Hindawi Publishing Corporation
Shock and Vibration
Volume 2014, Article ID 472524, 5 pages
http://dx.doi.org/10.1155/2014/472524

Research Article

Conference Room Reverberation Time Correction Using Helmholtz Resonators Lined with Absorbers

Hossein Namvar Arefi,[1] Seyyed Mohammad Amin Ghiasi,[2] Seyyede Mahshid Ghaffari,[2] Farhad Ramezanghorbani,[2] Shiva Sharifpour,[2] Peyman Irajizad,[2] Seyede Delaram Ghoreishi Langroudi,[2] and Ahmad Amjadi[2]

[1] *Audiology Department, Tehran University of Medical Sciences, Mirdamad Street, Tehran 1348715459, Iran*
[2] *Physics Department, Sharif University of Technology, Azadi Street, Tehran 111558639, Iran*

Correspondence should be addressed to Hossein Namvar Arefi; hnamvar91@gmail.com

Received 19 October 2012; Accepted 19 November 2012; Published 27 May 2014

Academic Editor: Hamid Ahmadian

Echo and sound resonance in a conference room cause obscure speech and make listeners tired. Thus, the acoustical properties of a conference room are vitally important. The conference room 412 at Sharif University Physics Department failed to meet basic acoustical standards. The aim of this research is to improve reverberation time (RT) of the conference room using Helmholtz resonators with defined dimensions, diffusers, and sound absorbers. Helmholtz resonators are widely used to absorb sound noise especially at low frequencies. They are particularly useful when noise has a narrow-frequency band. One of the advantages of using Helmholtz resonators is their capacity to be tuned on different frequencies. We enhanced acoustical properties of Helmholtz resonators using proper absorbers and diffusers. In order to decrease the RT, a large number of Helmholtz resonators have been made and installed in proper positions in the conference room. The RT was measured before and after installation. The measurements indicate that the acoustical characteristics of the conference room have been significantly improved.

1. Introduction

Helmholtz resonator is an acoustical tool frequently used in applied acoustics. Basically it is a cavity that is connected with the outside space through a neck or an opening and collects sound waves within its resonance frequency [1]. Acoustic resonators with sound absorbers efficiently absorb sounds near their resonance frequencies [2]. They have been in widespread use since Ancient Greece [3]. Today they are employed to enhance sound fields in large reverberant spaces such as churches [4] and as mufflers in ducts [5].

A well-tuned Helmholtz resonator is very useful for attenuating low-frequency noises [6], which makes them useful as low-frequency sound absorbers in large reverberant halls [7].

Reverberation time (RT) is a temporal parameter to evaluate properness of the acoustical properties in indoor spaces. It is defined as the time required for the sound pressure level to decay by 60 dB [8]. Since reverberation prolongs acoustic events, RT is an important parameter influencing the quality of our hearing [9]. Speech intelligibility improves at some defined RTs ranges. Thus, it is necessary for speech oriented rooms, such as conference rooms, to have short RTs. On the other hand, early reflection of reverberating sound improves speech intelligibility in large spaces [10].

In this research, we used Helmholtz resonators in order to reduce the RT at low frequencies. When a sound is reradiated from the resonator's opening, it tends to spread as a hemisphere; thereby, it diffuses unabsorbed energy and improves sound quality in a studio or listening room [11].

2. Description and Experiment

The reverberation time has always been the basic indicator of acoustical behavior [12]. In the present work, we measured

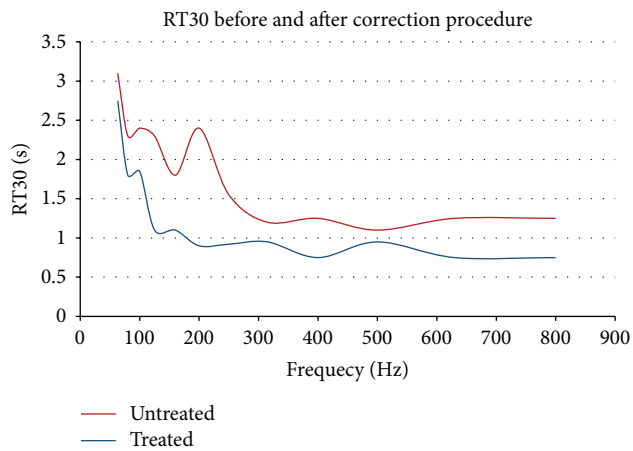

Figure 1: The RT30 of the conference room (a) before and (b) after correction.

