AES 147th International Convention

University of Huddersfield

3D Microphone Array Recording Comparison (3D-MARCo)

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About me

- Director of the Centre for Audio and Psychoacoustic Engineering, University of Huddersfield (2019-Present).
- Leader of the Applied Psychoacoustics Lab, University of Huddersfield (2013 – Present).
- Senior Lecturer (i.e. Associate Professor) in Music Technology at the University of Huddersfield, UK (2010 – Present).
- Senior Research Engineer at LG Electronics, Korea (2006 – 2010).
- PhD in surround sound psychoacoustics, University of Surry, UK (2002 – 2006).
- BMus in Sound Recording (Tonmeister), University of Surrey (1998 – 2002).
- Freelance sound engineer (2002 – Present).
- Assistant sound engineer at Metropolis studios, London, UK (2000 – 2001).
- Intern sound engineer at Aspen Music Festival, Colorado, USA (1999, 2000).
- Assistant sound engineer at Sound Hill studios, South Korea (1997 – 1998).

Content

- 45 minutes: Recording session summary / Tutorial on 3D mic arrays
- 45 minutes: Demo, discussion, Q&A

Motivation

- Various different microphone techniques for 3D sound capture have been proposed over the years.
- However, no scientifically rigorous study has been conducted to compare the perceived qualities of the techniques yet.
- More importantly, perceptual differences of different techniques have not been formally elicited yet → Attribute scales for the evaluation of 3D acoustic recording need to be established.
- A need for a database of 3D microphone array recordings and impulse responses for research & education.

Recording Session

- Venue: St. Paul's Concert Hall at the University of Huddersfield (RT60 = avg. 2.1s)
- 3 – 5 June 2019.
- 96 kHz / 24 bits for all microphones except Eigenmike (48/16).
- Software: Reaper DAW / Eigenstudio / HAART (for IR capture).
- A total of 71 microphones used simultaneously.

Microphone Techniques Used

3D Main Microphone Arrays (9-channel)

- PCMA-3D
- OCT-3D
- 2L Cube-inspired
- Decca Cuboid

3D Ambience Arrays (8-channel)

- Hamasaki Square with height at 0m and 1m

Ambisonics/Spherical Array

- Eigenmike EM32 (HOA)
- Ambeo FOA

Binaural

- KU100 dummy head

Additional Microphones

- Side/height pairs
- Floor L, C, R
- ”Voice of God”
- ORTF
- Spot mics

Equipment

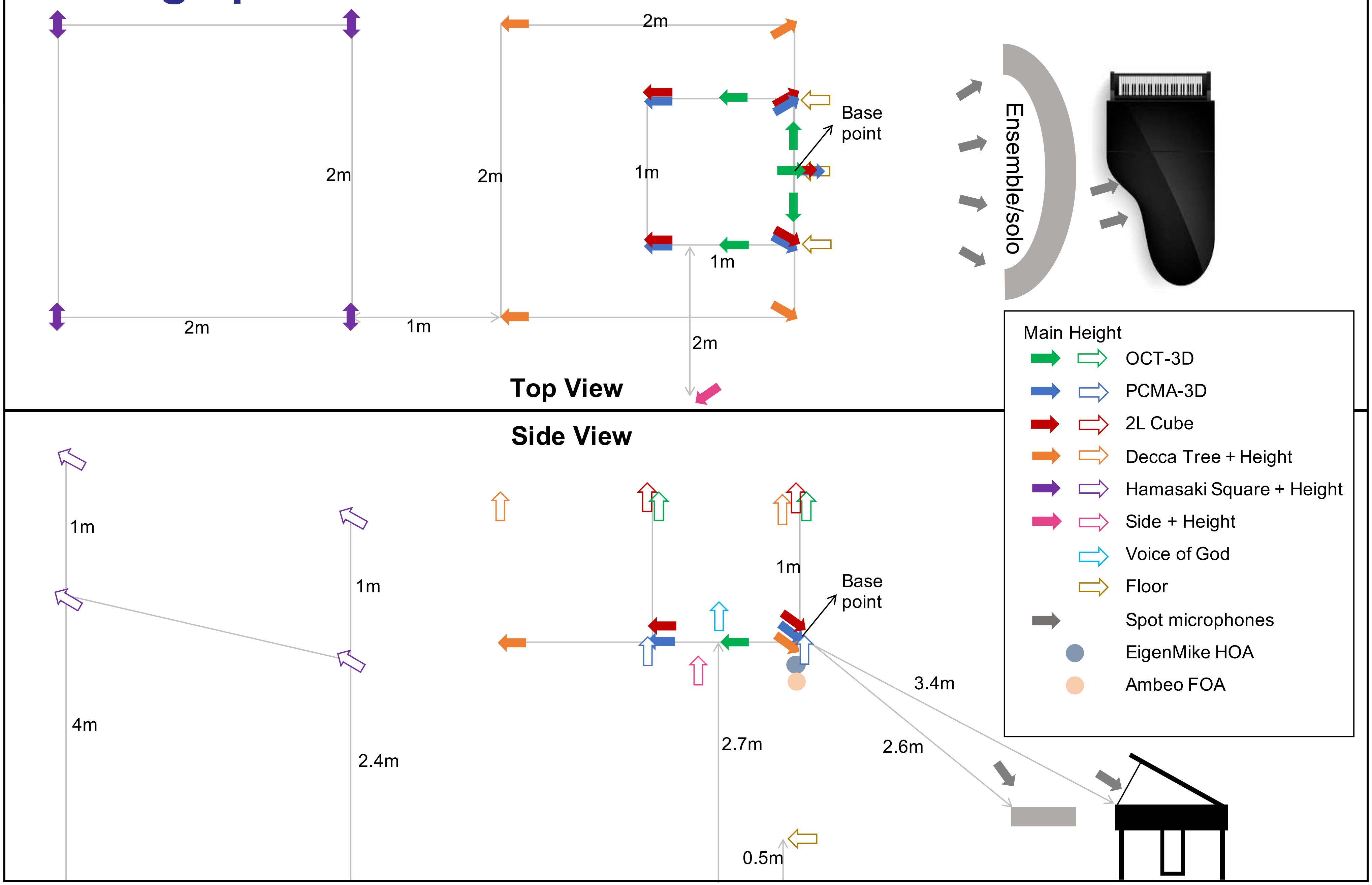
- All main and ambience arrays used DPA d:dicate series (except for Hamasaki Square using Schoeps CCM8 (Fig-8).
- Interface/Mic pres: Merging Technologies Horus/AD8P.
- Loudspeakers for IR: Genelec 8331A.
- Grace Design Spacebars + custom made joiners/polls

Sponsors

Recorded Materials

- **String Quartet:** Dvorak string quartet in G major op.106.
- **Piano trio (violin/cello):** Beethoven piano trio in E flat major, op. 1, no. 1.
- **Piano solo:** Chopin Nocturne in C sharp minor op. 27 & Chopin Mazurka in B flat op. 7.
- **Pipe organ:** improvisation
- **A cappella group:** Amber Run - I found
- **Anechoic single sources (male speech, cello, conga and trumpet)** placed at 0°, -15°, -30°, -45°, -60° and -90° (in the right-hand side).
- **Room impulse responses** for 13 source positions with 15° resolution, captured by all microphones.

