Optimization of the measurement system for determination of the diffusion and reflection coefficients

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Summary

This paper focuses on a new design of the measurement system for the characterization of reflective materials. The main aim of this work was to effectively and reproducibly measure the diffusion and reflection coefficient. Presented measurement system allows to provide the multichannel synchronization record from 47 microphones in the real-time. The measurement system consists of the microphone frame, connection cables and electronic devices (for amplifying, converting, processing of the signals etc.). The microphones are distributed uniformly in the frame with the shape of the semicircle with the radius of 5 m. This fixed microphone frame ensures the reproducibility of each measurement. The frame is multifunctional: (1) mechanical protection, (2) electrical connection and (3) it ensures the first stage of amplifier and it also provides the power supply for the microphones. The frame can be also decomposed into smaller parts for easy transport. Because of the very low value of the noise background it is possible to use this system in spaces commonly used for the characterization of the diffusers. The measurement in the real hall demonstrated the applicability of this system in the common practice.

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1. Introduction

Acoustic materials are widely used for modifying of the room acoustics. The possibility of tuning the room acoustics is very important in areas such as concert halls, sound studios, lecture rooms etc. Acoustic materials can be divided into two groups: absorbers and reflective materials. Each of these groups of materials can be characterized by different coefficients. In the case of the reflective materials it is the diffusion and reflection coefficient. Both coefficients are determined by the impulse response of the reflective materials (it is necessary to have high signal-to-noise ratio). The method which is used for measuring of the diffusion and reflection coefficients can be found in [1]. This method is based on the measurement of down scaled prototype of the reflective material. In this case, it is necessary to multiply the frequency of the measurement signal by relevant coefficient. This paper focuses on the new design of the measurement system for the characterization of reflective materials. The main aim is to reduce the time needed for the measurement and design of the portable system for the reproducible measurement in scale 1:1 without scaling down and without the need of producing of the prototype. The output data from the newly designed measurement system also allow to increase the accuracy of the mathematical model [2] developed in the software Agros2D [3].

2. The measurement system

2.1. Design of the measurement system

The new measurement system is designed to characterize of the reflective materials, such as diffusers, with the size 600×600 mm. Figure 1 shows the representation of the specular zone. The scheme of the measurement system is shown in Figure 2. The size of the diffuser (600×600 mm) and the condition under which 80% of the microphones should be out of the specular zone [4], specify the parameters of the measurement system, which are as follows:

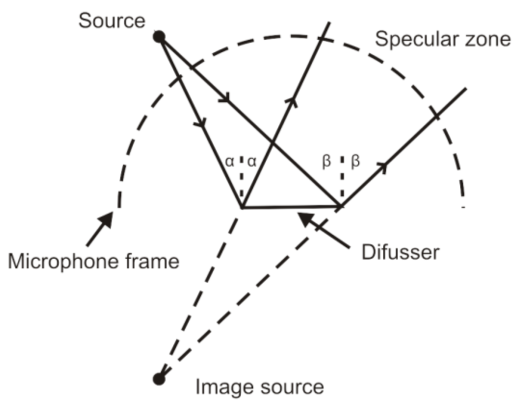

Figure 1. The schematic representation of the specular zone.

1. the distance between the diffuser and the microphones on the microphone frame, i.e. the radius *R1*,
2. the distance between the diffuser and the source of the measured signal (loudspeaker) *R2* = 2 × *R1*.

In order to cover the entire area (180°), 5 loudspeakers were used (each covering 30°). For the high resolution of the measurement method 47 microphones were uniformly distributed on the frame (the angle between the two microphones is 3.8°). This system should be used in the simulated free field [1], thus it is very important to abide by the condition that the measurement system can be used only in large spaces.

2.2. The microphone frame

The radius of the microphone array is 5 m (the total length of the frame is approximately 15.8 m). In order to design the portable measurement system it is necessary to separate the frame into several parts. The length of each part of 1 m is sufficient for comfortable transport, hence the frame was divided into 16 parts. The total width of the frame is 210 mm and the height is only 22 mm. The medium-density fibreboard (MDF) was proof the most suitable material. This material has affordable price and it is well machinable. It also has good acoustic properties e.g. high internal dumping. Each part of the frame includes 3 uniformly distributed microphones. For better protection against mechanical damage, all microphones were imbedded into the frames. The effect of the location of the microphones on their acoustic properties was discussed in [5]. It was found that imbedded microphones show slightly different behavior, but this difference is not essential for their proper work in the frame. In [5] the method for finding the suitable microphones for the measurement system was also discussed. The microphones Shure MX150B-TQC were found as the most suitable, thus all 47 microphones in the microphone frame are of this type. For every 3 microphones, each part of the frame has the electronics for power supply and for amplifying of the signal. The block diagram of the electronics in one part of the microphone frame is shown in Figure 3. This electronics also allows to set the position of the 3 microphones in the microphone frame and thus all the parts of the

