MEMS PIEZO LOUDSPEAKERS
THE CASE OF 3D SOUND

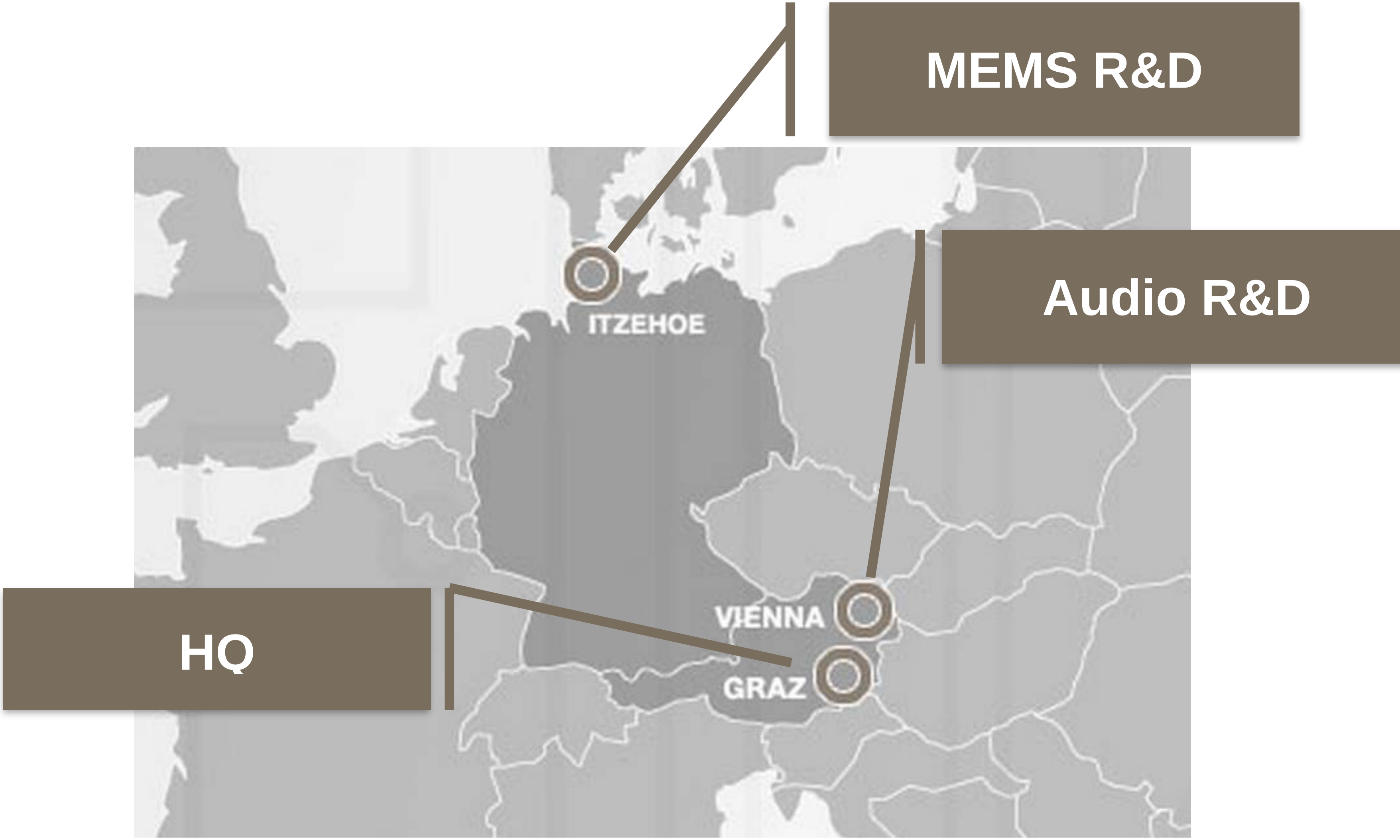
MICROBIC NORD 2017

U))SOUND

enabling a new paradigm for audio smart systems in portable device

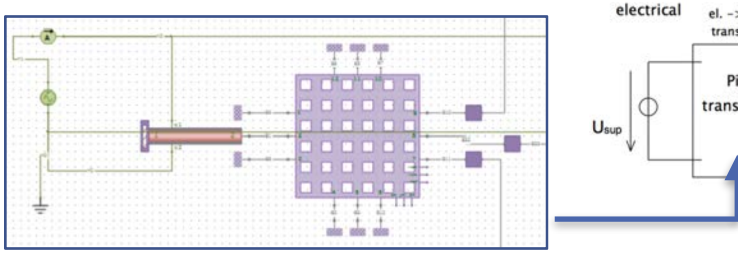
Headphones | Portables | Ultrasound

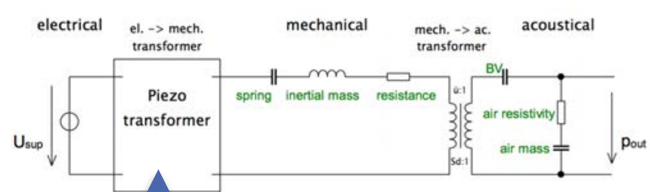
Locations and workforce
Total of 30 full time equivalents

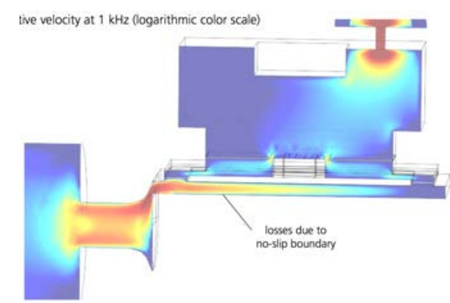


state-of-the-art MEMS innovations in Microacoustics

- **Piezoelectric materials deposition:** PZT and AlN 8” silicon manufacturing; maximised material properties and performances; high deposition rates and film thickness.
- **MEMS Process Integration:** integration of Piezo materials in MEMS process architectures; enable high force and displacement actuators; arrangement in arrays.
- **Embedded IC Assembly Concepts:** efficient integration of logic and passive elements at PCB level.
- **Hybrid Assembly of Acoustic Components:** leveraging innovation in assembly technologies to couple a MEMS actuator with acoustic components; integrate ASIC and passives into a smart component.





