Coupled Speakers Directivity Measurements for Small Acoustic Omnidirectional Source Development

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Abstract

Acoustic monopole construction is unsolved task, which engineers try to solve for many years. In the past they constructed many innovative solutions, such as spark or laser-gap sound sources, but those concepts caused many equipment troubles. It is impossible to select type of the measurements signal for this kind of sound sources, also any sparks and laser beams can provide strong electromagnetic distortions around the operation zone. In current state of art we are trying to provide non-standard solutions while traditional omnidirectional sound source, based on spatial configuration of electroacoustic transducers, is not described correctly and can be expanded.

Paper presents concept of acoustic monopole source based on coupled configuration for electrodynamic loudspeakers, similar to isobaric setup but non-constant volume between the speakers. By using FEM modelling we will present directivity patterns and project ideas, describing how overall results corresponds with geometrical parameters of speaker configuration and parameters. Presentation summary contain results of prototype device directivity patterns measurements. Received characteristics shows big potential in using cone-to-cone coupled speaker setup to reach acoustic monopole in frequency range defined by distance between transducers. Achieved knowledge allows to provide broadband, easy to build and small acoustic monopole with many possible applications.

Keywords: omnidirectional, point sound sources, coupled speaker set, sound radiation patterns

1. Introduction

Proper sound propagation directivity patterns are important for any acoustic measurements because radiation characteristics of sound source used for measurements can affect them. For in situ measurements in highly diffused sound fields like industrial halls or other rooms with high reverberation, also for reverberation chamber, we can neglect influence of sound source directivity or compensate it with higher number of the measurement averages[1]. For the free field measurements like anechoic chamber we should pursue for best possible omnidirectionality to avoid serious mistakes in measurements for example in HRTF measurements [2].

Acoustic monopole construction provides many problems as none universal method and design procedure exists [3]. Sound sources require different features for assumed measuring function, such as scale measurements, in-situ rooms measurements or near-field HRTF measurements – all those purposes requires different characteristics for sound sources.

Current approach provide coupled speaker solution similar to isobaric speaker, which is rarely used solution, invented in 1994 (patent granted in 1997), mainly for improving low frequency response of subwoofers [4]. It uses combination of two loudspeakers, facing each other and using the same signal (in-phase or out-of-phase). In this paper we investigated directivity patterns of loudspeakers in isobaric setup, deriving the dependencies between the driver parameters, box volume or distance between the drivers. Using isobaric speaker technology has huge potential in acoustic omnidirectional source design, allowing for development of small and efficient sound sources for multiple applications. Currently the only limitation seems to be narrow frequency range. Presented coupled speakers setup looks similar to isobaric configuration, but diaphragms are moving in opposite directions and the volume between the speakers is non constant. Paper discuss advantages and disadvantages of this solution and possible construction methods.

2. Omnidirectional speaker development and usage

Current state of the art contains many innovative solutions provided to reach correct, omnidirectional directivity patterns in wide frequency range and improve the accuracy of measurements performed in the requirements of point source simulation. It is pointed, for example in ISO 354 or ISO 17497 standards [5], that source directivity affects the measurements together with the measuring environment [6]. Despite the role they are designed for, omnidirectional sound sources have different sizes, working principles and are based on different types of transducers. Example of some previously developed device, such as commercial use Microflown low frequency source or developed by AGH spark gap sources are shown in Figure 1.

Figure 1. Microflown low frequency omnidirectional source (left) [7]
and spark gap sound source for scale modelling [8]

Different constructions have one common feature which is possibly closest to the uniform, omnidirectional spatial response, but differ in the terms of reachable frequency ranges, powers and device dimensions, which also define the possible usages.

This paper is focused on development of small point source with electrodynamic microspeakers. Main application of this device could be loudspeaker arrays and remote controlled, variable directivity sources. This solution is easy to apply and can be expanded in many projects where point source simulation is required.

3. Isobaric loudspeaker configuration

The concept of isobaric speaker is known from 1997 [4], but so far there are very few scientific reports on this technology. This configuration was used mainly in subwoofers few decades ago, usually with the bandpass enclosures (Figure 2).

Figure 2. Typical isobaric loudspeaker based subwoofer [9]

Main features of this solution are: halving the V_{AS}, R_e and L_e parameters and reducing or amplifying the efficiency by 3 dB (regarding the connection in parallel or series). Possible speaker connections are explained in Figure 3.

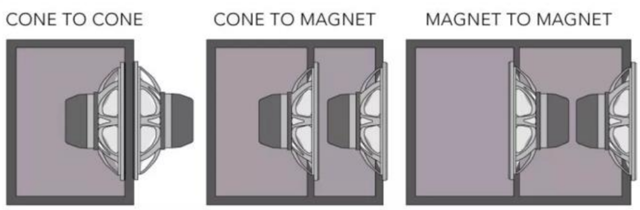

Figure 3. Possible isobaric speakers configuration [10]

In this research we focused on rarely considered feature and currently not measured for isobaric loudspeaker systems, which is directivity and spatial response. As in commercial applications we usually have the enclosure with vents (bandpass type) or closed enclosure assume omnidirectional sound propagation for low frequencies. On the other hand we also have known loudspeaker configuration in infinite baffle, considered omnidirectional in low frequencies and dipole in high frequencies, getting similar to piston radiation. To consider different types of propagation and compare them with isobaric speakers we used FEM modeling in COMSOL multiphysics (Figure 4).