Stage plan



2m
2m
2m
2m
1m
1m
1m
1m
2m
Base point
Ensemble/solo
Top View
Side View
1m
1m
1m
4m
2.4m
2.7m
Base point
3.4m
2.6m
0.5m
Main Height
OCT-3D
PCMA-3D
2L Cube
Decca Tree + Height
Hamasaki Square + Height
Side + Height
Voice of God
Floor
Spot microphones
EigenMike HOA
Ambeo FOA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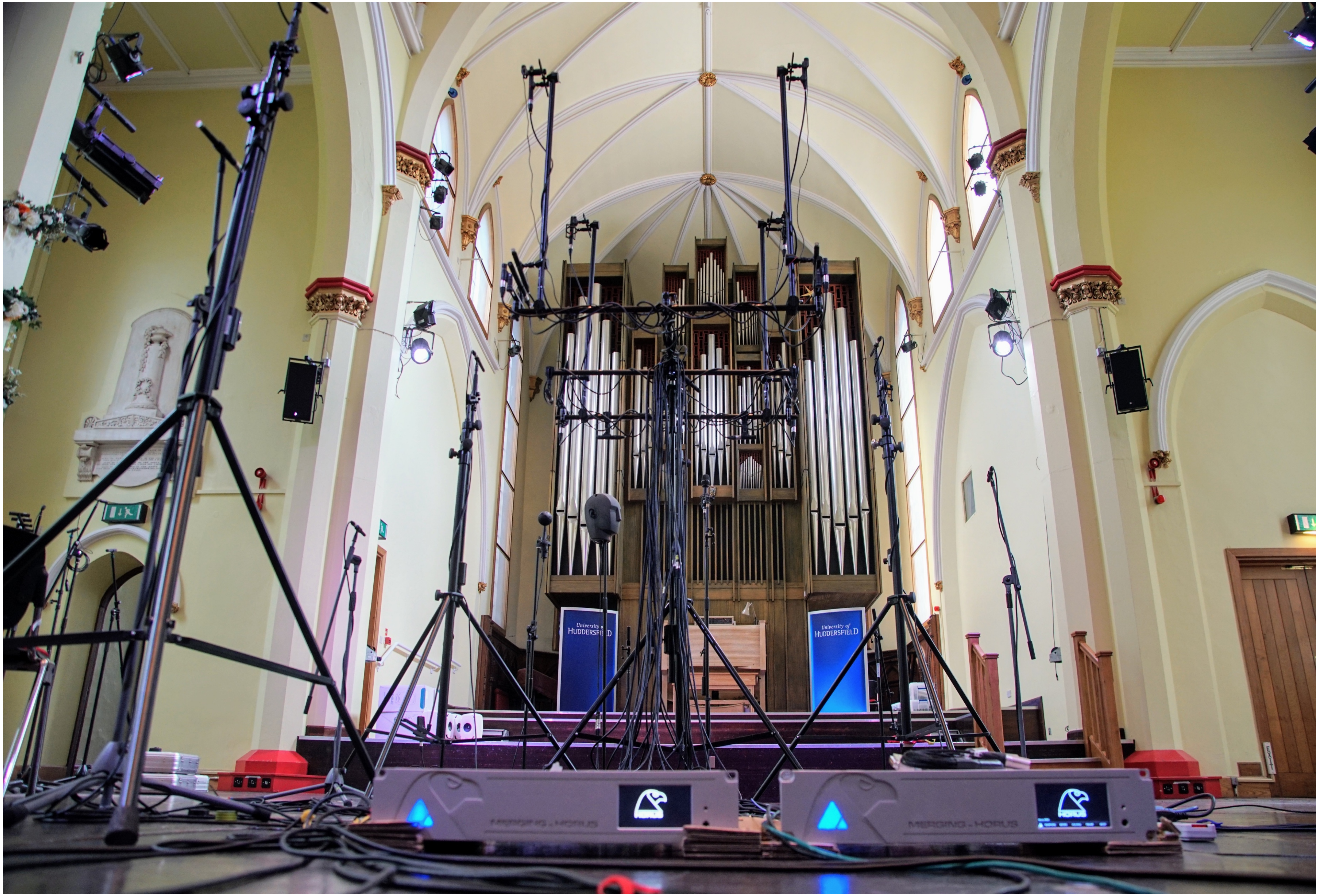
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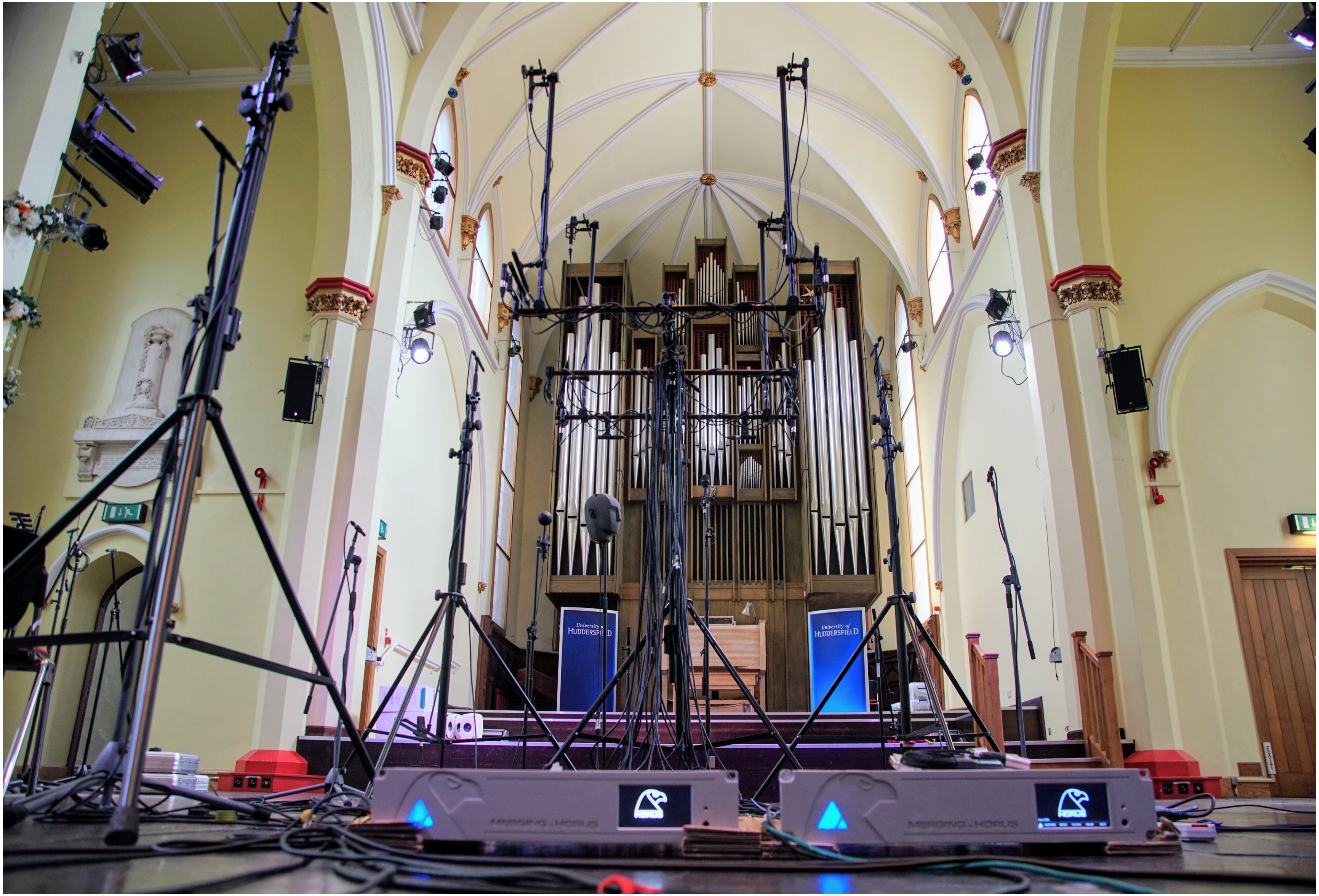
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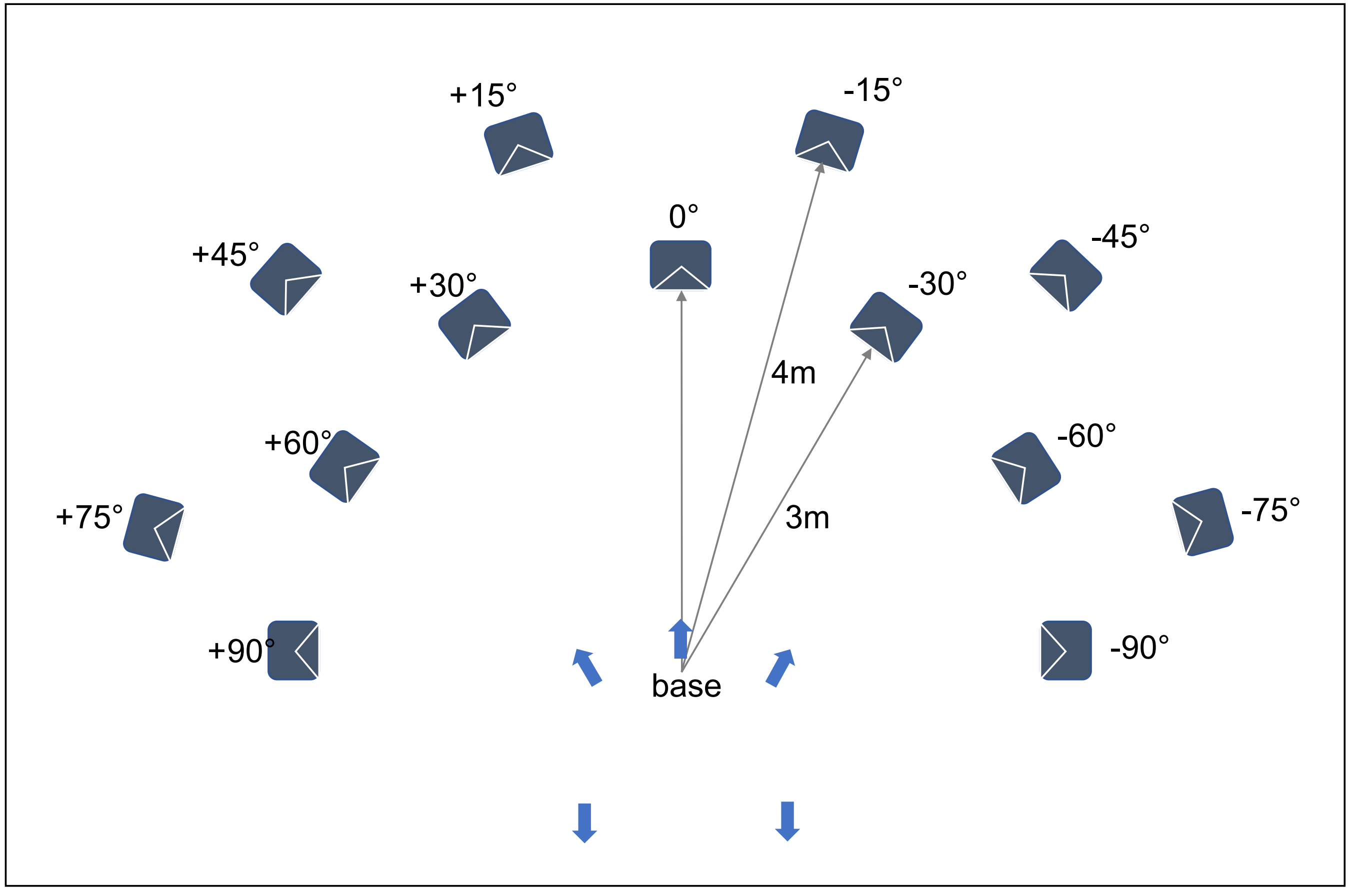
VAN DAMME TOUR GRADE


VAN DAMME

Mic array impulse responses (MAIRs)

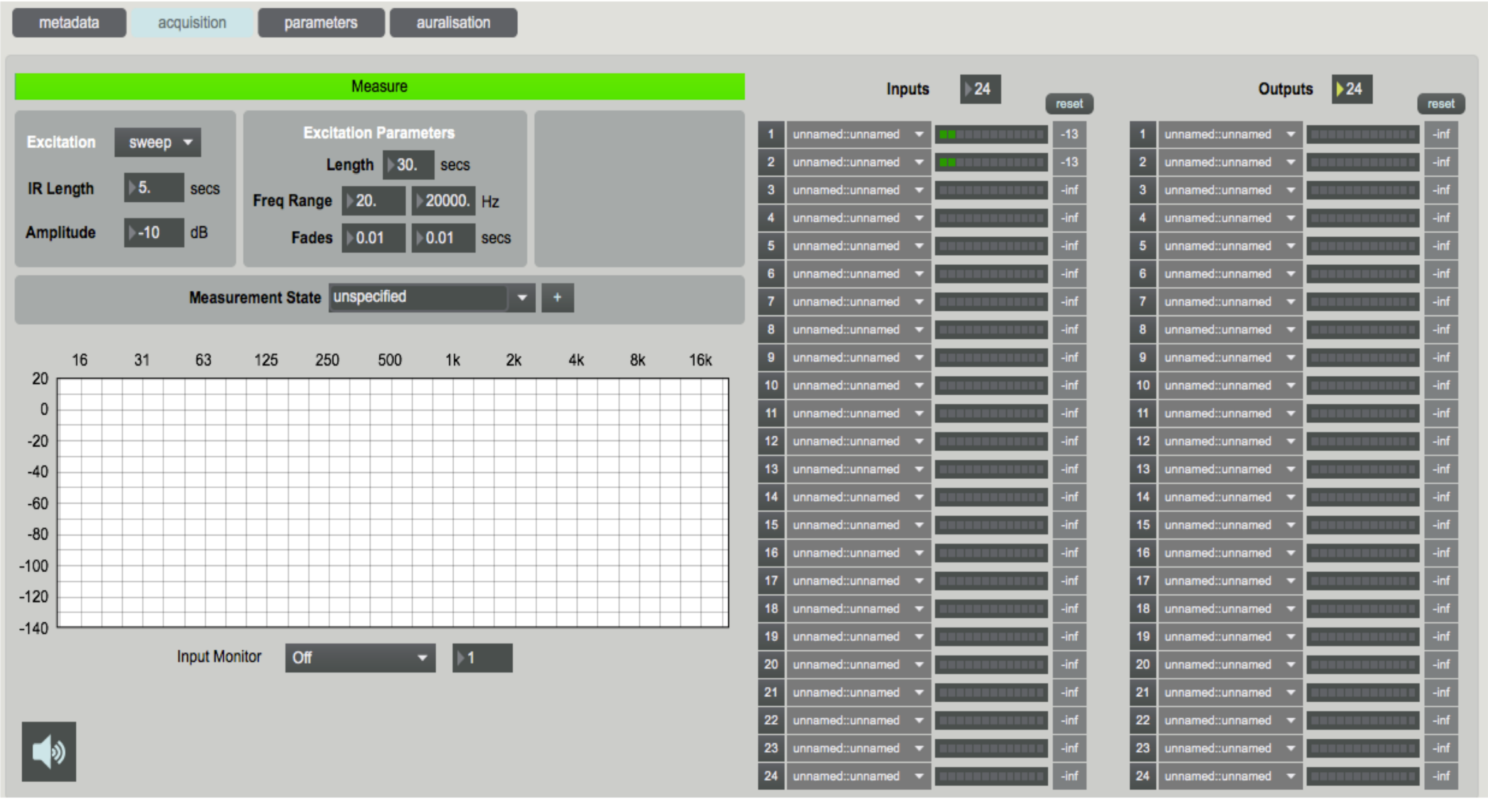
- 13 source positions with 15° angular resolution for all mics.
- Exponential sine sweep method / HAART (24 in/ 24 out)