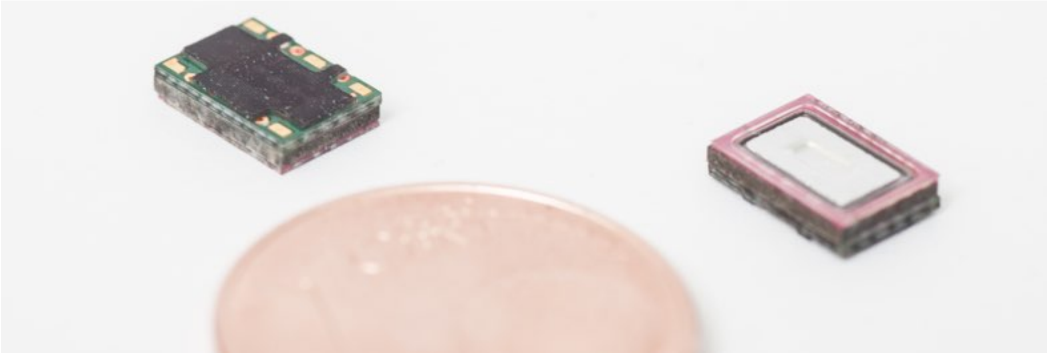


USound Solutions Strengths and Advantages

Compared to incumbent technologies

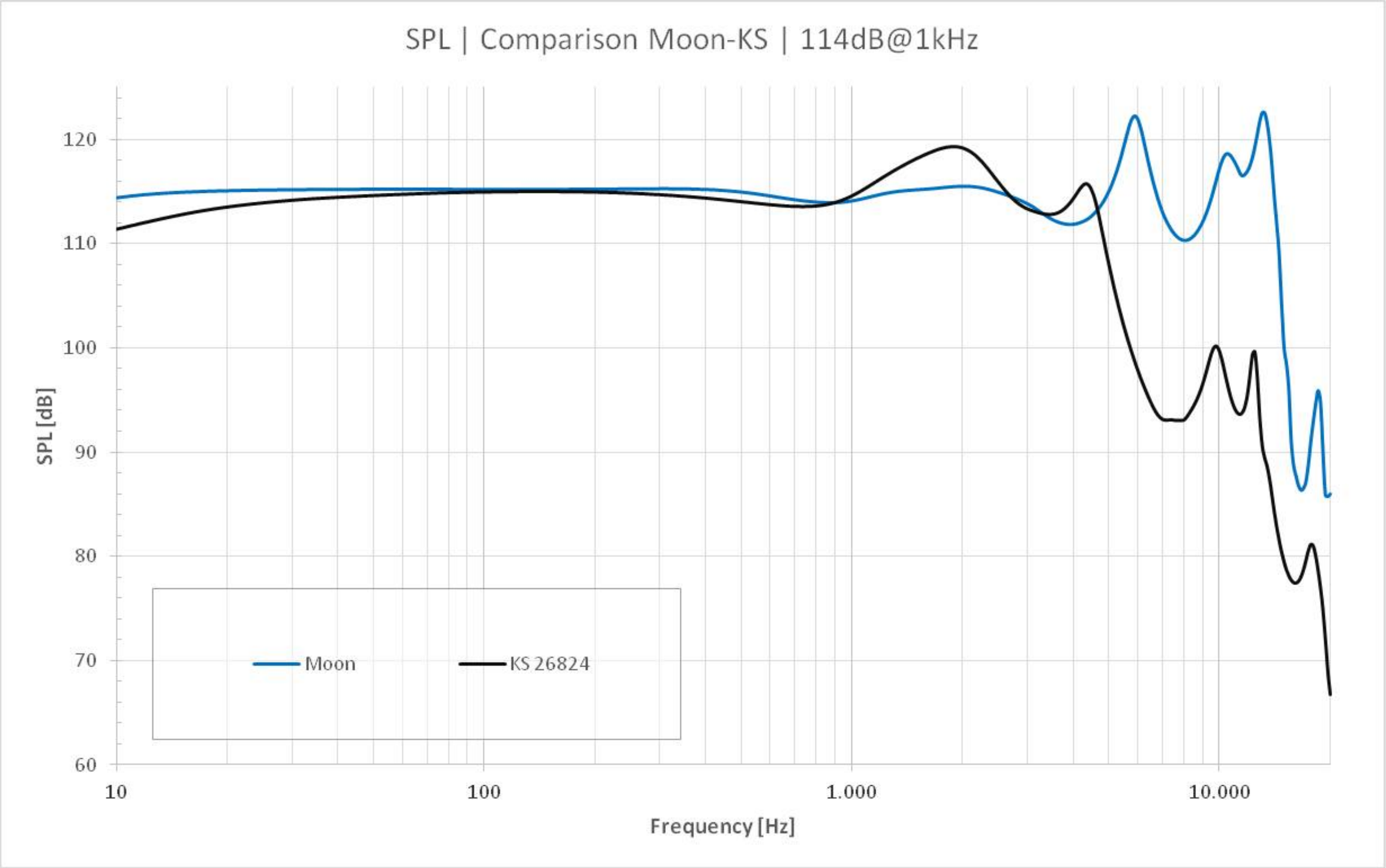
PZT MEMS

- Thin form factors
- Small footprint
- Low power consumption
- Faster time response than voice coil
- Accurate sound reproduction and clarity
- Performance repeatability lot to lot
- Light weight
- Low vibrations



