Localization of a virtual point source within the listening area for Wave Field Synthesis

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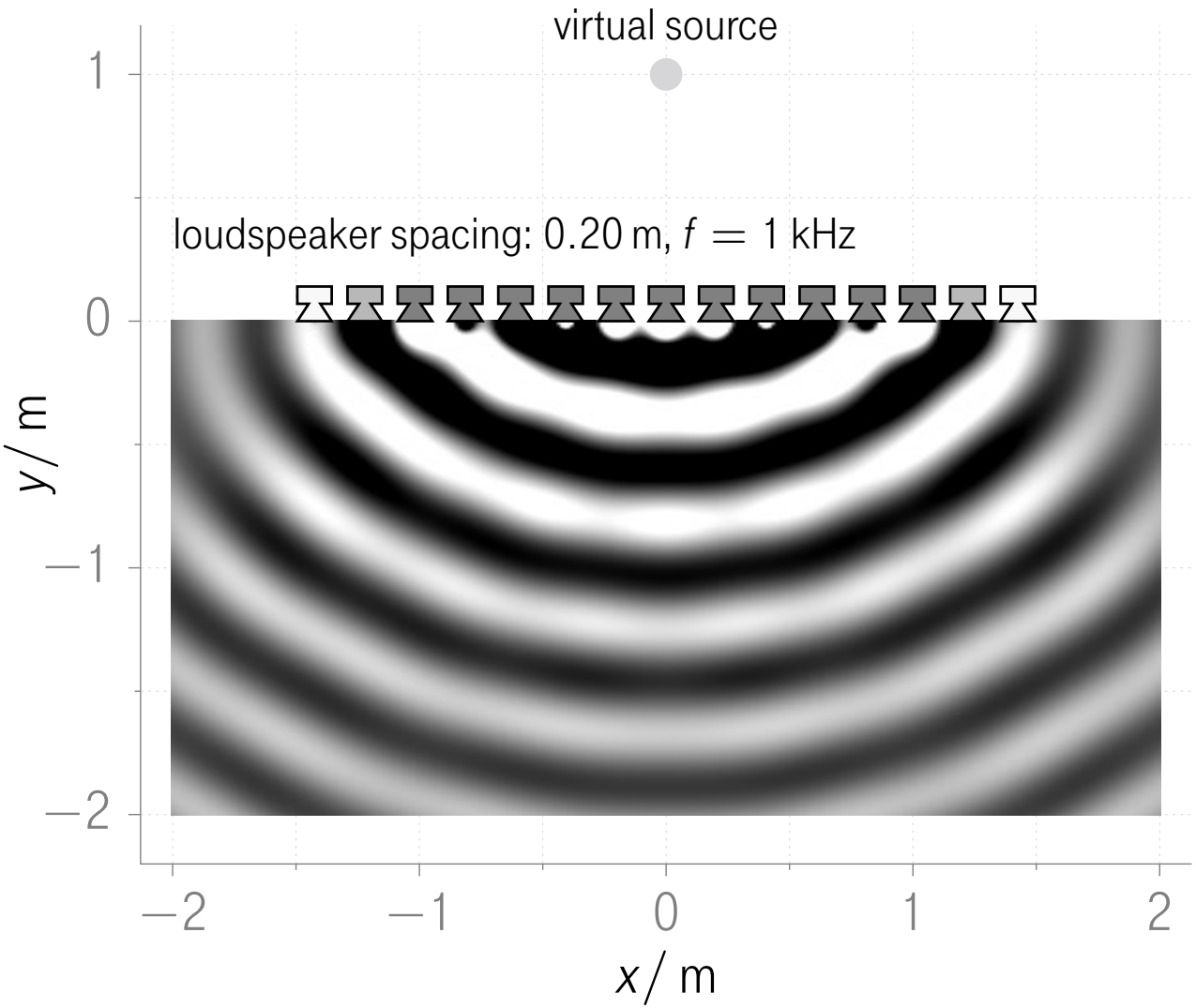
Deutsche Telekom Laboratories

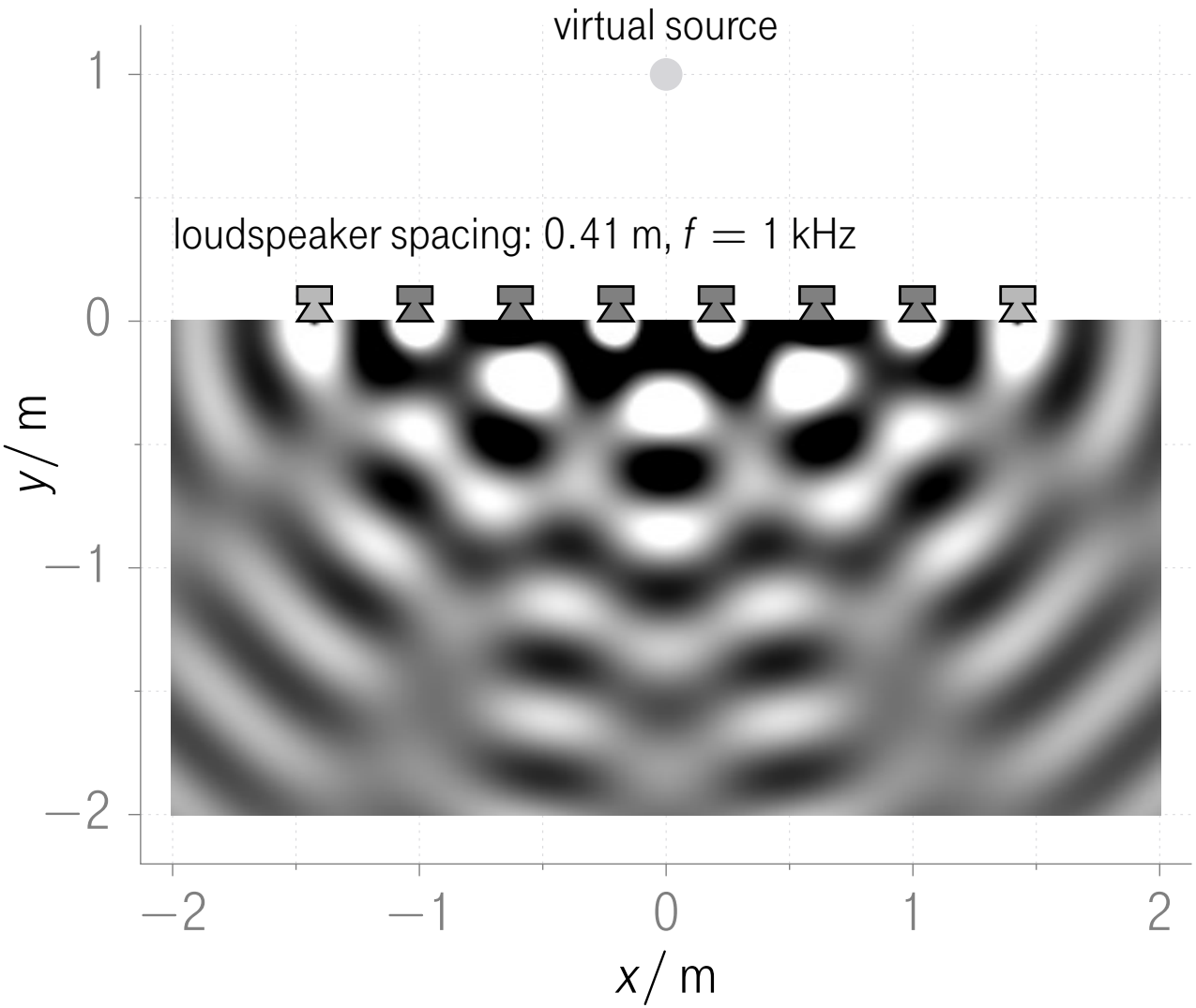
Wave Field Synthesis (WFS)

correct field for the whole listening area



Wave Field Synthesis (WFS)

artefacts in the whole area



Research questions

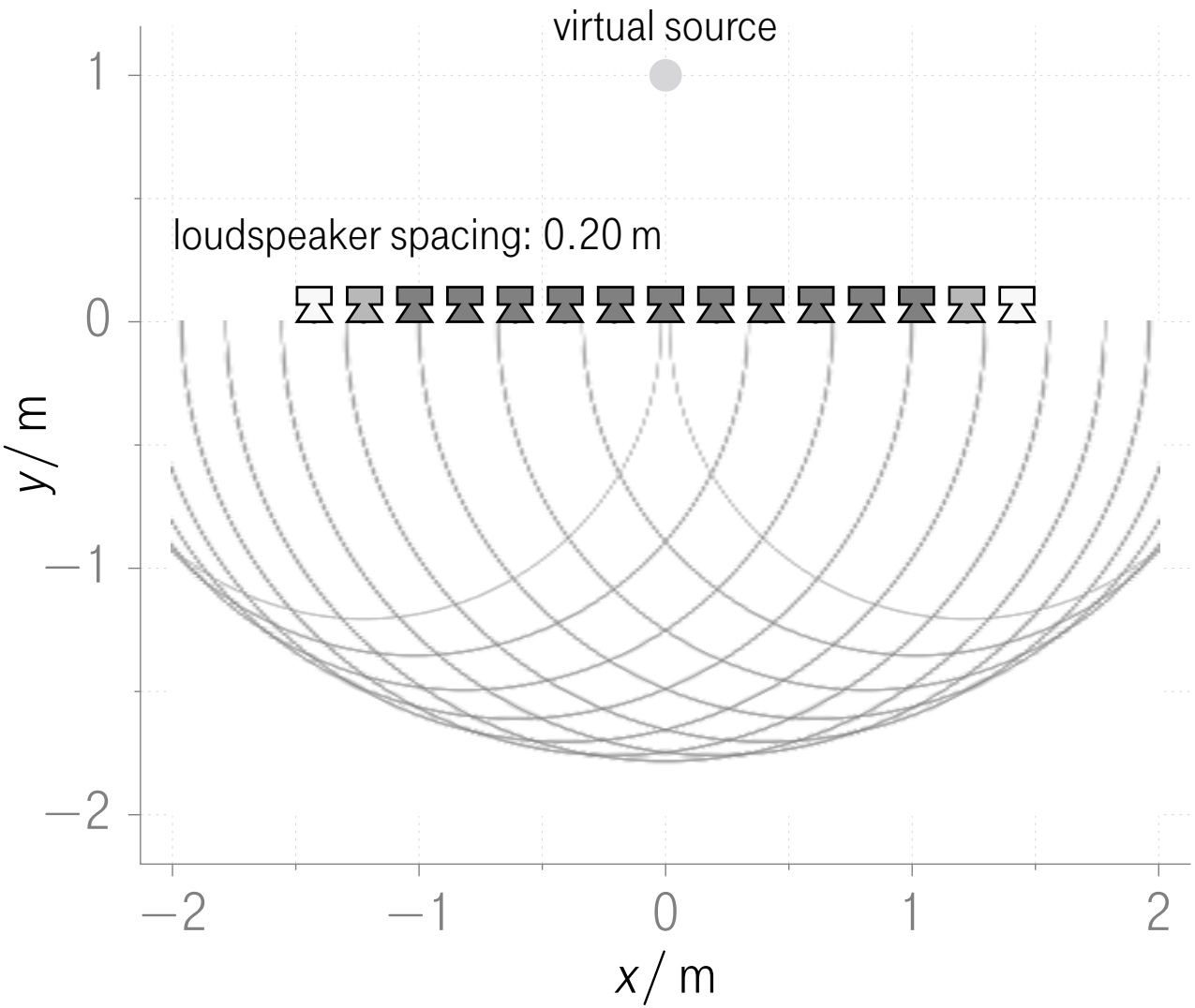
Is the localization in Wave Field Synthesis equal over the whole listening area?

