Reducing Artifacts of Focused Sources in WFS

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Deutsche Telekom Laboratories

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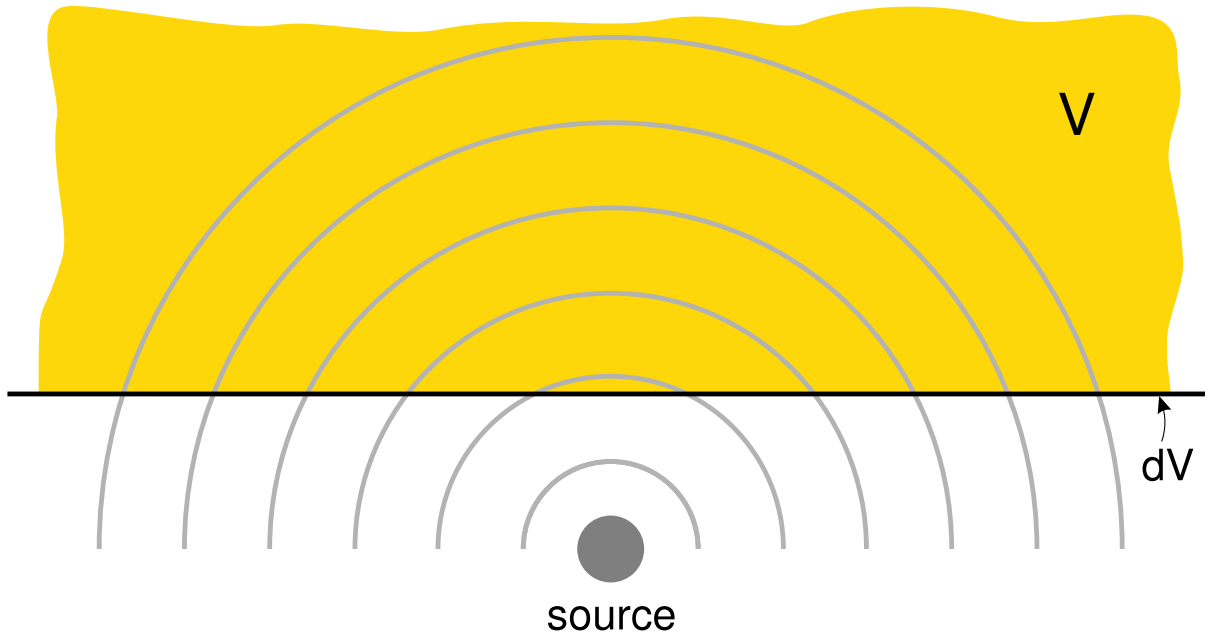
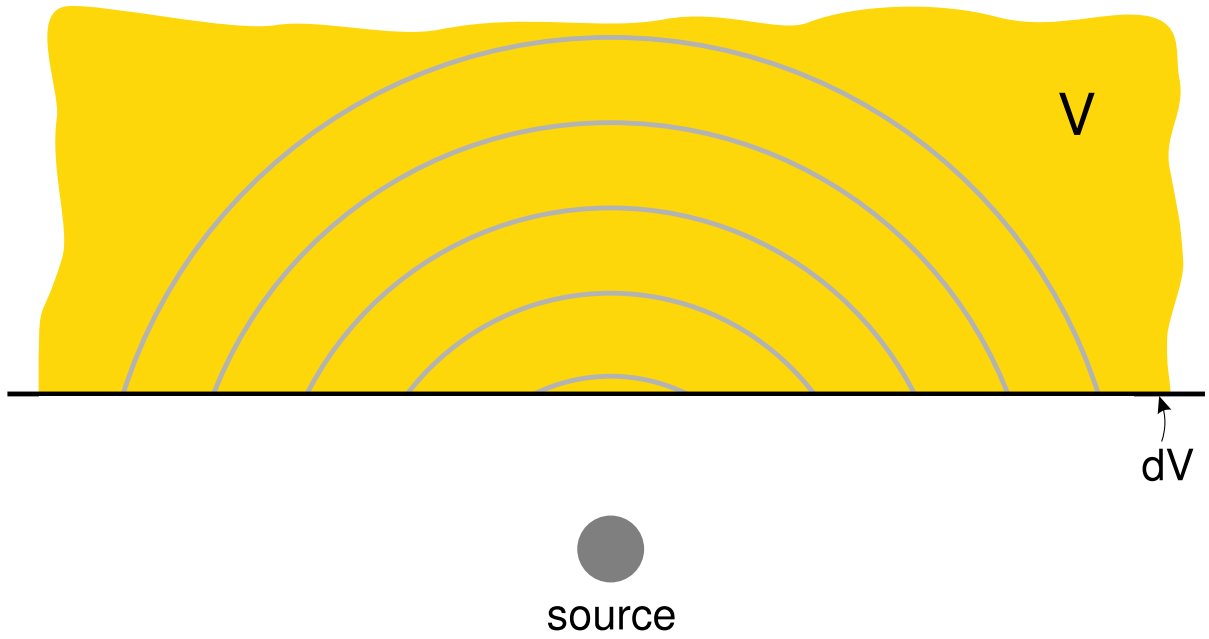
Wave Field Synthesis



- Huygens-Fresnel principle
- quantitative formulation by Rayleigh integrals
- sound field synthesis in a half-space V