RT30 (the time in which the sound intensity decreases by 30 dB) as Li and Lam [13]. It is measured in 1/3 octave frequencies before and after the placement of Helmholtz resonators in the conference room. The measurements were performed using a standard microphone calibrated by B&K 2250 Sound Level Meter (SLM) with ZC024 microphone. The accuracy of the SLM is 0.1 dB; therefore, accuracy of the microphone is also 0.1 dB.

The conference room number 412 of the Physics Department at Sharif University of Technology with dimension $11 \times 9 \times 4\,\mathrm{m}^3$ has moderately high RT30 for frequencies below 315 Hz. The standard RT30 for such a conference room is 0.5 seconds [11] but at the beginning of this work it was measured to be more than 1.5 seconds.

This phenomenon makes the speakers slightly obscure and the listeners uncomfortable by receiving a speech with high echo at low frequencies. Therefore, in this project, we tried to reduce RT of this room at frequencies below 315 Hz.

Figure 1 shows the measured RT30 before any acoustical correction in the conference room. The plot shows that there are three peaks in RT30 graph. The first peak is below 60 Hz, which human ear is not sensitive to [14]; that is, human thresholds below 60 Hz are very high [15]. The second and the third peaks are around 100 Hz and 200 Hz. We focused on decreasing the RTs of second and third peaks. The final results after positioning the designed resonators are shown in Figure 1(b).

It should be mentioned that when audiences are present in the conference room, RTs decrease from what is shown in Figure 1 [11]. Our focus is on low frequencies which are more difficult to be absorbed and have high RTs even in the presence of audience.

Helmholtz resonators were tuned at 100 Hz with desirable quality factor; they resonate approximately between 80 Hz and 140 Hz. Their resonance frequency is approximately given by [16]

$$f = \frac{c}{2\pi}\sqrt{\frac{A}{(L + 1.5a)\,V}}, \tag{1}$$

in which c is the speed of sound in air, A is the area of the neck, a, L and V are the radius of the neck, its length and chamber's volume respectively.

Regarding above equation, we calculated the area of neck and its length and the volume of the chamber. The calculations resulted in $A = 2.25\pi\,\mathrm{cm}^2$ (in circular form with radius = 1.5 cm), $L = 1.5$ cm, and $V = 5832\,\mathrm{cm}^3$. Dimensional restrictions also have contribution to these results, as we will discuss in the next paragraph.

Fortunately, the fluorescent lamps of the conference room had a suitable space to position our resonators. We put chambers above the fluorescent lamps and a velvet cloth was wrapped around them for beauty. We also lined the inner side of the Helmholtz resonators with carpet and placed some pieces of rock wool inside them with suitable acoustic absorption. The absorption of rock wool and carpet versus frequency were measured and shown in Figure 3. Selamet et al. investigated that the fibrous materials in the cavity lower the resonance frequency and the peak transmission loss. Due to this study it has been evidenced that using absorbers with different materials and thicknesses reduce resonant frequency [17].

The chambers were designed to be cubic, because of simplicity in production and stability after placement. The sides in cubic resonators were chosen equal to the lamps width. Then the length of neck acting as the acoustic reluctance was calculated from (1). In addition, we embedded the neck of resonators in its volume for protection (Figure 5). Embedding neck is discussed in [18]. Overall, we made 72 boxes of resonators. Figure 4 schematically shows position of fluorescent lamps and Helmholtz boxes in the conference room.

Helmholtz boxes were made of cardboard. We have analyzed cardboards in electroacoustic laboratory live room located at Physics Department. It was found that cardboards used in this study have a major absorbing characteristic from 200 Hz to 300 Hz. We covered approximately 70% of the live room floor by cardboards; and RT60 of the room was decreased from 3.2 seconds to 1.6 seconds in 250 Hz. But in other frequencies the changes were not significant.