How to assess the localization within the whole listening area?

How many speakers do we need for correct localization?

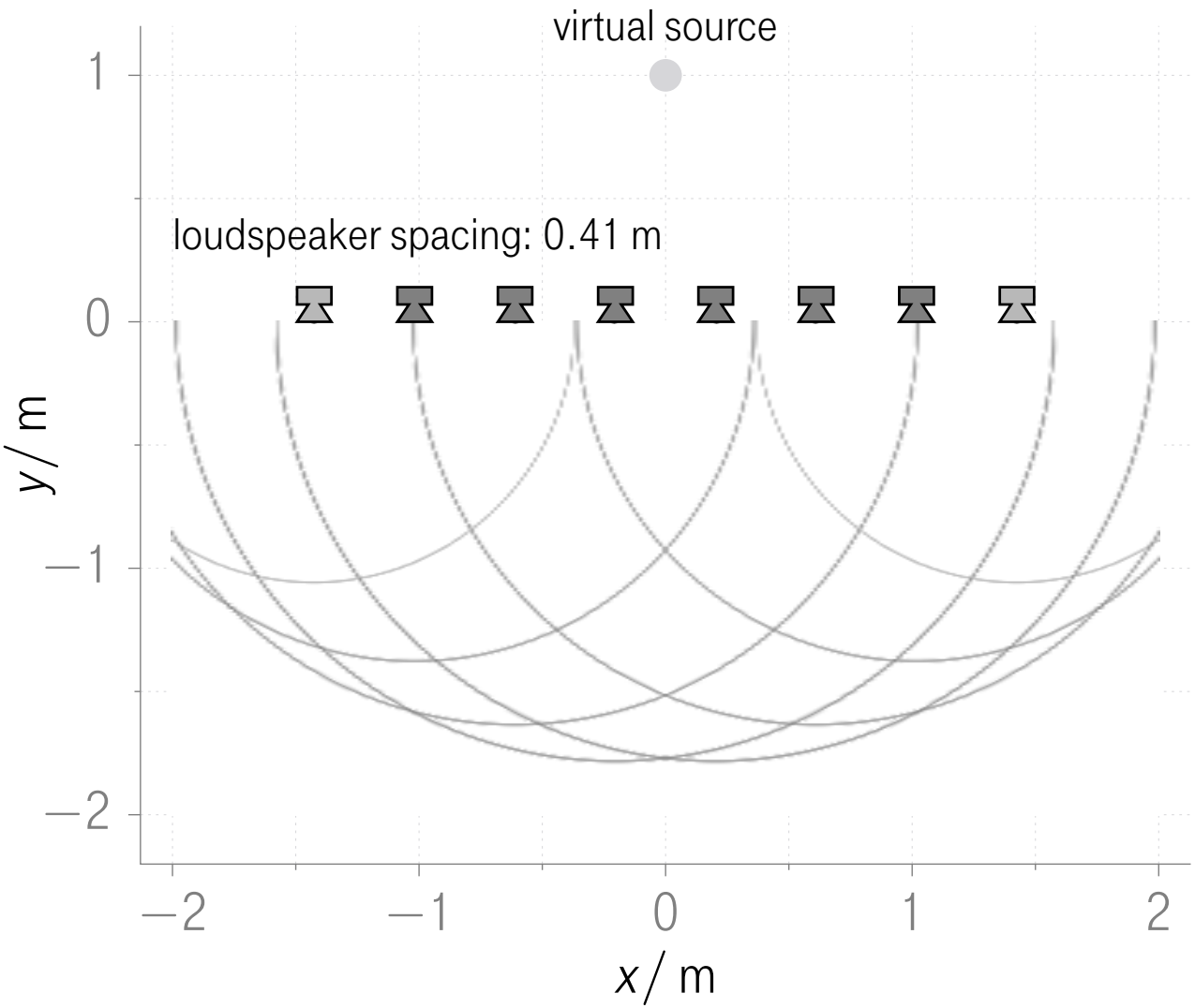
Theoretical considerations

law of the first wave front



Theoretical considerations

law of the first wave front



Theoretical considerations

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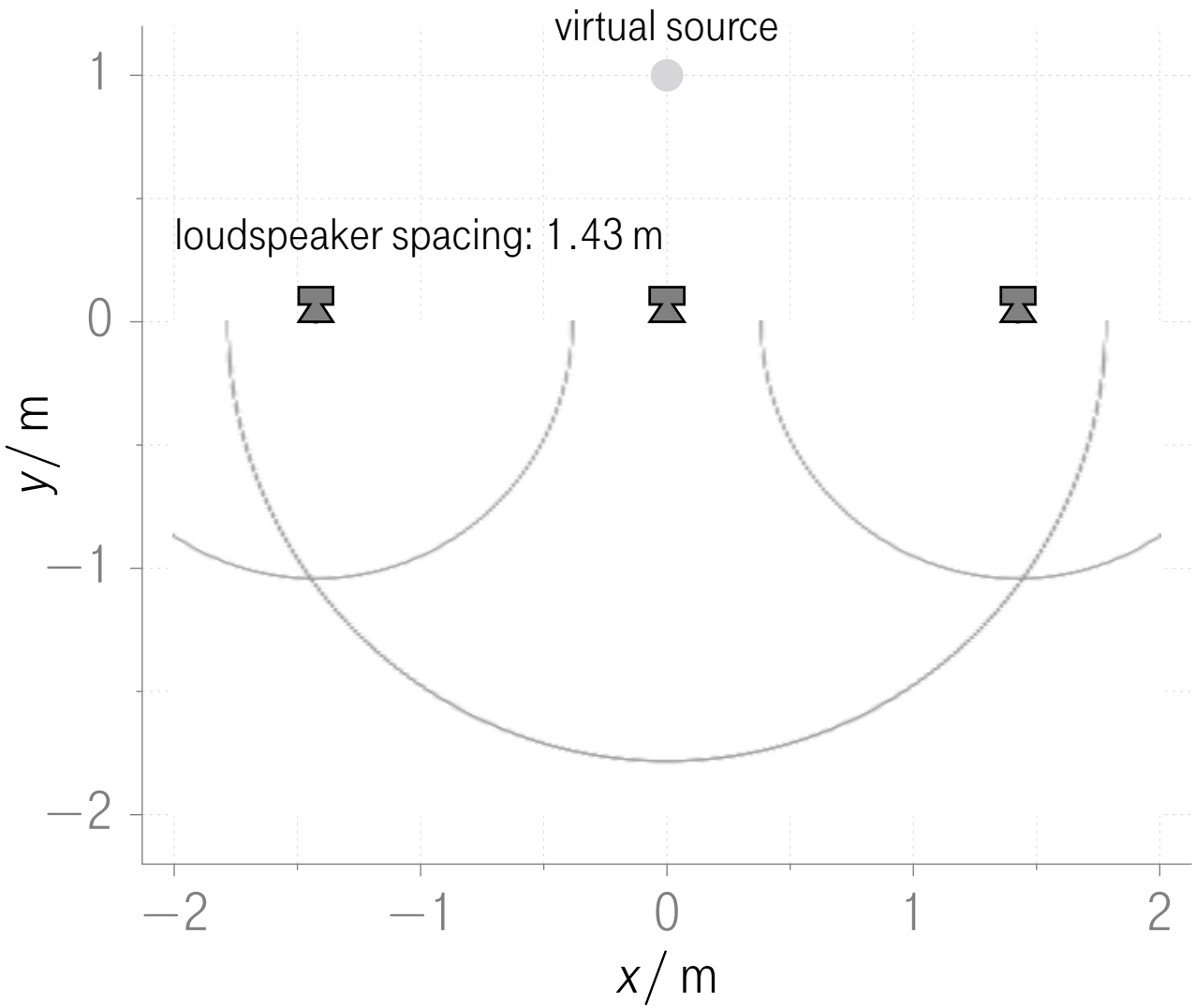


Localization in WFS

results from the literature

- Localization is the same for real and virtual sources for loudspeaker spacings around 0.12 cm
- Localization is slightly worse for virtual sources for loudspeaker spacings around 0.24 cm