Wave Field Synthesis



- Huygens-Fresnel principle
- quantitative formulation by Rayleigh integrals
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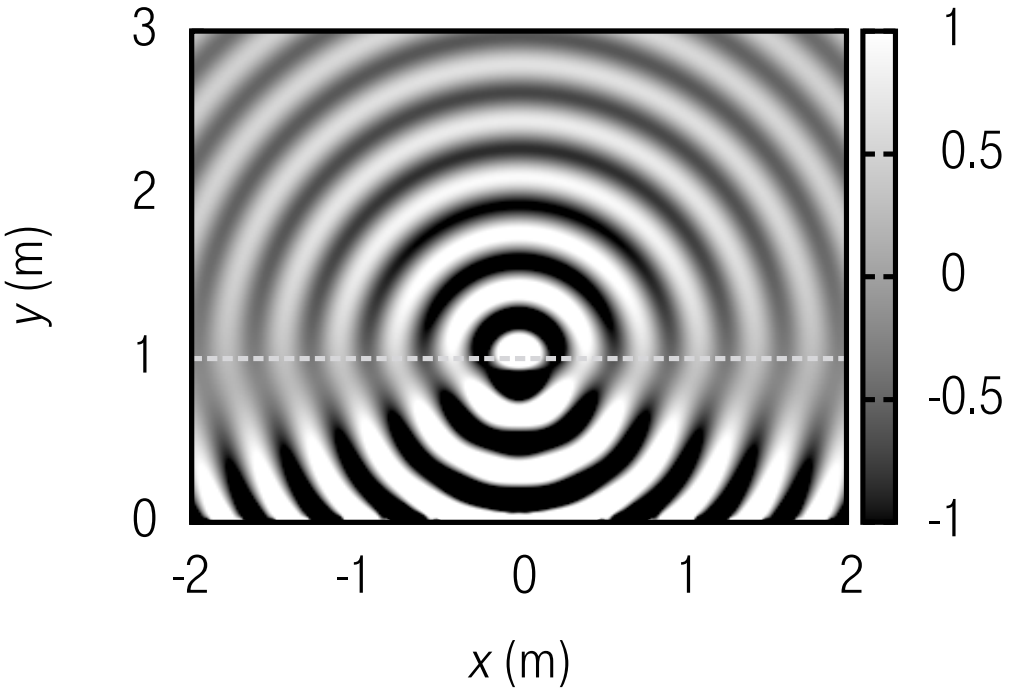
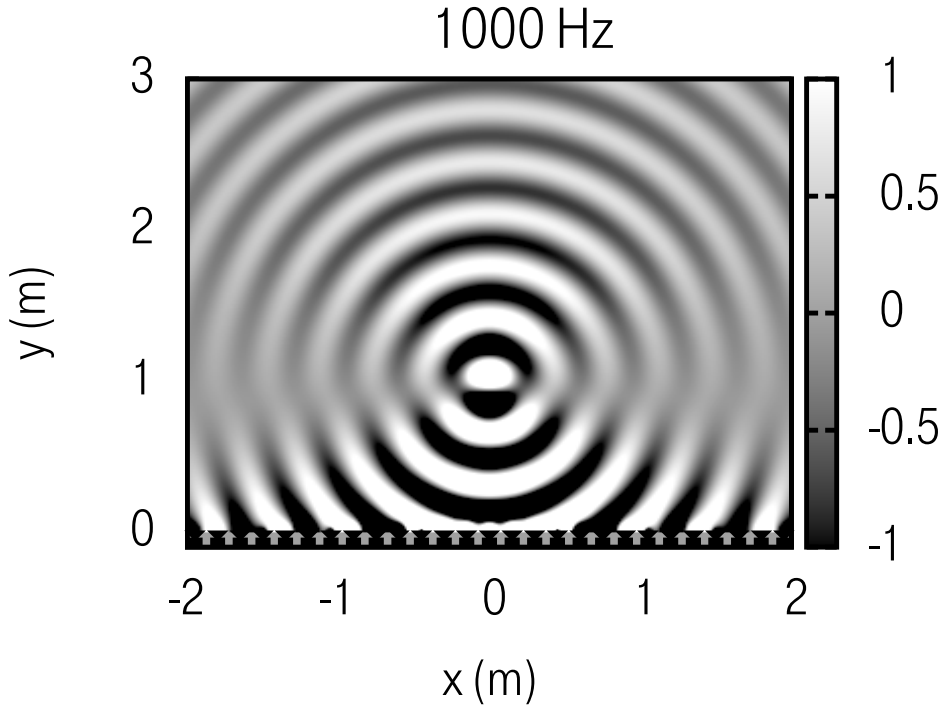
Focused Sources



- acoustic focusing based on time-reversal principle
- acoustic point sink as source model for WFS
- converging field from secondary sources to focus point
- diverging field from the focus point (field of a point source)

Focused Sources

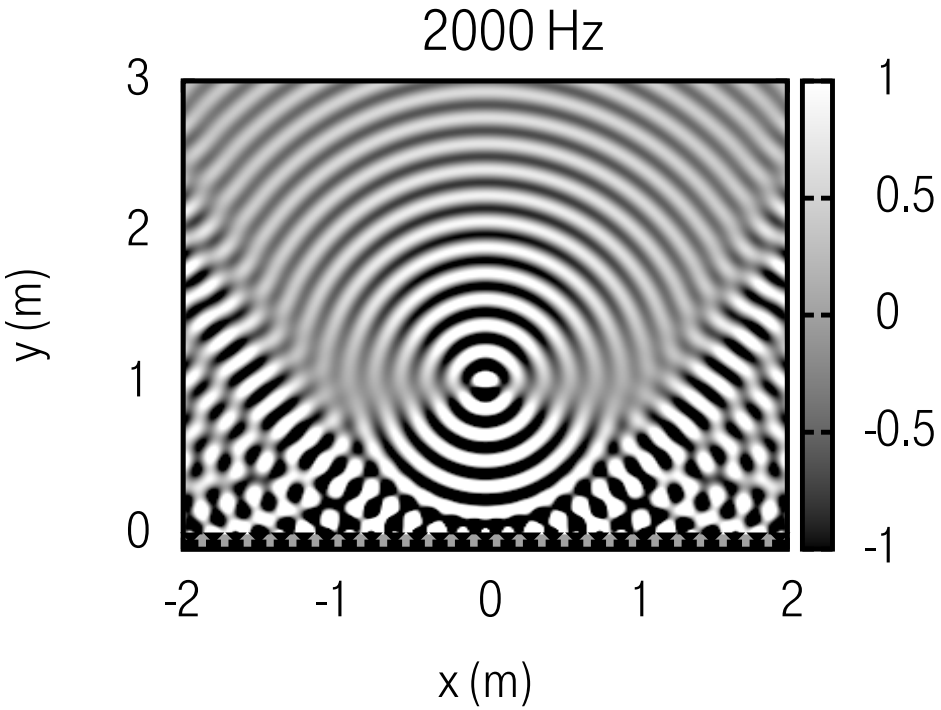
Sampling Artifacts



- loudspeaker spacing 0.15 m
- spatial sampling artifacts occur above approx. 1100 Hz
- focal point without artifacts due to spatial sampling

Focused Sources

Sampling Artifacts



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Focused Sources

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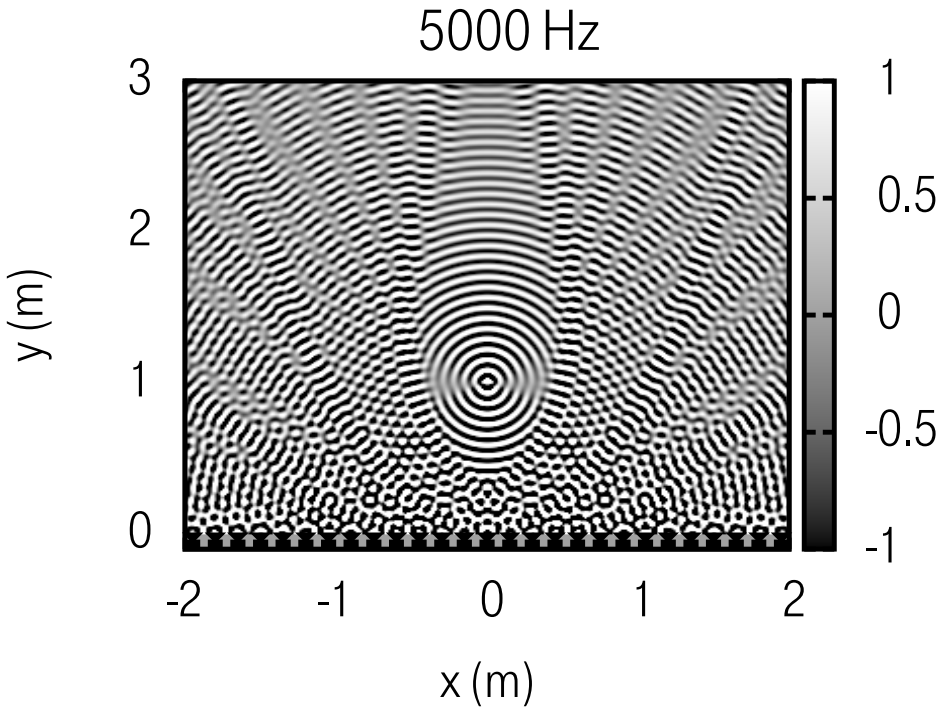

