Universität Rostock

Traditio et Innovatio

# Azimuthal Localisation in 2.5D Near-Field-Compensated Higher Order Ambisonics

*Fiete Winter,*[1] *Nara Hahn,*[1] *Hagen Wierstorf,*[2] *and Sascha Spors*[1]

[1]Institute of Communications Engineering, Universität Rostock

[2]Centre for Vision, Speech and Signal Processing, University of Surrey

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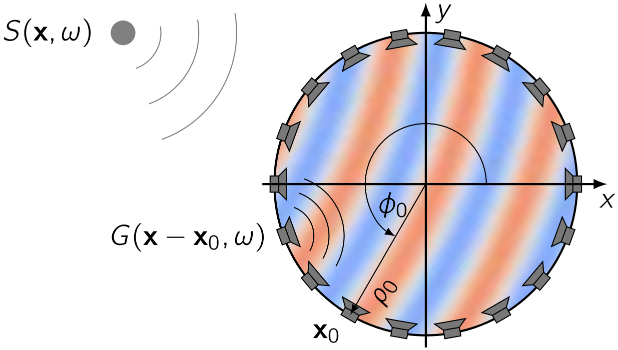
# 2.5D Near-Field-Compensated Higher Order Ambisonics




$$S(\mathbf{x},\omega) \stackrel{!}{=} \int_0^{2\pi} \underbrace{D(\mathbf{x}_0,\omega)}_{\text{driving signal}} \underbrace{G(\mathbf{x}-\mathbf{x}_0,\omega)}_{\text{loudspeaker}} \rho_0 \, \mathrm{d}\phi_0 \qquad \forall\, \mathbf{x} \,\big|\, |\mathbf{x}| < \rho_0$$

$$D(\mathbf{x}_0,\omega) = \frac{1}{2\pi\rho_0} \sum_{m=-\infty}^{\infty} \frac{\mathring{S}_m(\omega)}{\mathring{G}_m(\omega)} \mathrm{e}^{+\mathrm{j}m\phi_0}$$

Circular Array with 56 Loudspeakers

# Practical Implications for 2.5D NFC HOA

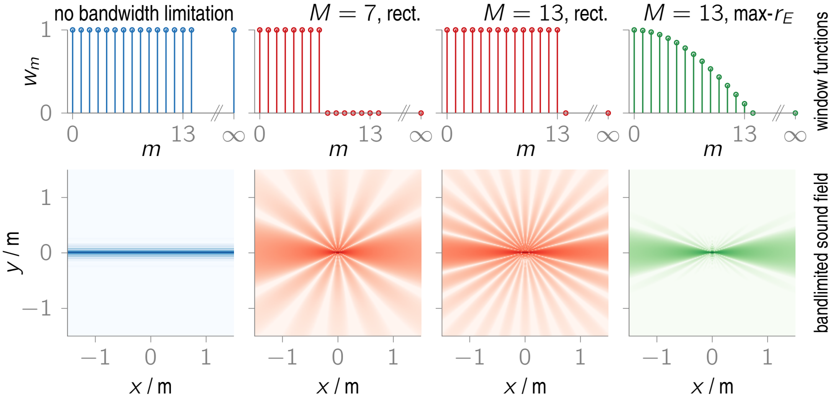
## Spatial Bandwidth Limitation

$$D^{(M)}(\mathbf{x}_0, \omega) = \frac{1}{2\pi\rho_0} \sum_{m=-M}^{M} \frac{\mathring{S}_m(\omega)}{\mathring{G}_m(\omega)} \mathrm{e}^{+\mathrm{j}m\phi_0} = \frac{1}{2\pi\rho_0} \sum_{m=-\infty}^{\infty} \frac{w_m \mathring{S}_m(\omega)}{\mathring{G}_m(\omega)} \mathrm{e}^{+\mathrm{j}m\phi_0}$$