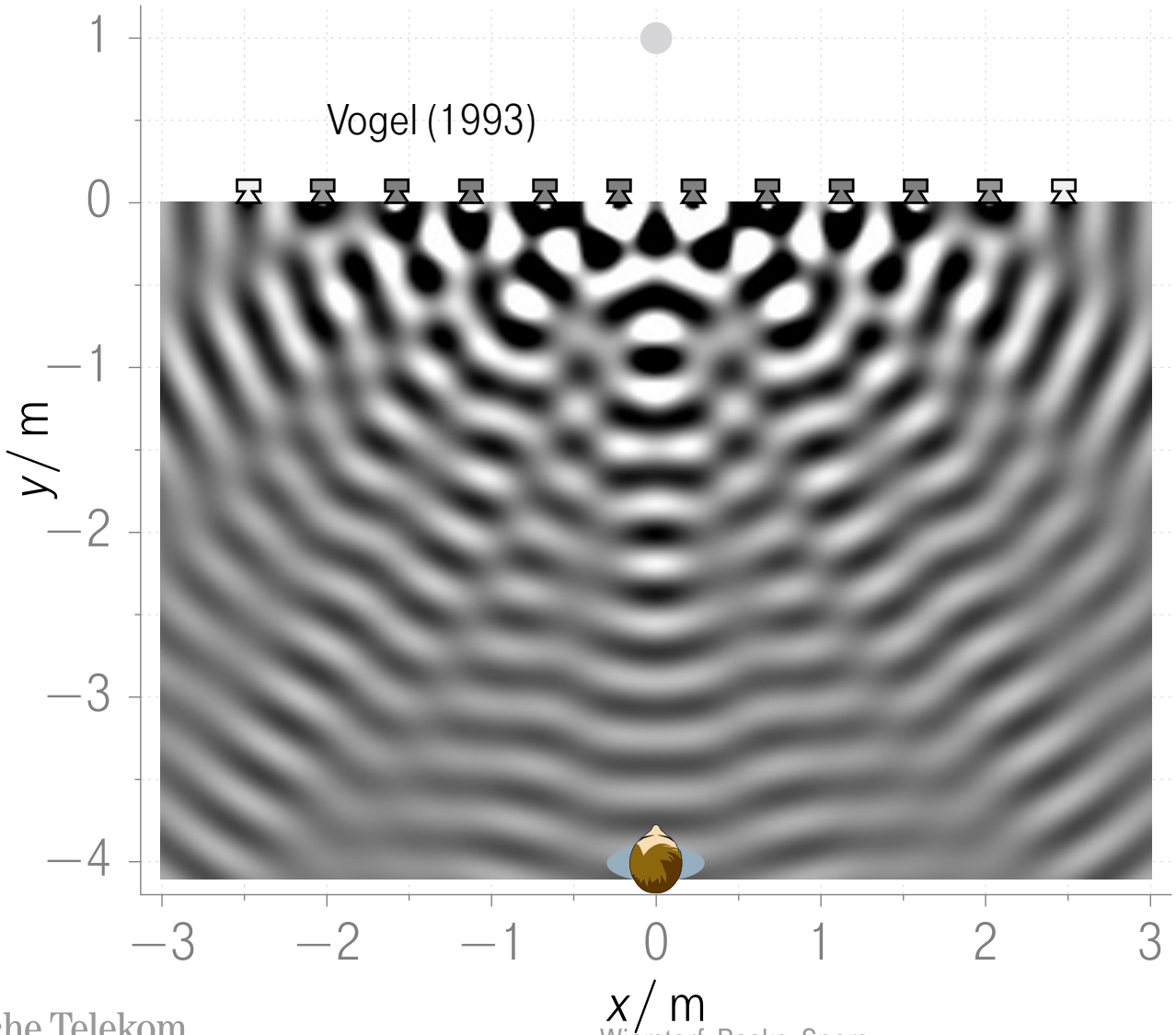
We are not interested in

- the influence of the reproduction room
- the ease of localization

Vogel (1993), *Application of Wave Field Synthesis in Room Acoustics*, Delft
Start (1997), *Direct Sound Enhancement by Wave Field Synthesis*, Delft
Verheijen (1997), *Sound Reproduction by Wave Field Synthesis*, Delft
Wittek (2007), *Perceptual differences between Wave Field Synthesis and stereophony*, Surrey

Localization in WFS

results from the literature



Localization in WFS

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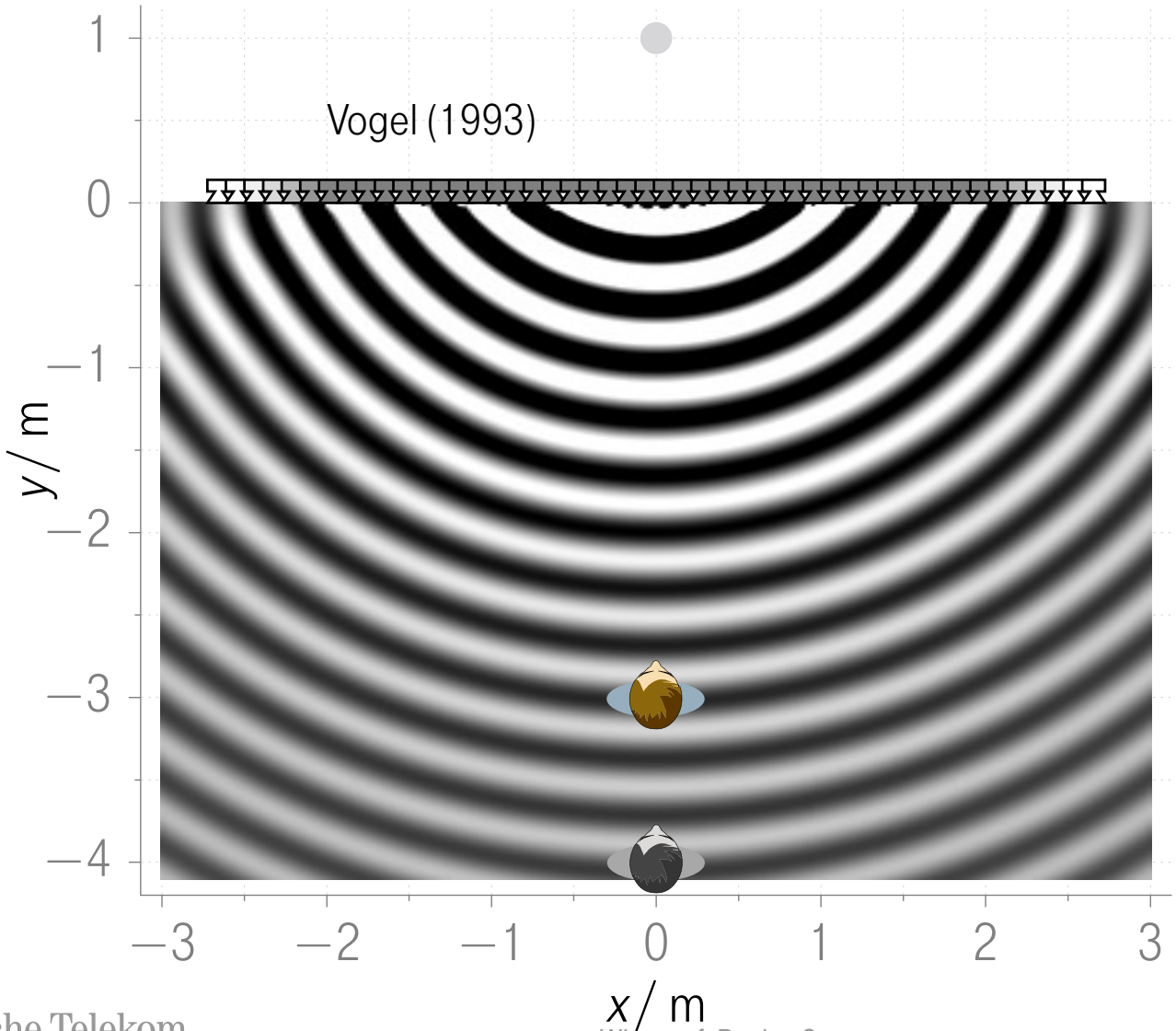

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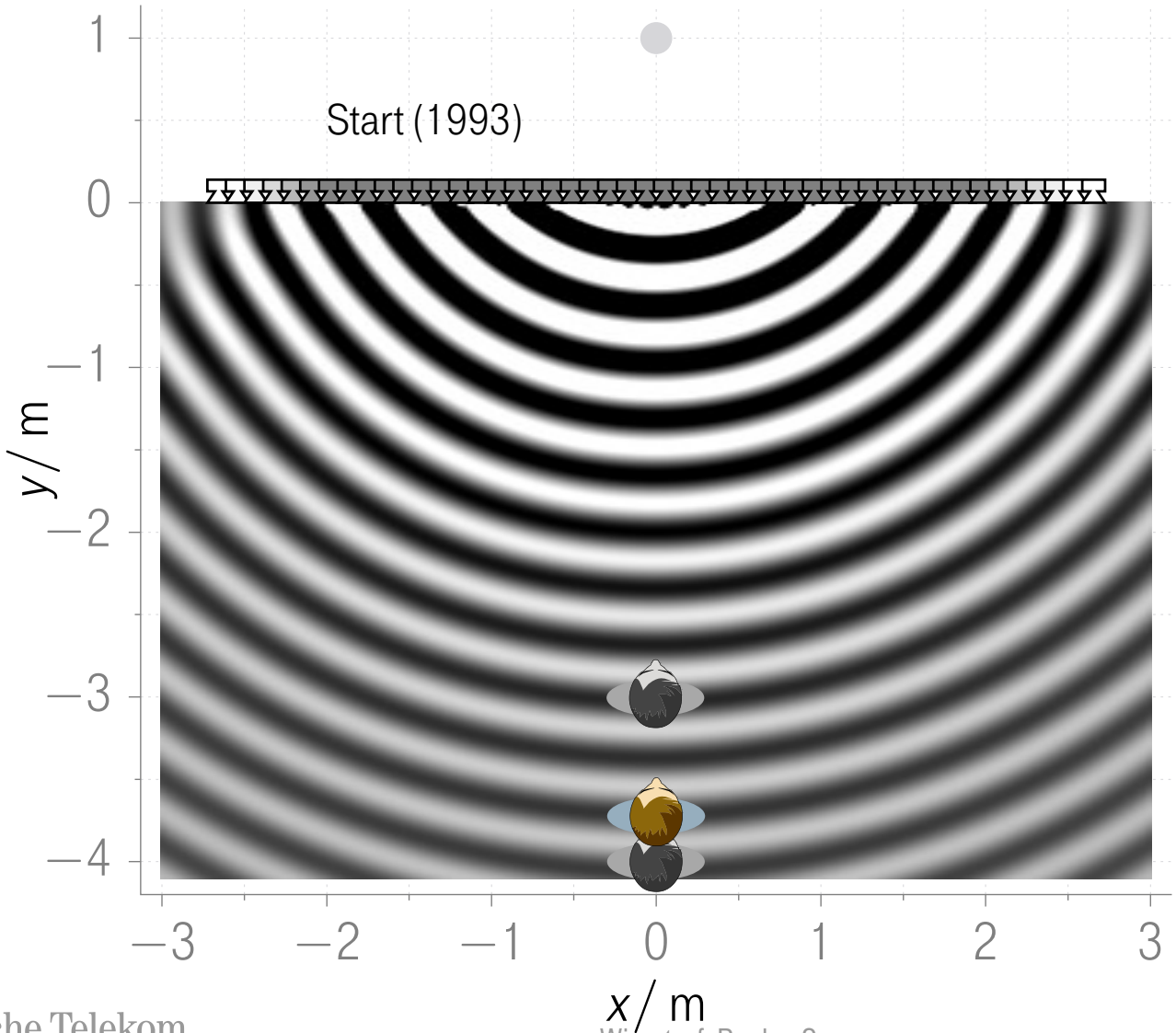