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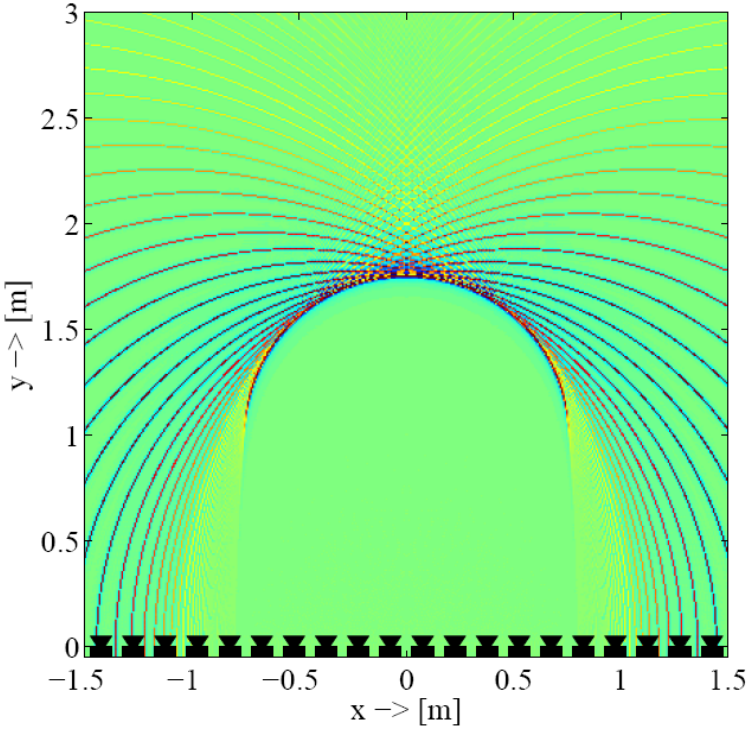
Focused Sources

Pre-Echoes



- spatial sampling causes pre-echoes in time domain
- pre-echoes very critical for perception (Spors et al. 2009, Geier et al. 2010)
- number of pre-echoes depends on size of loudspeaker array

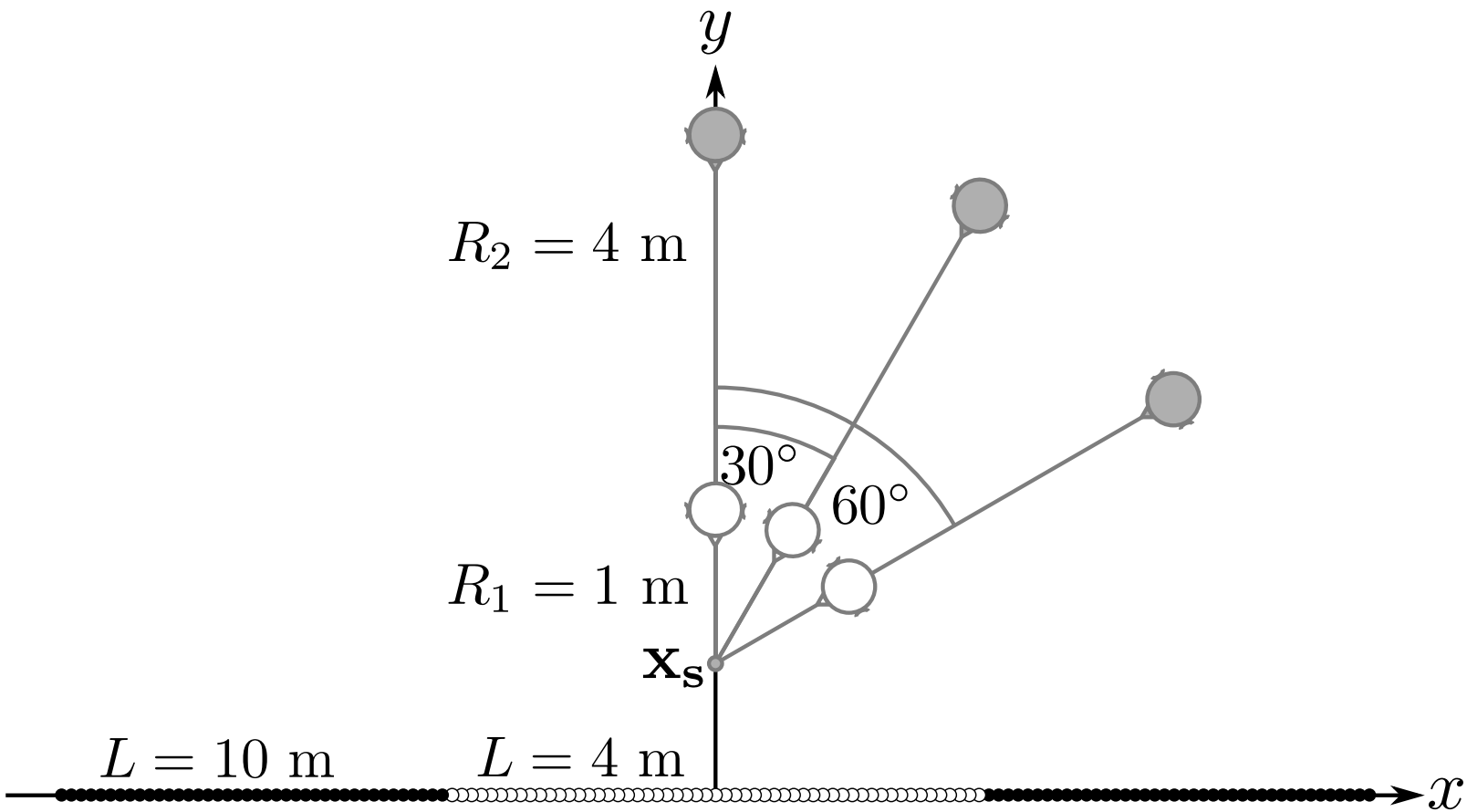
Experiment

Method

- array lengths: 10 m, 4 m, 1.8 m, 0.75 m, 0.3 m, single loudspeaker reference
- virtual array with dynamical binaural resynthesis using the SSR
- 6 subjects from our Lab
- rating the attribute pairs *few artifacts vs. many artifacts*, *left vs. right*
- castanets and speech as stimuli
- SSR and stimuli available at our Blog: `http://audio.qu.tu-berlin.de`