MEMS In-Ear Receiver Characterisation

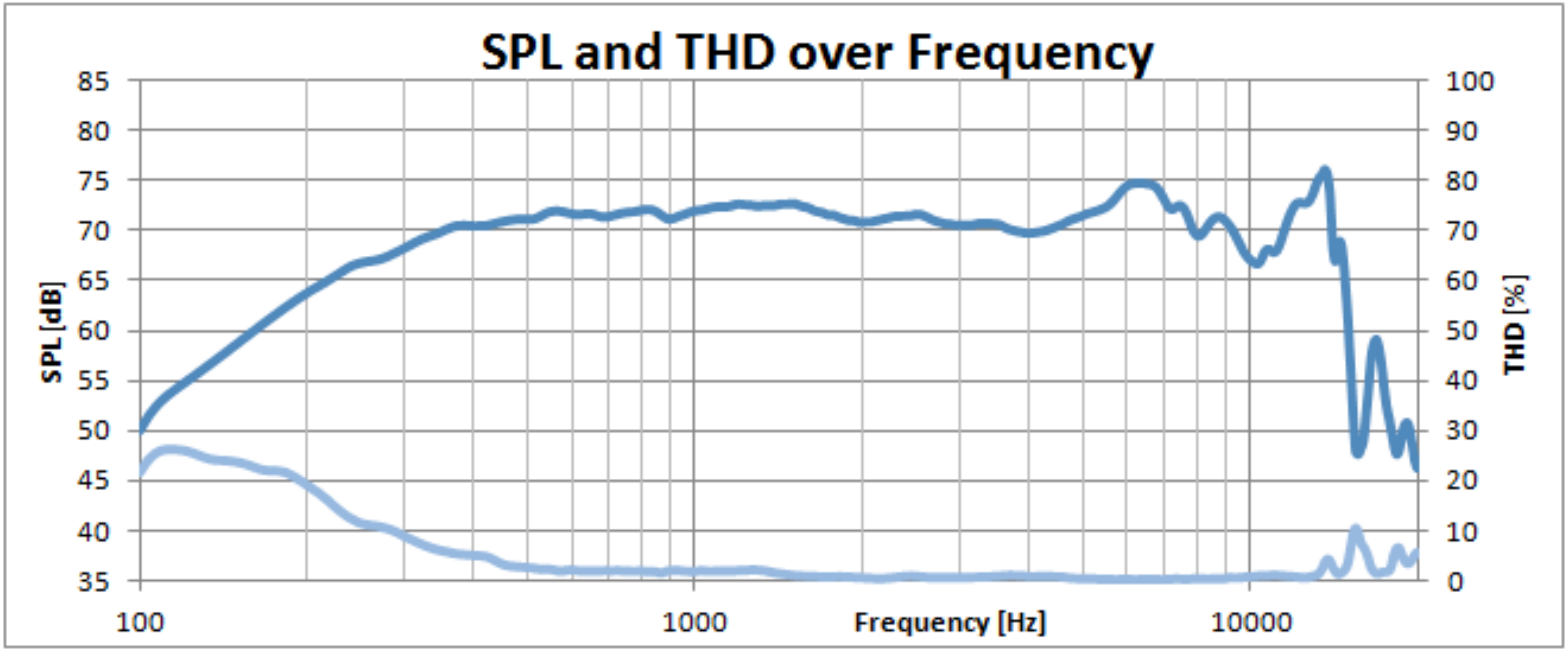
Moon SPL in 711 Coupler



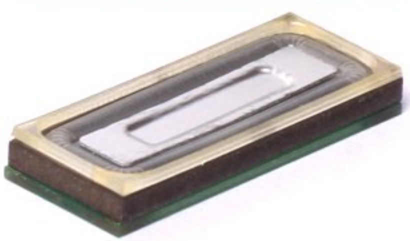
- Comparison with electrodynamic balanced armature eceiver
- Extended bandwidth up to 16kHz in a small form factor
- Superior sound clarity and low distortions over the whole bandwidth

2 Way System for Portable Applications

SPL and THD Free Field



Woofer



Tweeter

3D Audio Market Drivers

Audio Human-Machine interaction in the consumer electronics markets

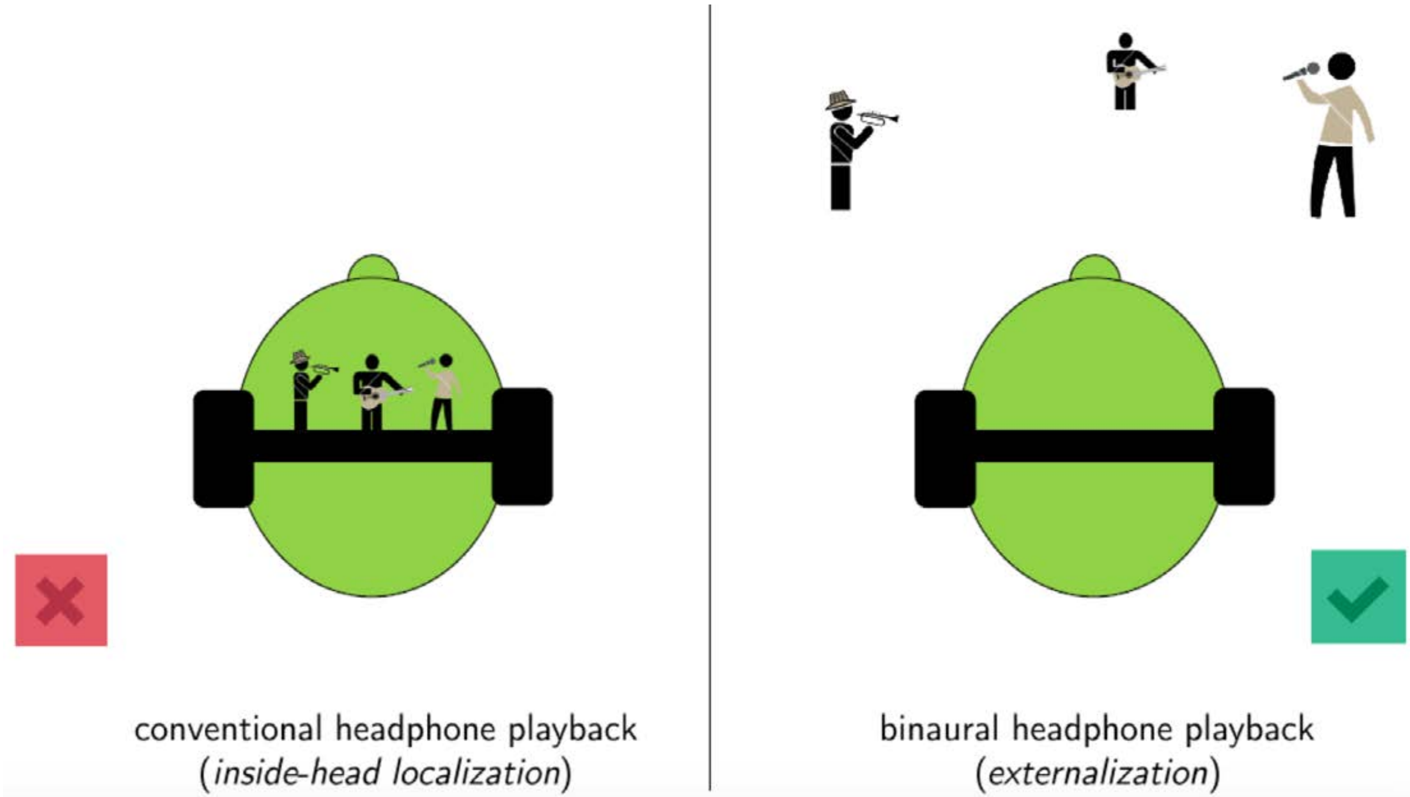
- 3D Sound is one of the biggest unsolved challenges in the audio industry
- Goal is to increase the immersion in virtual content

Augmented Reality | Virtual Reality | Gaming

3 main trends for Human-Machine interaction are laking the needed 3D spatial sound experience to enhance the sensory information.
The actual solutions are bases on HRTF algorithms and databases.

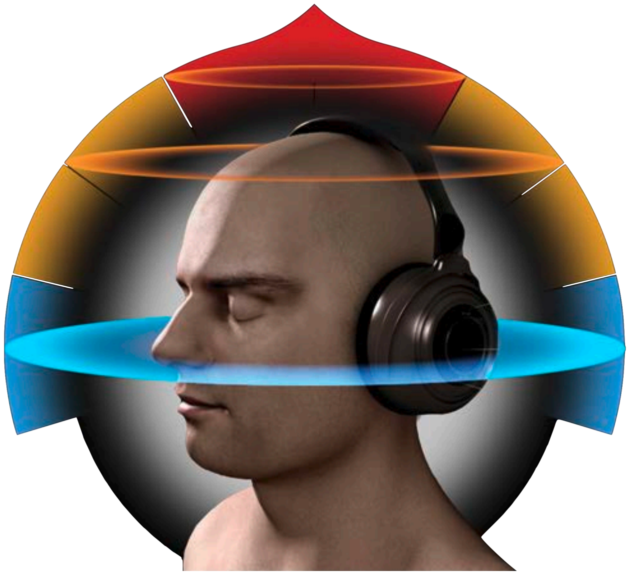
Binaural Reproduction of Spatial Audio

Why are standard headphones not good enough (beside stereo)?



