Coupled Speakers As An Improved Omnidirectional Sound Source For Architectural Acoustics Measurements

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COUPLED SPEAKERS AS AN IMPROVED OMNIDIRECTIONAL SOUND SOURCE FOR ARCHITECTURAL ACOUSTICS MEASUREMENTS

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ABSTRACT

The omnidirectional sound source is an essential device in acoustic measurements according to standards ISO 354, ISO 3382, or ISO 140. In the current state of the art, we can found papers (Ingo 2005, San martin 2008, Knuttel 2013) showing the impact of the sound source's not-ideal omnidirectional character and its impact on parameters measured in room acoustics investigation. Obtained results of acoustic parameters, such as C80, D50 can differ by few JND orders regarding the source rotation on the stand, changing the direction faced by loudspeakers in the standard dodecahedral source. In this paper, we propose a new type of omnidirectional sound source based on coupled speakers. The proposed device contains two electrodynamic loudspeakers in a closed enclosure. Using this solution, we receive an omnidirectional spatial response with only two speakers. The effect of source rotation is remarkably limited. The research presents the proposed solution's directivity rating and sample room acoustic measurements to investigate the influence of source directivity on received results. Results comparison with previous research findings will be discussed to review a new type of the source improved room acoustic measurements.

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1. INTRODUCTION

Omnidirectional sound sources are standard devices in architectural acoustics measurements. We can found many commercial applications of dodecahedral sound sources [1][2] or single speaker spherical sound sources [3]. However, they are often expensive. For this reason, scientists try to achieve good omnidirectional sound performance with non-conventional methods, hiring the commonly available devices or cheap techniques to simulate the point source [4][5]. Many impulse sound sources are in use [6], as they provide a perfect omnidirectional radiation pattern. However, they do not offer the possibility to select the measurement signal and offer worse measurement uncertainty [7]. In this research, we introduce the novel idea of coupled speakers assembly to achieve the omnidirectional source radiation character quickly and cheaply, incorporating only two standard loudspeakers and MDF-milled boards. The basic parameters of the sources are discussed together with a directivity rating based on commonly used standards. The comparison with existing B&K source type 4292 was made, proving that our design with some limitations can compete with commercial, expensive sound sources.

2. OMNIDIRECTIONAL SOURCES CONSTRUCTION AND ASSESSMENT

The most common omnidirectional sound source design method introduces multiple transducers in the spherical loudspeaker array, simulating one of the platonic shapes [8]. However, it is also proved that using many transducers may cause a more significant dispersion in acoustic parameter measurements, especially energetic parameters like C80/C50, while the loudspeakers are directly facing the microphone in the room [9][10]. This may lead us to assume that currently used omnidirectional sources should be improved to minimalize this problem or novel constructions, based on the lower number of loudspeakers, should be investigated. Investigating the omnidirectional source topic, it is possible to find several parameters used for omnidirectional performance assessment. Like those proposed by Mechel [11], there are some single-value parameters, but they are challenging to adopt in practical use as they do not have proper measurement definition and adaptation in a wide frequency range. The most common are the requirements provided by international standards ISO3382 [12] or ISO140 [13]. They are defined for 1/1 or 1/3 octave bands SPL measurements in an anechoic chamber, however, in some papers, it is indicated that their requirements are not sufficient and should be revised as they do not offer a strict assessment of the sound source and those criteria are smoothed across the measurement angles [14][15]. They also do not define the methods for the measurement of 3D radiation characteristics. For more strict comparison of omnidirectional sound sources design, we propose to use the method introduced by Leishman [16].

3. COUPLED SPEAKERS CONSTRUCTIONS

This paper briefly describes the proposed design of assembling two loudspeakers in the small, closed volume while the two loudspeakers are working in phase. Both speakers are powered with the same signal. The enclosure was made from MDF milled boards in the rings with the holes for mounting screws. This kind of assembly offered a straightforward increase in the speakers' volume, which was studied in this paper. Coupled speakers' design is

similar to isobaric loudspeaker setup [17][18]; however, in the isobaric setup, loudspeakers are moving in antiphase that provides dipole radiation pattern—reversing the phase of the signal provided to one loudspeaker results in achieving omnidirectional directivity. An additional 3D printed gasket from the flexible TPU material was added to seal the volume inside the enclosure. The last part of the proposed setup is 3D printed mounting socket prepared to be placed on a standard microphone or loudspeaker stand. Initial design and all parts used for the device construction are shown in Figure 1. Used loudspeakers were Visaton AL170 with aluminum membrane and a diameter of 18 cm in total. Based on our judgment and multiple trials, the aluminum membrane can be potentially the best for this type of device as the overall performance can be connected with the driver compliance, but this statement requires additional research.

Figure 1. Prototype and parts explanation for coupled speakers omnidirectional sound source

The critical question raised in the designing process was the size of the volume in this kind of construction. As we did not find any strong references for similar devices, we decided to test it empirically. By applying more MDF rings to the enclosure, we could easily modify the distance between the loudspeaker diaphragms. Tested variants were marked as D2, D8, and D16, with 2, 8, or 16 cm distance between speakers, respectively. The variant for 16 cm distance, fully assembled, is shown in Figure 2.