# Practical Implications for 2.5D NFC HOA

## Spatial Bandwidth Limitation

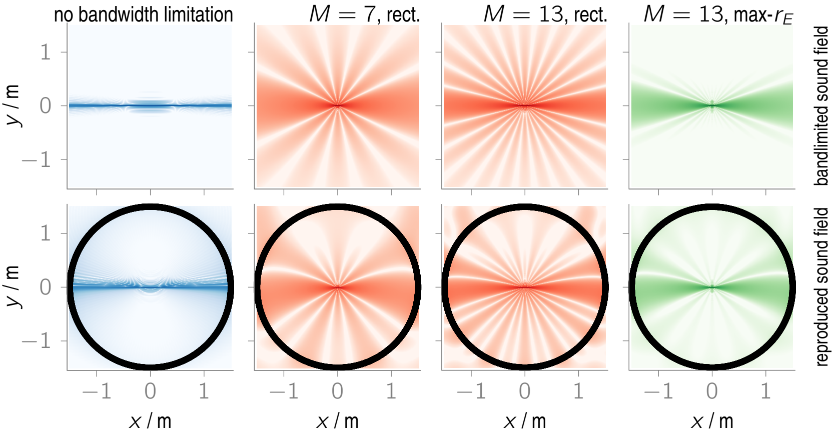
$$D^{(M)}(\mathbf{x}_0,\omega) = \frac{1}{2\pi\rho_0}\sum_{m=-M}^{M}\frac{\mathring{S}_m(\omega)}{\mathring{G}_m(\omega)}\mathrm{e}^{+\mathrm{j}m\phi_0} = \frac{1}{2\pi\rho_0}\sum_{m=-\infty}^{\infty}\frac{w_m\mathring{S}_m(\omega)}{\mathring{G}_m(\omega)}\mathrm{e}^{+\mathrm{j}m\phi_0}$$



# Practical Implications for 2.5D NFC HOA

## 2.5D Synthesis

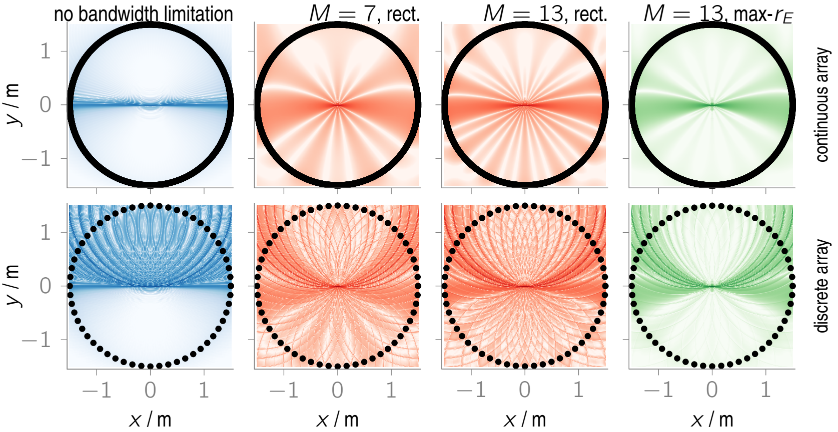
$$P^{(M)}_{2.5\mathrm{D}}(\mathbf{x},\omega) = \int_0^{2\pi} D^{(M)}(\mathbf{x}_0,\omega)G(\mathbf{x}-\mathbf{x}_0,\omega)\rho_0 \, \mathrm{d}\phi_0$$



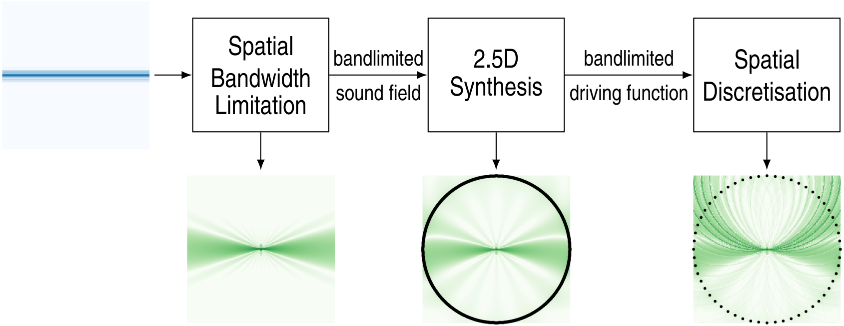
# Practical Implications for 2.5D NFC HOA

## Spatial Discretisation

$$P_{2.5\text{D}}^{(M,L)}(\mathbf{x},\omega) = \frac{2\pi\rho_0}{L}\sum_{n=1}^{L} D^{(M)}(\mathbf{x}_0^{(n)},\omega)G(\mathbf{x}-\mathbf{x}_0^{(n)},\omega)$$



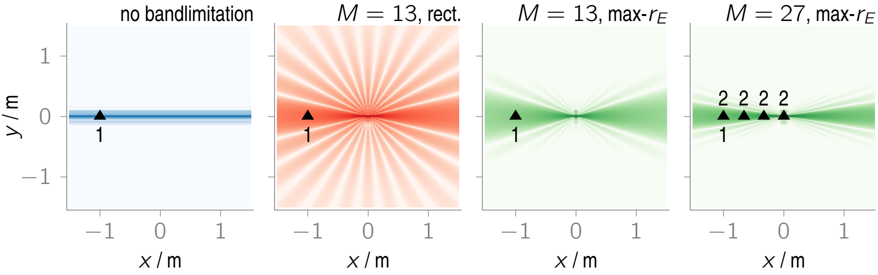
# Agenda




- evaluate impact of individual artefacts on major localisation cues (ITD, IC, and ILD)
- ear signals are generated via binaural synthesis using HRTFs
- ITD, IC, and ILD are extracted from the ear signals using a binaural model[1]

