Personal Sound Zones

Christoph Sladeczek, Daniel Beer, Andreas Franck, Albert Zhykhar, Jakob Bergner, Maximilian Wolf
Fraunhofer Institute for Digital Media Technology IDMT, Ilmenau, Germany

Introduction

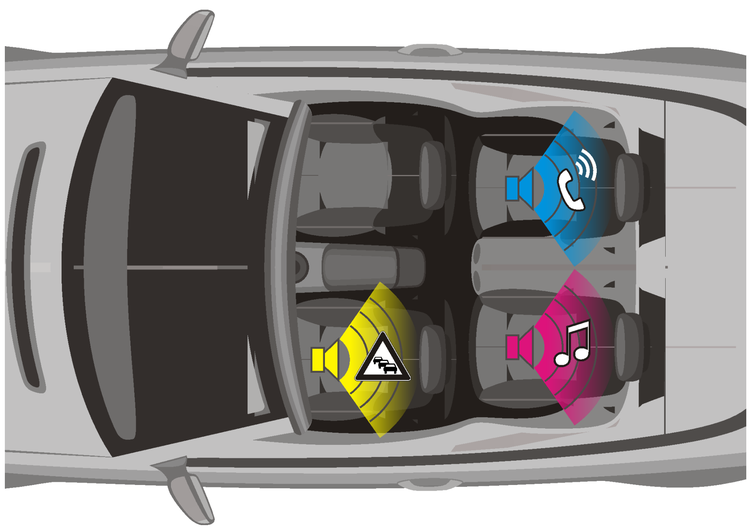
Demand for high quality audio reproduction for in-car environments has been increased

- Includes infotainment, driving assistance and hands-free communication
- Car compartment represents the primary listening environment for a remarkable number of users
- Readiness to pay a high supplementary price for premium sound systems

Challenge

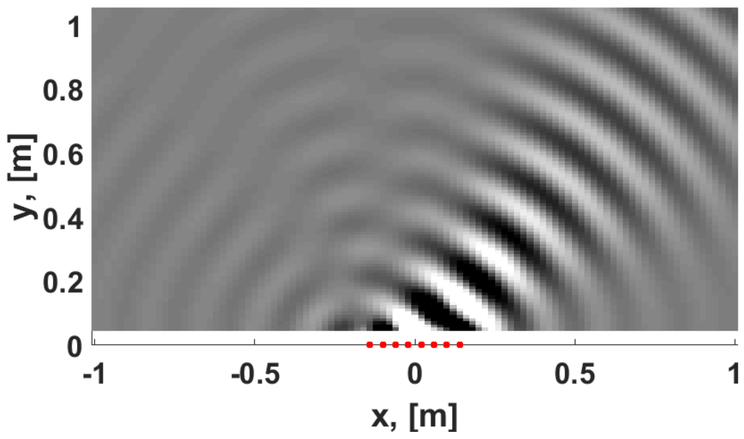
Common systems provide a variety of sound control options

- **State of the art:** Same content for all passengers
- **Goal:** Enable truly personalized entertainment experience per seat
- **Solution:** Personal Sound Zones



Personal Sound Zones Technology

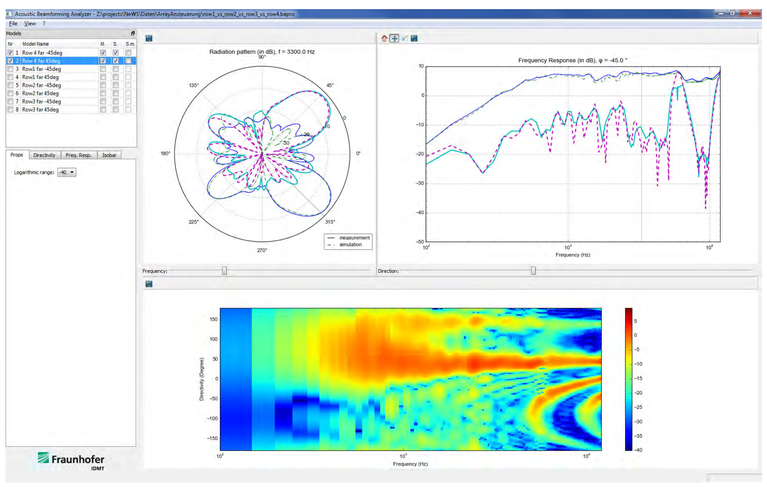
- IDMT technology based on beamforming with loudspeaker arrays [1]
  - Each source driven by dedicated signal
  - Superposition of multiple sound sources
  - **Result:** Super-directional sound radiation