- Standard Headphones may have great performances in therm of sound quality. But the audio experience is not natural, it is artificial: the sound plays IN the head.
- Binaural algorithms aim to modify the acoustic signal in order to externalise the perceived sound.

Head Related Transfer Function Approach
Pro and contra



HRTF is the response that characterises how the human hears receive sound from a point in space

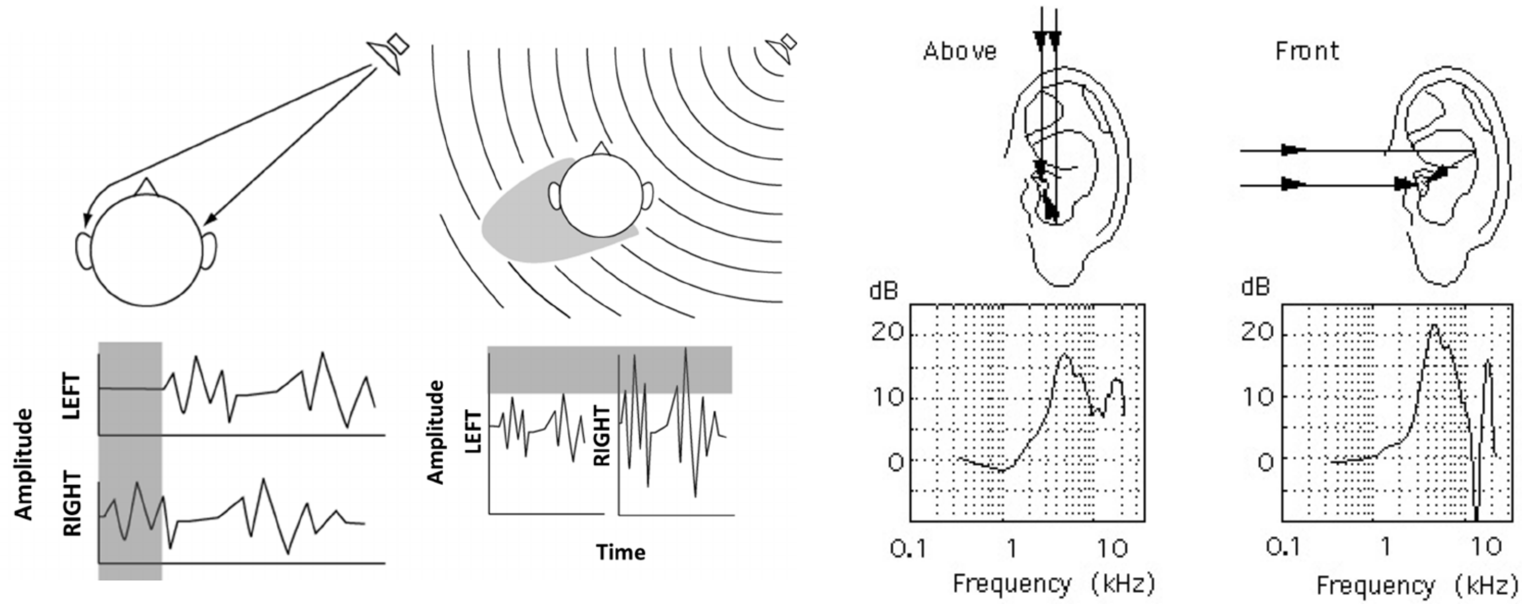
Pro
- Available today
- Based on algorithms and software
- Use of standard headphones

Contra
- Need detailed information on subject anatomy (pinna, head, shoulders)
- Data to be compared to databases with hundreds of avatar profiles
- Complex setup process required by the end user
- one-size-fits-all approach leads to very small listening experience
- Prone to front / back confusion
- This drawbacks lead to a limited adoption by users

Sound Localisation

Role of anatomy in spatial recognition

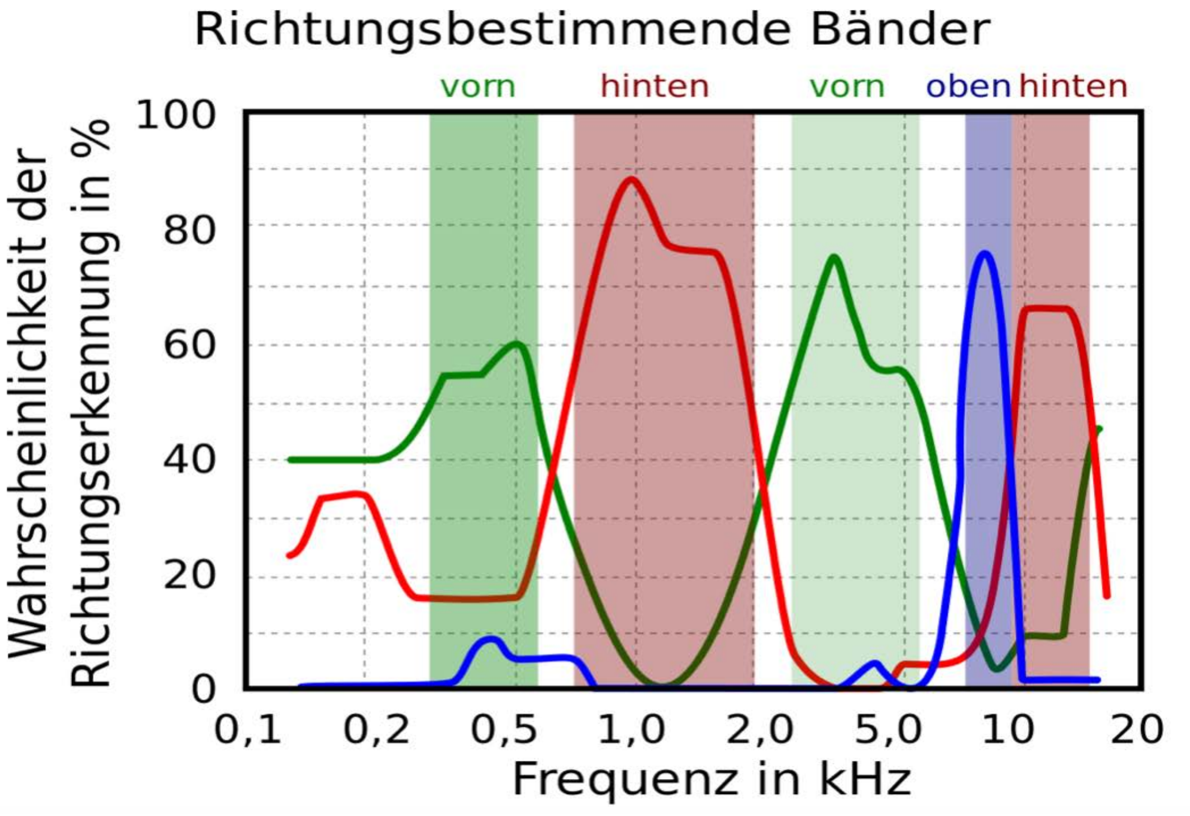
- Sound localisation is influenced by the anatomy of the ear pinna, head and shoulders.
- The human brain learns with the experience how to process and interpret the slight differences in signals generated at each eardrum.



