Measurement of sound absorption coefficient at low frequencies in reverberation chamber

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ABSTRACT

Acoustic features of materials are commonly evaluated in the frequency range 100 Hz – 5 kHz. This frequency range is not sufficient in these days, especially at low frequencies.

There are two measuring methods how to measure sound absorption coefficient at low frequencies in a reverberation chamber. Both of these methods are based on measurement of sound pressure level decay. The first measuring method directly uses of modal properties of a room and the decay curve is determined for each natural frequency separately. The second measuring method is based on measurement in accordance with ISO 354 standard. The frequency response of the reverberation room is adjusted by specifically placed a sound absorbing material, which damping isolated natural frequencies of the reverberation chamber.

The article will discuss the possibility of combining both of the above-mentioned measuring methods into one. This measuring method will not require additional acoustic treatment and will be based on measurement in accordance with ISO 354 standard. Measuring points will be selected with respect to modal properties of the room and damping of natural frequencies at low frequencies will be realized by the excitation signal. The signal is chosen that there is a minimal excitation of these natural frequencies.

Keywords: Reverberation Chamber, Decay, Low-Frequency Measurement
I-INCE Classification of Subjects Number(s): 25.1

1. INTRODUCTION

The amount of low-frequency sound sources increasing nowadays, this fact implies the need to know acoustic properties of the room at low frequencies. Once we know the acoustic properties, we need to design an appropriate acoustic treatment, which allows maximizing the potential of the room to serve its purpose. Low-frequency absorbent materials can be computed; however there is a great uncertainty of results. Verification of low-frequency absorbents is very desirable, but according to current standards quiet impossible. There are two approaches how to perform low-frequency measurement of absorbent materials in the reverberation chamber. The first is based on mode decay measurement and the second is based on damping of low-frequency modes (1). This article will explore another approach through the equalization of the excitation signal.

2. MEASUREMENT EXPERIMENT

2.1 Assumptions

Let's divide the frequency range of the sound field in the enclosed space into two areas. The first area is a diffuse field, where natural modes overlap each other and we are not able to recognize individual modes. According to ISO 3382, there is measured the decay of sound pressure level in one-third octave frequency bands. Each mode has its own decay and overall decay in the frequency band is given by the combination of these decays. It cannot be said that the combination of decays can be computed as a simple average (2).

If we utilize the same one-third octave band frequency analysis below diffuse field area, measured decay of sound will be strongly non-linear and relative standard deviations will be in the order of

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20-60% (2). This is caused by a small amount of natural modes in each frequency band. Assume that in the one-third frequency band there are only two natural modes with different decay times. The overall decay will be composed of the dynamic behavior of each mode in time and quite probably the decay curve will present two slopes.

2.2 Preliminary measurement

Before the measurement experiment, natural frequencies were measured in the reverberation chamber at low frequencies (below 100 Hz). The reverberation chamber was driven by the 18-inch low-frequency sound source, which was placed in one corner. The frequency response of the reverberation chamber was measured in another corner. Pink noise was used as the excitation signal. The frequency response of the reverberation chamber is depicted in figure 1. In table 1 is a list of measured natural frequencies.

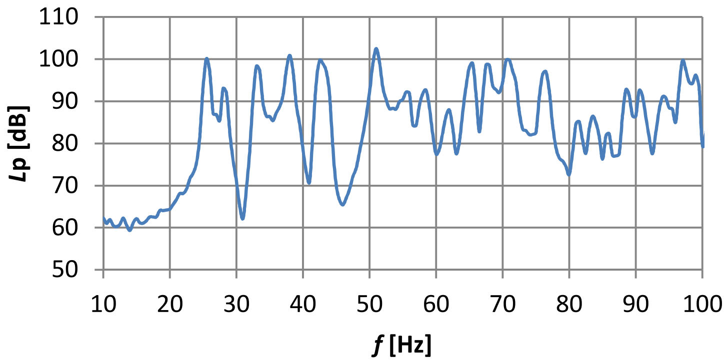

Figure 1 – Measured frequency response of the reverberation chamber

Table 1 – List of measured natural frequencies of the reverberation chamber

f_n [Hz]	25,5	28,0	33,0	38,0	42,5	51,0	55,5	58,5	62,0	65,5	67,5
f_n [Hz]	70,5	76,0	81,5	83,5	85,5	88,5	90,5	94,0	97,0	98,0	

