A new omni-directional source based on a ring radiator

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Introduction

Omni-directional sound sources are of general interest for room acoustical measurements. For an ideal omni-directional sound source, the response is such that the sound that is emitted has a flat spectrum independent of direction. In this way all the reflected sound waves that are generated by this sound source result from the same flat spectrum excitation signal.

In our research in directionality of loudspeakers and its influence on perceived quality and realism, we are interested in an omni-directional sound source that can serve as a reference sound source for measuring room impulse responses cf. [1].

For the omni-directional sound source, two aspects are of particular importance. Firstly, the free field frequency response should be as flat as possible. Any coloration can interfere with directional hearing that is influenced by the spectral coloration created by the Head Related Transfer Function. Secondly, the total emitted sound energy should be uniformly distributed across space for all frequencies. In many listening situations, the reverberant sound field has more energy than the direction sound field and any coloration of the emitted sound energy will influence the perceived timbre of the sound.

In principle, a small loudspeaker could serve as an omni-directional sound source. However, in order to produce a sufficient Sound Pressure Level at low frequencies, the source volume velocity should be rather high, which requires a large loudspeaker, limiting the omni-directional behavior. An alternative solution that has been proposed is to use a larger loudspeaker that is placed in an enclosure with a small orifice (cf. Fig. 3). In this case the size of the orifice needs to be large enough to gain efficiency, but small enough to maintain an omni-directional behavior. These requirements limit the frequency range in which the omni-directionality can be established. A very commonly used solution is the dodecahedron-shaped loudspeaker cabinet with 12 loudspeakers mounted at the sides (e.g. [2]). Due to the 12 loudspeakers it has a high maximum power, but also a rather irregular frequency response for practical implementations.

In this paper we will present a new approach that is based on a ring radiator. Various measurements will be shown comparing the proposed solution to existing approaches. Finally, a measurement of the efficiency of the new speaker will be presented.

Ring radiator

In Fig. 1, the cross section of an axial symmetric ring radiator is shown which is based on two opposing loudspeakers placed within conical enclosures.

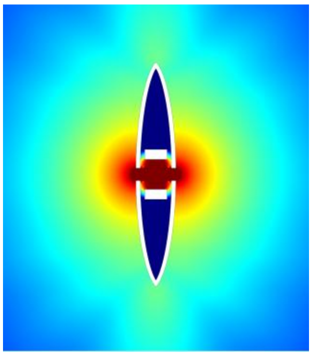

Figure 1: *Cross section of an axial symmetric ring radiator consisting of two loudspeakers placed in the middle, enclosing a cavity (dark red). Above and below the loudspeakers two conical enclosures (white lines) are placed, filled with damping material (dark blue). Sound is emitted from the edge of the cavity which has a ring shaped form. The color pattern outside the ring radiator represents the sound pressure distribution.*

Due to its axially symmetric design, the radiation pattern should be independent of the azimuth angle. Based on a theoretical analysis of a pure ring radiator (with pressure sources on a ring without enclosures being present) it is also expected that the radiation pattern will be rather independent of elevation around elevation angles of 0 degrees.

Finite Element Method simulations of the configuration shown in Fig. 1 support the assumption of independence of radiation patterns of elevation and suggest even better performance as a result of the presence of the smooth conical enclosures.

In Fig. 2, measurements are shown for a practical implementation of the ring radiator shown in Fig. 1. The ring radiator had a diameter of 10 cm and was driven in phase by two broadband drivers with an effective surface of 38 cm^2 each. As can be seen this ring radiator has rather uniform radiation patterns up to about 8 kHz with deviations of the order of 3 dB. Interestingly, the patterns are very uniform around elevations of 0 degrees. This is a convenient property for room acoustical measurements because the measurement microphone needs to be placed only approximately at an elevation of 0 degrees in order to obtain a flat frequency response of the ring radiator. The larger deviations from a flat response occur around the north and south poles (90 and 270 degrees). The total spatial angle associated with these deviations is small and therefore also the effect on the total energy emitted is relatively small.

