A Study of Low Frequency Sound Propagation through Listeners

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Introduction

It's become common lately to use distributed arrays of subwoofers for large outdoor concerts or festivals. Subwoofers are placed in a row on the ground in front of the staged, and delays are used to control the directivity of the array. This technique helps to create an even sound pressure level distribution over the listening area, but it's not clear how the presence of the listeners influences the sound propagation. The paper presents the first steps made to study the low frequency sound propagation through large crowds. A crowd of people is a complicated inhomogeneous medium, where additional absorption or scattering between single objects can take place; several ways to approach the problem were tried and are presented in the paper: scale measurements, live measurements and simulation.

Scale Measurements

As a first step to find out if the presence of listeners effects the sound propagation, 1:10 wooden models of people were built. Since no data on low frequency (20-100 Hz) sound absorption by human body were available, sound reflecting material was chosen for the models in order to study the effect of geometrical arrangement of figures. The measurement setup is shown on the fig. 1. Several layouts with different densities (up to two persons per square meter) and regular and irregular arrangement of “listeners” were tested.

Fig 1: A scale measurements setup consisting of fifty 1:10 wooden models people, a loudspeaker and three microphones, which can be placed on different distances from the loudspeaker.

Sound pressure levels with and without “public” were measured on different distances from the loudspeaker and compared, an example result for one position is shown on the fig. 2.

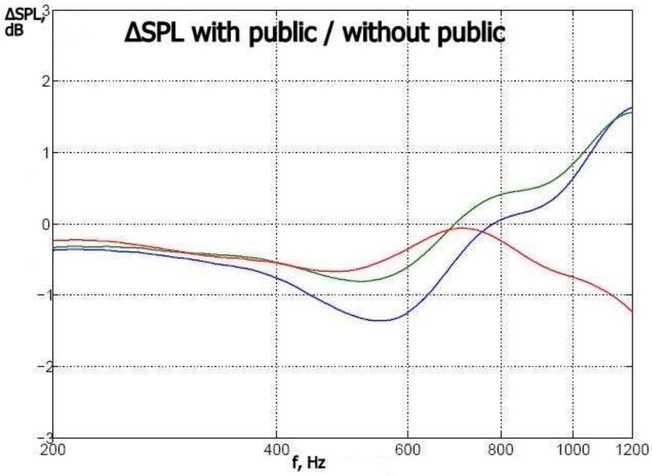

Fig 2: Difference of the sound pressure level in the presence of public and in free field. Red curve – upper microphone, green – middle, blue – bottom.

The values below zero indicate addition attenuation of sound at the given position in comparison to the free field sound propagation, values above zero – additional reinforcement. Measurements of different arrangements on different positions show generally similar picture: there is attenuation and reinforcement present, all within ±3dB

Live Measurements

As the next step, a series of live measurements on several open air concerts was done to compare the sound propagation through the crowd with the free field propagation. Microphone positions were marked before the concert (usually 5-6 position 5 meters apart from each other, fig. 3).

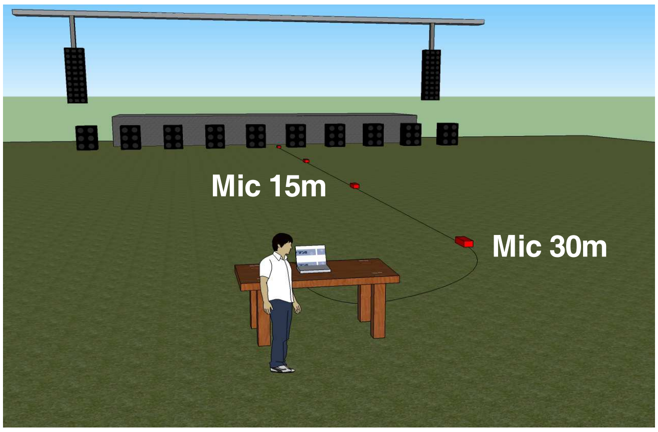

Fig 3: Microphone positions for live measurements.

Right before admission, when the sound system is already set up and tuned, transfer function of the subwoofers is measured. When listeners are already in but the band hasn't started to play yet (fig.4), the transfer function of the subwoofers is measured again at every position, but this time using the background music as the measurement signal [1] and a measurement technique described in [2], which gives the measurement uncertainty within ±2dB.

Fig 4: A live measurement setup, public density is about 2.1 persons per square meter close to the stage.