One one-third octave band, where the experiment will be conducted, was selected based on the frequency response of the reverberation chamber. The one-third octave band with the 25 Hz center frequency seem to be the best option because there is only one axial mode with the 25.5 Hz frequency. Close to the 25 Hz frequency band is also another axial mode with 28 Hz frequency, its influence has been eliminated by the position of in the reverberation chamber.

Not all natural frequencies could be found in the list of natural frequencies in table 1. The reason is that some modes overlap each other and cannot be distinguished. The 25.5 Hz mode is the first mode of the reverberation chamber and it is the axial mode as can be seen from the figure 2.

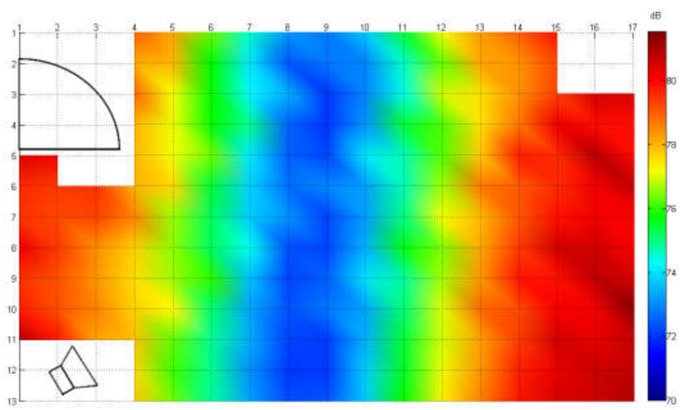

Figure 2 – Axial mode with frequency 25.5 Hz

2.3 Measurement setup

The measurement experiment was performed by commonly used the measuring technique for the reverberation time measurement, except the digital sound processor was included in the route of the excitation signal. As a sound analyzer was used the PULSE system from Danish company Brüel and Kjaer; it acts also as the signal generator. The digital sound processor Sabine equalizes by demand the excitation signal. This processor manages the nearest notch filter 1/48 octave and uses the Linkwitz–Riley approximation. The reverberation chamber is driven by the 18-inch loudspeaker placed in the corner. The loudspeaker has a closed construction, so there is no problem to work bellow its resonant frequency. The frequency range of the loudspeaker is from 25 Hz to 200 Hz (-3dB), SPL_{max} is 135 dB. Omnidirectional measuring microphones B&K 4943 were used in this setup. Block diagram is shown in figure 3.

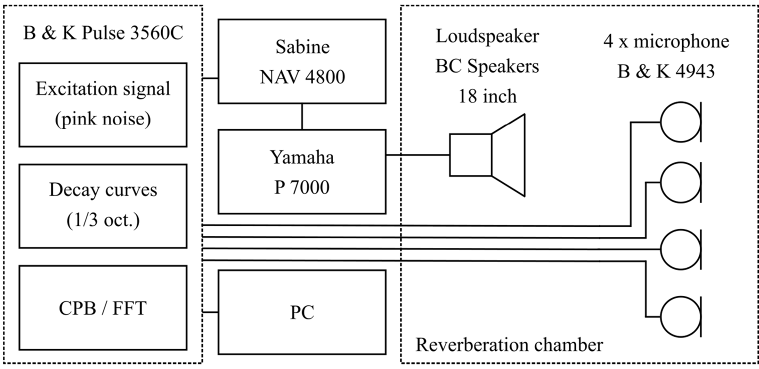

Figure 3 – Block diagram of measuring chain

This measurement setup was also used for the preliminary measurement. Instead of four microphones in the preliminary measurement, only one microphone was used in the corner of the reverberation chamber.