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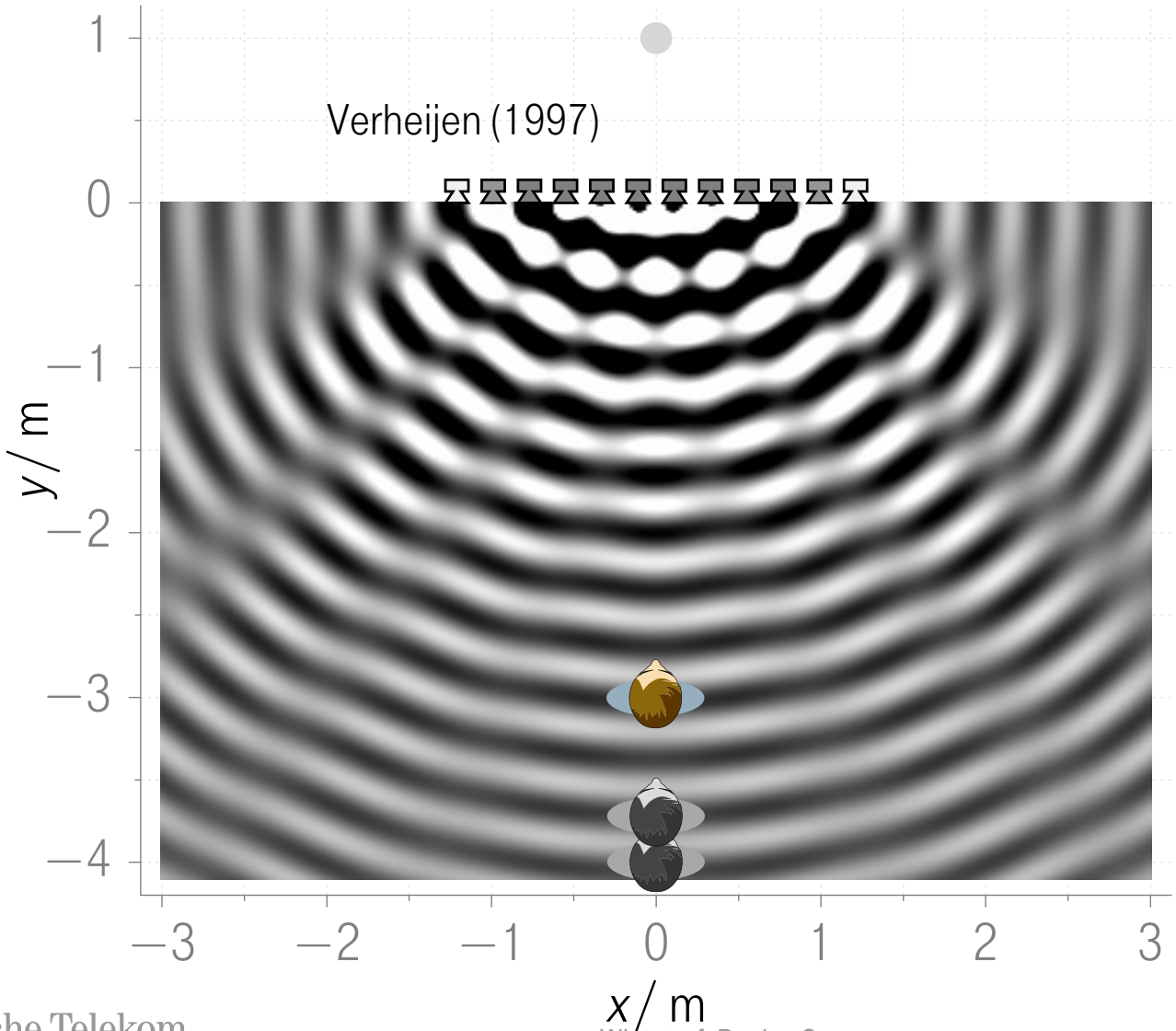

Localization in WFS

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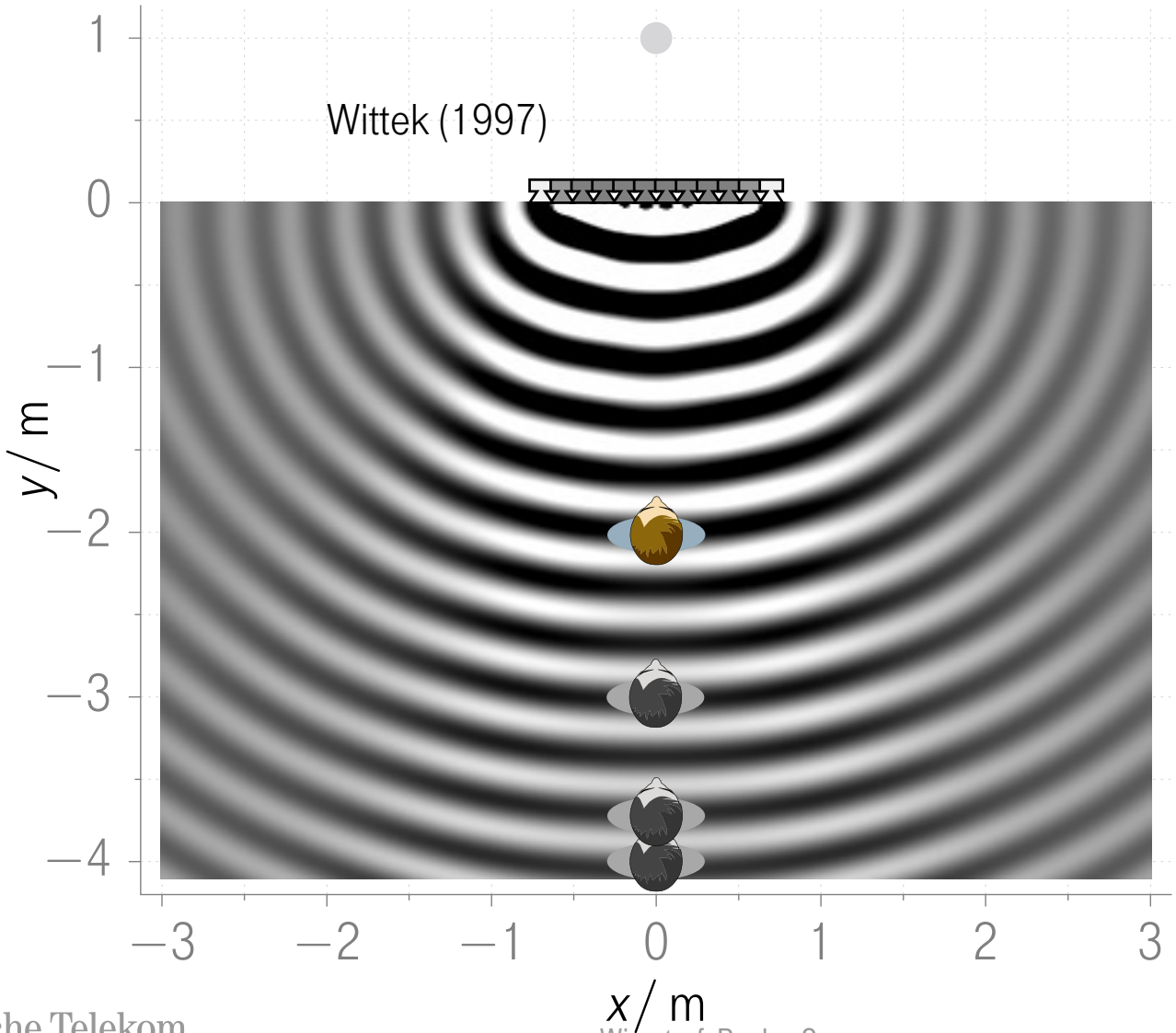
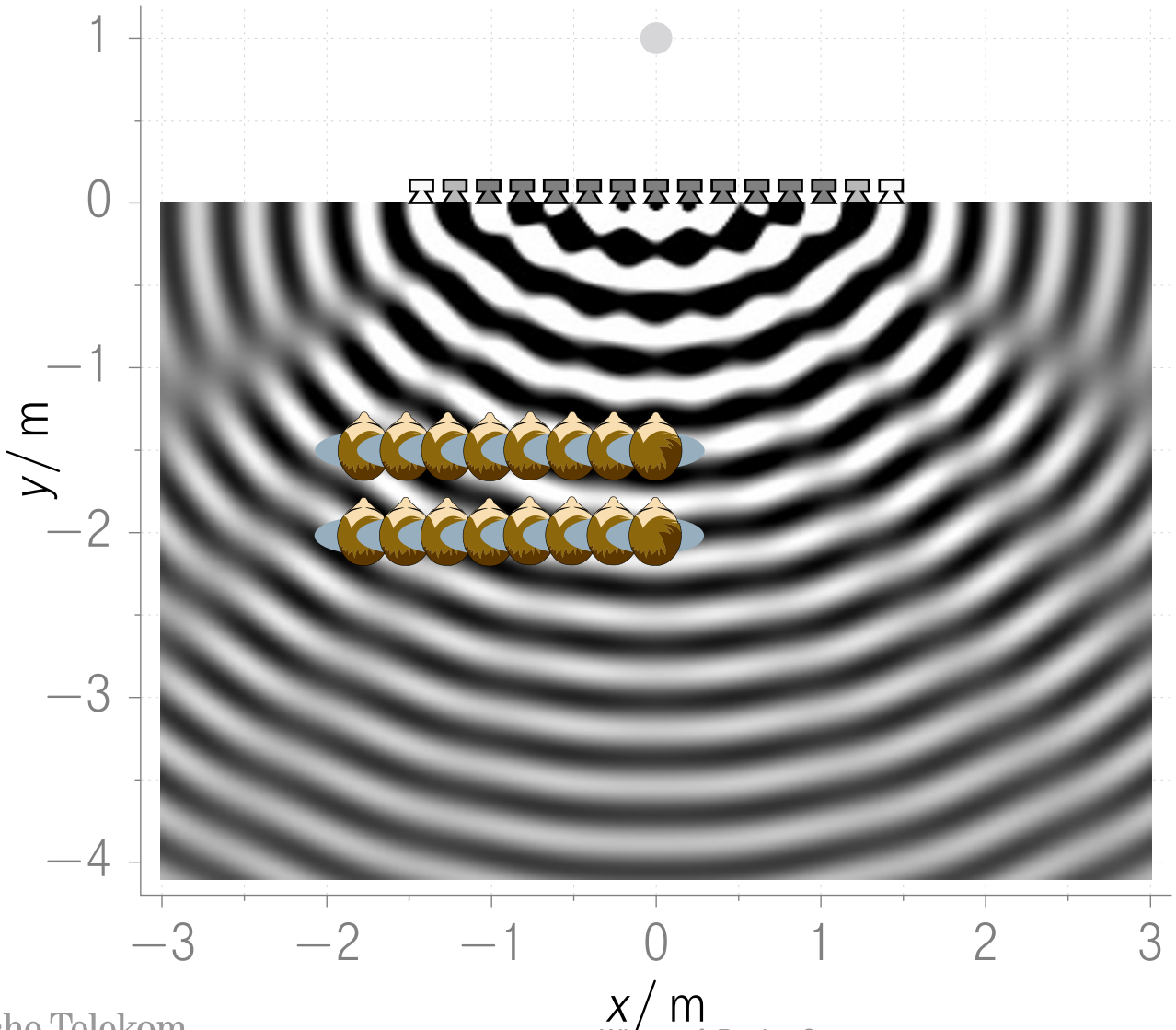