Mic array impulse responses (MAIRs)

- HAART (Huddersfield Acoustical Analysis Research Toolbox)

http://eprints.hud.ac.uk/id/eprint/24579/



“3D-MARCo” Open-Access Database

- 3D Microphone Array Recording Comparison (3D MARCo)
- **Free download from https://doi.org/10.5281/zenodo.3474285**

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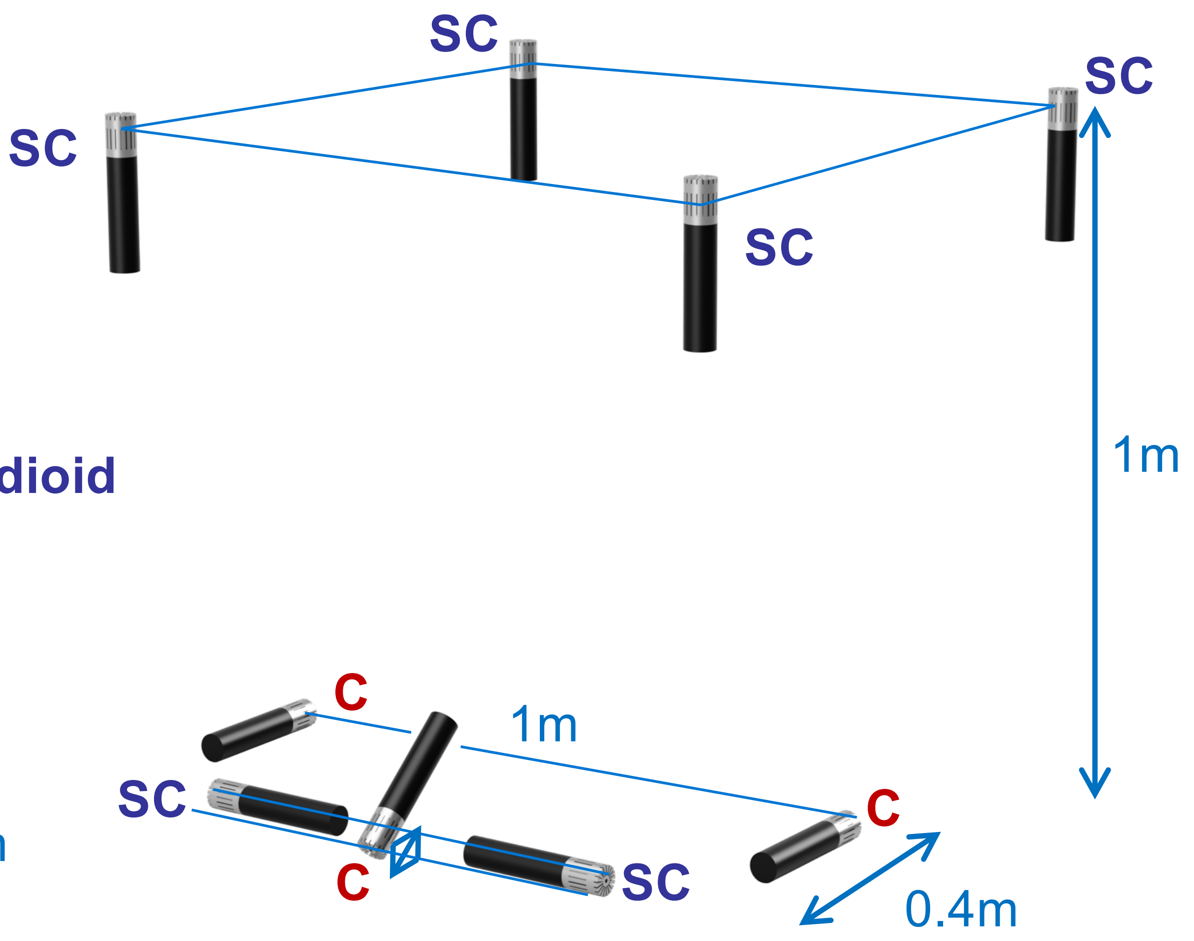
- **Applications**
  - Recording education.
  - Critical ear training.
  - Spatial audio research (e.g. virtual 3D stimuli creation)
  - Acoustic analysis using IRs.

3D Microphone Arrays

OCT-3D

- Based on Theile 2001, Theile and Wittek 2012.



C - Cardioid

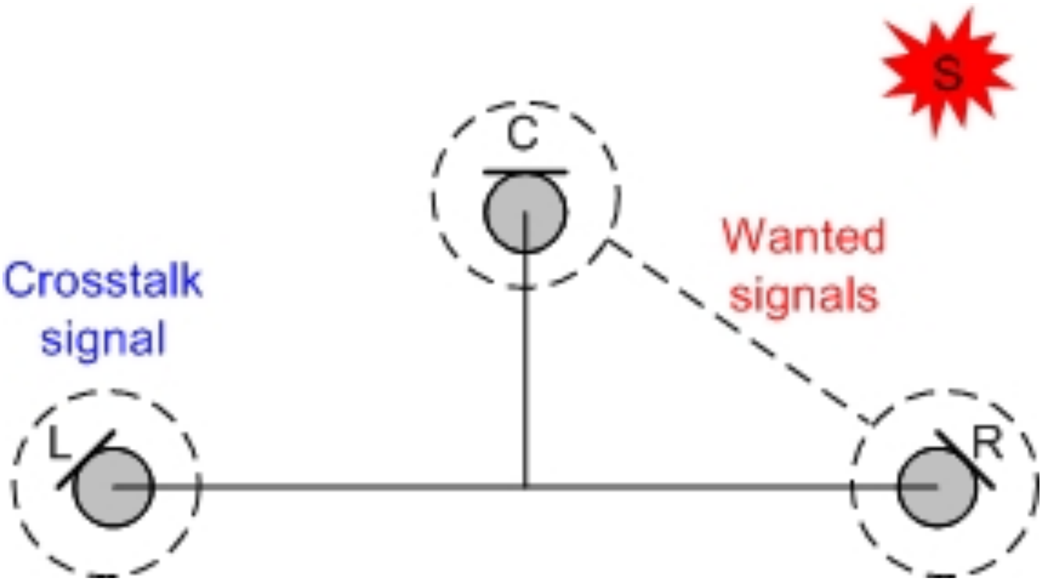
SC = Supercardioid

FL – FR: 70cm

FC – base: 8cm

OCT-3D

- OCT (Optimal Cardioid Triangle): Optimised for horizontal localisation by reducing L-C-R interchannel crosstalk (using supercardioids facing sidewards).
- Crosstalk effect: Increase source width, decreased locatedness.
- Vertical extension (~1m spacing) with omni or supercardioid

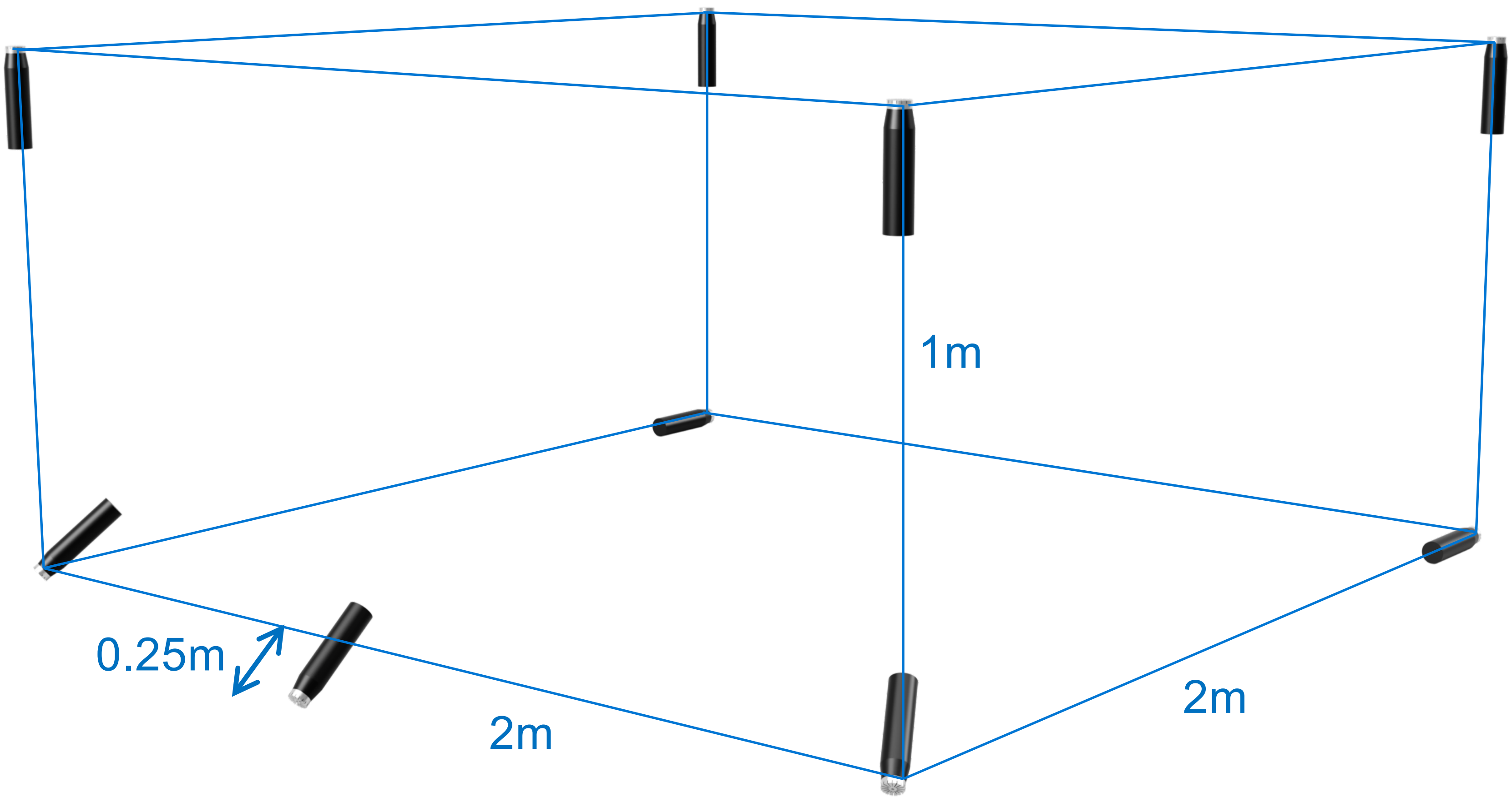


2L Cube-Inspired

- Originally developed by Morten Lindberg of the 2L Record Label.
- 9 omni microphones arranged in 1m x 1m x 1m cube.

