Design of variable acoustics by means of resonators

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Abstract

Variable acoustics could be really useful whenever musical performances require peculiar sound behavior of concert halls. The typical acoustical resonance of string instruments, accomplished with resonance of the acoustic space, could definitely improve sound quality in the audience area, and solve problems related with lack of partials or focalization, that characterize many concert halls.

In this paper, a mindful study about Helmholtz resonators and their application on a 1/8 reverberant room scale model has been undertaken.

About two hundred resonators with circular section and with a variable room each have been applied to the scale model along three lateral surfaces. Measurements of Impulse Responses (IRs) in the model, accomplished by some experiments by means of a pure tone sound source have highlighted the following results:

A single resonator that for his frequency can absorb about 11 dB, changing his room, the same resonator can emphasize the same frequency of 16 dB.

A couple of resonators located in different points of the scale model, absorb in a very different way, or to be precise, for absorbing the same frequency they have to change their room.

Key words: - Resonators, Impulse Response, Acoustical Parameters, scale model

INTRODUCTION

In room acoustics is nowadays sometimes utilised variable acoustics in order to enhance sound field in stalls and balconies. However, variable acoustics is commonly obtained by means of different panels often located above stage or on lateral walls. In this paper a new approach is introduced. Variable room acoustics is achieved by means of Helmholtz resonators located on lateral walls and ceiling. In order to verify the performance of the resonators in real environments, a scale model is here presented, and experimental results conducted both in the scale model and in the single resonator are shown.

THE SCALE MODEL

The performance of resonators has been tested in an aluminium scale model (1/8) of a reverberant room. It has been realized in the following dimensions: (V = 0.41 m^3 S = 4.78 m^2)

Height: m 0,62 width: m 0,78 length: m 0,98

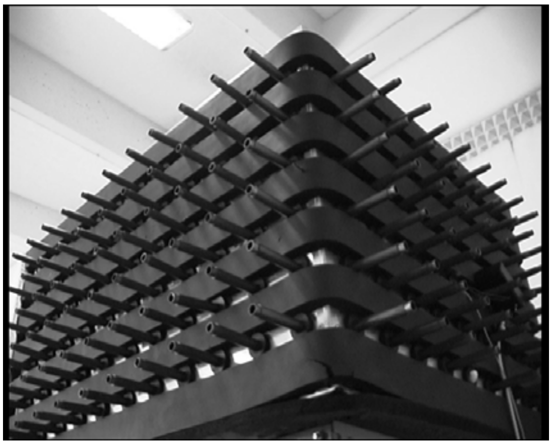

Figure 1: The scale model

The resonators have been designed paying particular attention to their absorption frequency variable from 700 Hz to 1400 Hz, with a definition level, Q factor, about of 1/12 octave.

