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Sound Insulation Measurement by Impulse Method

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***Abstract* – One of the most important features of building construction elements from acoustical point of view is sound insulation. There are different alternatives how to measure this quantity. Generally, it could be measured in special laboratories or in situ where the elements and walls are mounted. Also, there are different methods for its measurements: classical method using stationary broad-band noise, and a new method based on impulse response measurement.**

This paper analyses some aspects of the application of a new impulse method for the measurement of sound insulation both in laboratory and in situ. The sound insulation determination is based on the measurements of impulse responses both in a source and receiver room. For the processing of these responses, the software module is developed. The influence of some parameters of the impulse method is investigated, such as the repetition and spatial standard deviation, signal to noise ratio, etc. As the illustration of the impulse method application, the results for sound insulation measurements of several partitions in the laboratory, and of a wall with the ventilation duct in situ are presented.

***Keywords* –Acoustical measurements, Impulse method, Sound insulation, Standard deviation.**

I. Introduction

Sound insulation as one of the main acoustical descriptors of a building construction element can be measured in a specialized laboratory, but also *in situ* where the element is built in. Regarding the method, two measurement methods have been used for this measurement, and both of them are standardized [1], [2]. The classical method based on stationary broad-band random noise is usually applied for laboratory measurements. On the other hand, the recently developed impulse method can be used for both laboratory and field measurements of sound insulation [3].

Although this new impulse method is standardized and it has been applied relatively often in practice, there is hardly data in the literature presenting the results of this method [4]. Thus, the implementation of the impulse method for sound insulation measurement is investigated here. For that purpose, the measurements were carried out in both specialized laboratory of IMS Institute, and in situ. In order to process the measured responses, the software module is developed. The accuracy of sound insulation determination using room impulse responses could be affected by the influence of certain parameters, such as the excitation signal and the excitation level, signal to noise ratio, etc, some of which are analyzed here. The complete procedure for measurement of sound insulation in situ is illustrated by the insulation measurement of the wall with the ventilation duct at the Faculty of Electronic Engineering in Niš.

II. Impulse Method for Sound Insulation Measurement

From the general signal theory it is known that a linear and time invariant system can be characterized by its impulse response. This is valid for a particular room, but also for the sound transition from one room to another. Thus, it is possible to measure the sound insulation between two rooms, that is the sound insulation of a particular partition area by measuring impulse responses in both source and receiving room, Fig. 1. The adequate processing of these responses can result in sound pressure levels of both rooms and corresponding sound insulation value.

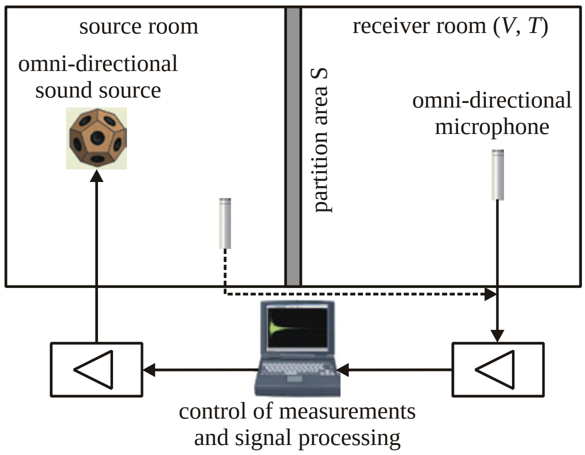

Fig. 1. Setup of measurement system for the sound insulation measurement by impulse method

The measurements of the room impulse responses can be done by different methods including widely used and standardized Maximum Length Sequence (MLS) technique and SineSweep technique [2].

The signal processing for sound insulation determination can be performed in time domain, but also in frequency domain. Here, only processing in time domain will be used and presented. This processing is based on the determination of sound pressure levels of source and receiver room from the measured impulse responses by

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$$L_{s/r} = 10\log\left[\frac{W_0}{C_{ref}}\int_0^\infty h_{s/r}^2(\tau)d\tau\right] \quad (1)$$

where W_0 is a constant specifying the signal power per unit bandwidth of the excitation signal, and C_{ref} is arbitrarily selected reference value for the level calculation.