Localization in WFS

what we want to do



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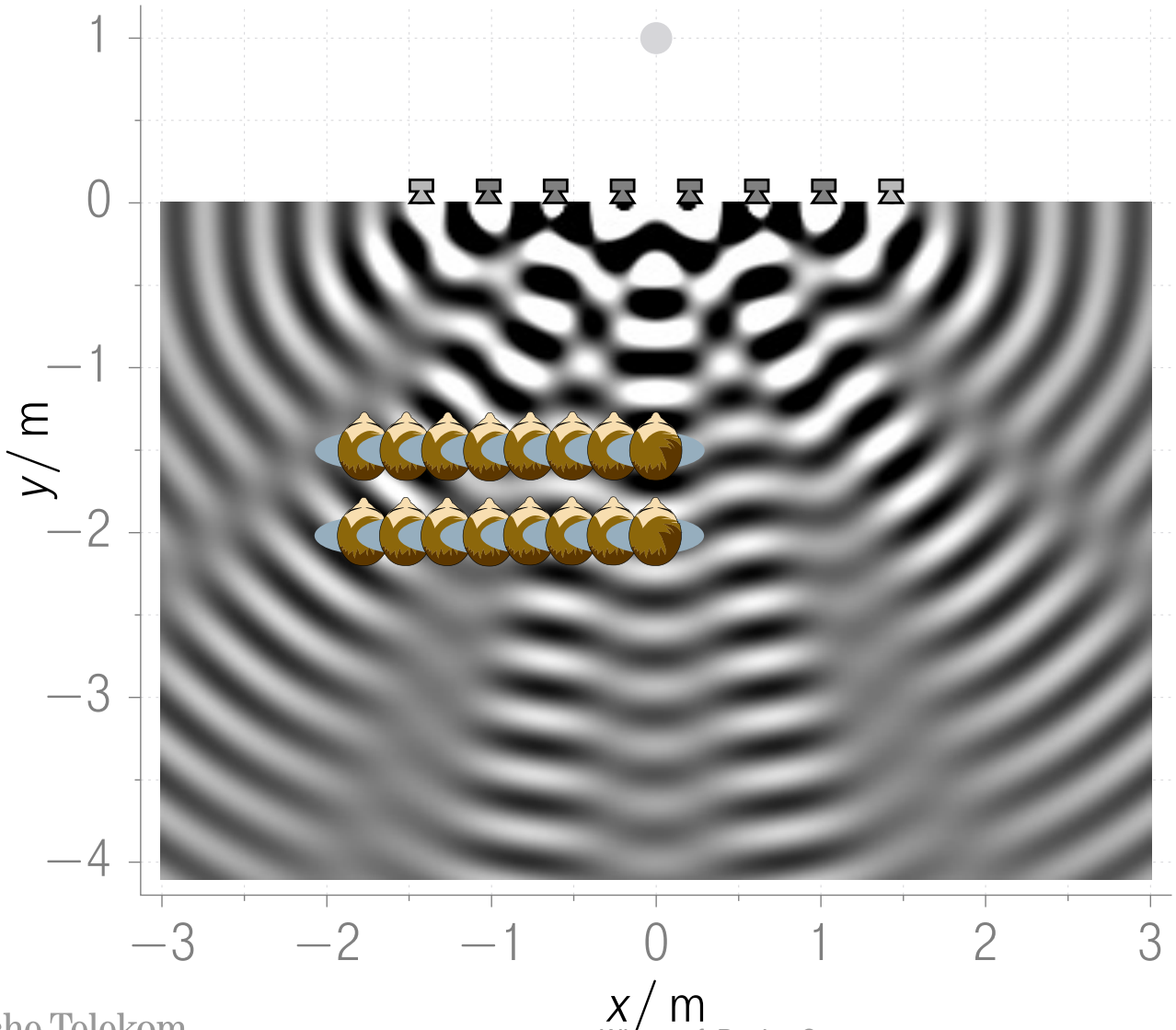

Localization in WFS

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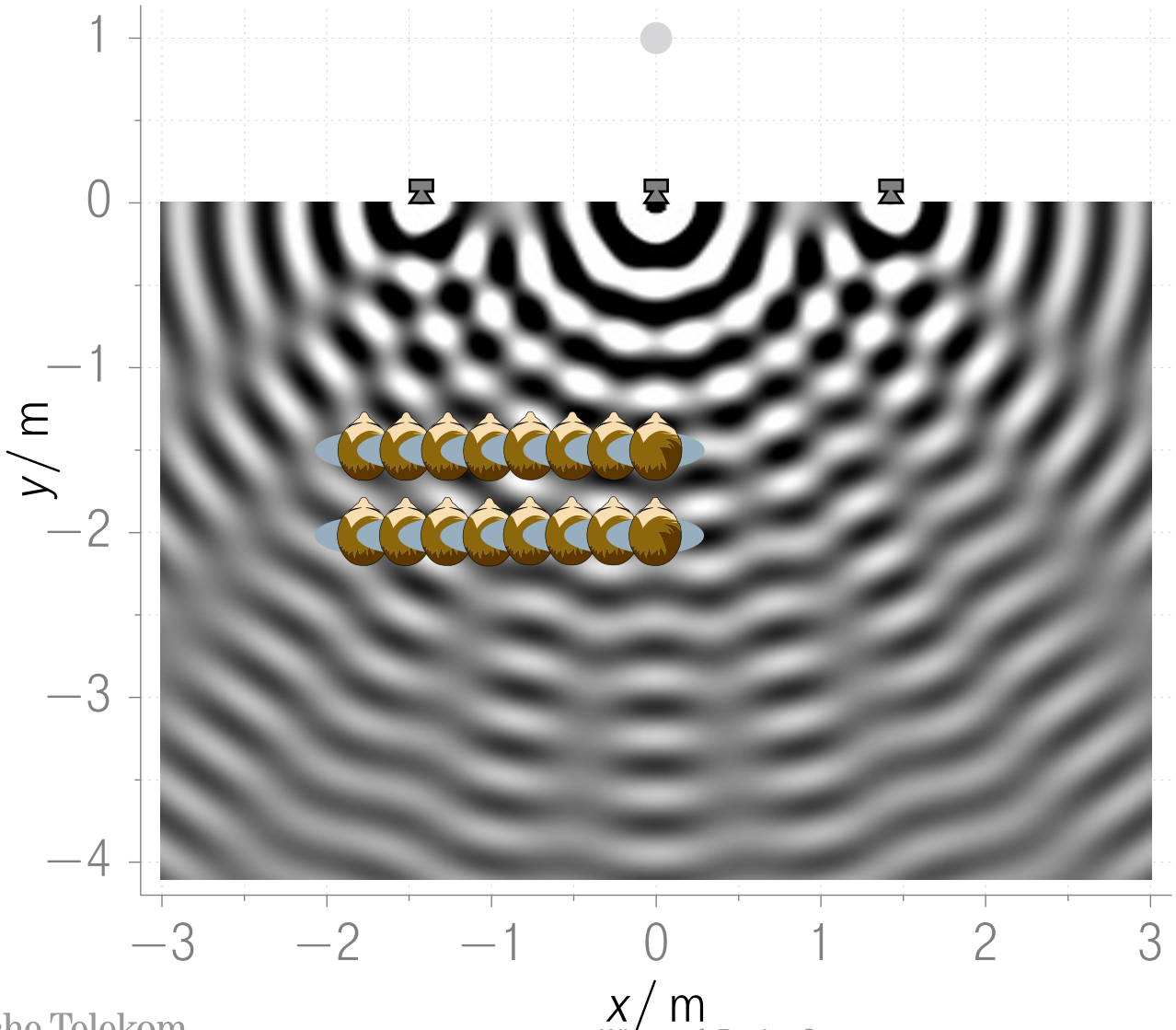
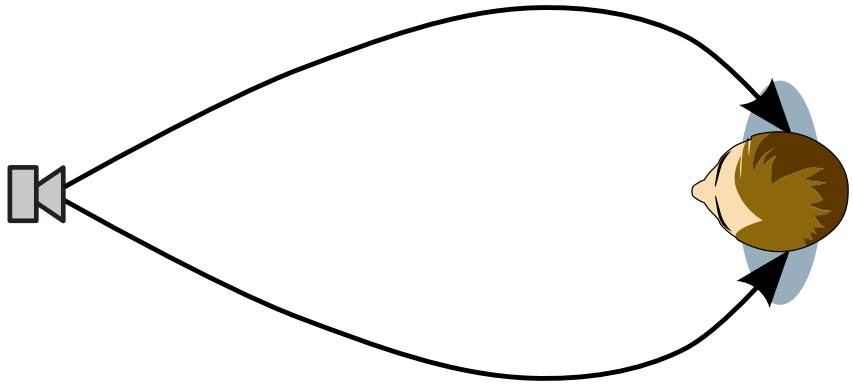


Localization in WFS

How to measure localization in the whole listening area?