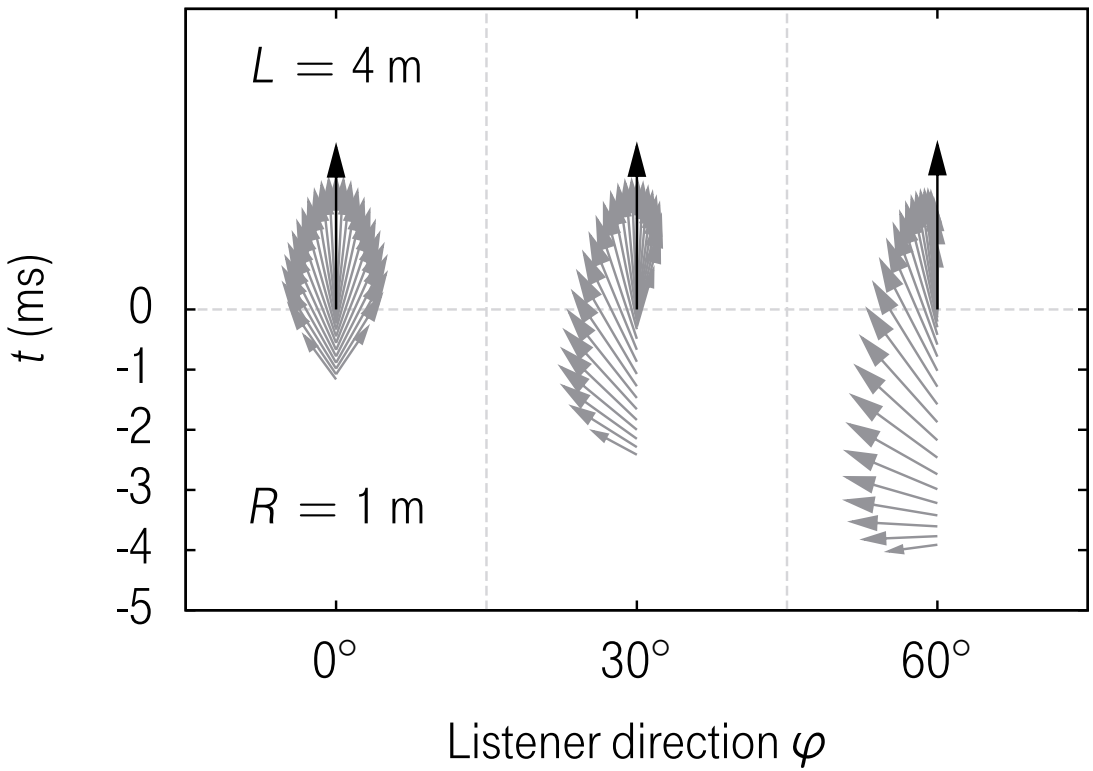
Experiment

Geometry



Focused Sources

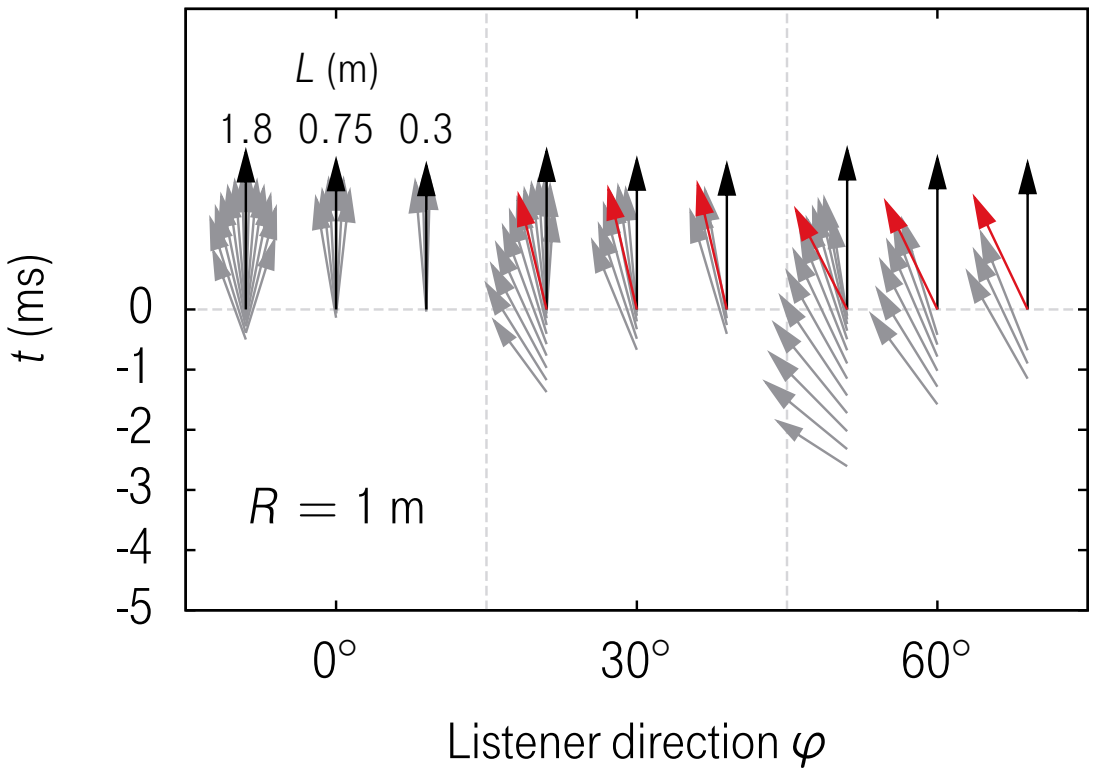
Pre-Echoes



- wrong perception of direction
- perception of more than one source

Focused Sources

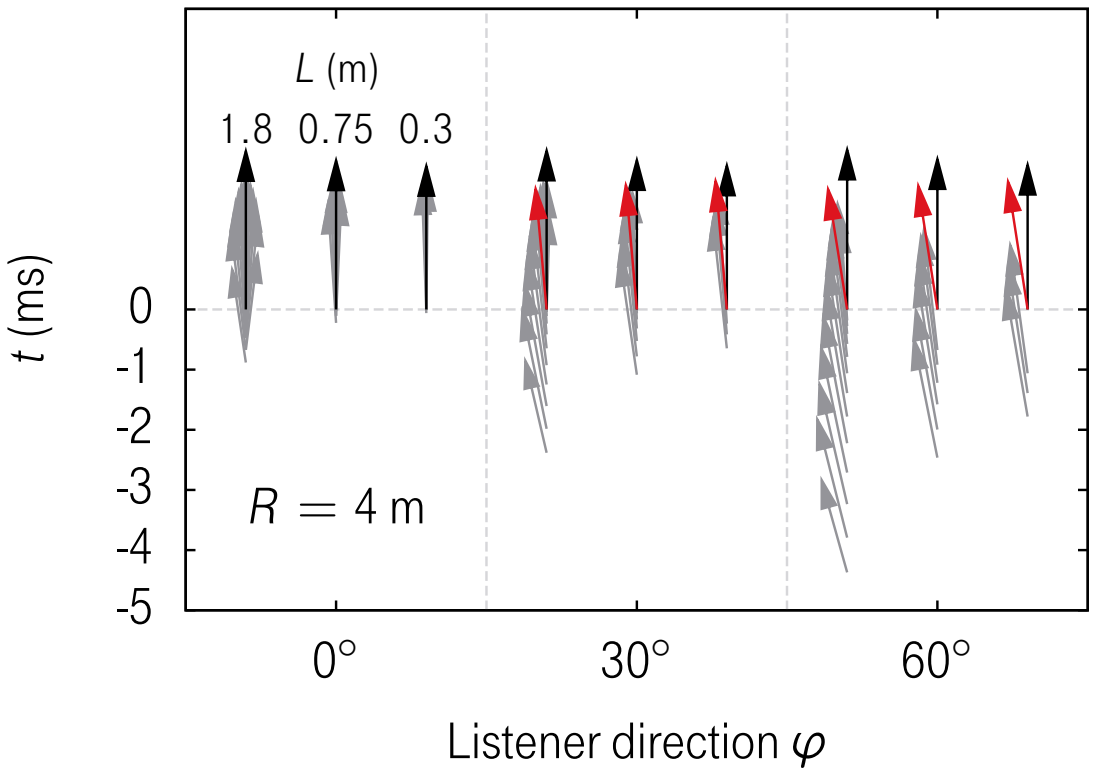
Pre-Echoes



- artifacts hypothesis: the shorter the array the fewer artifacts are audible
- position hypothesis: the perceived position depends not on the array length