Azimuth Cues: Inter-aural time and level difference
Elevation Cues: Mono-aural cues generated by the pinna
Range Cues: timbre due to distance, head movement

Sound Localisation

Frequencies dependance of spatial recognition

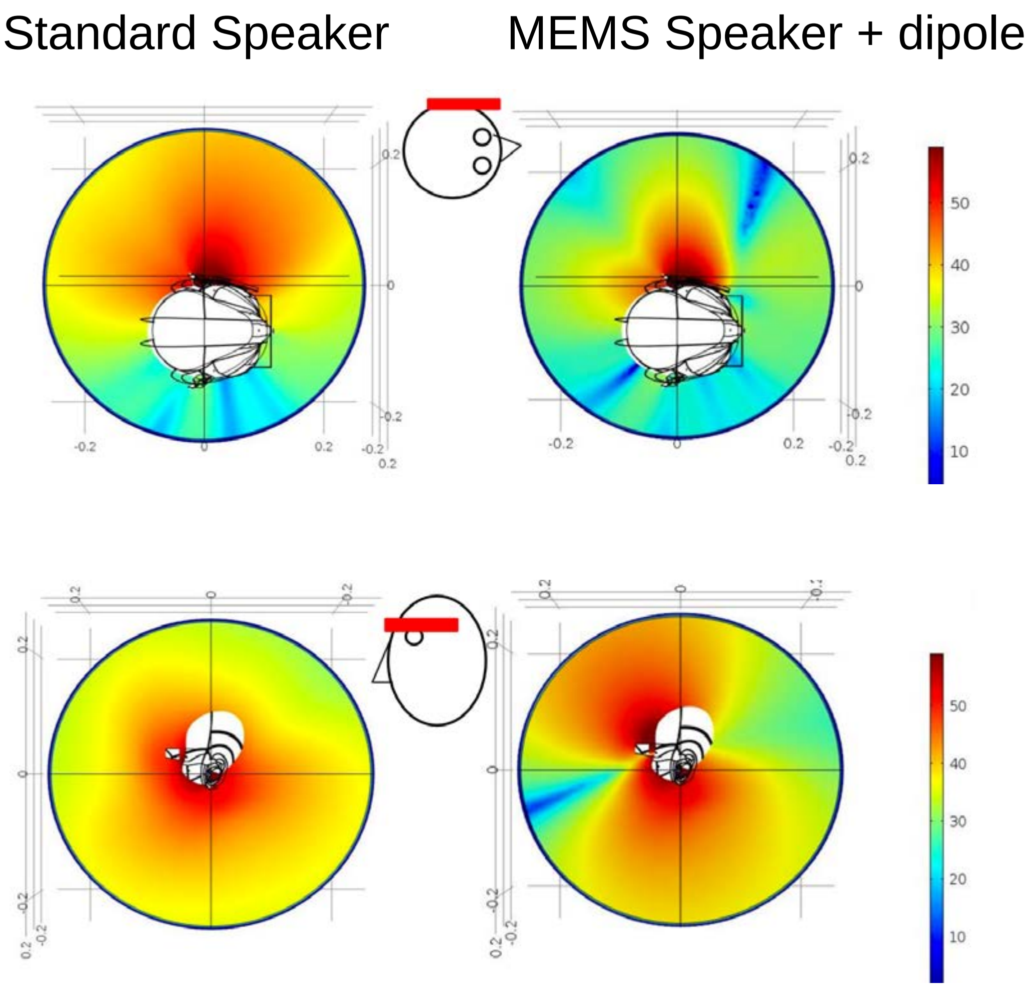


- Directional bands (Blauert et al.):
  Low and mid-high frequencies are most probably recognised from front
  Mid and high frequencies are most probably recognised from behind

MEMS Loudspeaker Directivity Characterisation
in presence of human head

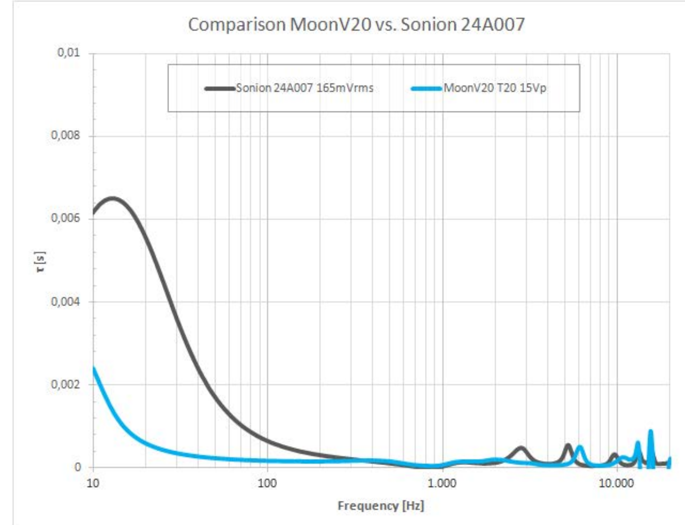
- MEMS Speaker shows good directivity.
  Performance is enhanced in dipole configuration.
  Top view shows sound pressure concentrated in the ear region.

- Side view shows the directivity pattern in dipole configuration.

