Directivity and Electro-Acoustic Measurements of the IKO

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Introduction

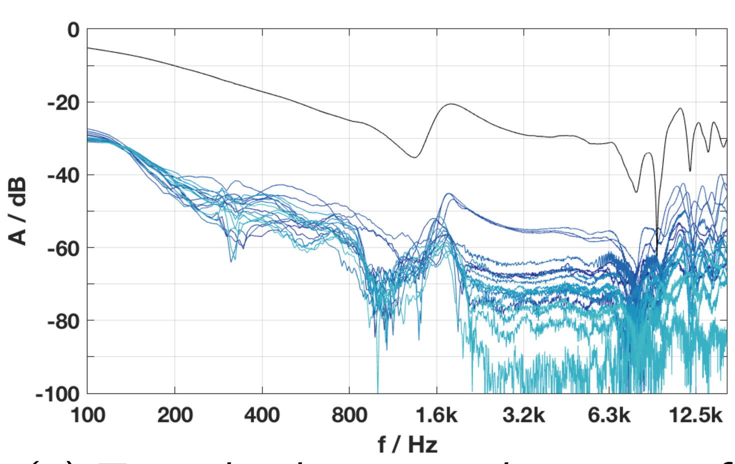
The icosahedral loudspeaker (IKO) as a compact spherical array is capable of 3rd order Ambisonics (TOA) beamforming into all directions, with rotation-invariant beam patterns over several octaves, here from 100 Hz to about 1-2 kHz [1].

The IKO can be used as technical and musical instrument, such as for (room) acoustic measurement, media installations and computer music. The latter introduced a convenient approach for composing sonic sculptures, also called plastic sound objects [2] by IKO's sound beams exciting room reflections.

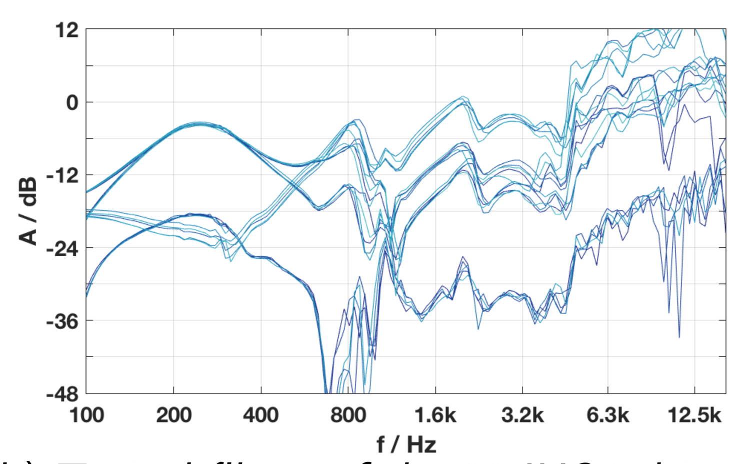
Figure 1: Icosaehdral loudspeaker "IKO by IEM and sonible" with about 0.3 m edge length and 20 six-inch drivers, available at iko.sonible.com.

Open Data and Open Source

To develop and verify beamforming with 20 drivers flush-mounted into the faces of the regular icosahedron, electro-acoustic properties were measured for IEM's three IKOs, a.ka. IKO1, 2, 3. For each IKO
(i) 20x20 transfer impulse responses from driving voltages to driver velocities using laser vibrometry
(ii) 20x16 FIR TOA decoding filters derived from the velocity measurements
(iii) 648x20 (IKO1,2) and 540x20 (IKO3) directional impulse responses from driving voltage to calibrated microphone receiving voltages
are available as SOFA files, see link below.



(a) Typical voltage to velocity transfer functions of IKO2. Black...active driver, blue...passive drivers.



(b) Typical filters of the 20 IKO1 drivers for beam steering to a vertex.

Figure 2: IKO measurements and filters.

For analyzing IKO beamforming the open source tool balloon_holo is provided, cf. Fig. 3. The software is capable of loading the SOFA data and of interactively inspecting balloon, polar and surface directivity plots with the provided beamforming filters.

Surface directivities for IKO1, 2, 3 are shown in Fig. 4. Balloon visualizations for characteristic beam directions and frequency bands are depicted in Fig 5.

Face beam denotes a beam directed on-axis with an IKO loudspeaker/facet, edge beam denotes a beam directed through the middle of an IKO edge, where two facets meet, while vertex beam denotes a beam directed through an IKO corner, where five facets meet.