Then the sound pressure level drop between microphone positions is calculated for both cases (with public and without) and compared using the following formula:

$$\Delta dB_{xy} = \Delta SPL_{full,xy} - \Delta SPL_{empty,xy}$$

Again, positive values mean additional reinforcement and negative mean additional attenuation of sound pressure in a crowd in comparison to free field. Example result for the venue on fig.3 (Energy in the Park in Stuttgart) is given on the fig. 5:

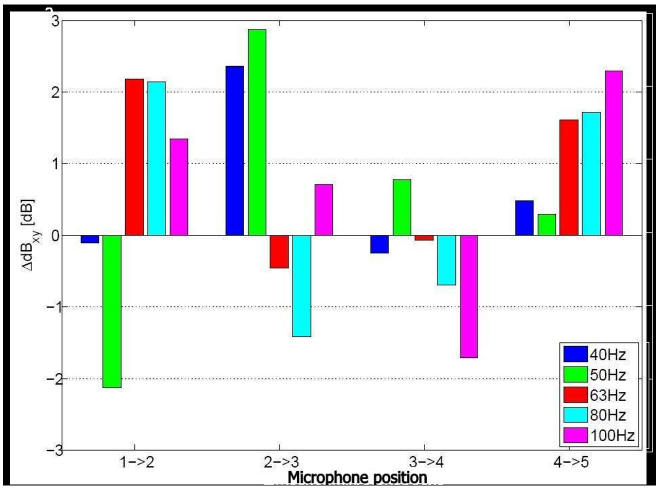

Fig 5: The influence of the presence of public on the low frequency sound propagation. Positive values mean reinforcement, negative – attenuation.

Simulation

A BEM-simulation was done to study the influence of the form of the crowd on the sound propagation within it. Fig.4 shows SPL distribution (free field + scattered field) within a 10x17m "crowd" of 350 rigid cylinders, 1.7m high, about 25 cm radius.

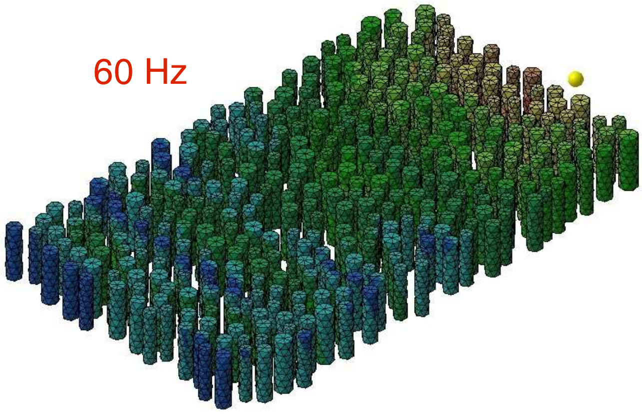

Fig 5: SPL distribution at 60 Hz within a 10x17m "crowd" of rigid cylinders, 1.7m high, about 25 cm radius. Density 2 persons/m².

The SPL distribution has a mode-like structure, which disappears with decrease of density (fig. 6).

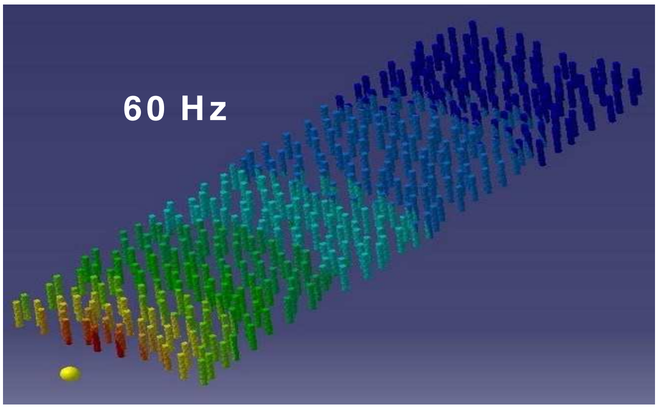

Fig 6: SPL distribution at 60 Hz within a 10x30m "crowd" of rigid cylinders, 1.7m high, about 25 cm radius. Density 1.3 persons/m².

Conclusions

- a crowd creates additional attenuation and reinforcement of sound in comparison to free field, which might be caused by multiple scattering between single objects
- the sound field structure seems to be highly dependent on the density of the crowd

Literature

[1] W. Ahnert, S. Feistel, A. Miron, E. Finder, Software based Live sound measurements. 121st AES Convention, 2006

[2] M. Kaiser, J. Ramuscak, E. Shabalina, Live Sound Measurements of Subwoofers' Performance. 128th AES Convention, 2010