[1] May et al. (2011), *A Probabilistic Model for Robust Localization Based on a Binaural Auditory Front-End*

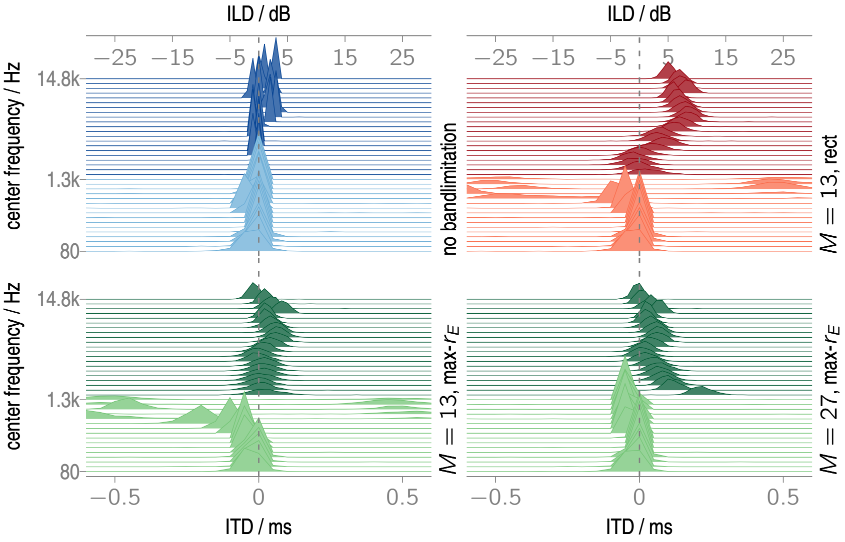
# Spatial Bandwidth Limitation




- plane wave propagating "downwards"
- listener oriented towards the plane wave
- evaluation scenarios:
  1. different truncation windows (order + shape)
  2. different listening positions