Now, since it is necessary to determine the spatially average sound pressure levels in both rooms based on measurements in several points in both rooms, the level difference is calculated by

$$D = L_s - L_r = 10\log\left[\frac{\frac{1}{m}\sum_{i=1}^{m}10^{L_{s,i}/10}}{\frac{1}{n}\sum_{i=1}^{n}10^{L_{r,i}/10}}\right] \quad (2)$$

The quantity that is usually used to represent the sound insulation is the sound reduction index that is calculated as

$$R = D + 10\log\left[\frac{ST}{0.16V}\right]. \quad (3)$$

where S is the area of the test element, and T is the reverberation time of the receiver room. The sound level difference or sound reduction index is usually determined for subset of third octave bands in certain frequency range. This number of third octave bands as well as number of microphone positions depend on the standard to be applied. For instance, the standard ISO 140-3 [1], defines at least frequency bands from 100 Hz to 5000 Hz, and five microphone positions in each room.

For the determination of a sound pressure level from the room impulse response, the important parameter is the range of the response in which the level is calculated according to Eq. (1), since it is not possible to use the range from 0 to infinity. Some recommendations are that this range should be from the response beginning to 20 or 15 dB down point from the peak of the squared impulse response, or alternatively it could be to the knee, where the main decay intersects the noise floor [2], [5], [6].

III. MEASUREMENT PROCEDURE

The measurements were carried out in the laboratories of IMS Institute in Belgrade that are certified for the sound insulation measurements by the classical method. However, sound insulation in this case was measured by application of the impulse method. The central component of the measurement system was the notebook computer used for the excitation signal reproduction, recording of the response and overall signal processing, as shown in Fig. 1. Besides, the measurement system consists of the amplifier, the omni-directional sound source, the omni-directional microphone and the microphone amplifier.

Beside the measurements in the specialized laboratory, they were also performed in situ, that is, the sound insulation of the partition wall between two laboratories at the Faculty of Electronic in Niš was also measured. Geometry of the source and receiver rooms together with the sound source and microphone positions are presented in Fig. 2. Important characteristic of the partition wall is that it contains the ventilation duct directly joining two laboratories from either side of the wall, that is, the source and receiver room. Thus, the sound insulation of this concrete wall is significantly reduced, which disturbs the working activities in these laboratories. The dimensions of the source and receiver rooms are 6×7.5×4 and 9×7.5×4 m^3, respectively. The mentioned ventilation duct has the dimension 0.4×0.7 m^2, and it is in the vicinity of the ceiling. The microphone positions are chosen in such a way that the distance to the closest wall is not smaller than 1.5 m, and from the sound source in the source is not smaller than 2 m. The height of the microphones is about 1.5 m, while the height of the sound source is about 1.8 m.

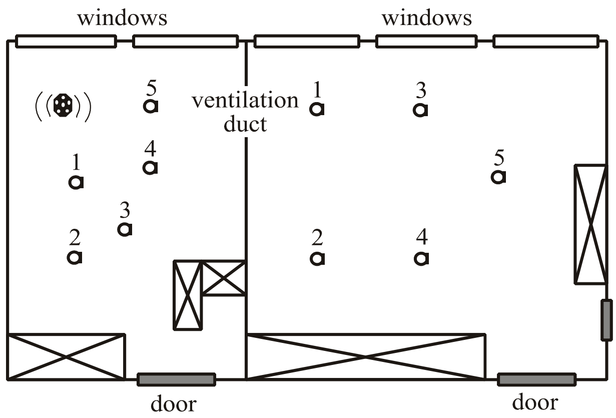

Fig. 2. Position of the sound source and microphone locations in the source and receiver room for measurement of sound insulation in situ

For both measurements, in the specialized laboratory and in situ, the Matlab software is developed for extraction of the room impulse responses and their complete processing for the purpose of calculation of the sound level difference and the analysis of the results. Room impulse responses were measured by application of SineSweep technique [7].