Focused Sources

Pre-Echoes



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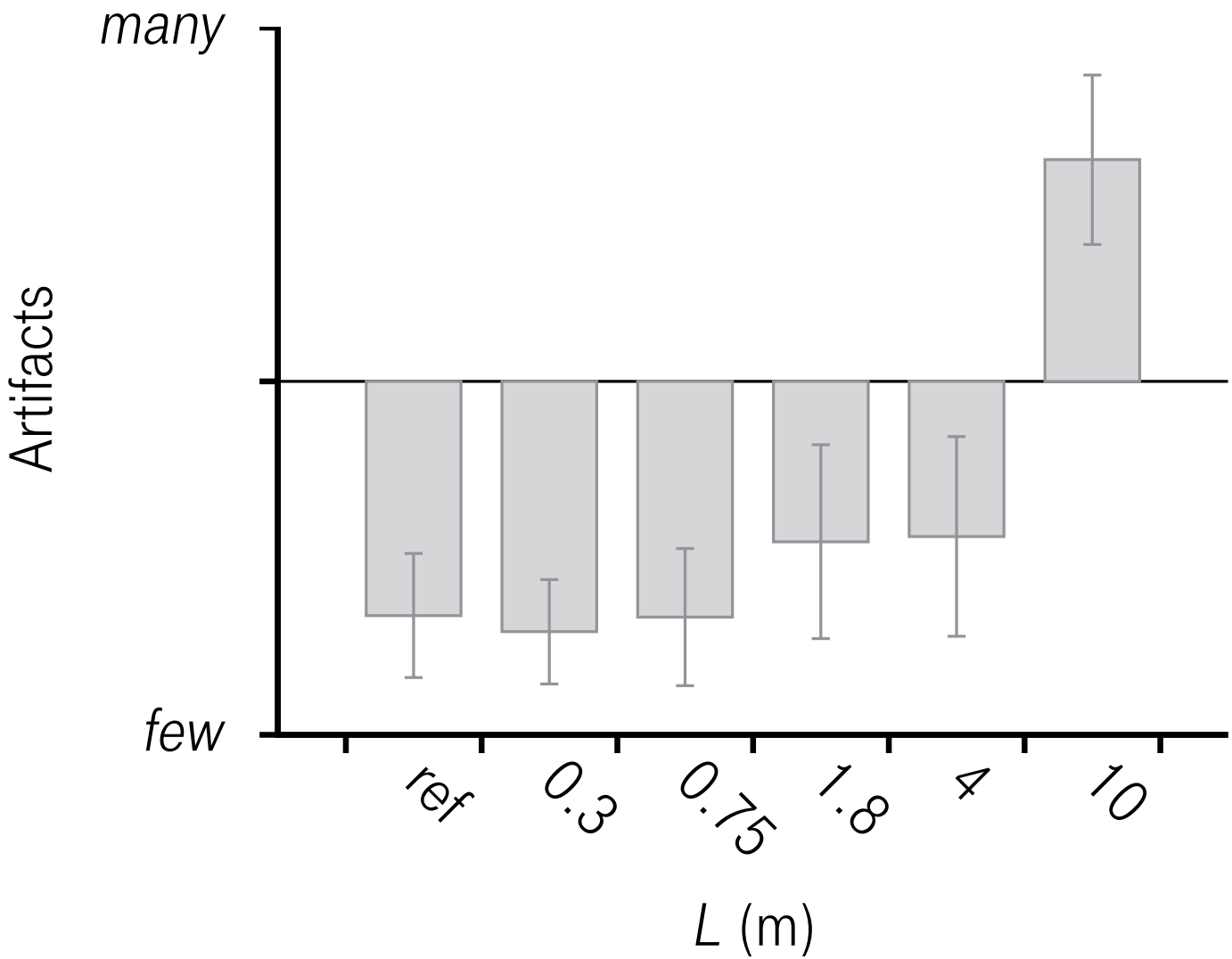
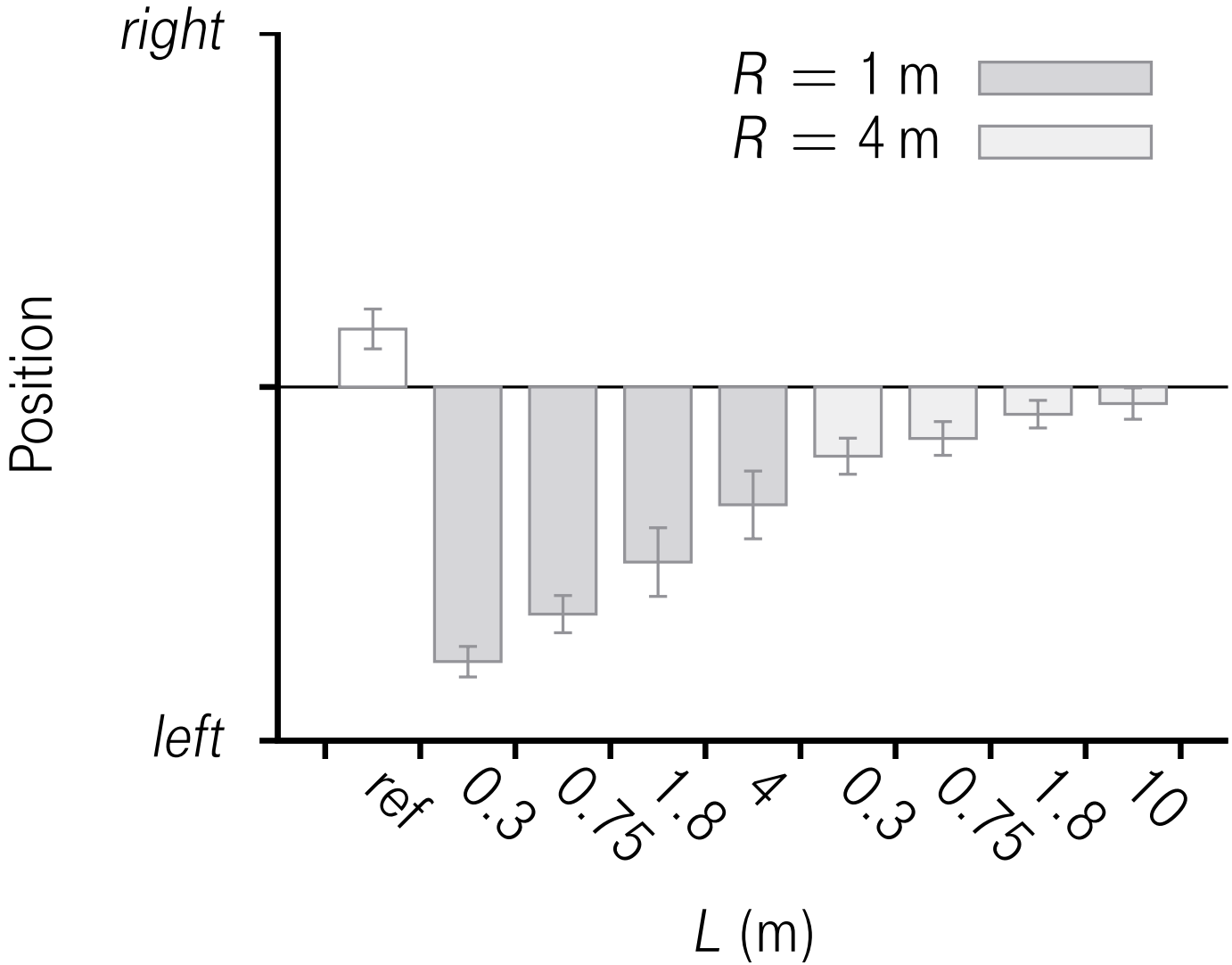
Results