Binaural synthesis



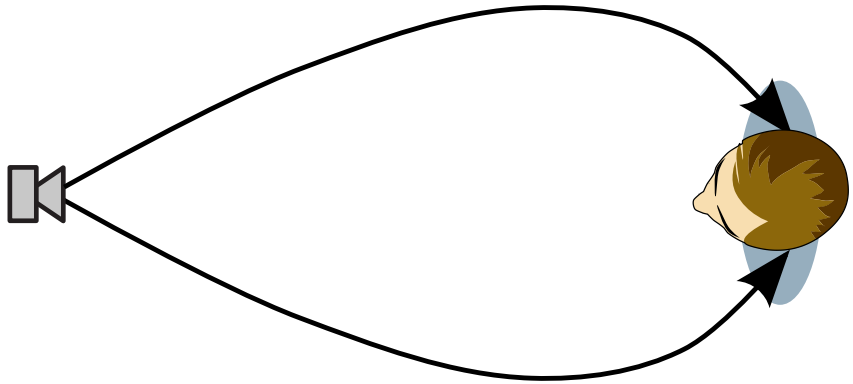
- connection between sound field synthesis and psychoacoustics (Völk, 2008)
- dynamic binaural synthesis via head tracker
- transparent with individual HRTFs (Langendijk, 2000)

Völk et al. (2008), *Simulation of wave field synthesis*, Acoustics

Langendijk und Bronkhorst (2000), *Fidelity of three-dimensional-sound reproduction using a virtual auditory display*, JASA

Wierstorf et al. (2011), *A free database of head-related impulse response measurements in the horizontal plane with multiple distances*, 130th AES

Binaural synthesis



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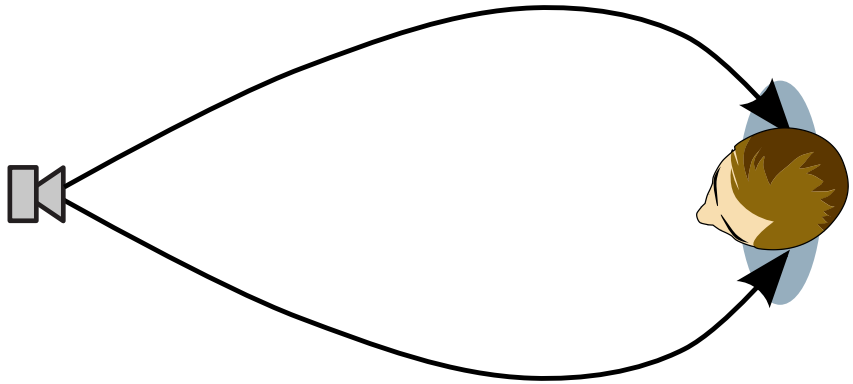

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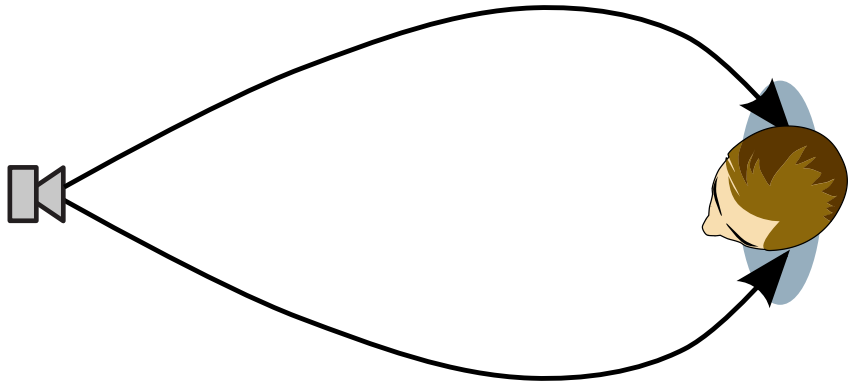

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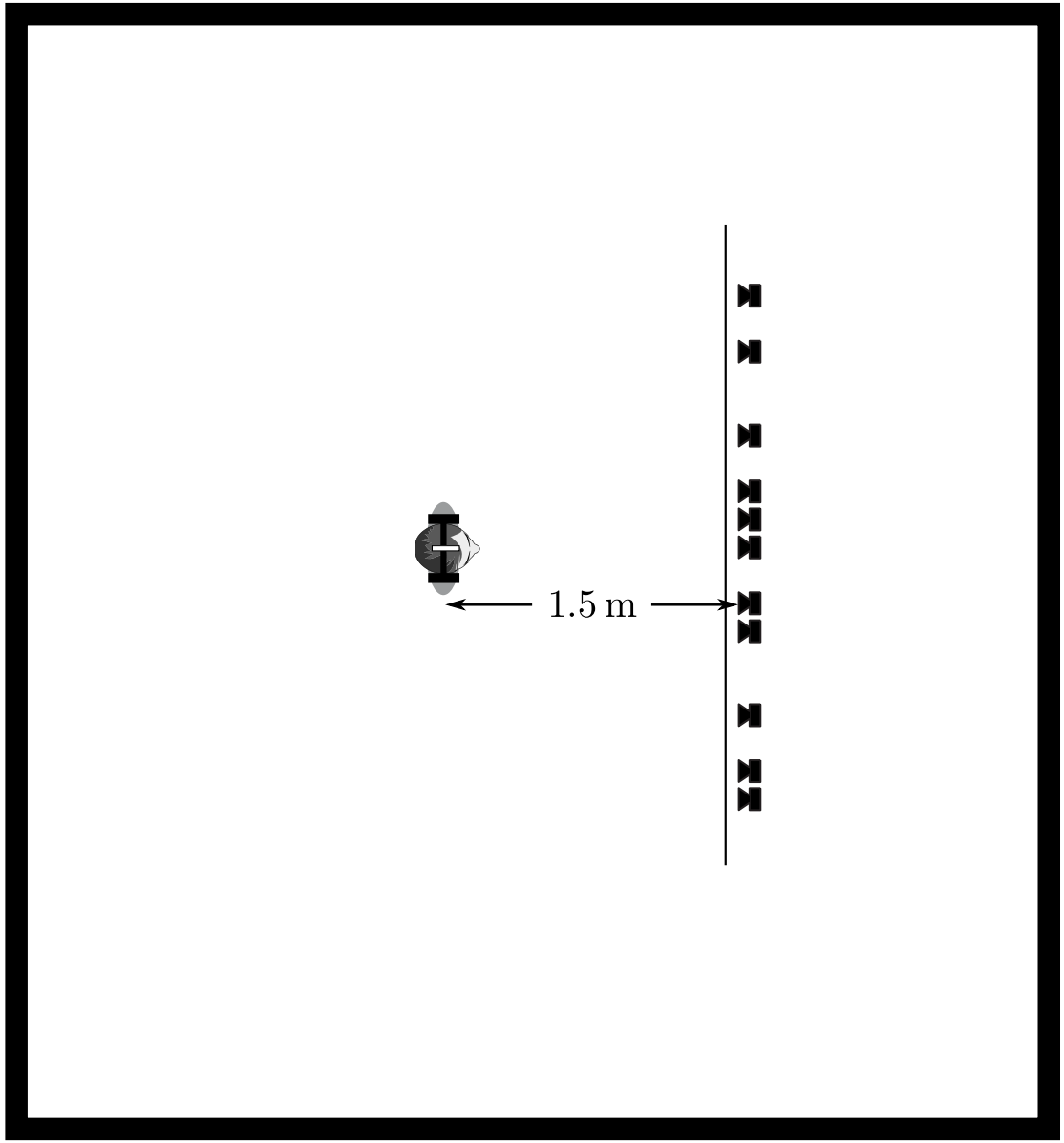
Procedure