IV. RESULTS OF MEASUREMENTS IN LABORATORY

In order to illustrate the possibilities of the impulse method, the analyses of a dynamic range in the critical measurement of high sound insulation of porous concrete panels performed in the specialized laboratory of IMS Institute is done here. Since the sound level is determined from room impulse responses, then it is more appropriate to calculate Peak-to-Noise Ratio (PNR) or equivalently Dynamic Range (DR) of the decay curve representing the logarithm of squared impulse response filtered in third octave bands. DR represents a difference of the maximum level from the decay curve beginning and the knee where main decay intersects the noise floor.

Thus, PNR and DR values are determined from the impulse responses filtered in third octave bands and the results for the receiver room are presented in Fig. 3. The difference between these quantities is the consequence of non-stationary background noise level [8]. The presented values are almost in the whole frequency range of interest greater than 20 dB. Thus, even in this extreme case of high sound insulation, the dynamic range of the impulse responses is high enough for reliable determination of the sound levels.

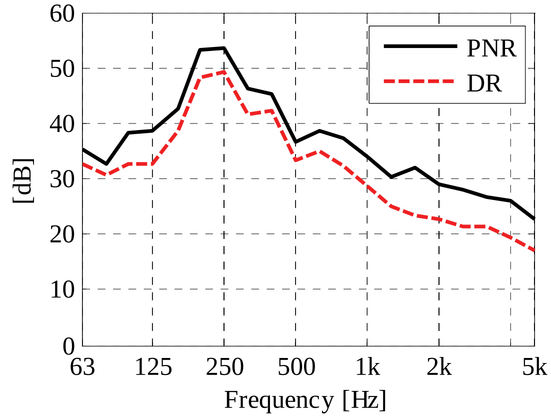

Fig. 3. PNR of the receiver room impulse response together with DR of the corresponding decay curves

In order to illustrate the gain enabled by the extraction of impulse responses, the level of the response to excitation signal in the receiving room and level of background noise in the same room are calculated and presented in Fig. 4. In great part of the frequency range of interest, their difference representing SNR has low values (below 5 or 6 dB) and only in the range around several hundred hertz it is above 10 dB.

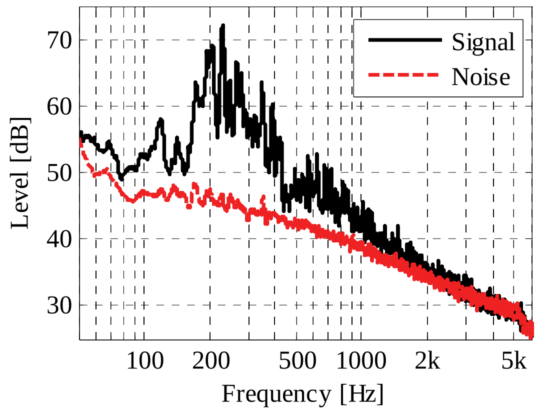

Fig. 4. The level of the response to excitation signal and level of background noise in the receiver room

The repeatability is tested on relatively small set of repeated measurements performed using the same excitation signal and level, but also using different excitation signal durations and levels. All the measurements were done in the same point in the source room, and in the same point in the receiver room of the IMS Institute laboratory. The results for standard deviation of the repetitions for nine measurements using three excitation sweep durations and three excitation levels are given in Fig. 5 together with the required values from ISO 3741 [9]. The presented values for the standard deviation are relatively small confirming the reliability of the measurements. These values are even smaller when the same excitation signal and level are used.