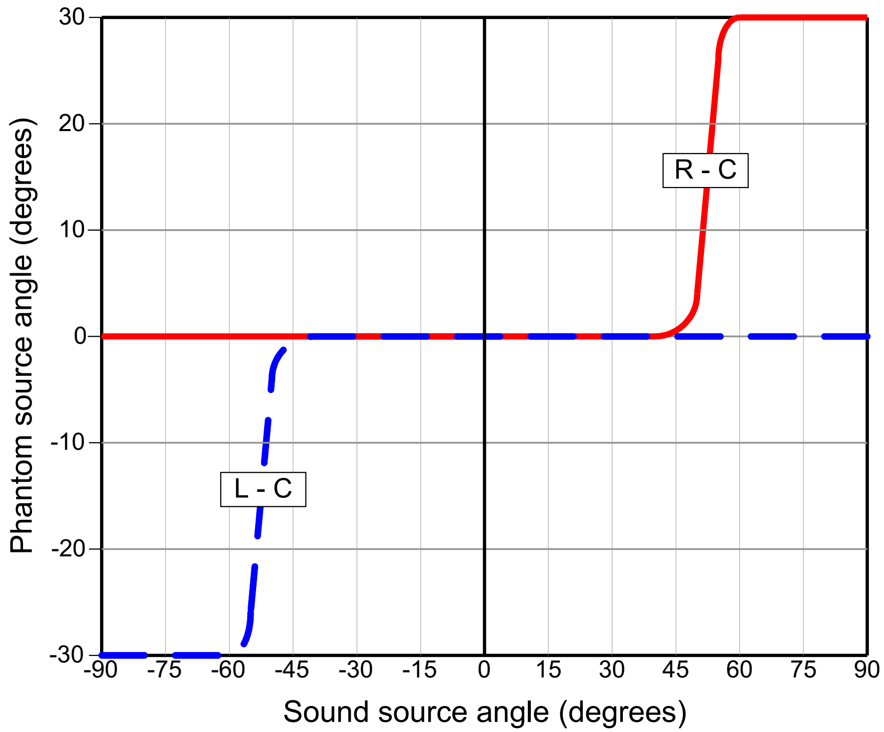
Decca Cuboid

- A modified Decca Tree augmented with rear and height mics.
- 9 omnidirectional mics.



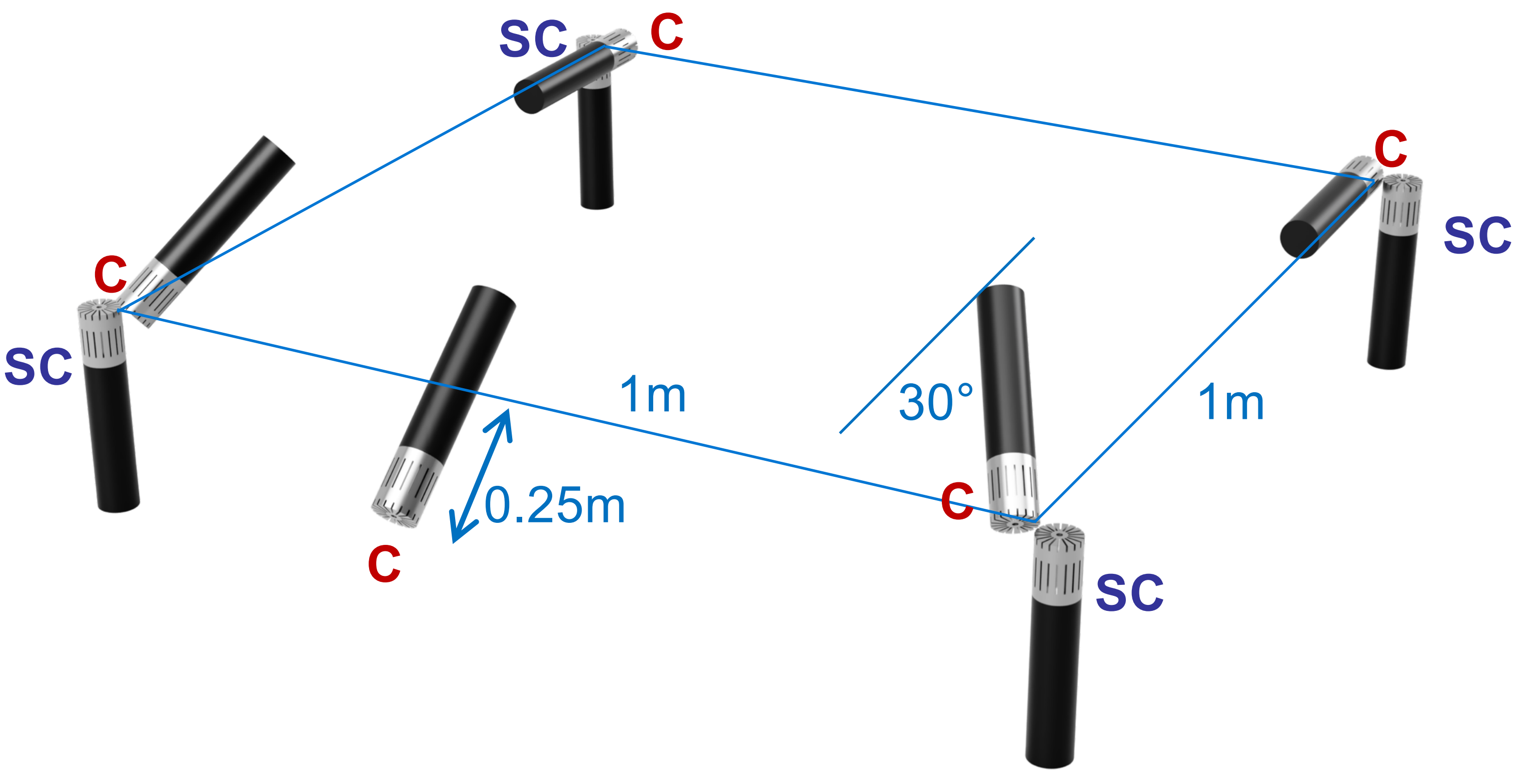
Decca Cuboid

- Original Decca Tree: 2m x (1m to 1.5m)
- Too much centre image dominance.
- Great spaciousness, but only 3 effective localization points (L, C, R) due to strong precedence effect.



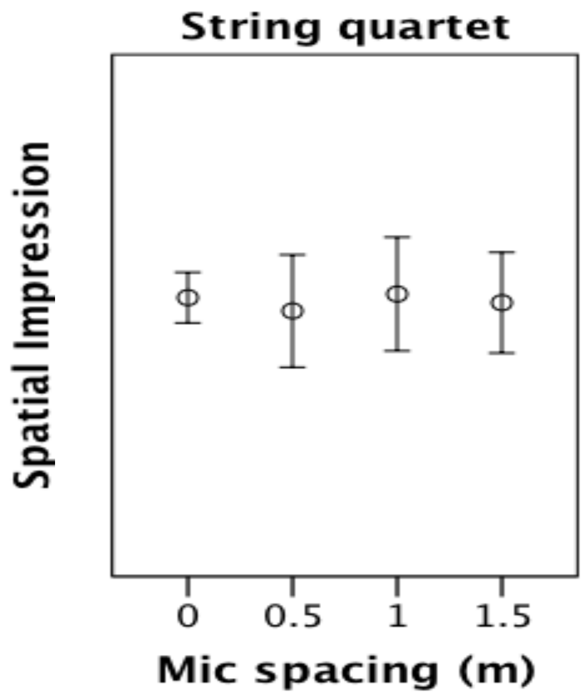
PCMA-3D

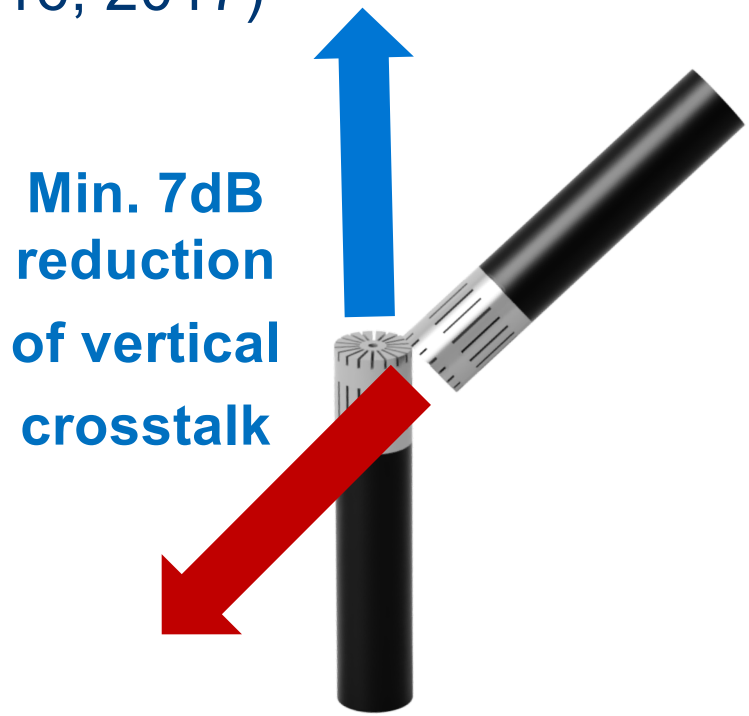
- Based on Lee 2011, Lee and Gribben 2014.
- Horizontally spaced, vertically coincident.



