Investigation of Indoor Performance of Bass Directivity Control Techniques

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Introduction

The paper investigates the performance of low frequency loudspeakers in large sound reinforcement systems. The key task for sound amplification system design is to provide an even sound pressure level distribution on the whole listening area with the same frequency response, reduce noise level on the stage and radiation in wrong directions. This can be quite challenging in low frequency domain due to low subwoofers directivity, strong interference between clusters in common left/right setup and room modes. The present work, being the beginning of a bigger project, aims to investigate indoor performance of some common outdoors bass directivity control techniques and to define further steps to improve low frequency sound reproduction in large venues.

Bass Directivity Control Techniques

The usual setups of PA subwoofers for directivity control are:

- "standard" cardioid, which uses a stack of two or three subwoofers, one facing backwards, time-delayed and polarity reversed. The best cancellation backwards is achieved at one selected frequency, directivity is strongly frequency dependent [2].
- cardioid subwoofer array (CSA), a stack of three subwoofers, one of them facing backwards, with frequency dependent delay. Directivity is constant in operating frequency range [3].
- endfire array, made of two or more subwoofers, placed one behind another with delay times increasing from the back to the front. The best cancellation backwards is achieved again at one particular frequency, directivity is strongly frequency dependent [2].
- line array of subwoofers. Several subwoofers are placed in a row at a certain distance to each other. The directivity can be constant up to the limiting frequency, which depends on the spacing between single cabinets. Introducing delays to single cabinets, various directivity patterns can be achieved.

Further the cardioid subwoofer array (CSA) and the line array are considered.

Indoor application

The measurements were performed in two different venues: a large reverberant hall and a relatively small concert club. Sound sources (subwoofers) were located in front of the stage, and microphones' positions formed a 1.5mx1.5m grid. We assumed both rooms to be symmetrical, so just one half of each room was measured. Impulse response of the room was measured for every setup of subwoofers at each microphone position.

Large reverberant room

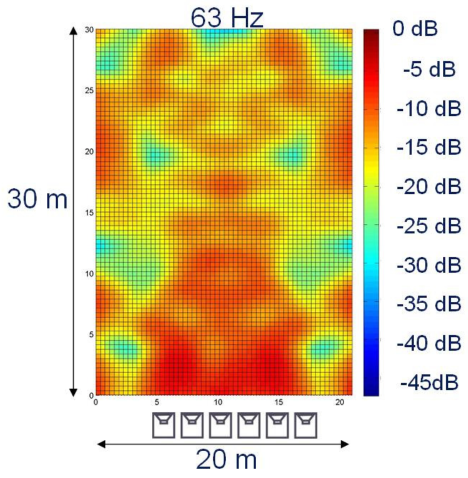
At first a line array of 6 subwoofers was installed in a large reverberant hall (picture 1). Each subwoofer included 3 drivers and worked either in omnidirectional or in cardioid mode.

Picture 1 Reverberant hall, V=11830m³, T30=2.75s, Fs=18Hz.

Eight setups were tested: left and right, all six subwoofers without any delays, "optimal" delays (calculated in free field to cover the given listening area), delays for wider dispersion; each setup in omnidirectional and cardioid modes.