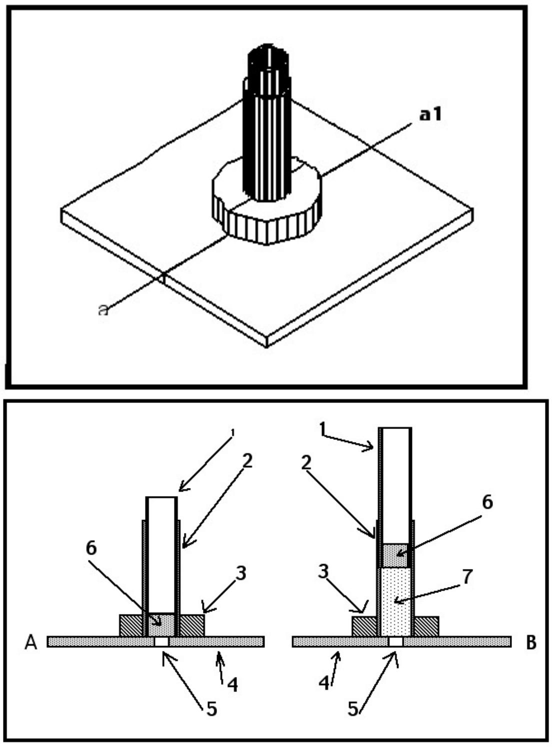

Figure 2: The resonator

MEASUREMENTS OF IMPULSE RESPONSES IN THE SCALE MODEL

Acoustical measurements were performed both in order to quantify the absorbing coefficient caused by the opening of the resonators, and in order to establish the different distribution of sound energy vs. frequency by opening the resonators. The measurements of the absorption of the resonators (built by a sliding copper duct, aluminium slab and cylinder, and a trimming rubber) were conducted with standard ASTM C 384-95 [1].

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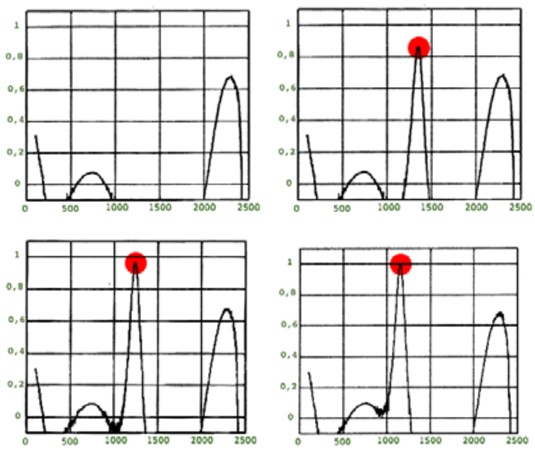

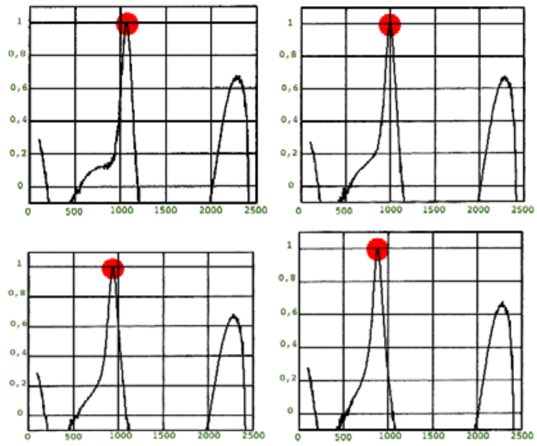

Figure 3: Different frequency resonance (from 1400 to 900 Hz) achieved opening the chamber

The acoustical behavior of the scale-model has been analyzed. The results are shown in the pictures above. The absorption coefficient between 2k and 2.5k Hz, more evident with the variable resonator in closed position, is due to the aluminium slab absorption.

Frequencies (Hz)	absorption coefficient
1350	0,86
1250	0,95
1135	1
1065	1
1000	1
935	1
870	1
820	1

Table 1: Values of absorption coefficient from 1400 to 870 Hz

In a second step, measurements of IRs were performed inside the scale model, by means of an omni-directional sound source and a couple of miniaturized microphones. The experiments were conducted with the resonators in the closed positions. A sine-sweep signal was generated, and by means of a multi-channel sound-board (Layla, by Event) the IRs were measured in 40 different measuring points [2]. In a following step, the *strength* (G) was calculated in third-octave band, and represented in a bi-dimensional map.

The last measurements were conducted by means of a pure tone, generated by the sound source, and positioning the microphones in the same positions as explained above.