PCMA-3D

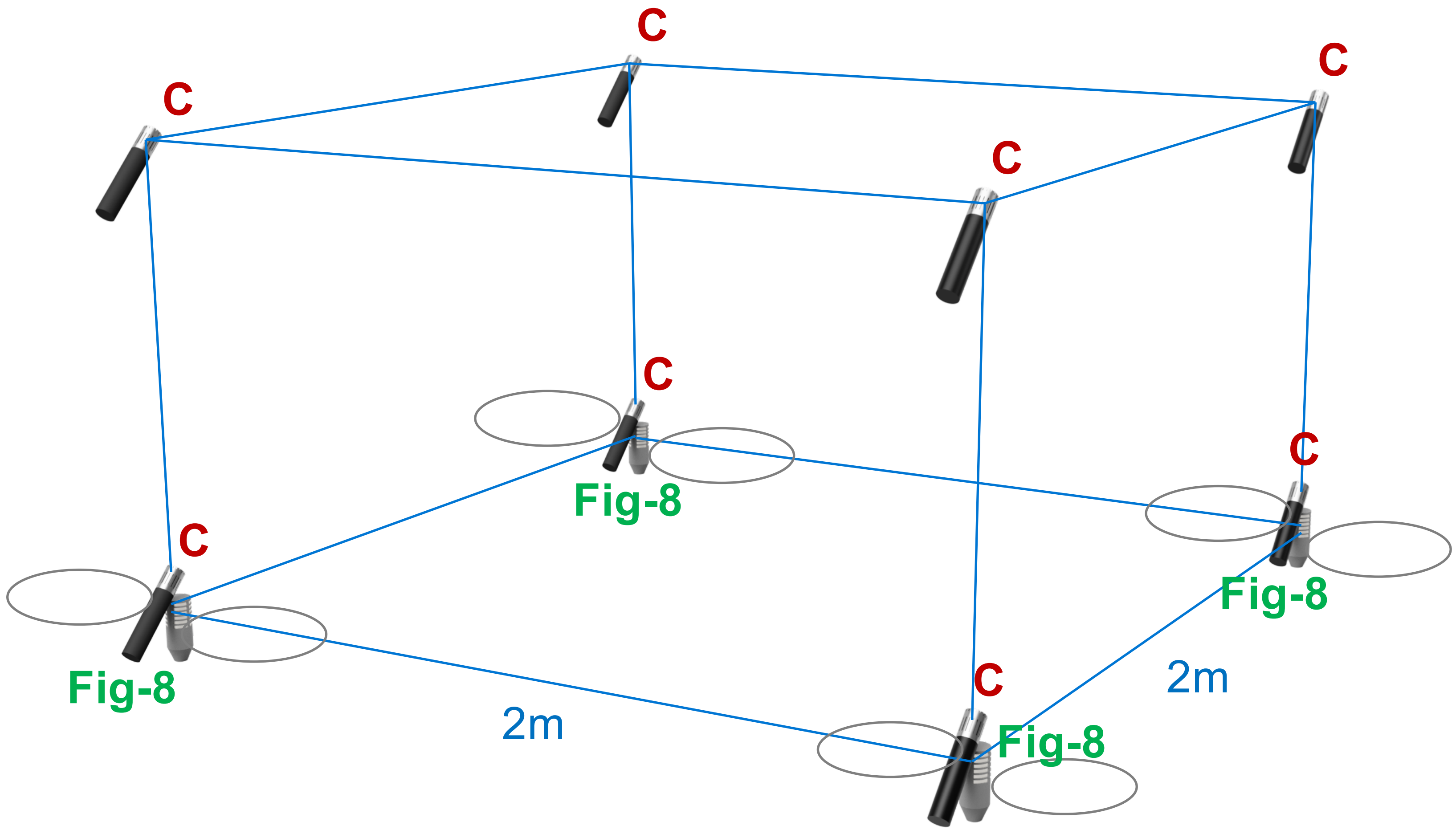
- The effect of vertical mic spacing & decorrelation is little or none for 3D spatial impression (Lee and Gribben 2014, Gribben and Lee 2018)
- Reducing vertical interchannel crosstalk for stable vertical imaging (Lee 2011, Wallis and Lee 2016, 2017)





Hamasaki Square + Height

- Hamasaki Square (4 side-facing Fig-8s in a 2m x 2m square)
- Plus back-facing cardioids for Height at 0m and 1m.



Hamasaki Square + Height

- A popular surround ambience capture technique.

- Horizontal spacing: originally proposed to be 2 to 3m spacing.
- For sufficient low-frequency decorrelation down to 100Hz, based on the Diffuse Field Coherence model assuming two Omni directional mics.

- But with directional mics, the spacing could be made shorter.

- Vertically, is there any perceptual difference between 0m and 1m spacings?

Ambisonics / Spherical Array

- Eigenmike EM32: 32 capsules on a sphere.
- HOA encoding / Beamforming up to 4th order
- Various decoding plugins available (IEM, SPARTA, Harpex, etc.)

mhAcoustics
Eigenmike EM32

Sennheiser
Ambeo FOA

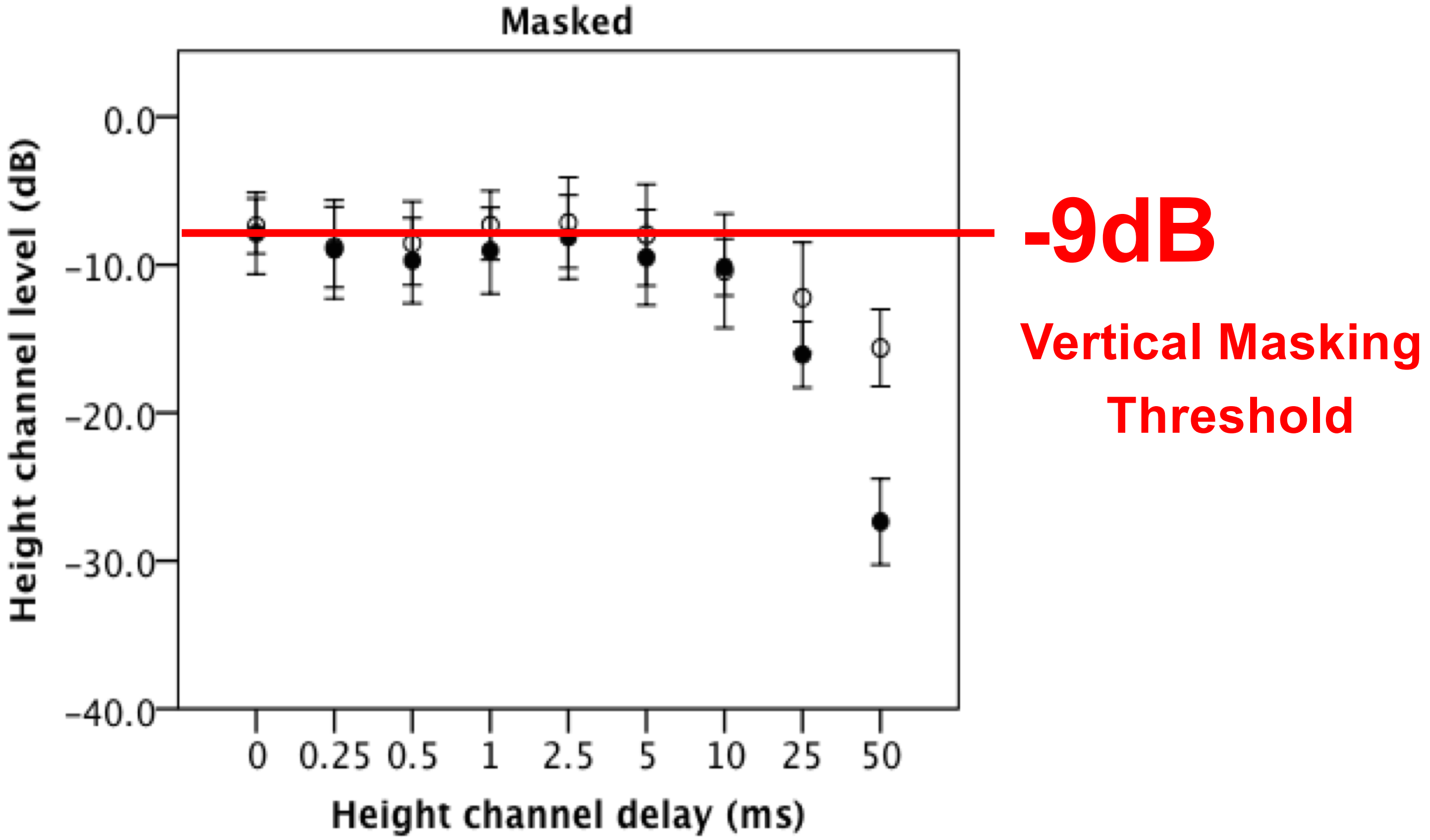
Let's have a listen!

What to listen for?

- Vertical height spacing
  - PCMA 0m vs 1m
  - Hamasaki 0m vs 1m
- Vertical localisation
- Source width
- Perceived depth

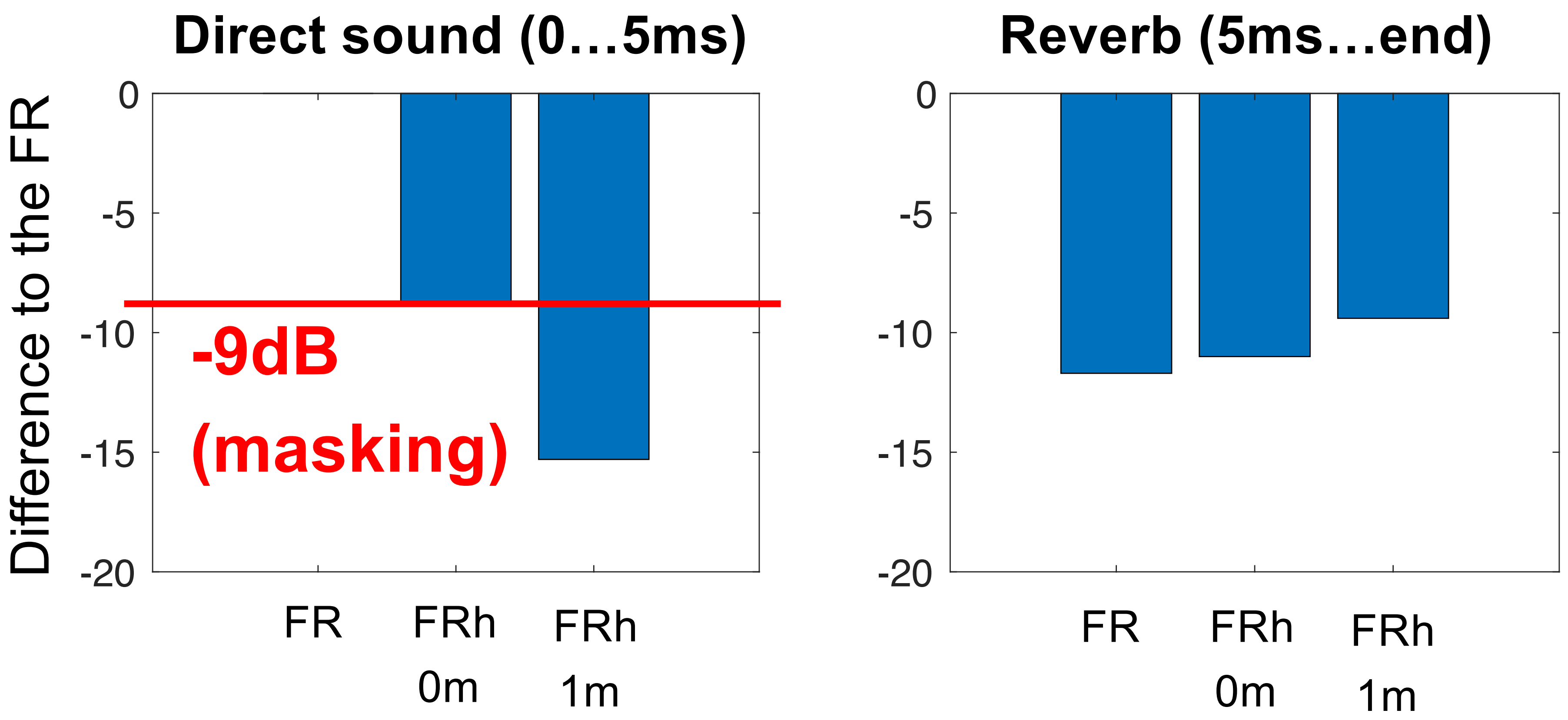
Vertical Interchannel Crosstalk

- **Up to crosstalk delay of 5ms**, the height channel level should be attenuated by at least **9dB** to make the crosstalk inaudible (Lee 2011).



