the crash. The loudspeakers and their grids shouldn´t disturb the integrity of the design of the interior of the cabin.

These limitations cause serious problems with the quality of the sound reproduction. One of possible solutions how to improve the sound reproduction is to make a detailed analysis of the sound field inside of the cabin and based on this analysis to propose subsequent signal path adjustment in digital signal processing (DSP).

[1] zuzjak@ket.zcu.cz
[2] turecek@ket.zcu.cz

2. METHOD FOR MEASUREMENT OF THE SOUND FIELD IN THE CAR CABIN

For the measurement of the sound field inside of the cabin it is not possible to use modern methods such as acoustic cameras (based on the principle of NAH, Beamforming, SONAH, etc. algorithms). These methods can´t be used because of the limited space inside the cabin, thus the distance of the sources is also limited and secondly the composition of the materials in the cabin is unsuitable (hard plastic surfaces and leather seats strongly reflect acoustic waves).

Measurement of the properties of the acoustic field in the car cabin is of key importance in the site of the assumed listening (in the site of the listener heads). In order to improve the distribution of the sound field it is possible from obtained parameters by additional analyzes determine the necessary adjustments in the signal path using DPS.

For the detailed measurement the microphone array with a large number of microphones is used. This setup allows measuring of the acoustic field in small steps for a large area (1).

The main aim of our research is to develop measurement method (similar to Nowak J. and Strauss M. (1)) which can measure properties of the acoustics field in a limited range (not the whole car, but only the site of the listener) and will be applicable for in-situ analysis in the car cabin. These demands are based on demand of deployment of this method in serial car, where it is necessary to get the properties of the acoustic field in relatively short time and subsequently use these properties for the feedback for the changes in the signal path.

For the measurement of the acoustic field it is possible to use some of the features of the acoustic cameras – especially in terms of measurement microphones, some mechanical components (microphone holders) and parts of the signal processing (A/D convertor).

Further software signal processing will be designed and reprogrammed with respect to specific application.

For microphones used in acoustic cameras are important especially these parameters (they are also important for the measurement of the acoustic field):

- phase characteristics,
- frequency characteristics in the prescribed range,
- sensitivity,
- low cost.

Mechanical components of the acoustic cameras are usually modularly constructed. Producers of these cameras supply individual parts separately, which makes the construction of the microphone array easier (see Figure 1).

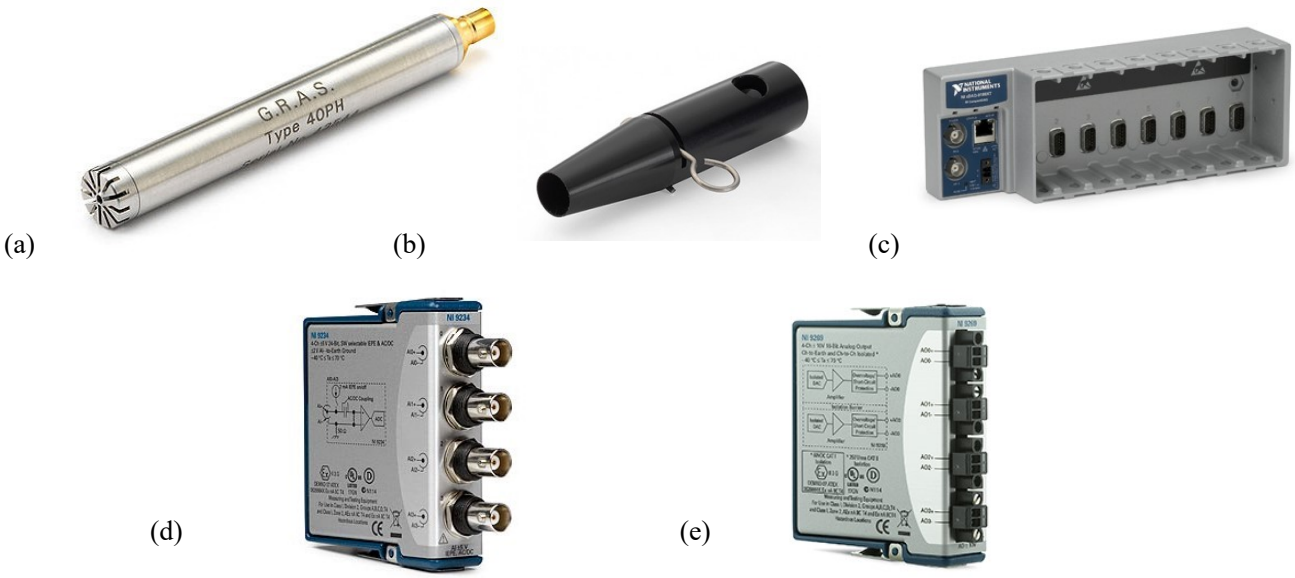

Figure 1 – Mechanical components of acoustic cameras (a) microphone GRAS PH40, (b) microphone holder RA 0185, (c) 8-slot NI cDAQ-9188, (d) input module NI 9234 and (e) output module NI 9269.