Measurement positions for microphones were selected with regard to the shape of 25.5 Hz axial mode. The axial mode changes only in one axis, so the measurement points reflect this phenomenon. One measurement point was placed in the corner (where the preliminary measurement was carried out) and it acts as a reference point. The stability of the sound pressure level from the sound source was for example monitored in the reference point. Measurement points and position of the sound source are depicted in figure 4.

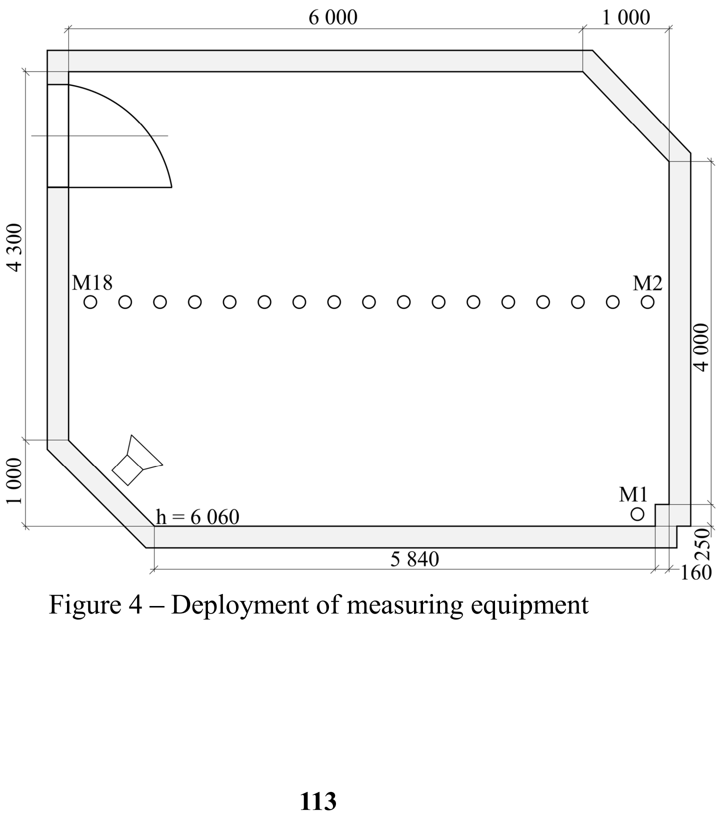

Figure 4 – Deployment of measuring equipment

Measurement positions form a row, which is intentionally placed in the middle of the reverberation chamber. The closest mode to the 25.5 Hz axial mode is the 28 Hz axial mode. The 28 Hz mode is perpendicular to the 25.5 Hz mode and therefore the 28 Hz mode has its node along the row of measurement positions. This measure eliminates the influence of the 28 Hz axial mode.

As was mentioned previous, pink noise was used as the excitation signal. This signal was filtered by the digital sound processor to the one-third octave band with the 25 Hz center frequency. This filtering helps improve the signal to noise ration. This modified excitation signal drove the reverberation chamber and after interruption of the sound source, the decay of the sound was measured. The same situation was repeated, but from the excitation signal was cut out the frequency of the natural mode. The frequency range of the notch was changed and the decay curve measured.

2.4 Measurement results

Decay curves of the sound were evaluated in all microphone positions. The slope of decay curves is not consistent along the microphone positions. The worst situation becomes regardless of the excitation signal in the middle of the reverberation chamber. In this place, there is the lowest signal to noise ratio, therefore the decay curve is not possible to evaluate.

Because in the one-third octave band with 25 Hz center frequency is only one mode, the decay is linear even with this measurement method. Cutting out the frequency of the natural mode causes a change in the slope of the decay curve. This may be attributed to the limiting the influence of the natural mode. The equalization, unfortunately, creates a warp in the decay curve, which causes uncertainty in the evaluation of the reverberation time. This effect is shown in figure 5.