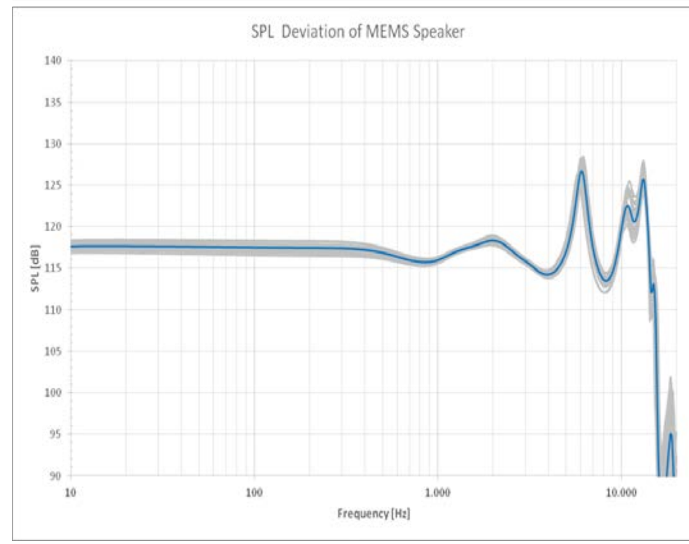


In-Ear Receiver Characterisation

Time response and manufacturing capability



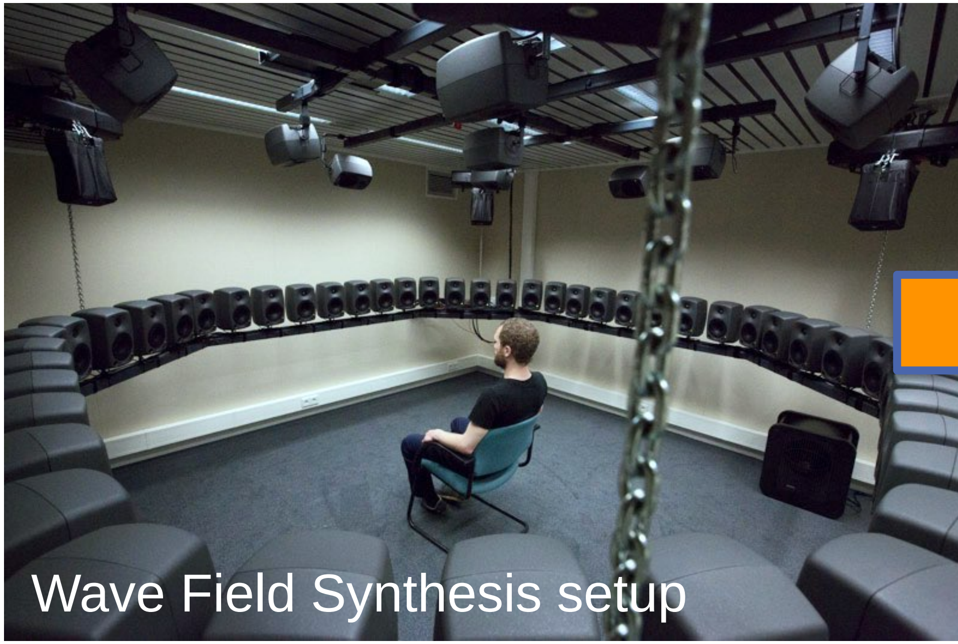
- Comparison with standard electrodynamic receiver
  Piezo Time response is faster than voice coil



- Superior part-to-part repeatability of acoustic performances thanks to silicon manufacturing

Both characteristics are important for building array or multi driver systems

Concept and Targets



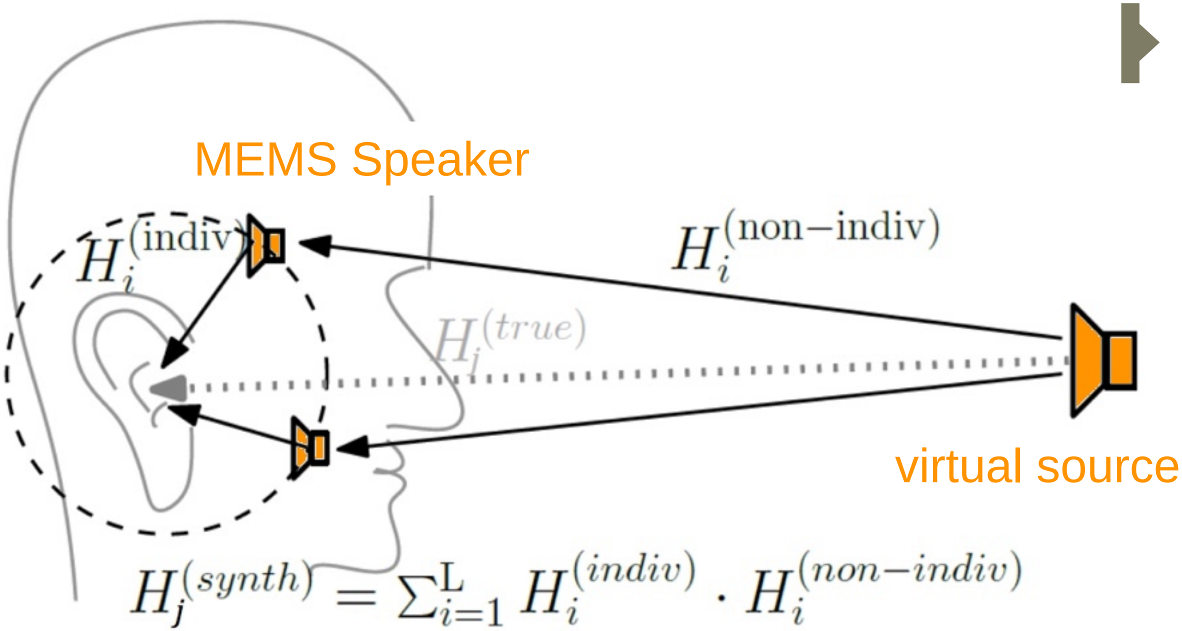
Target: Reproduce spatial sound by developing a multi-driver Headphone.

- multiple MEMS Tweeters around the ear. High frequencies have good directivity.
- one central Woofer. Low frequencies have very poor directivity
- use of software and HRTF algorithms working with the multi driver system
- MEMS microphones both monitoring the inside and the outside of the headphone

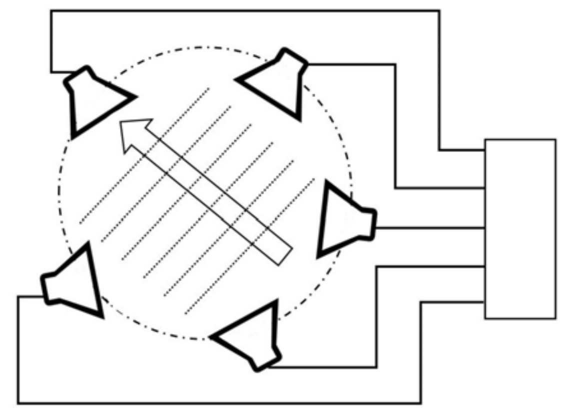
- Ongoing R&D Project
- International Patent Pending

Spatial Audio Rendering via Wave Field Synthesis (WFS)