Measurement microphones will be connected into the input modules (National Instruments type 9234), which can provide the necessary power constant current (IEPE). A signal generator will be used the input modules National Instruments 9269. Number of the output modules will be variable according to the number of the loudspeakers in the car cabin. The 8-slot NI cDAQ-9188 will be used for connection input and output modules and also for the connection to the computer. Complete measurement system is fully portable. Block diagram of the measurement system is shown in Figure 2.

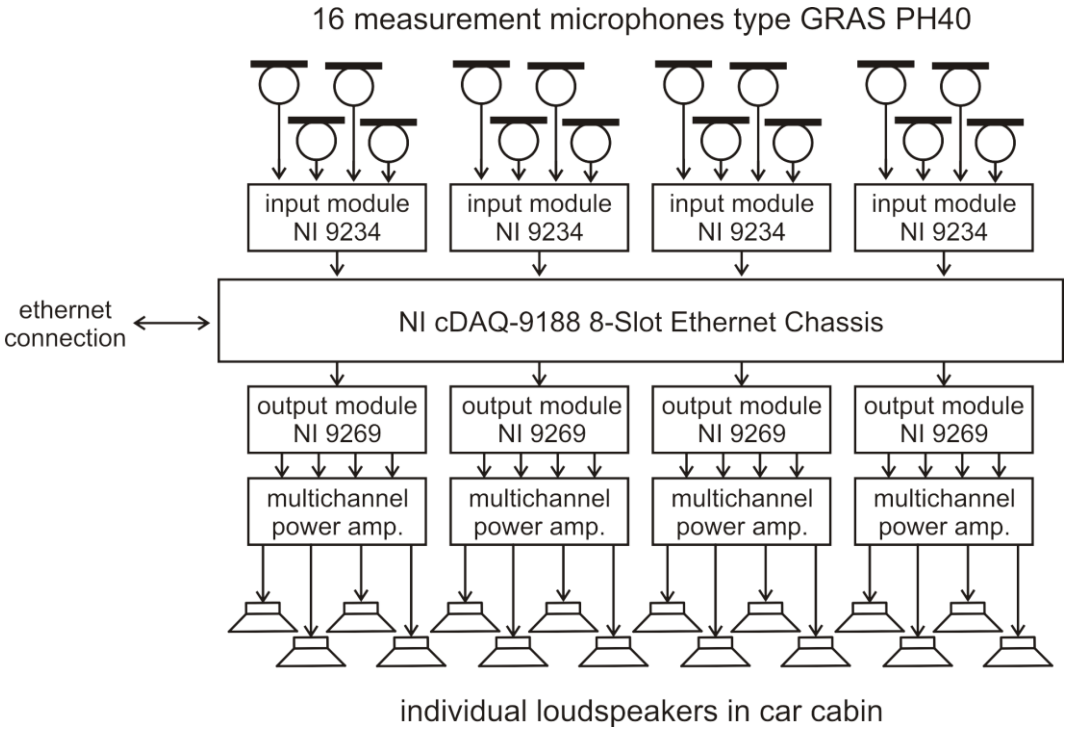

Figure 2 – A block diagram of the measurement system.

3. CONCLUSIONS

The main aim of this paper was to describe design of the measurement system for the analysis of the sound field inside of the car cabin. This method will be in-situ and it will be fast and portable. Designed measurement method provides a sufficiently detailed description of the acoustic field and it allows get important parameters of the acoustic fields such as transmission frequency and phase characteristics including the impulse response of the measuring chain and car cabin.

ACKNOWLEDGEMENTS

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1. Nowak J, Strauss M. Sound Field Reproduction Analysis in a Car Cabin Based on Microphone Array Measurements. AES Convention paper presented at the 48th International Conference: Automotive Audio; Munich, Germany, 2012.