- Complex mathematical/physical algorithms for filter design
- Consideration of several parameters, including:
  - Directivity of transducers
  - Frequency dependent beam-shaping (direction, width)
  - Definition of quiet zones
  - Desired frequency response
  - Geometry of loudspeaker array
- **Result:** static FIR filter set
- Technology is highly adaptable to use case

IDMT Beamforming Analyzer

- Complex and time-consuming filter design process
- Performance analysis prior to real prototype implementation
- Analysis by synthesis: numeric simulation
- Prediction of array behavior on anechoic conditions
- Comparison to measured sound fields



Application

- Two individual zones
  - Driver: important infotainment sounds; no distraction by in-car entertainment
  - Front passenger: entertainment without noteworthy quality loss
- Use of linear loudspeaker array
  - 12 miniature-transducers
  - Installation in headliner of IDMT company car
  - Alignment centered between front seats
  - Realization of sound zones via two audio beams

Measurement

- Practical evaluation of different array prototypes
- Polar response measurement
- Free field conditions (anechoic chamber)

- Measurement of two microphone positions
  1. desired beam area
  2. desired quiet zone

Performance

- Frequency responses of beam and quiet zone:
  - Sound separation of 10-20 dB over large frequency range (f=150. . . 5000 Hz)
  - Aliasing due to speaker spacing impairs clear separation above 6 kHz

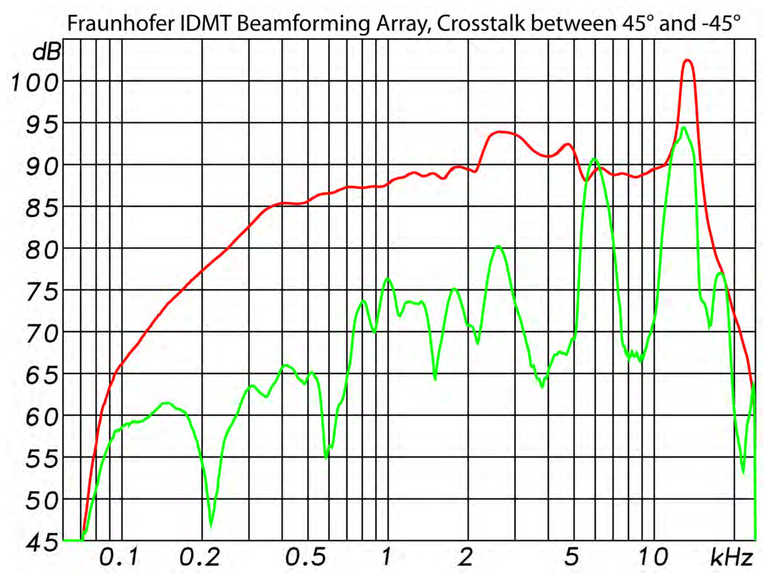


Figure 1: Frequency response of beamforming array in direction of desired beam area (red) and quiet zone (green)

Discussion

- IDMT technology is a promising approach for personal sound zones
- Main influences on performance:
  - Array geometry
  - Room acoustics
- Future development:
  - Ongoing room acoustical treatments
  - Benefits of psychoacoustic effects

Acknowledgment

This work has been supported by the NeWS project, funded by the Fraunhofer Zukunftsstiftung.

References

[1] Keele, Jr., D. B. (Don); The Application of Broadband Constant Beamwidth Transducer (CBT) Theory to Loudspeaker Arrays; In: *109th Convention of the Audio Engineering Society, 2000*

Fraunhofer IDMT