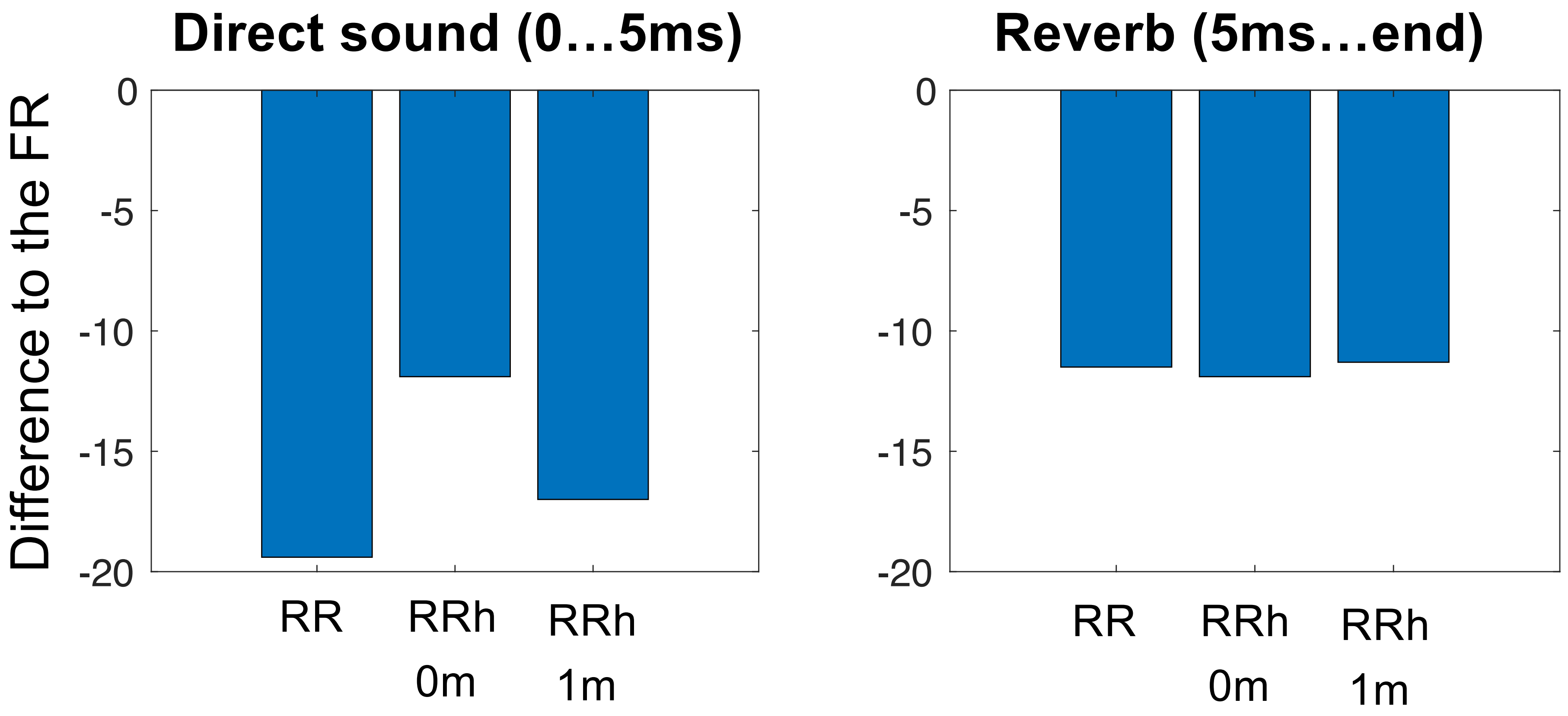
Vertical Interchannel Crosstalk

Energy difference to Front Right (FR)

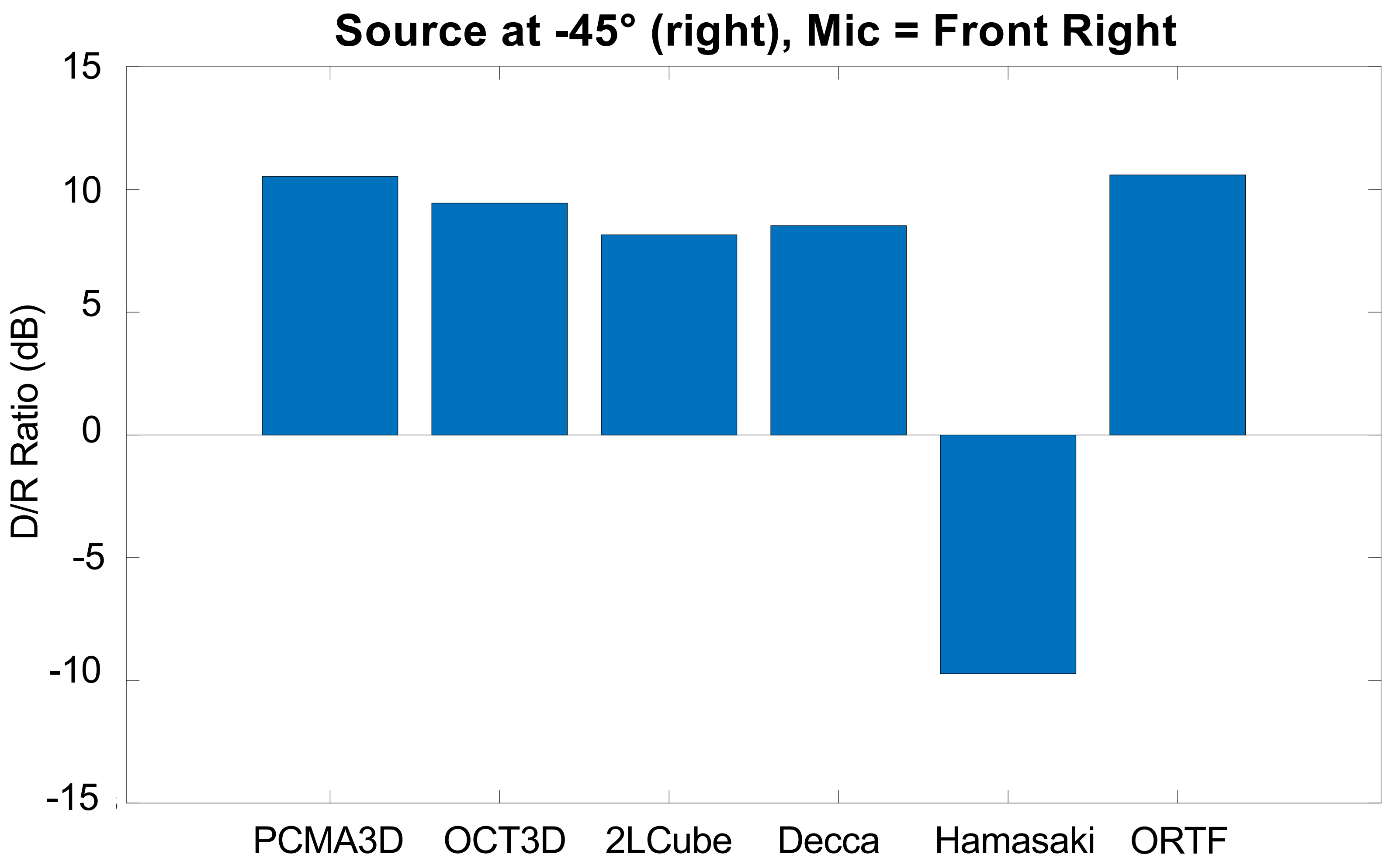


Vertical Interchannel Crosstalk

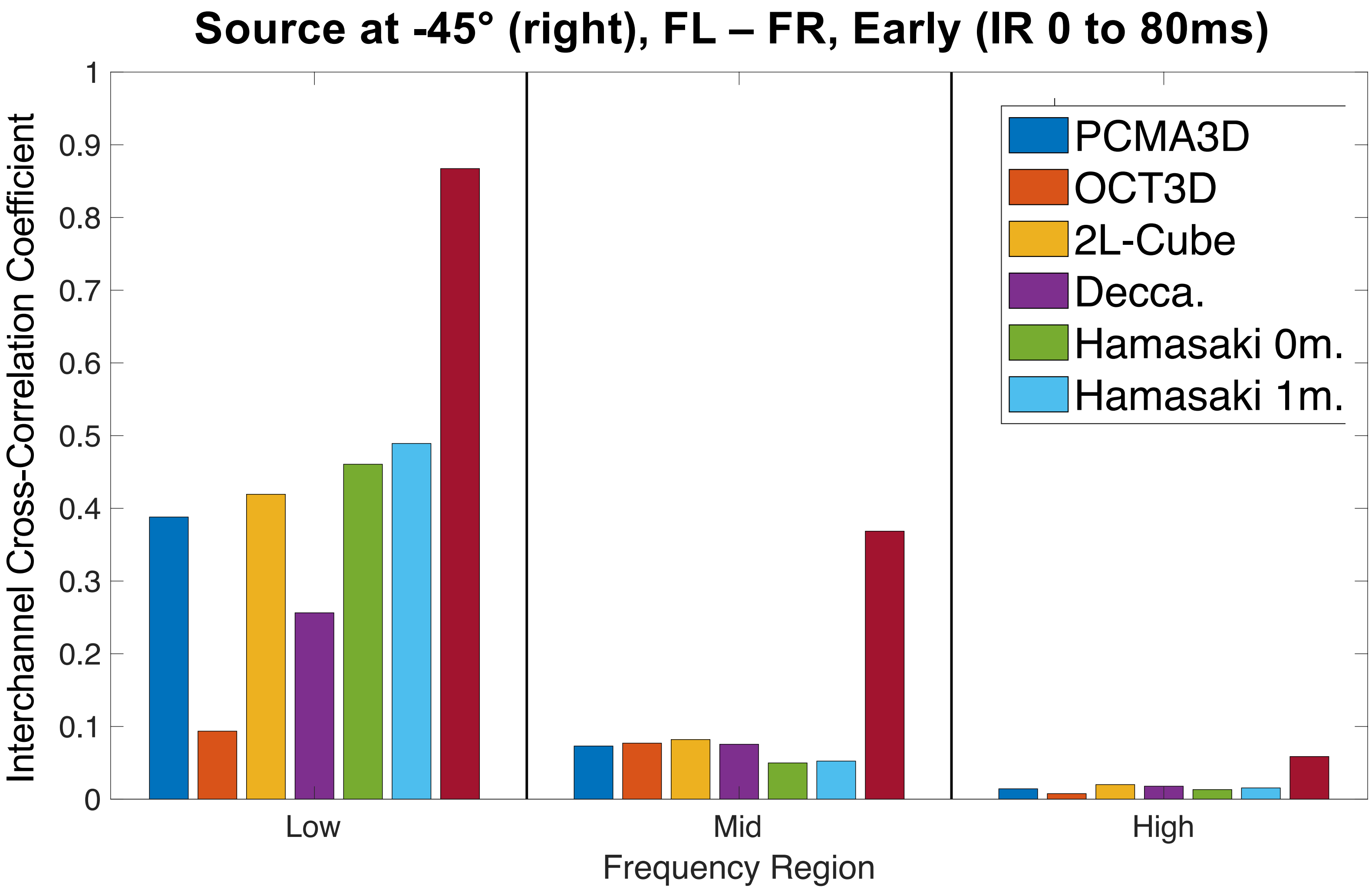
Energy difference to Front Right (FR)