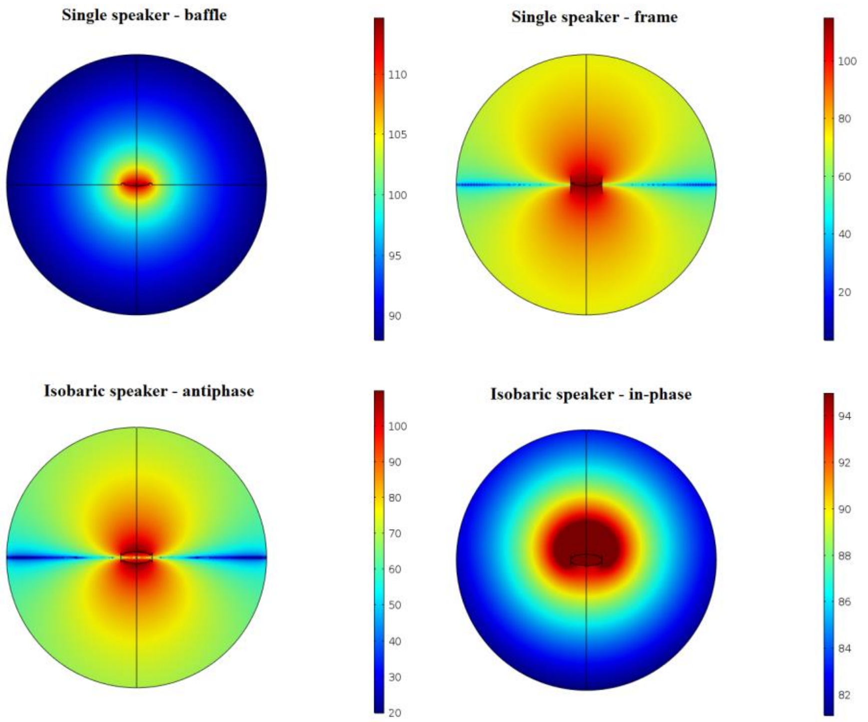

Figure 4. Simulated directivity for tested configurations – single speaker in infinite baffle (top left), single speaker in small frame (top right), isobaric speakers working in antiphase (bottom left) and isobaric speakers working in phase (bottom right)

Decreasing the frame size to minimum (Figure 4), basically, floating the speaker in the air, provide the dipole issue with the spatial speaker response. The same way occurs to be in the isobaric speaker configuration while the drivers are connected and driven with antiphase signal (one is moving forward while second is moving backward). Connection of the speakers in phase, so in the given time frame the diaphragms are moving to the centre and outside in the same way, allow us to avoid the dipole issue caused by lack of infinite baffle dividing the space and allowing to neglect the effect of back side propagation. This lead us to consider this as a possible point source and acoustic monopole. However, when the diaphragms of speakers are moving in opposite directions, the volume between them aren't constant anymore, so the name "isobaric" is no valid anymore. In this case we propose name "coupled speakers" to be used.

4. Experimental verification of miniature omnidirectional source

At this part of the study we performed only preliminary tests in anechoic chamber. Sample set of isobaric speakers was used with Visaton K28 microspeakers, 28 mm of diameter. Figure of test samples is shown on Figure 5.

Figure 5. Test samples for the experiment – single speaker (left) and isobaric in-phase (right)

To verify performed FEM modelling we measured directivity patterns in 1/24 octave bands, using the rotating table in anechoic chamber and pink noise as a test signal. Spatial resolution was 10 degree in horizontal plane. As a omnidirectionality measure we used standard deviation calculated for each frequency band from 35 measurements, representing the full circle around the speaker (Figure 6), which is proved and simple way to assess the omnidirectionality [11].

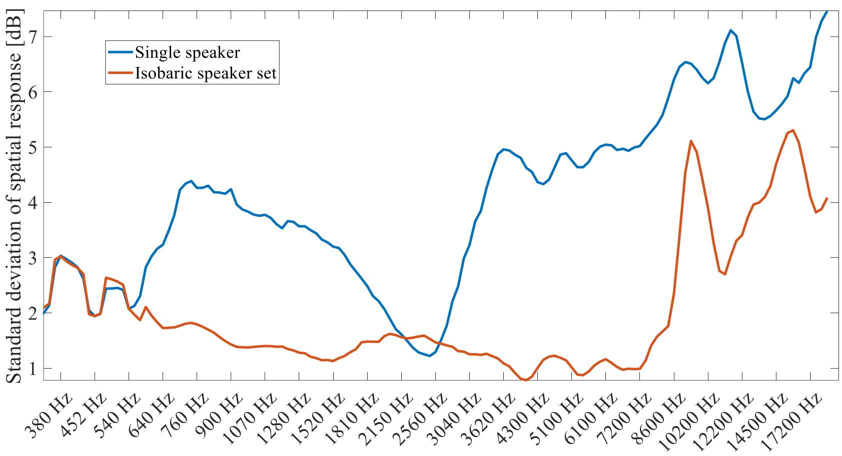

Figure 6. Standard deviation of spatial response for single driver and isobaric loudspeaker

Using this parameter we rate the result as closer to omnidirectional source if the standard deviation is smaller. Analysing Figure 6 we notice great increase in speaker omnidirectionality for isobaric in-phase configuration.

5. Conclusions

Paper presents the solution of coupled speakers set to provide small, omnidirectional sound source with narrow-band frequency response, limited by speaker size and distance between the speakers in coupled setup. Preliminary experimental verification proved initial concept and FEM modelling. There is a need to perform further estimation of isobaric speaker set concept in the terms of omnidirectional sources construction, such as geometrical dimensions of the inner volume and relevant speaker parameters for this type of speaker setup, however preliminary research prove the possible utility of this solution in further omnidirectional sources development.

Acknowledgments

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