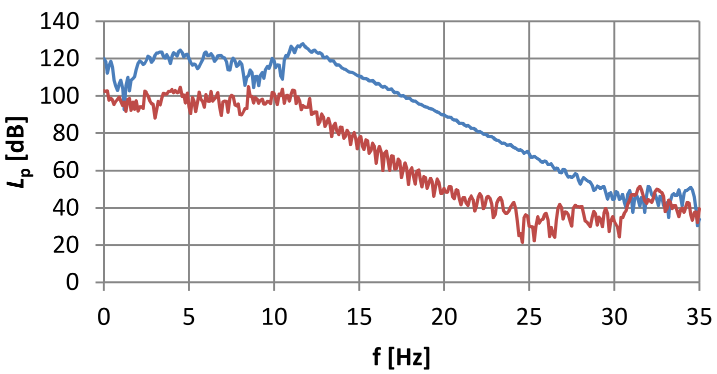

Figure 5 – Decay curves; blue = without equalization, red = with equalization

The effect of the warping decay curve was not explained to the deadline of the article and it will be subject of the future research.

Except decay curve measurement, natural frequencies in the corner were measured. The next figure shows the difference in the frequency response of the reverberation chamber. With the equalization is the natural mode with frequency 25.5 Hz attenuated by 30 dB in comparison to the un-equalized excitation signal.

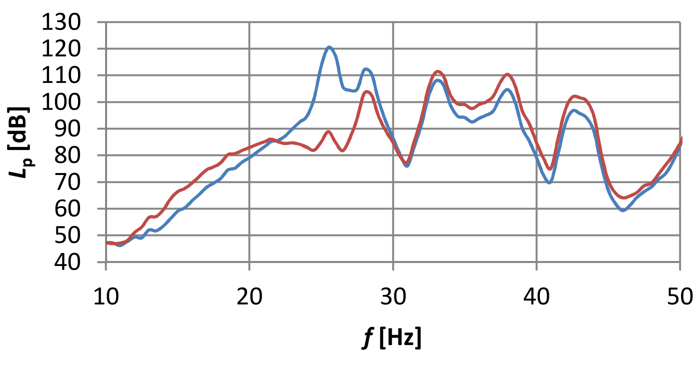

Figure 6 – Frequency response of the reverberation chamber; blue = without equalization, red = with equalization

There is a need to say that this measurement method puts very high demands to the low-frequency sound source. Each attenuated natural mode reduces the sound pressure level in the reverberation chamber and therefore it is necessary to make a compromise between the sound pressure level and the attenuation of the natural mode.

3. CONCLUSIONS

This article describes the measurement experiment whose aim was to verify, whether it is possible to reduce an impact of the natural mode to the decay of the sound through the equalization of the excitation signal. The measurement of the frequency response of the reverberation chamber shows that the natural mode is less excited by about 30 dB. This dampening cause a change of the decay curve slope, however it creates a warp in a decay curve. Subsequent evaluation of reverberation time is therefore more demanding. The effect of the warping decay curve has not been explained yet. The damping of natural modes puts very high demands to the low-frequency sound source and therefore a balance between the attenuation and demanded sound pressure level should be found. The measurement also shows that microphone position cannot be arbitrary.

In future, the subject of the research will be a wrapping of the decay curve and more energy-efficiency excitation signal.

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REFERENCES

1. Fuchs H., Zha X, Pommerer M. Qualifying freefield and reverberation rooms for frequencies below 100 Hz. Appl Acoust [Internet]. 2000 Apr;59(4):303–22.
2. Prato A, Casassa F, Schiavi A. Reverberation time measurements in non-diffuse acoustic field by the modal reverberation time. Appl Acoust [Internet]. 2016;110(May):160–9.