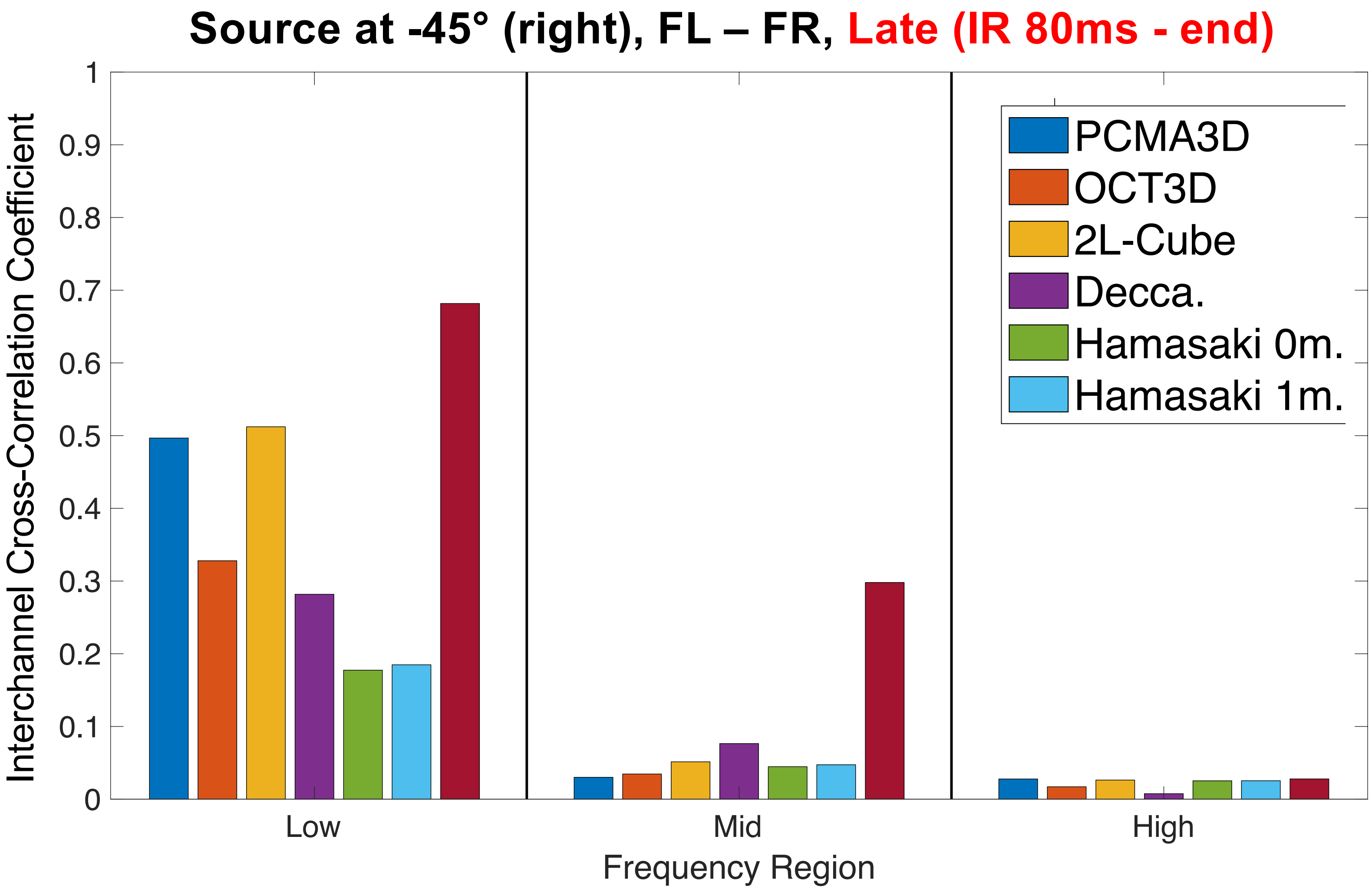
D/R Energy Ratio Comparison



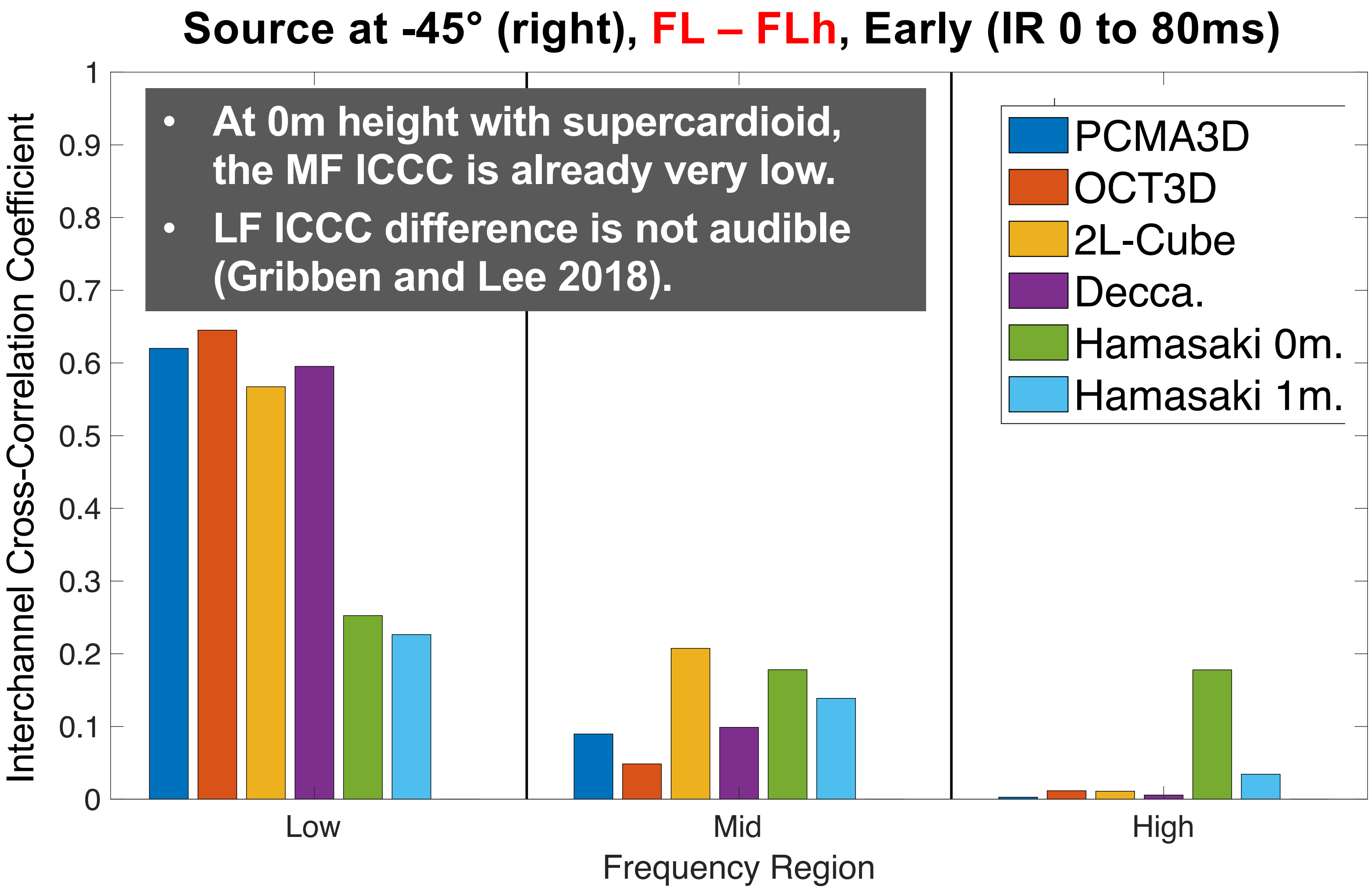
Interchannel Cross-Correlation Coefficient (ICCC)