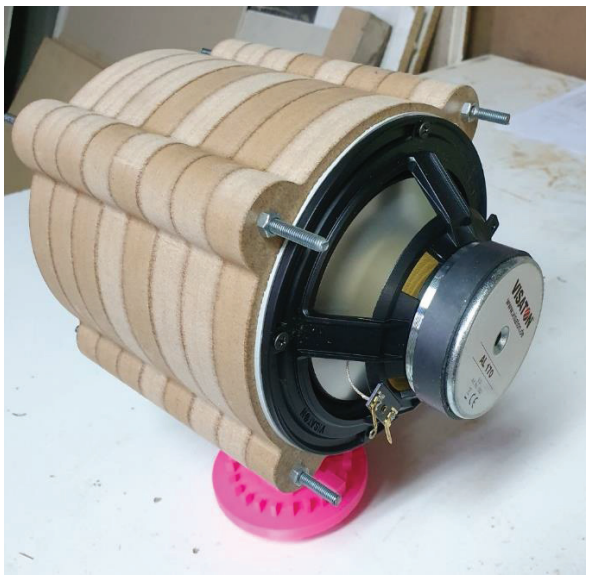

Figure 2. Coupled speakers assembly with the 16 cm distance between the diaphragms

4. MEASUREMENTS AND DISCUSSION

Provided variants were tested in the anechoic chamber of AGH University under the conditions of measurements for ISO140 and ISO3382, using the rotating table. The results are presented in Figure 3 and Figure 4, together with a commercial B&K type 4292 omnidirectional sound source.

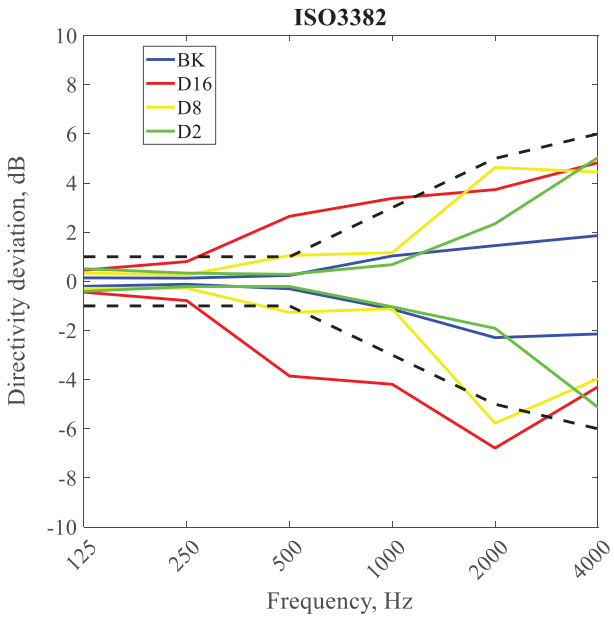

Figure 3. Coupled speakers variants directivity ratings according to ISO3382 in 1/1 octave bands with comparison to B&K type 4292

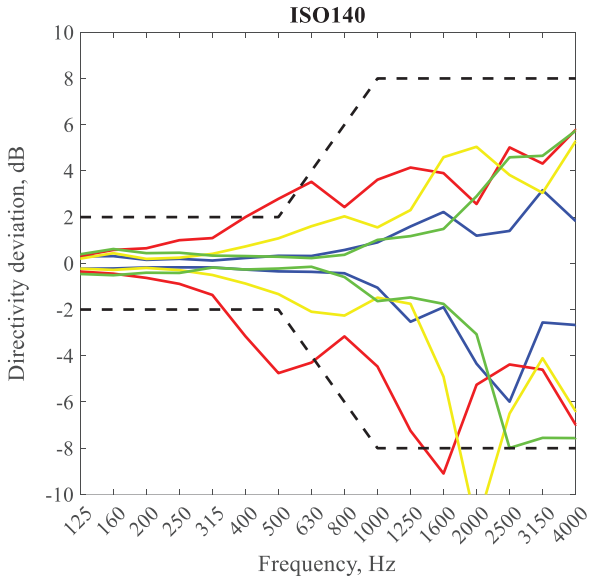

Figure 4. Coupled speakers variants directivity ratings according to ISO140 in 1/3 octave bands with comparison to B&K type 4292

Used assessment parameters have different frequency resolution, but the measurement methods are the same. Provided results show that the D2 variant – so the closest distance between speakers- met the called standards criteria. The D8 version was also very close to meet the standards criteria but exceeded the standard thresholds in one octave or third-octave band.

5. CONCLUSIONS

This paper contains a preliminary assessment and presentation of coupled speakers design as a new type of omnidirectional sound source for architectural acoustic measurements. We tested several variants of the coupled speakers assembly, investigating the role of volume and distance between speakers. Based on the provided results, the closer the loudspeakers are placed, the better the omnidirectional performance they offer. However, in the current state, with a distance of 2 cm between diaphragms, it is possible to meet ISO140 or ISO3382 standards requirement for omnidirectional sound sources, which is an achievement as the overall source cost do not exceed 200$ in comparison with costly commercial sources. Future research is planned, including electroacoustic tests of loudspeakers searching for the best Thiele-Small parameters for this kind of construction and further research if it is possible to receive a further improvement in the source performance. Experimental validation is planned, using the coupled speakers set together with commercial dodecahedral source in real room acoustic parameters measurements.

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