Artifacts



Results

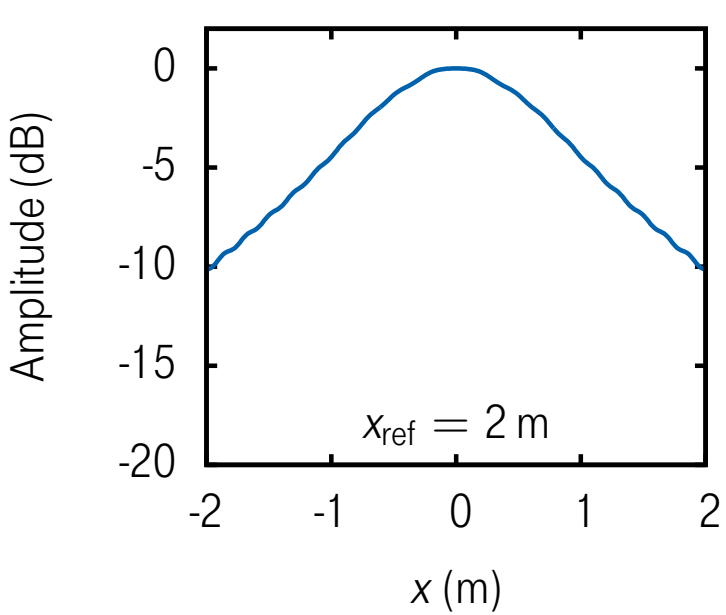
Position

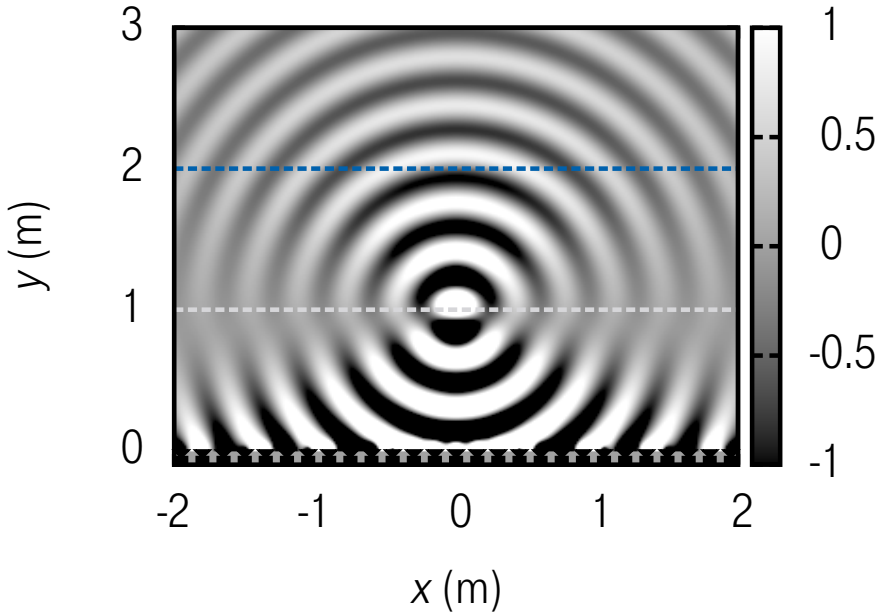


Focused Sources

Truncation Artifacts

$L = 100\,\mathrm{m}$

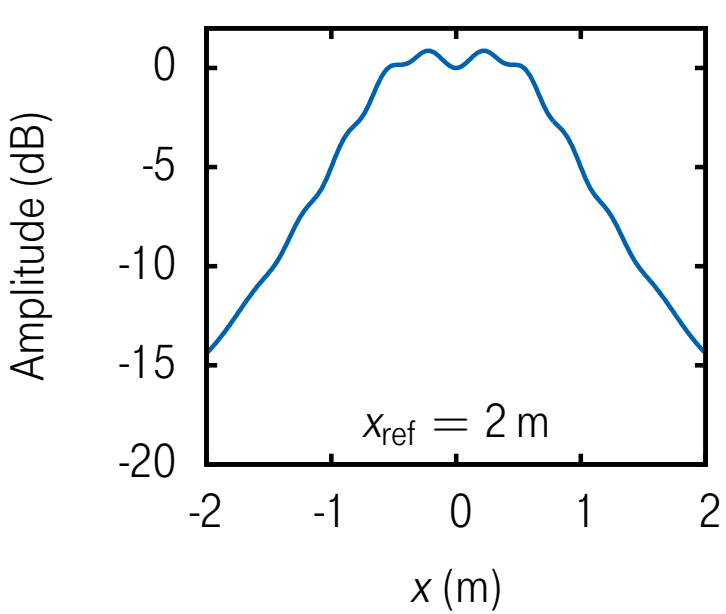


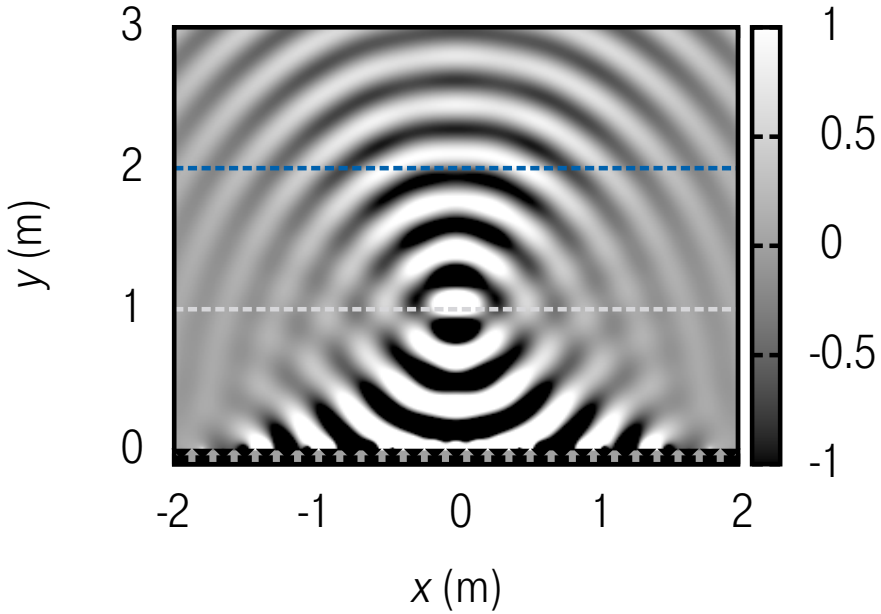


Focused Sources

Truncation Artifacts

$L = 4\,\mathrm{m}$

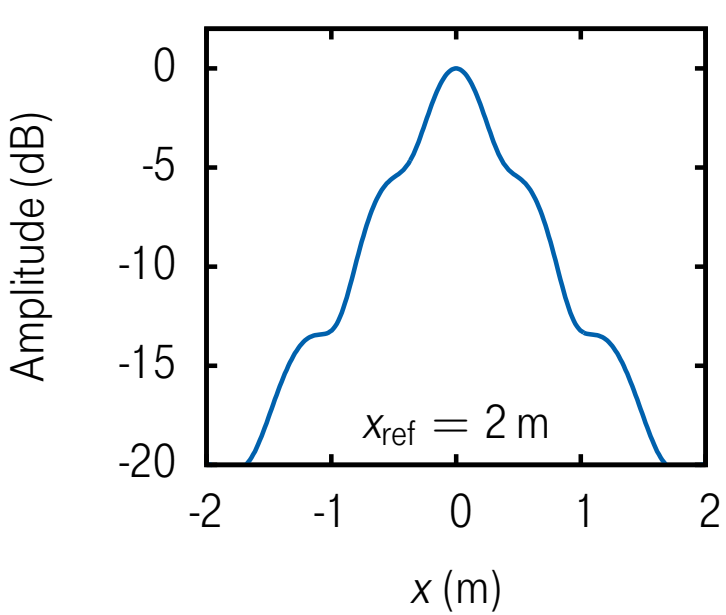


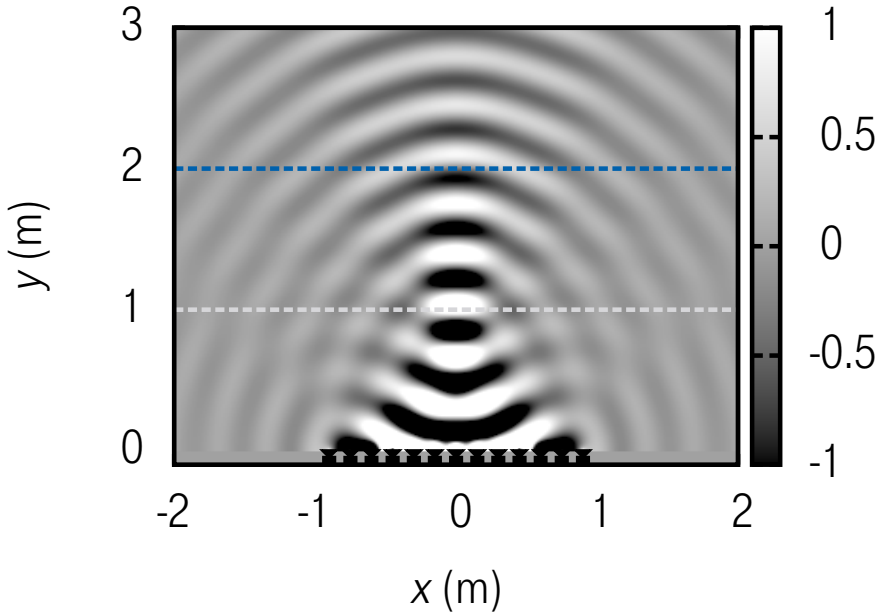


Focused Sources

Truncation Artifacts

$L = 1.8\,\mathrm{m}$

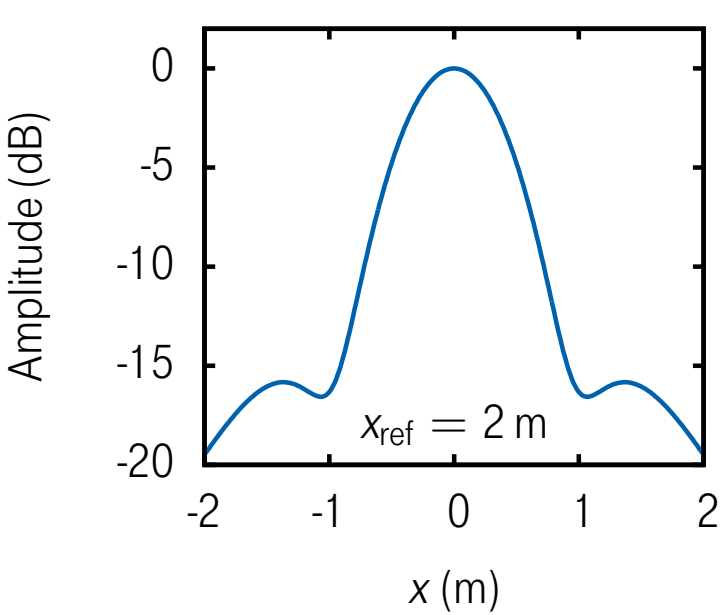


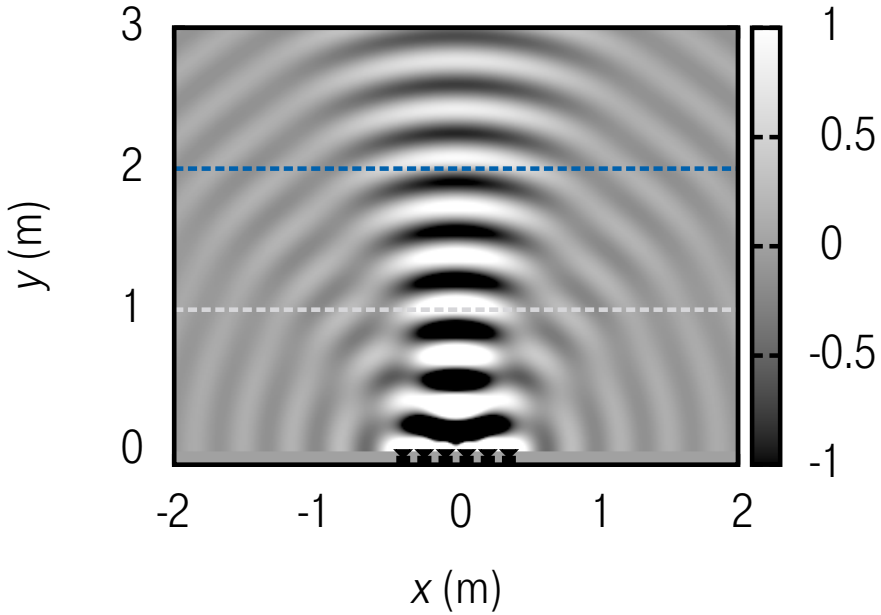


Focused Sources