Pre-test: Verification of binaural synthesis

Main test: Localization within a sound field for WFS

Apparatus



Apparatus

Pre-test: Verification of binaural synthesis

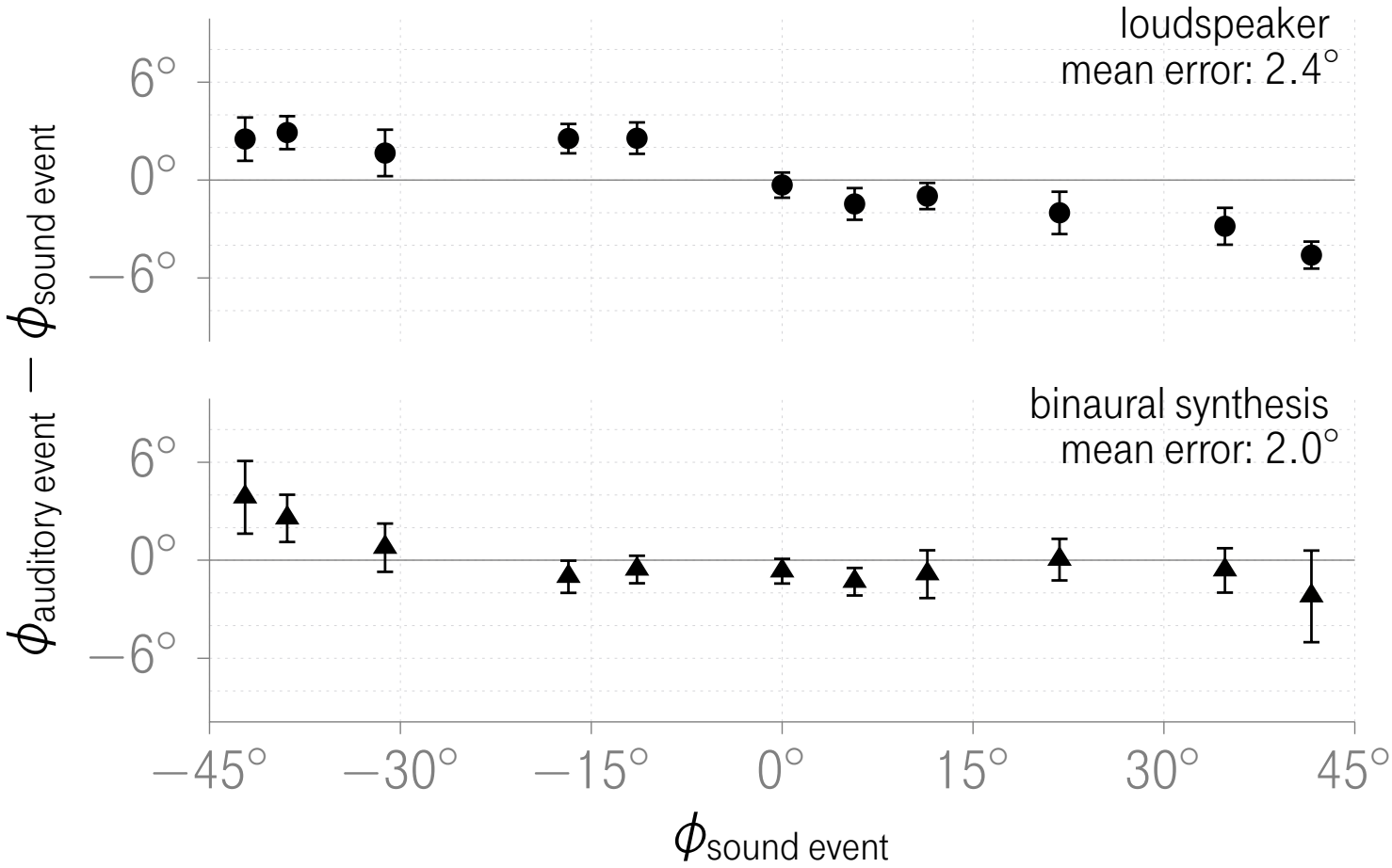
method

- head-pointing method with laser pointer mounted on the head (Makous 1990)
  $\Rightarrow$ listener has to face the source, smallest human localization error (Mills 1958)
  $\Rightarrow$ laser pointer gives visual feedback and enhances the cooperation with the motor system (Lewald 2000)
- white noise pulses 700 ms long, 300 ms pause
- 11 subjects, central position
- 22 conditions: 11 different positions of the virtual source/loudspeaker
- all randomized, 5 repetitions for each condition

Makous and Middlebrooks (1990), *Two-dimensional sound localization by human listeners*, JASA
Mills (1958), *On the minimum audible angle*, JASA
Lewald et al. (2000), *Sound localization with eccentric head position*, Behav Brain Res

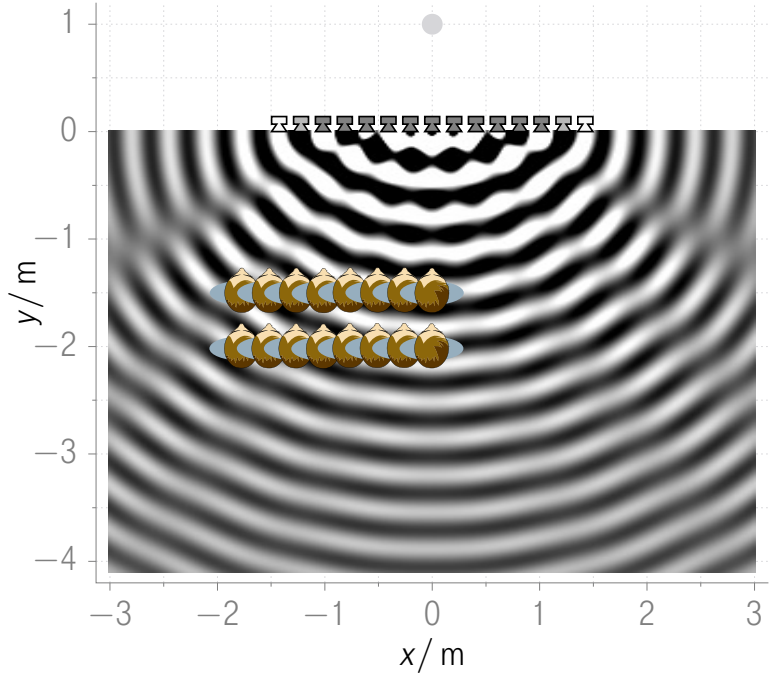
Pre-test: Verification of binaural synthesis

mean results + 95% confidence interval



Localization within a sound field for WFS

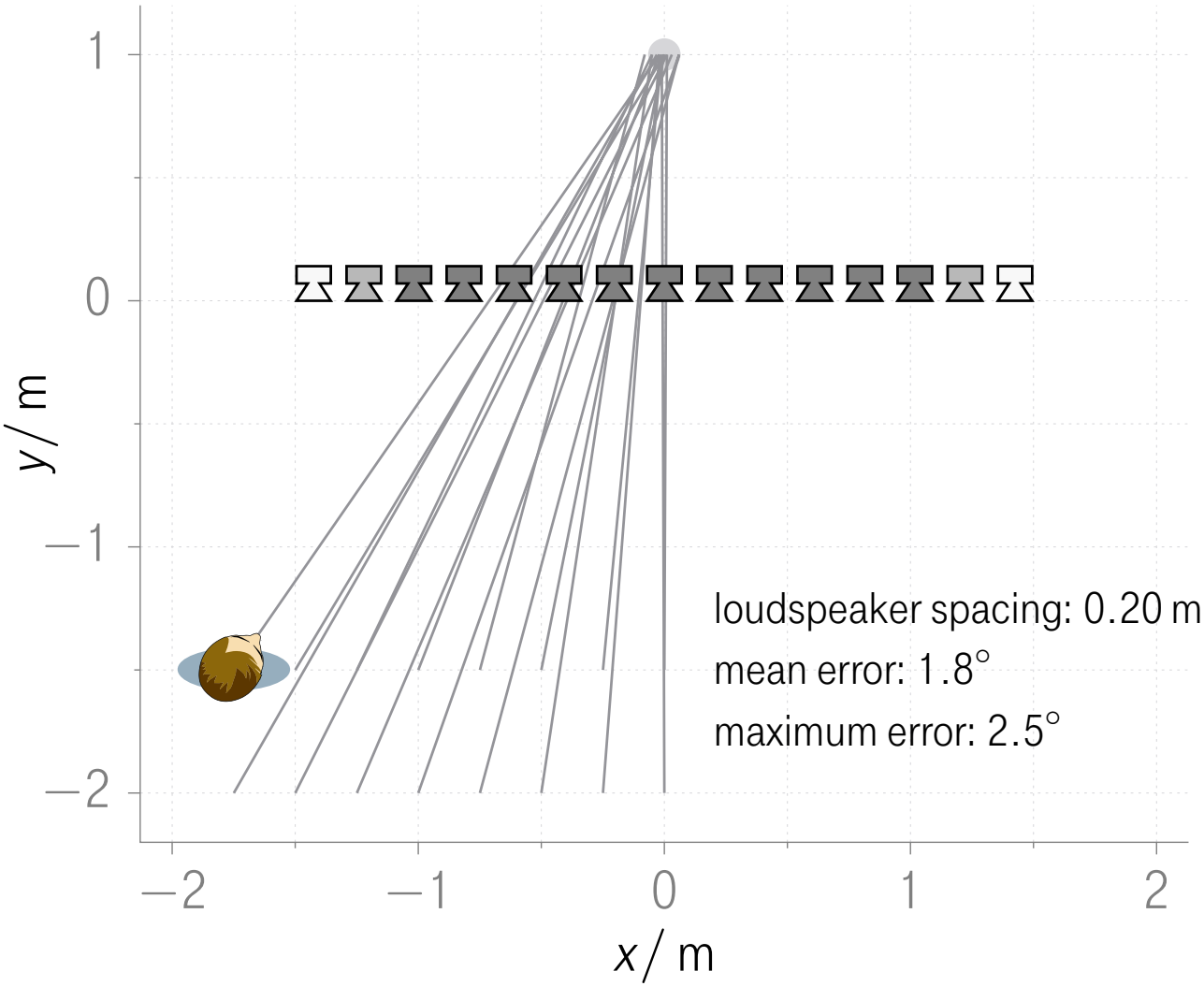
method



- white noise pulses 700 ms long, 300 ms pause
- 11 subjects, 16 different positions
- 3 conditions: 2.85 m loudspeaker array consisting of 3, 8, or 15 loudspeakers
- simulated by dynamic binaural synthesis
- all randomized, 5 repetitions for each condition and position

Localization within a sound field for WFS

mean results



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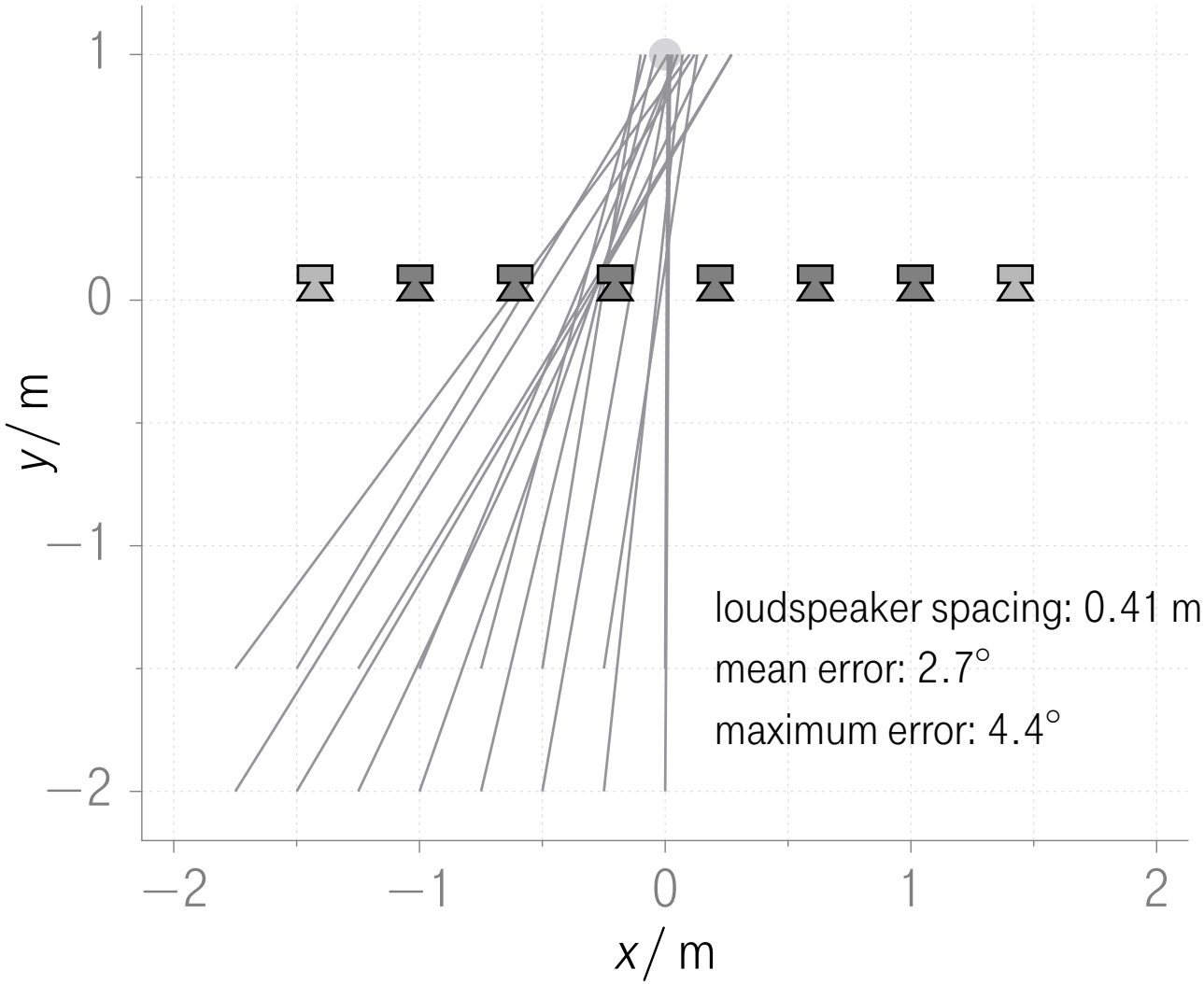