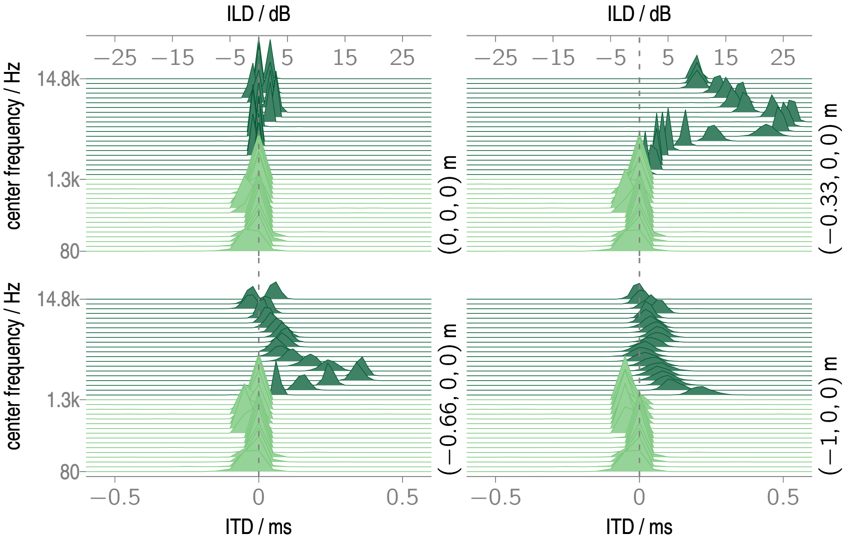
# Spatial Bandwidth Limitation

## 1. Different Truncation Windows (Listener at $(-1, 0, 0)$ m)



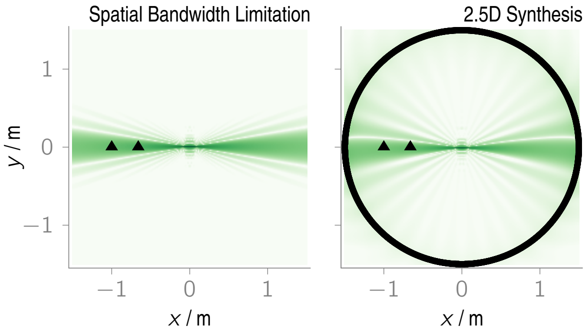
# Spatial Bandwidth Limitation

## 2. Different Listening Positions ($M = 27$, max-$r_E$)



# 2.5D Synthesis

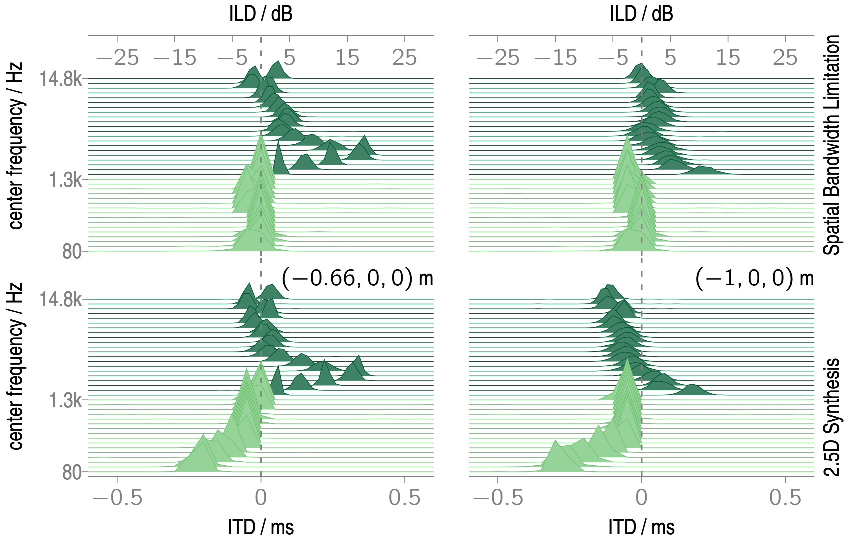
$M = 27$, max-$r_E$




- 2.5D synthesis uses a continuous array ($L = \infty$) of $1.5$ m radius

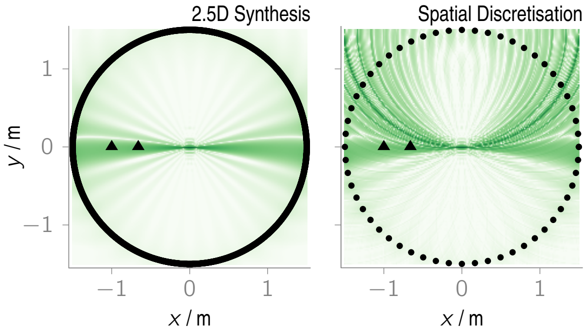
# 2.5D Synthesis

$M = 27$, max-$r_E$



# Spatial Discretisation

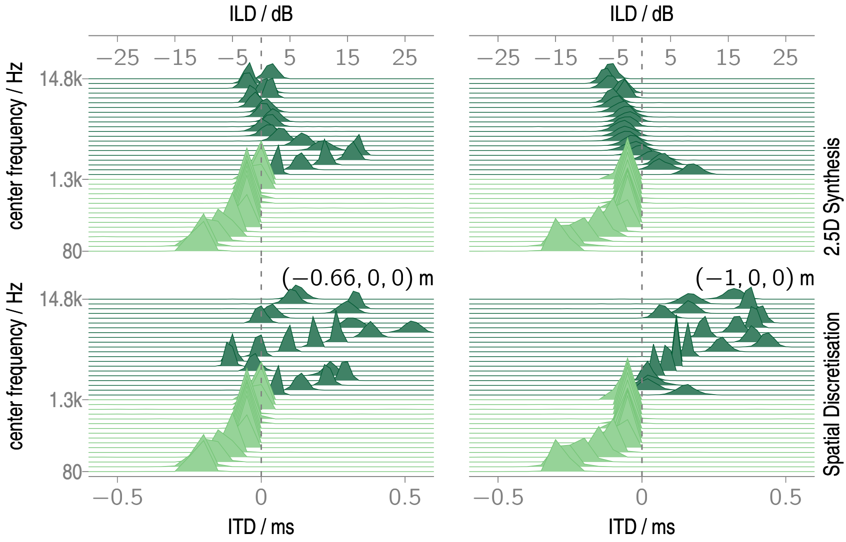
$M = 27$, max-$r_E$




- 2.5D synthesis uses a continuous array ($L = \infty$) of $1.5$ m radius
- Spatial discretisation uses a discrete array ($L = 56$) of $1.5$ m radius

# Spatial Discretisation

$M = 27$, max-$r_E$



# Conclusion

## Spatial Bandwidth Limitation

- low order for truncation window results in distorted ITDs
- ITD/ILD cues get less reliable the larger the off-axis distance gets

## 2.5D Synthesis

- "bending" of the wavefronts leads to ITD distortions at low frequencies
- ITD/ILD bias towards loudspeaker array increases with off-axis distance

## Spatial Discretisation

- spatial aliasing causes ILD bias towards the most active loudspeakers
- inconsistency between ITD/ILD cues can cause source-splitting[a]

[a] Wierstorf (2014), *Perceptual Assessment of Sound Field Synthesis*

Thank you for your attention!