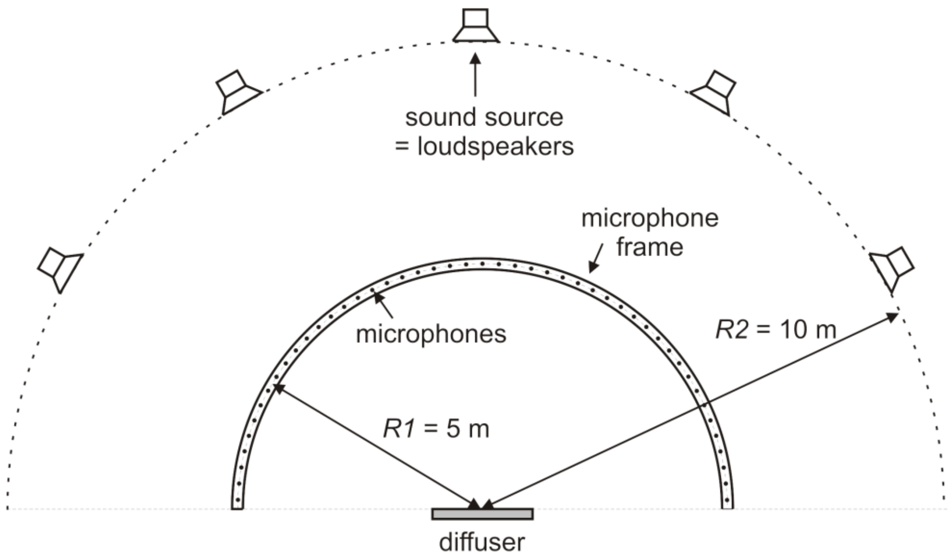

Figure 2. The scheme of the measurement system for the characterization of the diffuser with the size 600×600 mm.

frame have interchangeable position. The connection of the individual parts of the frame is ensured by 50-pin Mini D Ribbon connectors.

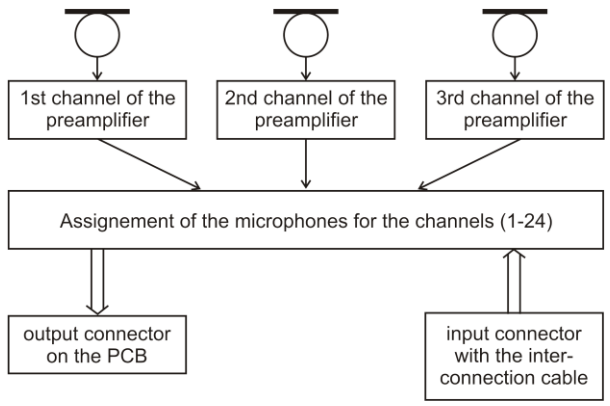

Figure 3. The block diagram of the electronics in one part of the microphone frame.

2.3. The measurement unit

The second part of the measurement system is the measurement unit. The microphone frame is connected to the measurement unit using the multipar cable. The total length of the cable is about 50 m. On one side, this cable is connected to the microphone frame with 50-pin Mini D Ribbon connector, while the other side of this cable is connected to the measurement unit with industrial 64-pin connector Harting. The measurement unit includes:

- 6× A/D-D/A converter Behringer ADA8000 with modified input section,
- 1× digital ADAT/MADI converter RME ADI 648,
- sound card HDSPe MADIface,
- power amplifier AKIYAMA ADM400,
- power switch for loudspeakers.

The A/D–D/A converter ensures the conversion of 8 analog signals from 8 microphones to the digital format ADAT. This type of converters (Behringer ADA8000) has good price-performance ratio. In order to improve the characteristic parameters of the signal-noise ratio and the dynamic range, the input section of these converters was modified. The digital ADAT/MADI converter ensures the conversion of 6 optical ADAT signals to one optical signal MADI. Further, it ensures the synchronization of the A/D–D/A converters and generates the world-clock source. MADI optical signal is connected to the sound card with 128 channels (64 channels in and 64 channels out). This configuration allows to simultaneously record 47 channels to the PC in real-time. In parallel, the sound card serves as the source of the measurement signal. This signal is converted to ADAT in the digital ADAT/MADI converter. Subsequently, it is converted to the analog signal in one of the A/D–D/A converters. The power amplifier is connected to this A/D–D/A converter. The output of the power amplifier is switched between the loudspeakers using the MIDI controlled switch. At one moment, only one loudspeaker is on. The measurement unit is located in 19" rack of the size of 9U. This setup allows safe and easy transport.