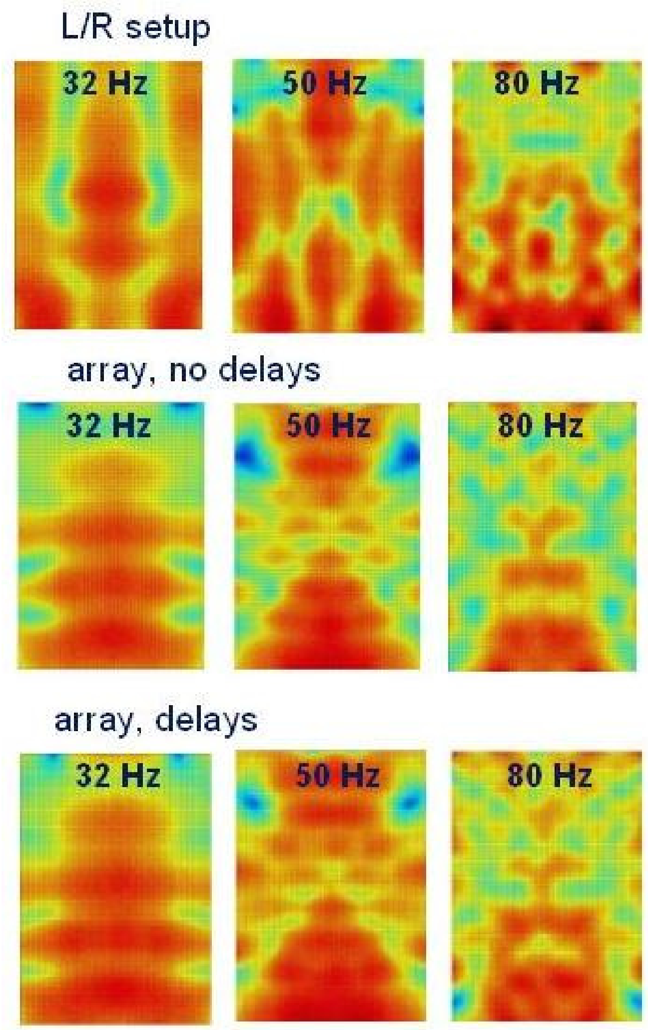
Picture 2 Line array of subwoofers in front of the stage.

As an example a resulting SPL (sound pressure level) distribution is shown (picture 3).



Picture 3 Example plot of the SPL distribution in the large room.

SPL distribution for different setups was compared. The difference between L/R setup and the bass array is significant, but not between different delay settings (picture 4).

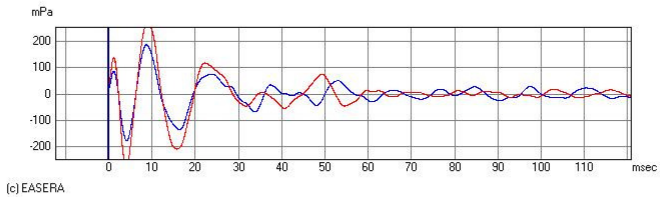


Picture 4 SPL distribution for three different (cardioid) setups at three different frequencies, normalized over the frequency response of a single subwoofer.

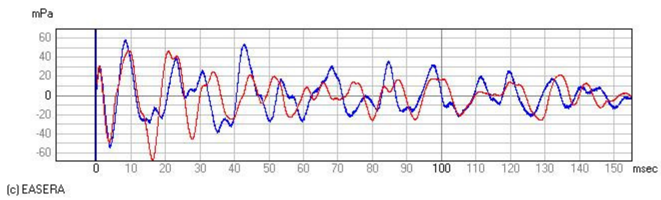
A certain spatial structure is present far above the calculated Schroeder frequency of 18 Hz for all setups.

Small concert hall

The second room had a volume of 1500m³, T30=1.08s, Fs=32Hz. The same measurement procedure was performed, two CSA stacks were used as sound source in left and right positions. The SPL distribution also has a spatial structure above the calculated Schroeder frequency (not presented in the paper). Pictures 5 and 6 show typical impulse responses at two neighboring microphones' positions. The difference is increasing with the distance from the sound sources.



Picture 5 Impulse responses at two microphone positions at 1.5m distance from each other and 1.5m distance from the stage.



Picture 6 Impulse responses at two microphone positions at 1.5m distance from each other and 15m distance from the stage.

Conclusions and Outlook

- using of bass arrays indoors makes difference in comparison to L/R setup
- different delay settings don't make drastic change to the SPL distribution

As further steps towards optimization of indoors sound reproduction at low frequencies, the following could be considered:

- listening tests: how sensitive are people to small changes of IR/FR at low frequencies
- influence of the audience: absorption
- optimization procedure: fitting an array into a room
- geometry uncertainties

Literatur

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[2] Bob McCarthy, Sound Systems: Design and Optimization, 2007

[3] d&b audiotechnik, TI 330 Cardioid Subwoofer Array, www.dbaudio.com

[4] Janko Ramuscak, Directional Low Frequency Sources, presented at SIEL 2009