Truncation Artifacts

$L = 0.75\,\mathrm{m}$

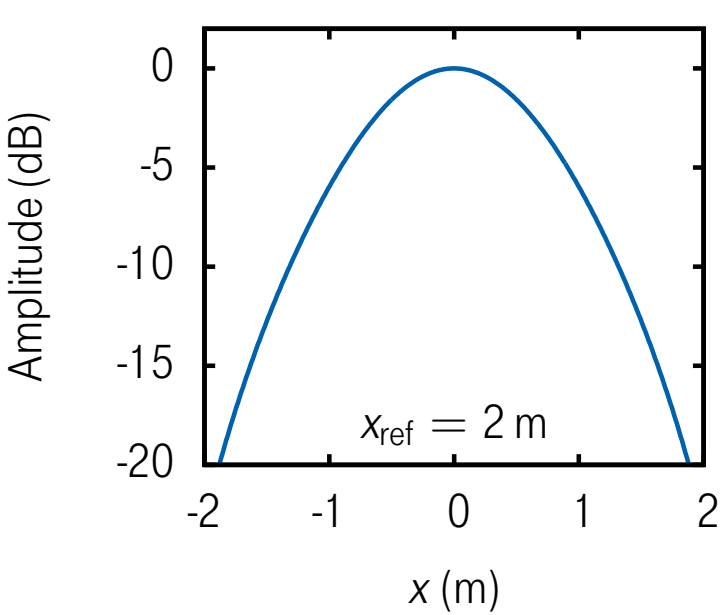


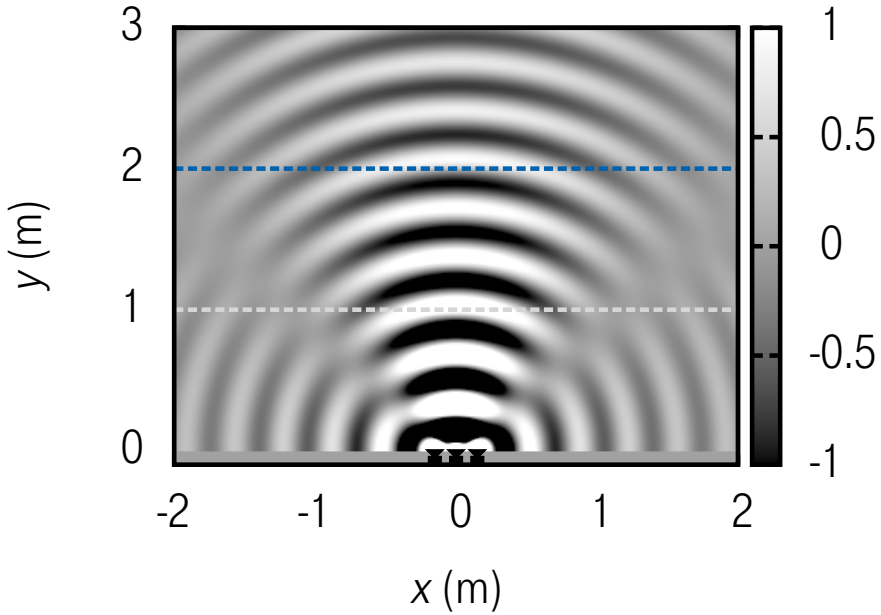


Focused Sources

Truncation Artifacts

$L = 0.3\,\mathrm{m}$



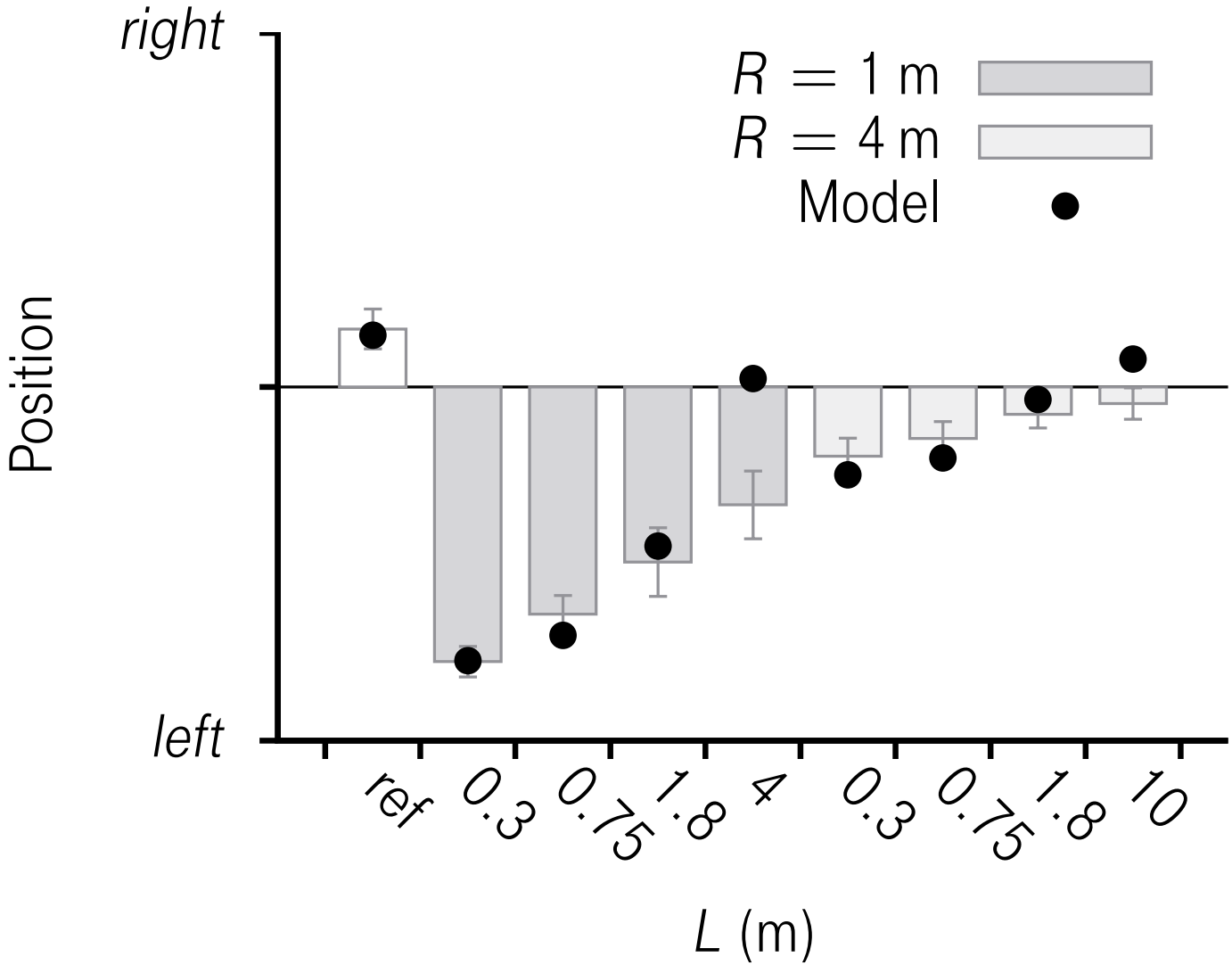


Modeling

- truncation leads to wrong ILD cues, pre-echoes to wrong ITD cues
- modeling of the binaural perception by the Lindemann model (Lindemann 1986a)
- as model parameter the ones from Lindemann were used
- model is available at `http://amtoolbox.sourceforge.net/`

Results

Position



Conclusion

- resynthesis of focused sources in WFS is a challenging task
- spatial aliasing leads to pre-echoes, which can be reduced by using only a sub-array of loudspeakers
- truncation artifacts lead to wrong binaural cues and a perception of the source from the wrong direction
- modeling of the perceived direction shows that the precedence effect may not be considered for $t < 3\,\text{ms}$
- there exists the possibility to enhance the direction perception by using image source (Oldfield et al. 2010, Caulkins et al. 2003)

Thank you very much for your attention!

Questions?

Get example audio files here: `http://audio.qu.tu-berlin.de/`