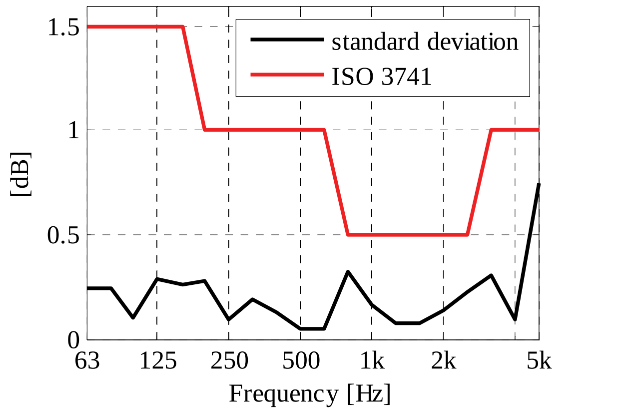

Fig. 5. Standard deviation of the repetition measurements for nine repetitions using three excitation signals and three excitation levels

The situation is somewhat different for the spatial standard deviation. The results for the standard deviation for the source room using five measurement points are presented in Fig. 6. These values are greater than the values for the repetition standard deviation. They are even greater than the required values defined in [9] at frequencies below 125 Hz.

The developed procedure for sound insulation measurement by impulse method was implemented for testing a number of partitioning structures within the project TR 21013 financed by Ministry of Science and Technological Development of Serbia. The results of sound insulation, that is, the level difference between the source and receiver room, for three characteristic examples – two porous concrete panels and the partition consisting of a window are given in Fig. 7. Thus, the porous concrete structures have somewhat different sound insulation values, but still significantly higher than the partition with the window in the whole frequency range. The results obtained by impulse method are confirmed by the classical measurement method that will be published in further publications of the authors.

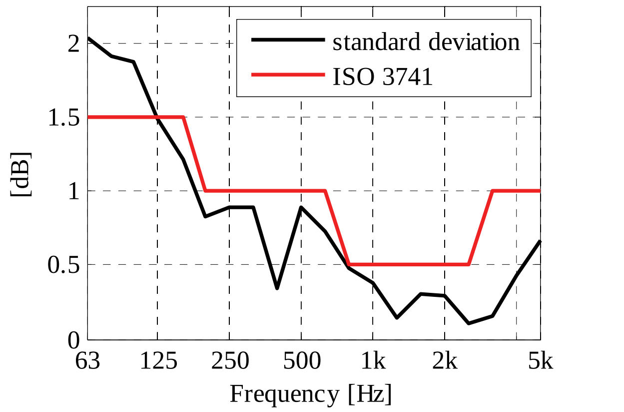

Fig. 6. Spatial standard deviation of the source room based on five measurement points

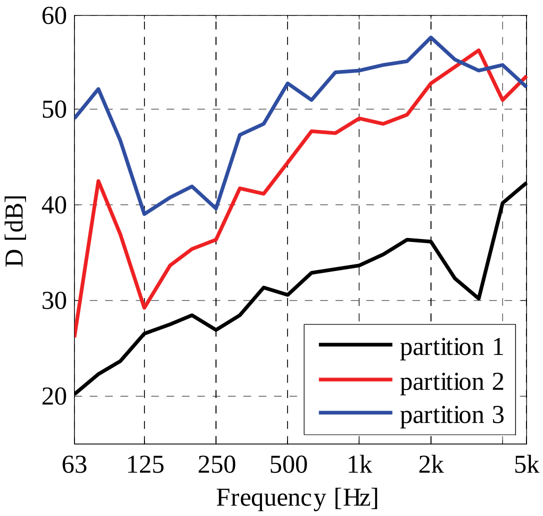

Fig. 7. Sound insulation (level difference) for three examples of partitioning structures measured in the laboratory: the window (partition 1) and porous concrete structures (partitions 2 and 3)

V. Results of Measurements in Situ

The sound insulation of the partitioning wall with the ventilation duct separating two laboratories was also measured by the impulse method representing measurement in situ. The sound levels in both source and receiver room determined from the measured and filtered impulse responses in third octave bands are given in Fig. 8(a). The difference of the spatially averaged levels in both rooms is presented in Fig. 8(b). The obtained values representing the sound insulation are rather low confirming already noted low insulation between these two laboratories.