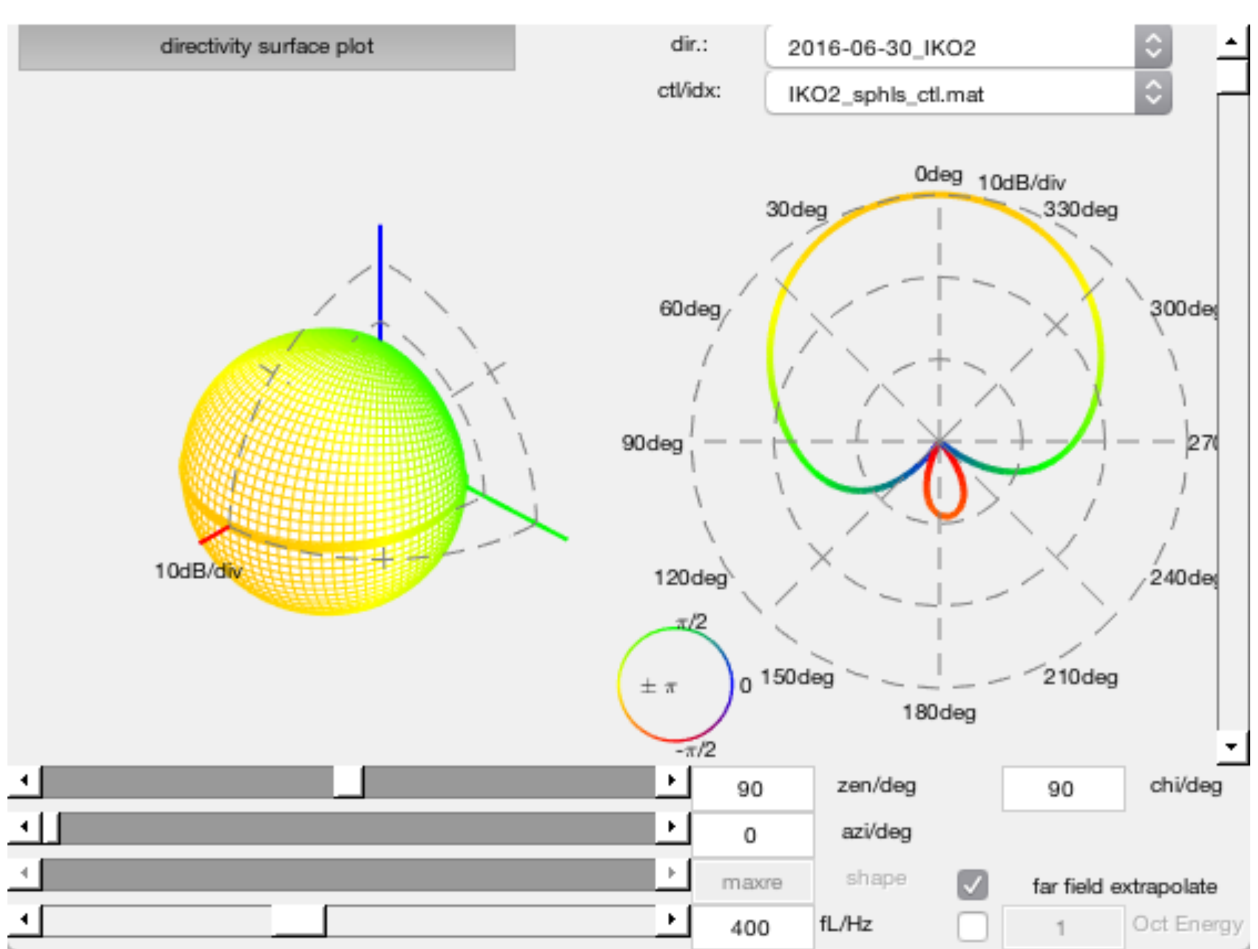


Figure 3: Matlab based GUI of balloon_holo as analyzing tool for IKO beamforming.