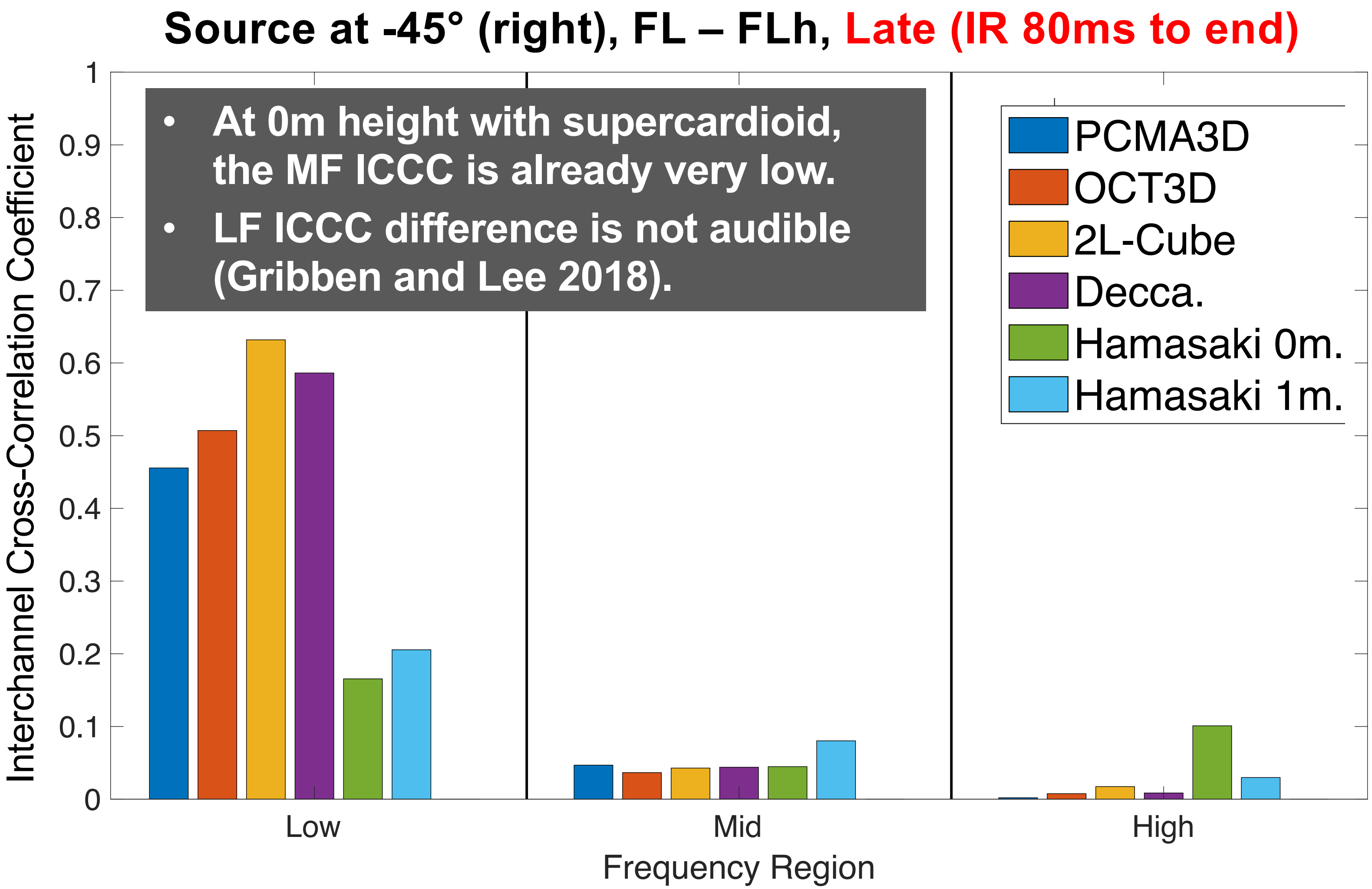
Interchannel Cross-Correlation Coefficient (ICCC)



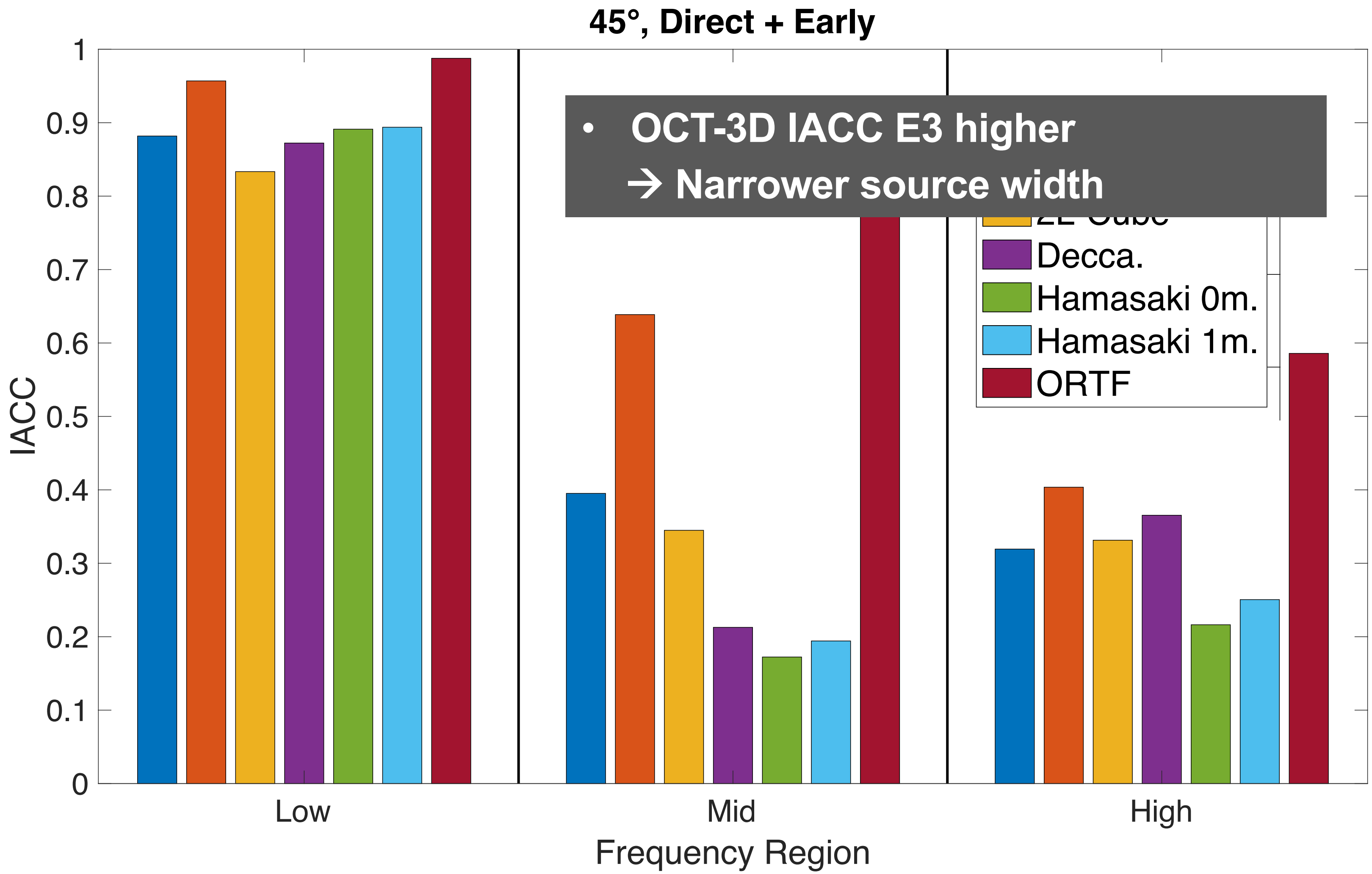
Interchannel Cross-Correlation Coefficient (ICCC)



Interchannel Cross-Correlation Coefficient (ICCC)

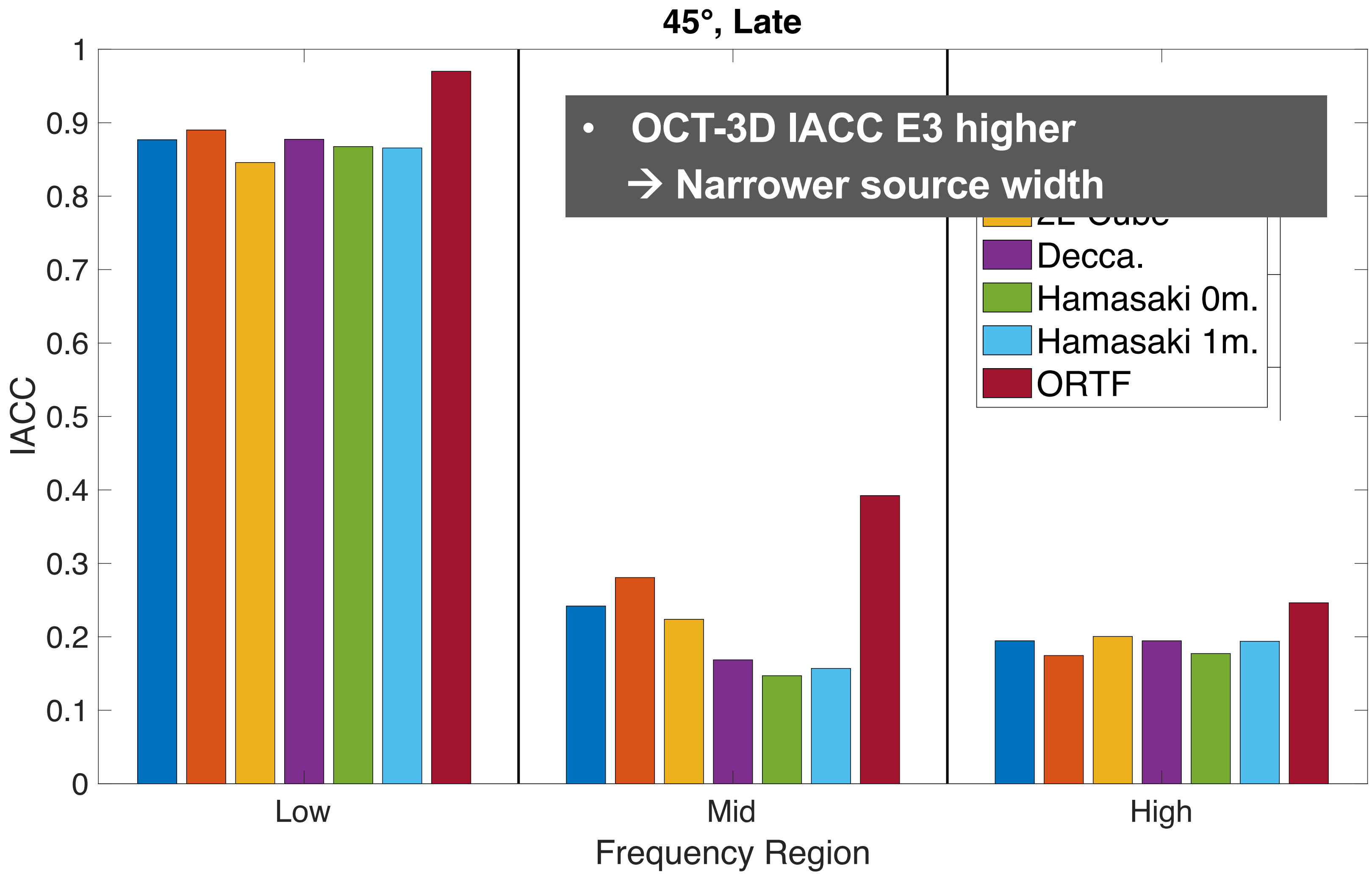


Interaural Cross-Correlation Coefficient (IACC)



- OCT-3D IACC E3 higher
  → Narrower source width

Interaural Cross-Correlation Coefficient (IACC)



- **OCT-3D IACC E3 higher**
  → Narrower source width

Summary

- There is no one winner. Different 3D microphone arrays have different pros and cons.

- Optimal technique depends on content type and acoustics of the venue.

- Train ears to critically listen for different attributes (localization, width, depth, envelopment, tonal balance, etc.)

- A formal experiment will be conducted to elicit perceptual attributes for acoustic recording quality evaluation.

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More Information

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Applied Psychoacoustics Lab (APL) **www.hud.ac.uk/apl**

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