Localization within a sound field for WFS

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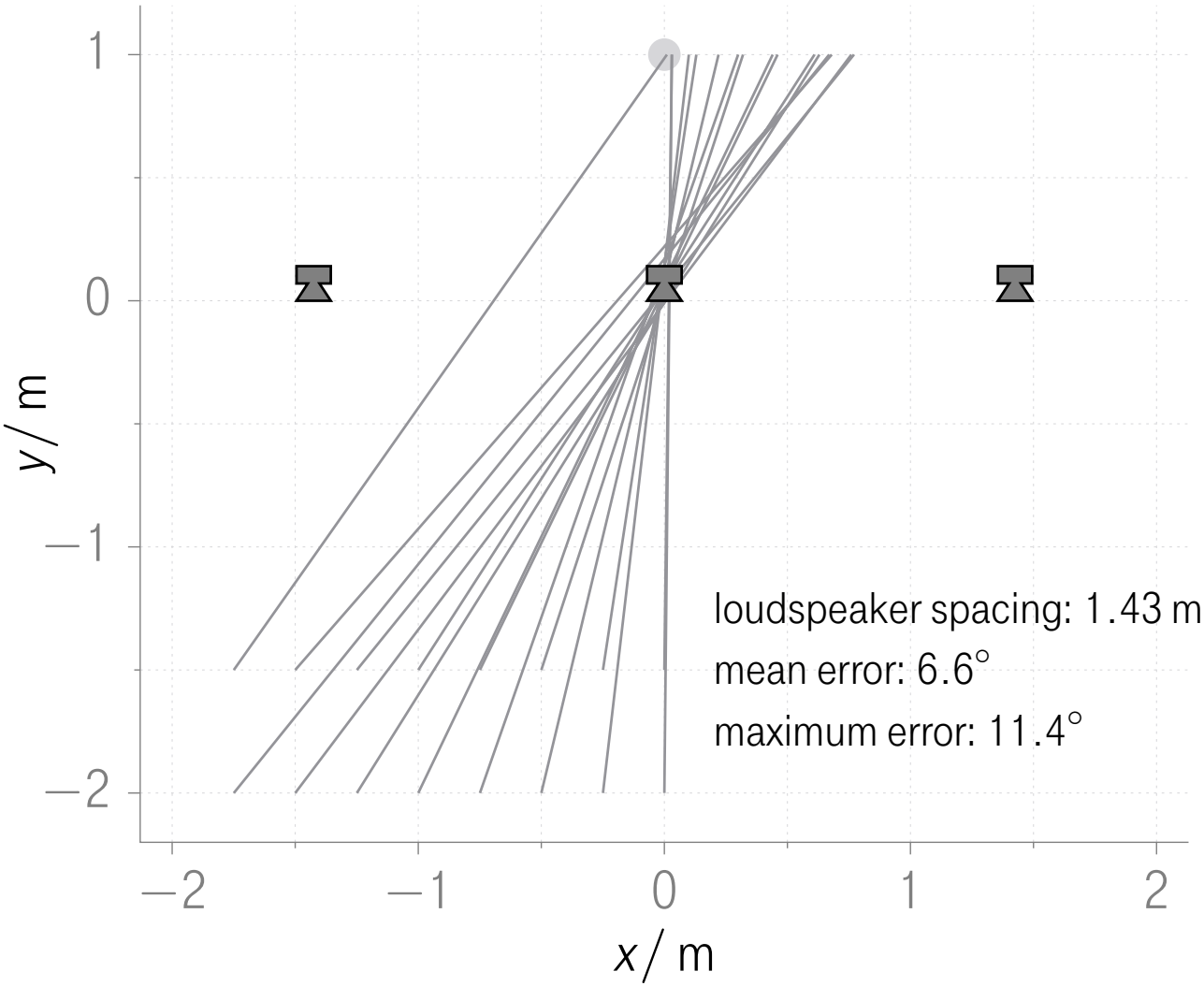


Conclusion

Is the localization in Wave Field Synthesis equal over the whole listening area?

Localization is equal, only for loudspeaker spacings of more than 1 m sweet spot like distributions occur

How to assess the localization within the whole listening area?

With dynamic binaural synthesis.

- full control of stimuli reaching the listener
- every position and loudspeaker array possible

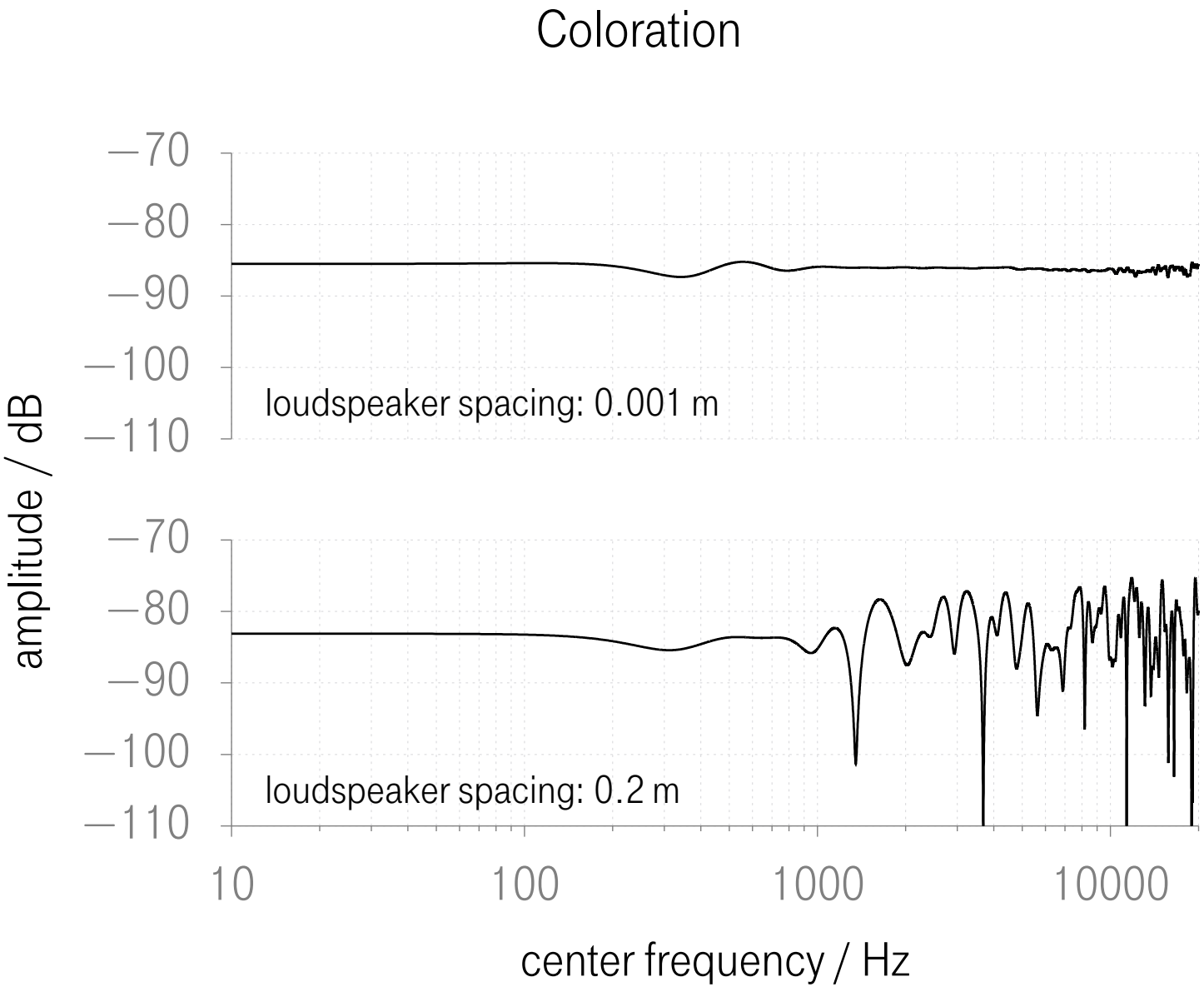
How many loudspeakers do we need for correct localization?

A loudspeaker distance of 20 cm is transparent, 40 cm still sufficient for localization

Open Questions

- what is the influence of the reproduction room?
- is the ease of localization affected?
- can these questions be investigated by binaural synthesis?
- focused sources, plane waves
- different array geometries, for example circular

Open Questions




Questions?
Oops!
I CRAPPED MY PANTS
http://audio.qu.tu-berlin.de/

Further analysis

interaural time differences