Directivity Plots

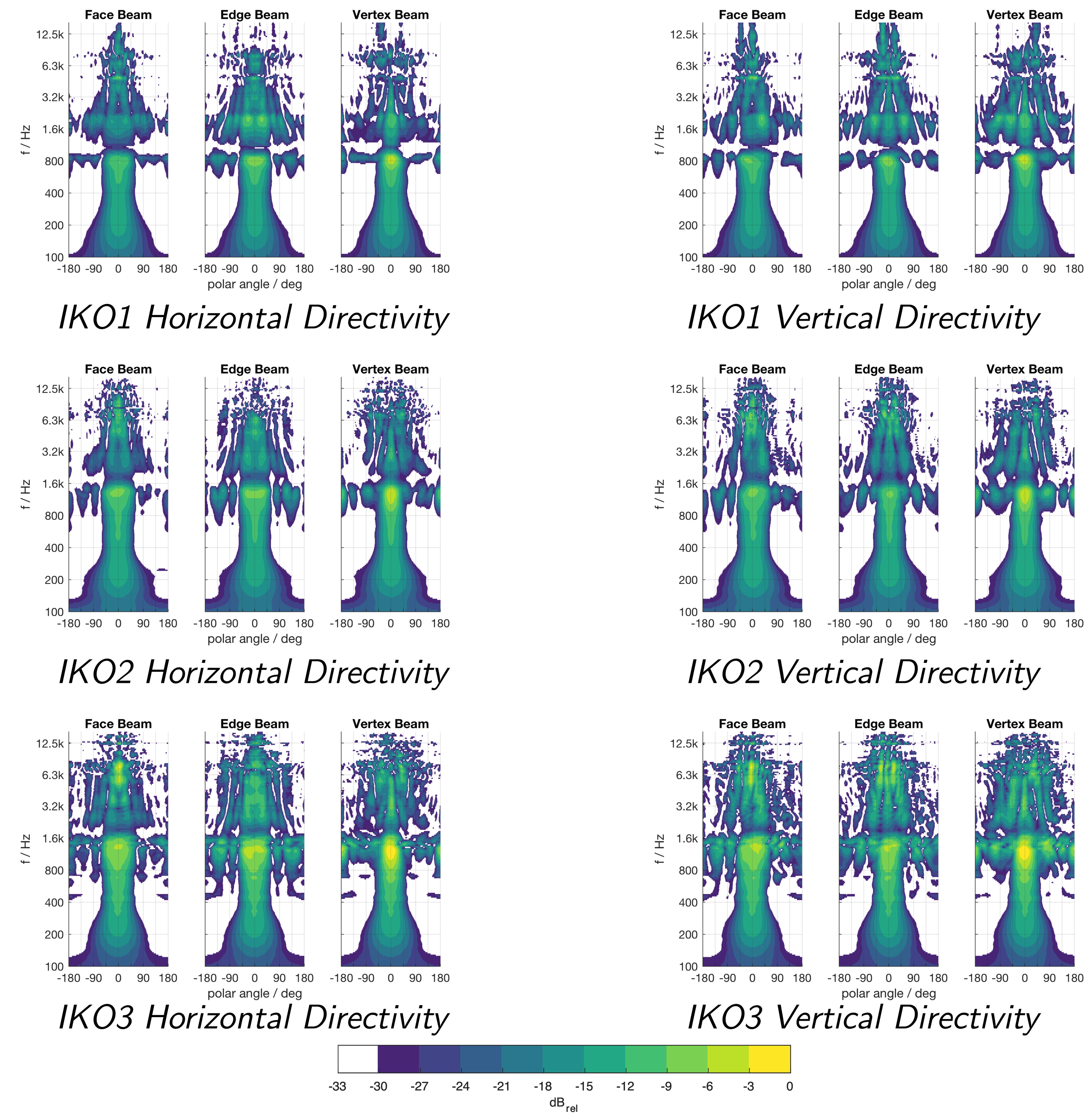


Figure 4: Horizontal and vertical directivity patterns for IKO1,2,3 using Ambisonic beamforming with frequency dependent order and max-rE weighting. IKO edge lengths: 0.345 m IKO1, 0.288 m IKO2, 0.294 m IKO3.