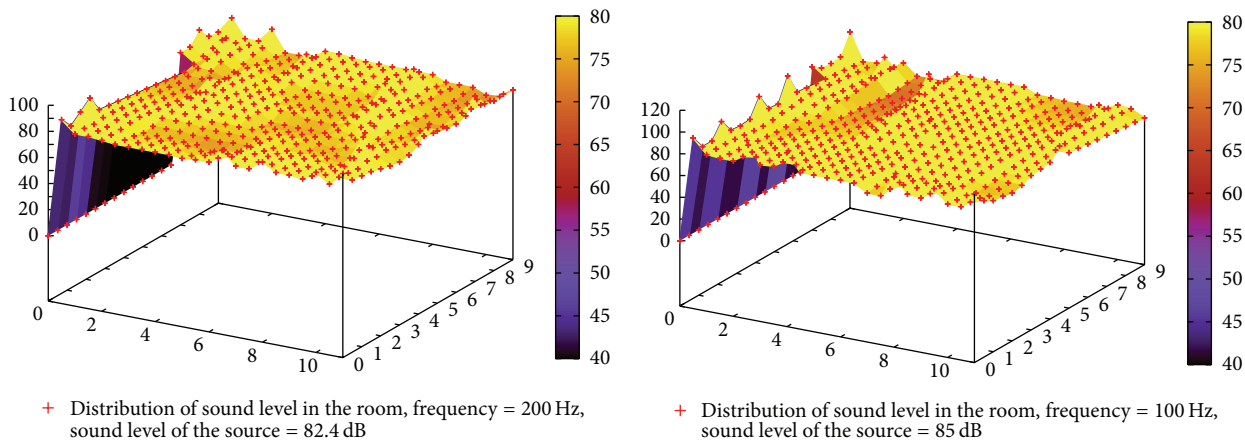

Figure 2: Noise map of the conference room in 100 Hz (a) and 200 Hz (b).

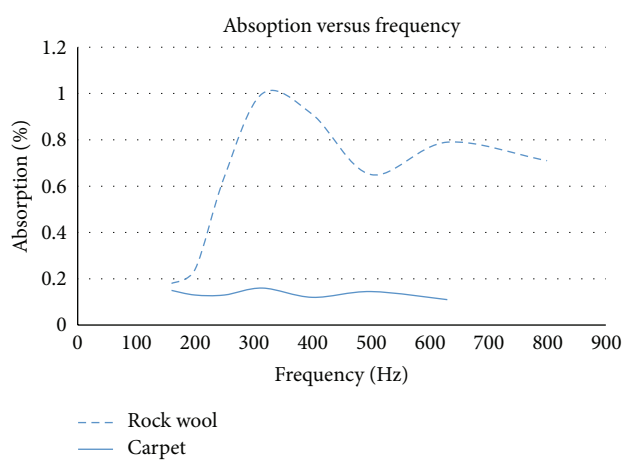

Figure 3: Absorption of rock wool and carpet versus frequency.

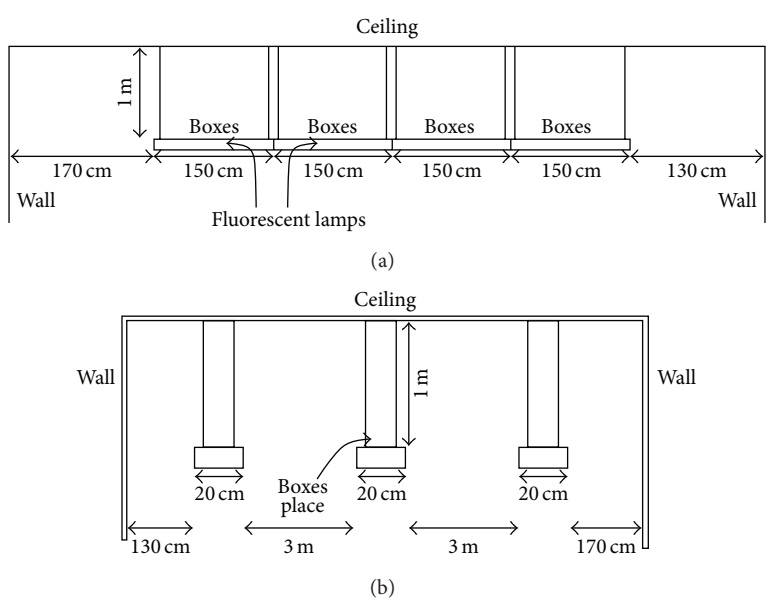

Figure 4: Schematic rear and side view of fluorescent lamps in conference room.

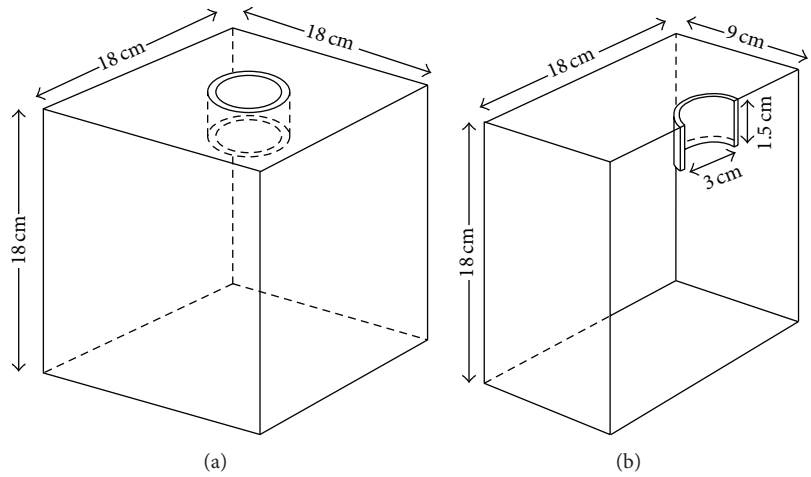

Figure 5: Schematic view of cubic Helmholtz resonators used in this project: (a) full view and (b) cross section view.