Multi driver system for rendering virtual acoustic environments



- Schematic of a wave field reproduced in the headphone

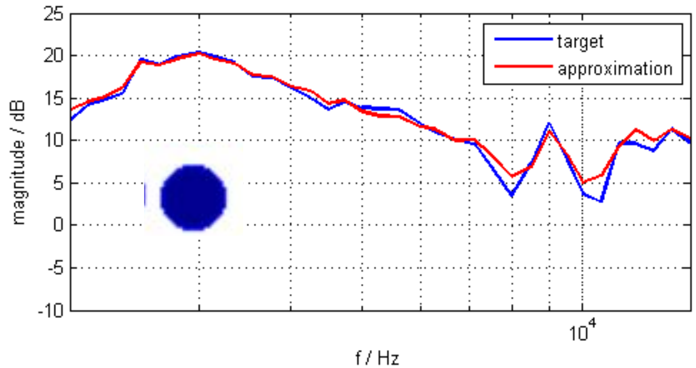


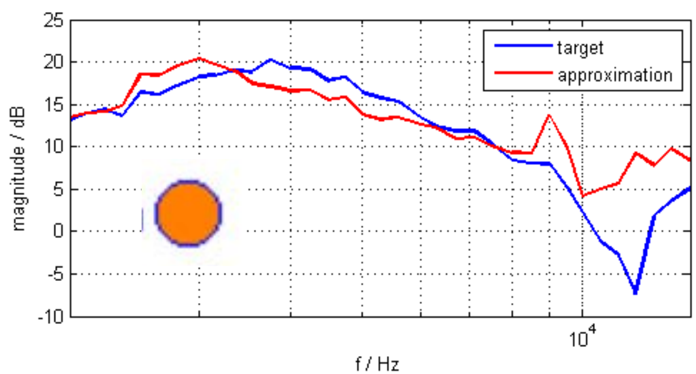
- Find best loudspeaker positions for a given source direction by minimising:

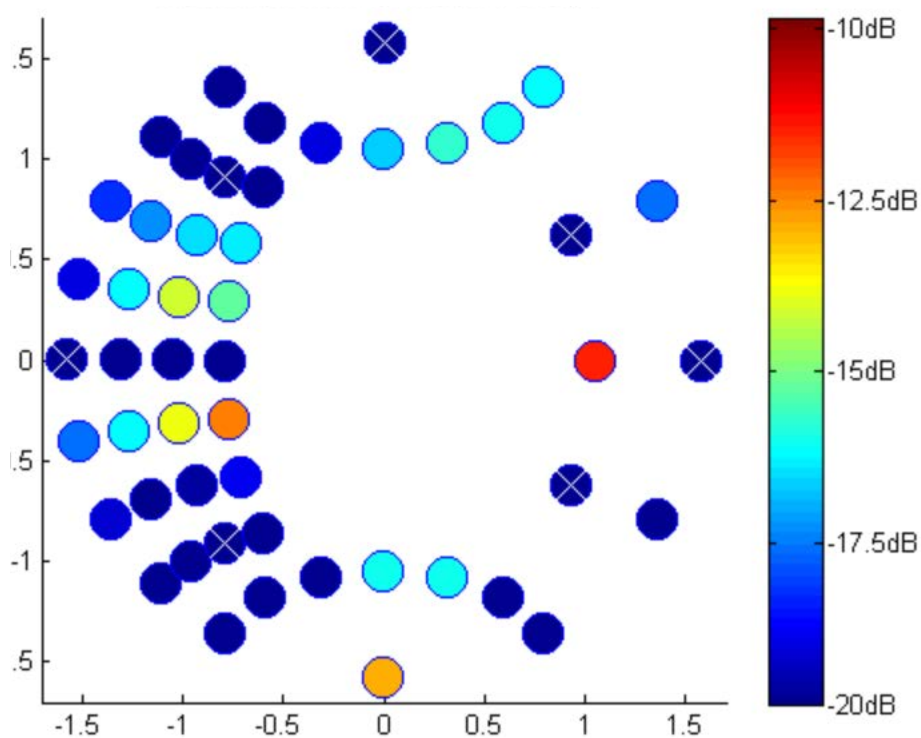
$$\min \left\{ \sum_{j=1}^{J} \left| H_j^{(true)} - \sum_{i=1}^{L} \alpha_i \, H_i^{(indiv)} H_i^{(non-indiv)} \right|^2 \right\} \quad \text{w. r. t. } \alpha_i \in \{0,1\},\ \sum_{i=1}^{L} \alpha_i = \mathrm{M}$$

Spatial Audio Rendering via Wave Field Synthesis (WFS)

Modeling of loudspeaker position by minimising transfer function error



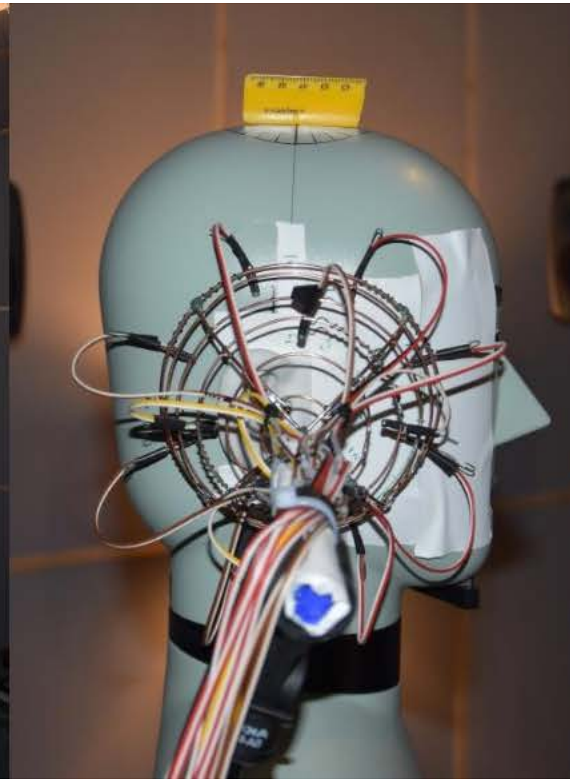


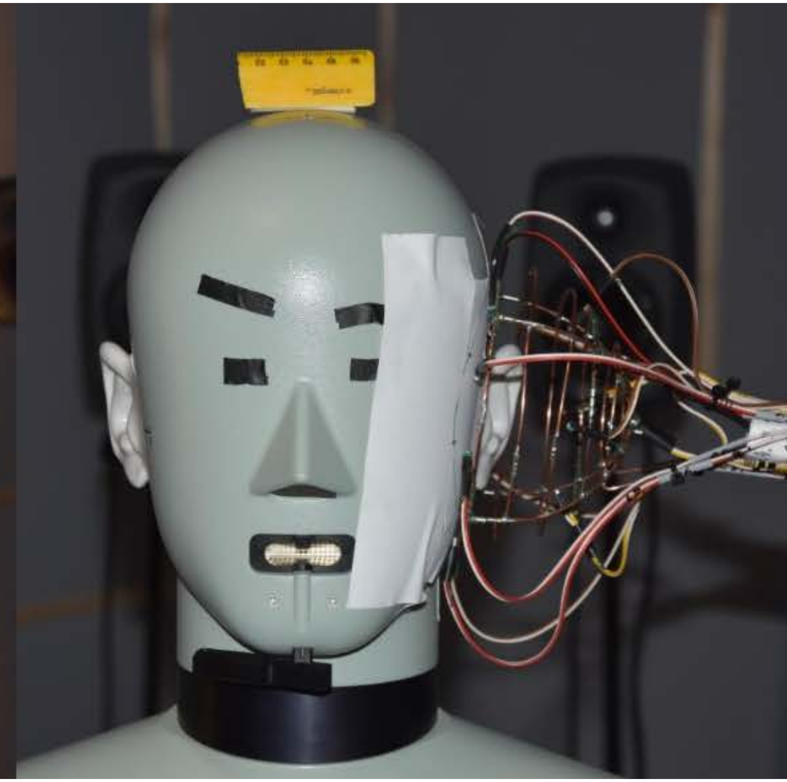


- Target: achieve optimal reconstruction of the transfer function in the direction where the MEMS loudspeaker is placed.