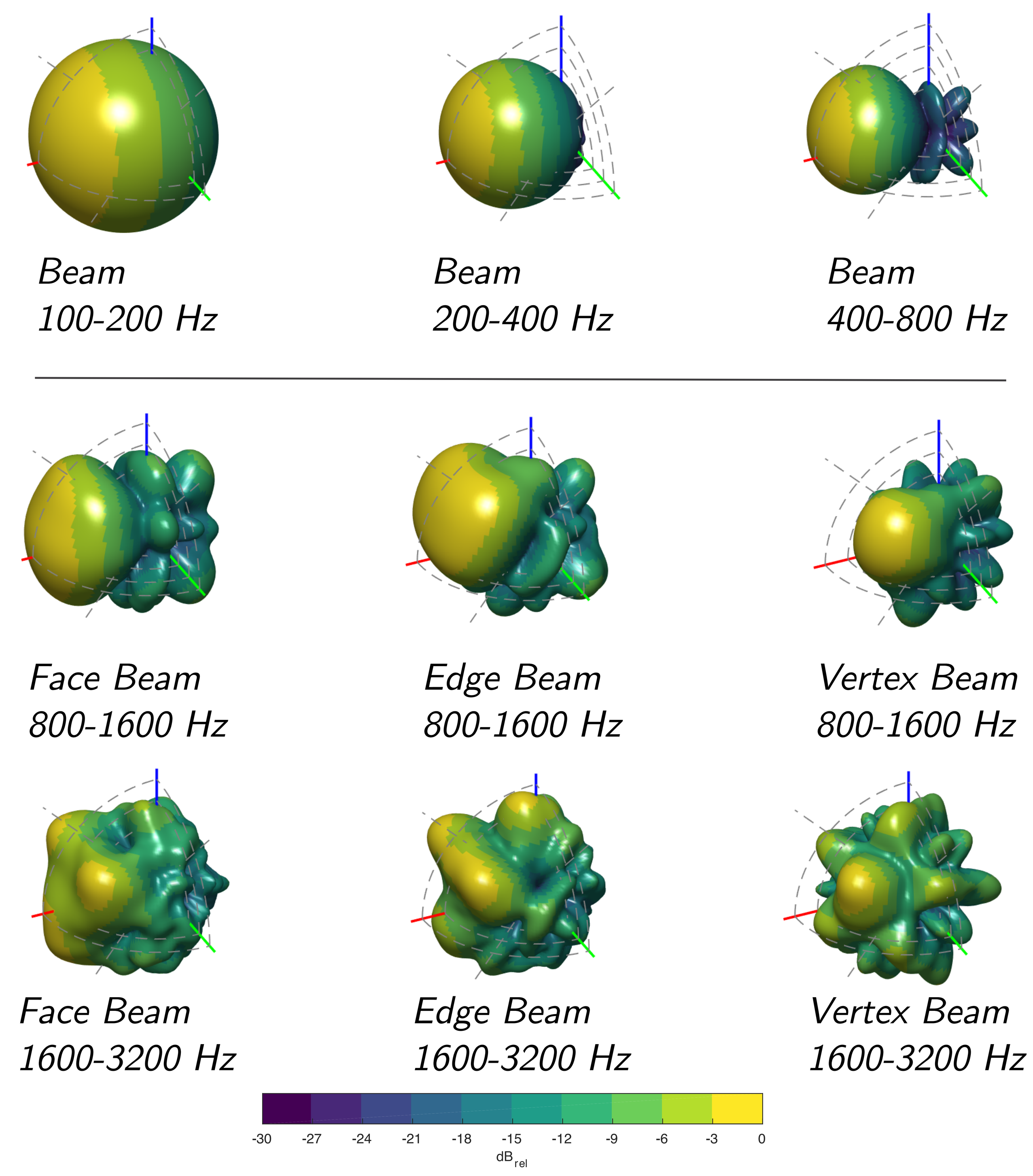


Figure 5: Directivity balloon characteristic for IKO3. The balloon radius and the color indicate dB-values of energy per frequency band from low to high cut frequency. Top row: up to about 1 kHz main lobe patterns are independent of the beam direction. Middle and bottom row: above 1 kHz grating lobes arise that yield characteristic patterns for beams into face (left column), edge (center column) and vertex (right column) direction of the IKO.

Links

Open Data: https://phaidra.kug.ac.at/detail_object/o:67609
Open Source: https://opendata.iem.at
OSIL Project: https://iem.kug.ac.at/projects/osil/about-osil.html

Reference

[1] Zotter, F.; Zaunschirm, M.; Frank, M.; Kronlachner, M. (2017): "A Beamformer to Play with Wall Reflections: The Icosahedral Loudspeaker." In: Computer Music Journal, 41(3):50–68.
[2] Wendt, F.; Sharma, G.K.; Frank, M.; Zotter, F.; Höldrich, R. (2017): "Perception of Spatial Sound Phenomena Created by the Icosahedral Loudspeaker." In: Computer Music Journal, 41(1):76–88.

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