3. The real measurement

The newly designed system was used for the real measurement of the signal-to-noise ratio of a diffuser in the gym hall at the University of West Bohemia. The proportions of this hall (45×25×10 m) are high enough and thus the conditions established in paragraph 2.1 are fulfilled. In the first step, one loudspeaker instead of the diffuser in the measurement system was used (see Figure2). This loudspeaker was directed towards the each microphone one by one in order to (1) determine the sensitivity (2) adjust the gain of each channel and (3) measure the frequency response of the measurement system. These parameters (the sensitivity, the gain and the frequency response) were acquired for all 47 microphones. It is very important to verify that all 47 microphones have similar frequency response. By comparison of this record with the remaining records from the other 46 microphones, it was found, that all microphones have similar frequency response. During this measurement, suitable gain setup was found. Finding of suitable gain is important for minimizing of the influence of the noise in the hall. The aim of this process is to achieve as high as possible value of the ratio of the reflected signal to the noise background in the hall. Secondly, the setup of the measurement system was identical as in Figure 2 and the real measurement of a diffuser was performed. Figure 4 shows measured frequency distribution of the power spectral density of measured signals. The power spectral densities were measured in third-octave-bands with center frequencies covering the frequency range from 20 Hz to 20 kHz. The source signal represents the real distribution of the power spectral density of the selected impulse signal (in PC). The signal from loudspeaker represents the real distribution of the power spectral density of the measurement system (this signal is affected by the presence of the microphone frame, reflective surface etc.). The reflected signal from the diffuser represents the power spectral density which is affected by the presence of the diffuser. It can be seen, that the measurement system is suitable for use in the frequency range of 100 Hz – 10 kHz. Figure 5 shows the corresponding time record of the impulse response from one microphone.

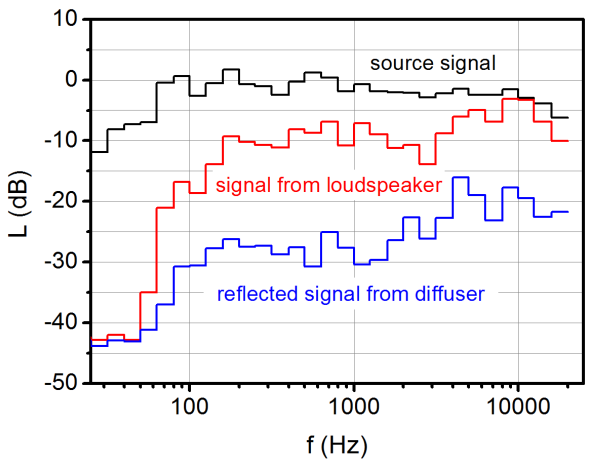

Figure 4. Measured frequency distribution of the power spectral density during real measurement in the hall.

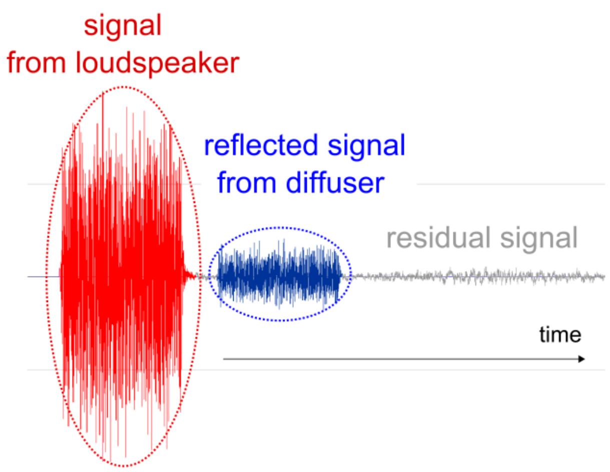

Figure 5. The time record of the measured signal recorded during real measurement in the hall.

From this time record two different parts (the signal from the loudspeaker and the reflected signal from the diffuser) can be recognize. Furthermore, it can be seen, that the part of the residual signal doesn´t interfere with the reflected signal from diffuser. The signal-to-noise ratio of the designed measurement system is 90 dB. Such high value of the signal-to-noise is sufficient and it testifies that this system can be universally used for characterization of the diffuser materials. The noise background of the measurement system is 40 dB, suggesting application of this system in the range of 40 – 130 dB. Such value of the noise background is much lower than the noise in the spaces commonly used for characterization of the diffuser materials. In parallel to this work, a mathematical model for the simulation of the diffusers behavior was developed [2]. The output data from the designed measurement system allow to increase the accuracy of this mathematical model. The preliminary results from the comparison of the model vs. real measured data were published in [3].

Conclusions

Using the newly designed measurement system, it is possible to reproducibly measure reflective materials, such as diffusers, in order to get the diffusion and reflection coefficients. The main advantages of this system are: (1) the system is comfortably transportable, (2) the measurement is reproducible, and (3) it is possible to characterize the materials without scaling down. Because of very low value of the noise background, it is possible to use this system in the spaces commonly used for the characterization of the diffuser materials. The measurement in the real hall demonstrated the applicability of this system in common practice.

Acknowledgement

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