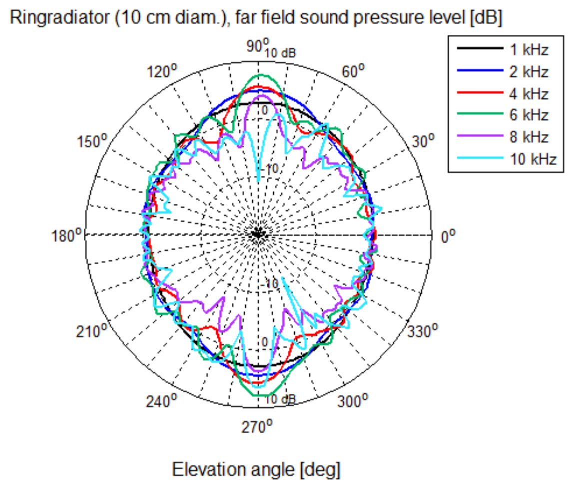

Figure 2: *Radiation pattern of a ring radiator as a function of the elevation angle (angle relative to the symmetry axis) for various frequencies. Sound pressure level in dB relative to 0° direction.*

For comparison, similar measurements are included for an orifice-based radiator and a dodecahedron in Fig. 3. The upper left panel shows the orifice based omni-source with a conical enclosure and a vibrating membrane in the middle. Below the membrane, absorbing material is placed, above the membrane, sound can propagate to the orifice at the top, which acts as an approximate point source. On the top right an example of a dodecahedron is shown with discrete loudspeakers at the surfaces. In the lower two panels of Fig. 3, the respective radiation patterns are shown for both configurations.

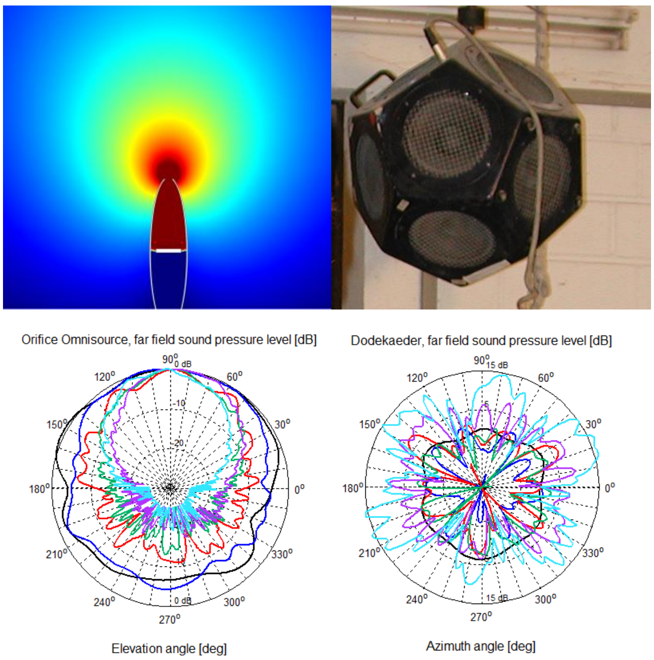

Figure 3: *Lay out (top panels) and measurements (lower panels) of an orifice-based radiator (left side), and a dodecahedron (right side). Results are shown with the same color coding as Figure 2.*

As can be seen the orifice-based radiator has a tendency to emit most acoustical energy in the upward direction for high frequencies. The dodecahedron configuration has a rather irregular radiation pattern. Clearly, the new ring-radiator-based sound source has a more uniform response.

To conclude the maximum sound pressure level that can be produced by the ring-radiator based omni-source was measured for the practical implementation that we made. With pink noise between 150 Hz and 6 kHz, driving the loudspeakers at their maximal specified power, a sound pressure of 107 dB at 1 meter distance was measured.

In Fig. 4 the frequency response of a 7 cm diameter ring-radiator based omni-source is shown. As can be seen, the transfer function is not flat. This function can be equalized, however, by pre-filtering the input signal. At about 2.5 kHz, a resonance can be observed associated with the diameter of the cavity enclosed by the loudspeakers. Experimentation showed that this resonance can be reduced by placing a sheet of damping material in the cavity. It can also be observed that the response falls off below about 180 Hz. Thus, for low-frequency measurements, support from a subwoofer is required.

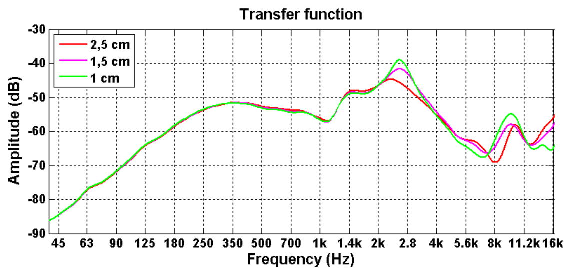

Figure 4: *Frequency response of a 7-cm-diameter ring-radiator omni-source measured in the direction of the north-pole (90 degrees elevation) for various heights of the ring-shaped opening.*

Summary

A new omni-directional sound source was presented which is based on a ring-radiator design. In measurements it showed a very uniform radiation pattern, where deviations of about 3 dB occurred mainly in the upward and downward directions. A total level of 107 dB SPL at 1 meter distance could be produced when the omni-source was driven by pink noise.

References

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