VI. Conclusion

The procedure for implementation of the impulse method for sound insulation measurement is developed and presented here. Its application for measurements in the specialized laboratory and in situ is analyzed. The values for repetition and spatial standard deviation confirm that reliable results can be obtained by this method. Moreover, the gain in signal to noise ratio as a consequence of the room impulse response extraction enables measurements in extreme conditions such as measurements of high sound insulation values and measurements with high background noise. The presented examples of sound insulation measurements emphasize the possibilities of the impulse method and its flexibility especially for the measurements in situ.

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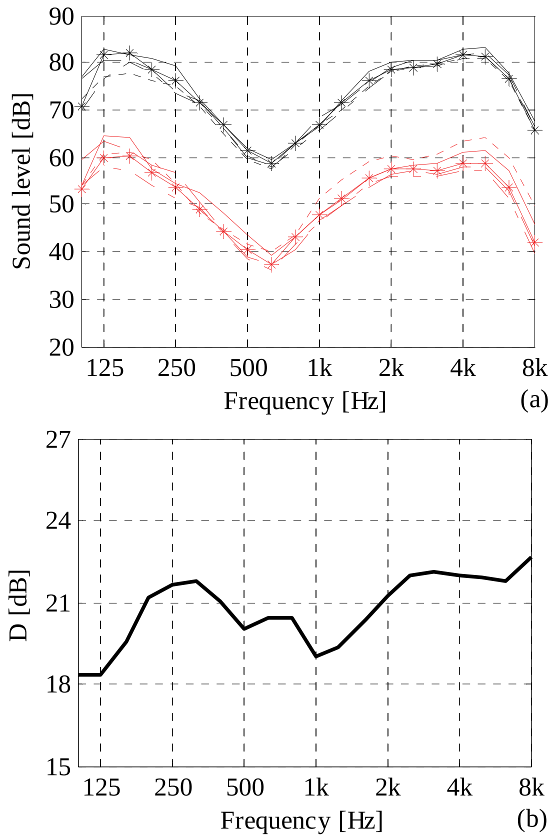

Fig. 8. Sound levels in the source and receiver room in situ measurements (a), and the difference of these levels (b)

References

[1] ISO 140: *Acoustics – Measurement of Sound Insulation in Buildings and of Building Elements – Part 3: Laboratory Measurements of Airborne Sound Insulation of Building Elements*, International Organization for Standardization, 1995.

[2] ISO DIS 18233: *Acoustics – Application of New Measurement Methods in Building Acoustics*, International Organization for Standardization, 2006.

[3] C. Hopkins, *Sound Insulation*, USA, Elsevier, 2007.

[4] R. Venegas, M. Nabuco and P. Massarani, "Sound Insulation Evaluation Using Transfer Function Measurements", Inter Noise 2005, Congress Proceedings, Rio de Janeiro, Brazil, 2005.

[5] M. Vorländer, M. Kob, "Practical Aspects of MLS Measurements in Building Acoustics", Applied Acoustics, vol. 52, pp. 239-258, 1997.

[6] D. Ćirić, M. Milošević, "Inaccuracies in Sound Pressure Level Determination from Room Impulse Response", Journal of the Acoustical Society of America, vol. 111, pp. 210-216, 2002.

[7] A. Farina, "Simultaneous Measurement of Impulse Response and Distortion with a Swept-sine Technique", 108th Convention of Audio Engineering Society, abstract in Journal of Audio Engineering Society, vol. 48, no. 4, p. 350, 2000, preprint 5093.

[8] D. Ćirić, M. Marković and B. Stojić, "Analysis of Background Noise Influence in SineSweep Measurements of Room Impulse Responses", proposed for ICEST 2010, to be held in Ohrid, FYR Macedonia, 2010.

[9] ISO 3741: *Acoustics – Determination of Sound Power Levels of Noise Sources – Precision Methods for Broad Band Sources in Reverberation Rooms*, International Organization for Standardization, 2003.