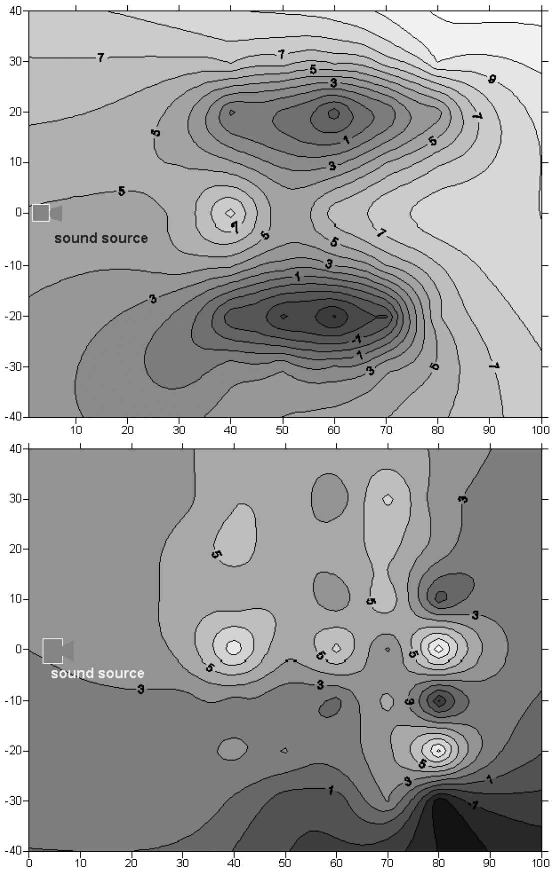

figure 4: spatial distribution of Strength (G) at 500 Hz (above) and 1 kHz (below)

Many test signals were utilized. In a first step, a single pure tone was used, and the microphone was positioned a different height. In a second step, a multiple pure tone signal was generated, in order to check the behavior of the resonators with reference to a more complex sound source, like during a musical performance. The experiments pointed out a stronger absorbing coefficient with a single pure tone, but with multi pure tones a strong absorbing coefficient was still present. Also Franzitta found similar results [3]. The results are summarized in the following table.

A) pure tone frequency: 1000 Hz
SPL (measured with photometer): 77 dB
result: SPL decrease from **77 dB to 24.6 dB**

B) 6 pure tones frequencies: 1000 Hz, 1100 Hz, 1180 Hz, 1260 Hz, 1340 Hz, 1420 Hz
results: (measured with spectrum analyser):

1 kHz: from –12 to –17 dB = 5 dB decrease SPL
1.1 kHz: from –10 to –15 dB = 5 dB decrease SPL
1.18 kHz: from –12 to –40 dB = **28 dB** decrease SPL
1.26 kHz: from –9 to – 3 dB = 4 dB decrease SPL
1340 Hz: from –9 to –14 dB = 5 dB decrease SPL
1.42 kHz: from – 9 to –33 dB = **24 dB** decrease SPL

Table 2: Effect of resonators in SPL

ANALYSIS

The measurements, carried on both by means of pure tones and measuring IRs revealed a strong absorption coefficient in some positions and a great influence of the variable room resonator. Considering the results coming from pure tones, a stronger influence of the wall at the opposite side (respect to sound source) in the scale model was found, whilst the lateral walls were found less absorbing. The measurements of IRs [4] allowed the calculation of strength (G) and other acoustical parameters. Strong focalizations were found in the scale model, and different results were found by changing the dimension of the variable room resonator. In particular, the influence of the resonators were found stronger in the positions far from the sound source, were strong influence of the dimension of the room were found especially at 500 and 1k Hz.

CONCLUSIONS

The design of a proper set of variable resonators could strongly improve sound characterization in spaces for music, especially where focalisations are found, due to a particular shape of the concert hall [5]. Furthermore, whenever a better sound balance and blend is required by musicians, the design of a set of variable resonators could give precious help in the optimisation of sound quality in the concert hall. In this paper the behaviour of a particular set-up of resonators was studied, by means of a physical model of a reverberant room. Measurements of sound distribution and strength, by opening the variable room resonator, revealed a decrease of sound level in some particular positions of more than 50 dB. The analysis of the results, in different frequency range, pointed out that a little movement of some resonators could provoke a great modification of sound distribution, and a very specific modification of sound absorption at a precise frequency. Therefore, the design of variable room resonators could be really important in sound distribution for specific musical performances, giving a strong variable acoustics to any space for music.

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