Spatial Audio Rendering via Wave Field Synthesis (WFS)

Experimental setup

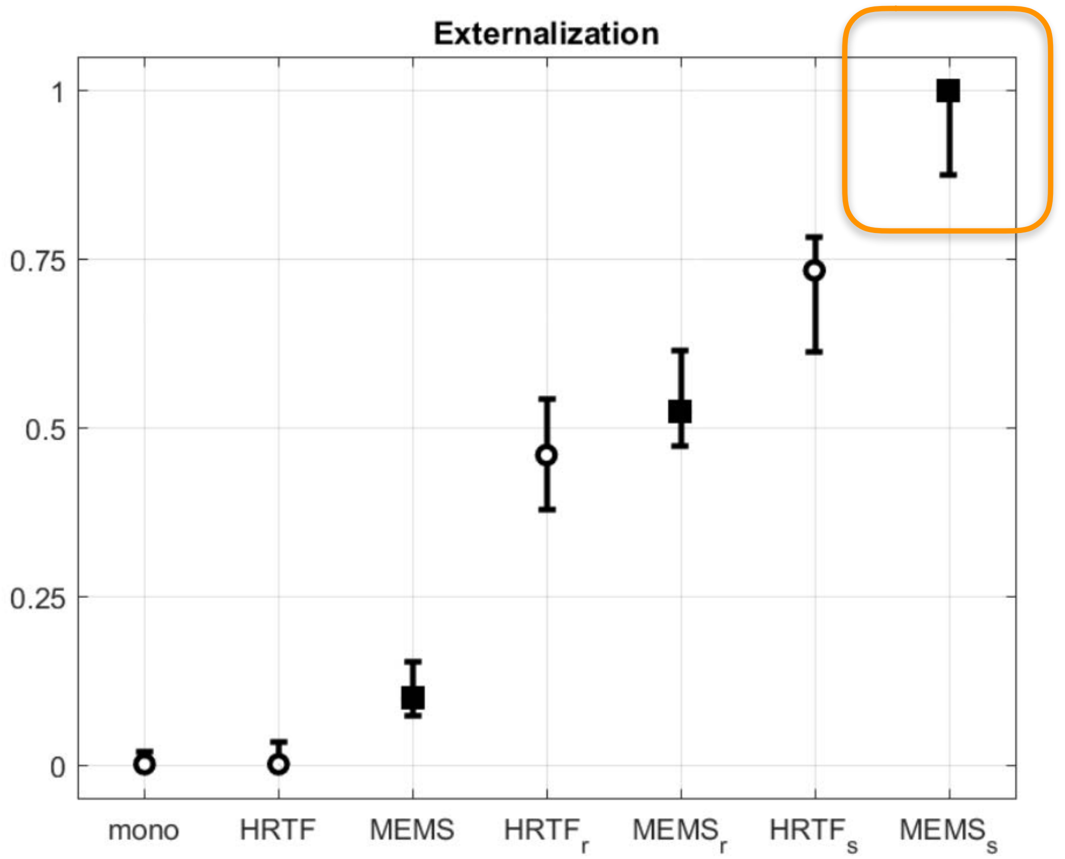




- Multiple sources in anechoic lab
- Placement of MEMS tweeters in specific positions around the ear
- Front view view of the dummy head microphone

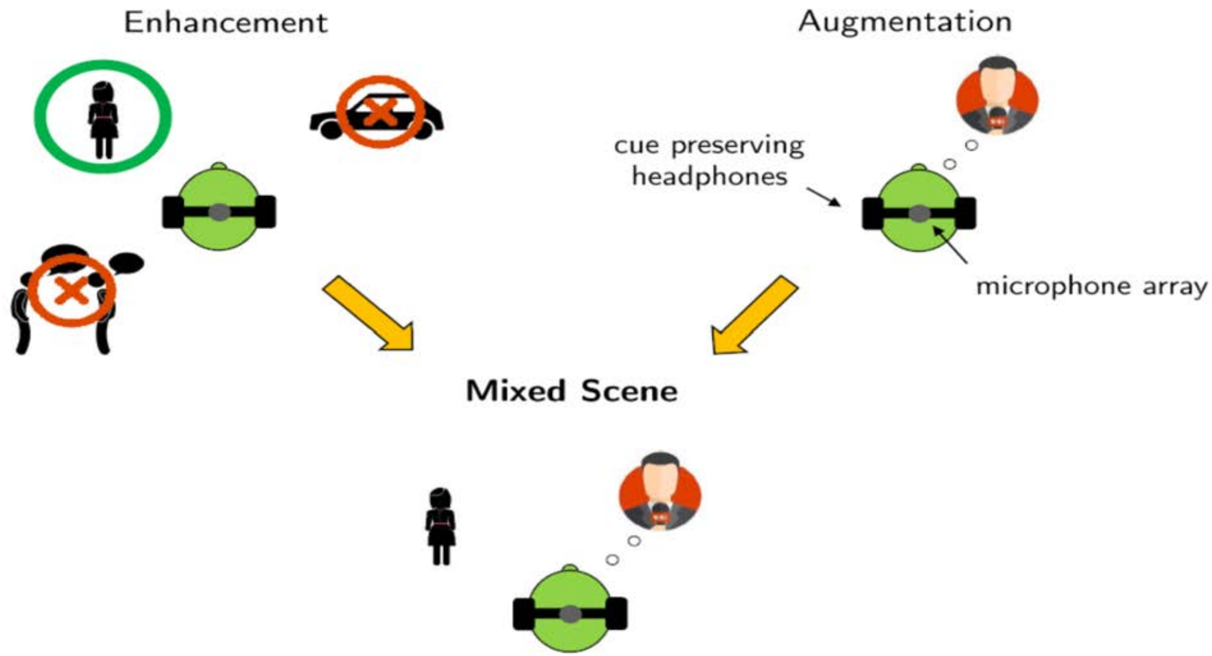
Results of listening panel

Group of experts evaluating qualitative results under controlled conditions



- Compared to HRTF Headphones, the MEMS cue preserving headphone prototype significantly increases the externalisation of sources.

Conclusions



Target: sound enhancement and maximisation of augmentation.

- A multi driver headphone have been demonstrated, where the ear can naturally interact with the 3D-sound field the same way it does in real life.
- MEMS will play an important role in designing multi driver systems.

Thank you