For instance, RT60 was decreased from 2.6 seconds only to 2.4 seconds in 150 Hz and from 1.8 to 1.6 in 350 Hz. Although Helmholtz boxes were made in order to resonate in 100 Hz, absorbing property of cardboards extends absorbing bandwidth up to 300 Hz. Thus, it can be used to remove 200 Hz peak in Figure 1.

Obviously, above approximately 100 Hz, we successfully decreased RT30 of the conference room below 1 second. This work took about 1000 student-hours' work.

3. Future Works

We have investigated that the presence of a spherical ball below the neck in a Helmholtz resonator increases its absorption while decreasing its bandwidth (Figures 6 and 7). The experiment was conducted using cylindrical Helmholtz resonator made of PVC. These measurements gave us the clue to insert a ball below the neck of the resonators in room number 412, in order to increase their absorption.

4. Conclusion

Our experiments indicate that there is a natural resonance frequency from 200 Hz to 300 Hz in the carton boxes used for construction of our Helmholtz resonators. By using this property and tuning the Helmholtz resonators in 100 Hz, we successfully reduced the reverberation time peaks in the conference room of Physics Department at Sharif University as shown in Figure 1. Also we are able to enhance the performance of Helmholtz resonators by positioning a sphere (ping pong ball) as a diffuser inside the resonator across the neck. The radius and the position of the sphere are the parameters which have to be investigated in more detail in the next work.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

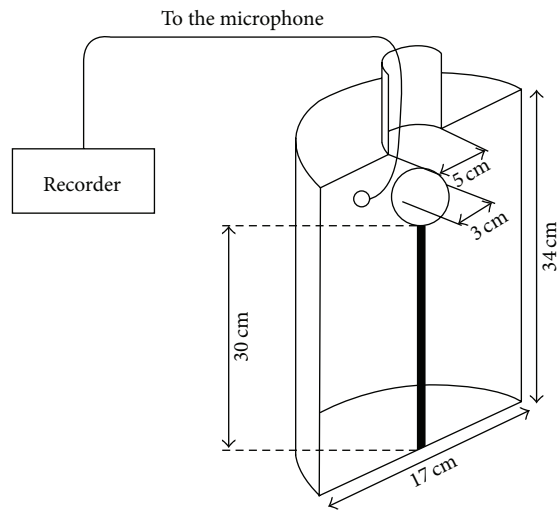

Figure 6: Schematic cross section view of the setup for ping pong ball below the neck of a Helmholtz resonator.

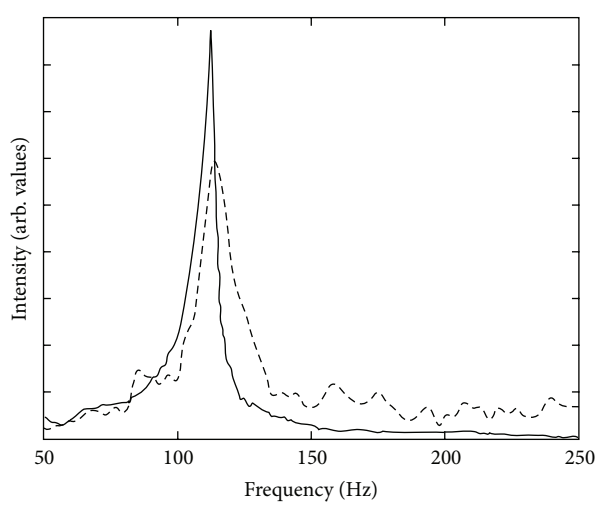

Figure 7: Response of a Helmholtz resonator with a ping pong ball below the neck (solid line) and the empty Helmholtz resonator (dashed line).

Acknowledgments

The authors thank Ramin Jafarzadegan, Zahra Mokhtari, Arezoo Dehghanfar, and Mohammad Alavi Tabar for measuring and plotting Figure 2 in this research.

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