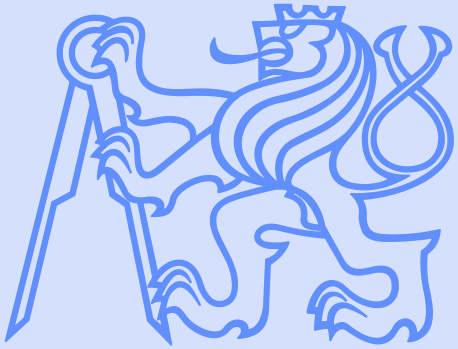
MTG

Multimedia Technology Group

Psychoacoustical measurements, auditory models and their application



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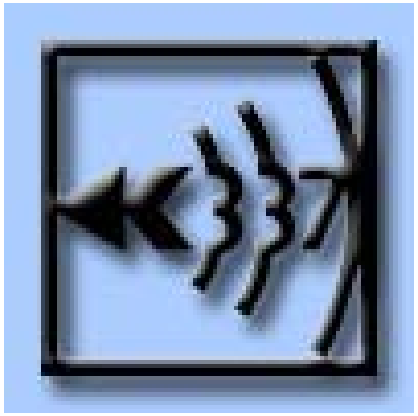
Outline

- **Introduction of MMTG FEE CTU**
  - MMTG
  - Audio group
- **Psychoacoustical measurements, auditory models and their application**
  - Human hearing system and models
  - Measurement
  - Applications

Department of Radioelectronics

- **Czech Technical University in Prague**
  - Faculty of Electrical Engineering
    - Department of Radioelectronics



Multimedia Technology Group

Radio Systems Research and Development Center

Digital RAdio Communications Research Group

Broadcast Technology and Measurement Group

CAD for RF circuits

RF Embedded Systems

Multimedia technology group

- http://mmtg.fel.cvut.cz
- Imaging systems and image processing in astronomy
- **Image/video and sound quality assessment, QoS, QoE**
- **Vision and hearing modeling, study of psychovisual and psychoacoustic processes**
- Image processing in biology
- **Image/video and audio compression and coding**
- **Multimedia information processing (audio, image/video)**
- **3D audiovisual systems**
- BCI and man-machine interface applications in multimedia technology
- Imaging systems and image processing in security
- **Multimedia applications in assistive technologies**
- **Measurement and analysis of electro-acoustic and audio systems**

Audio group

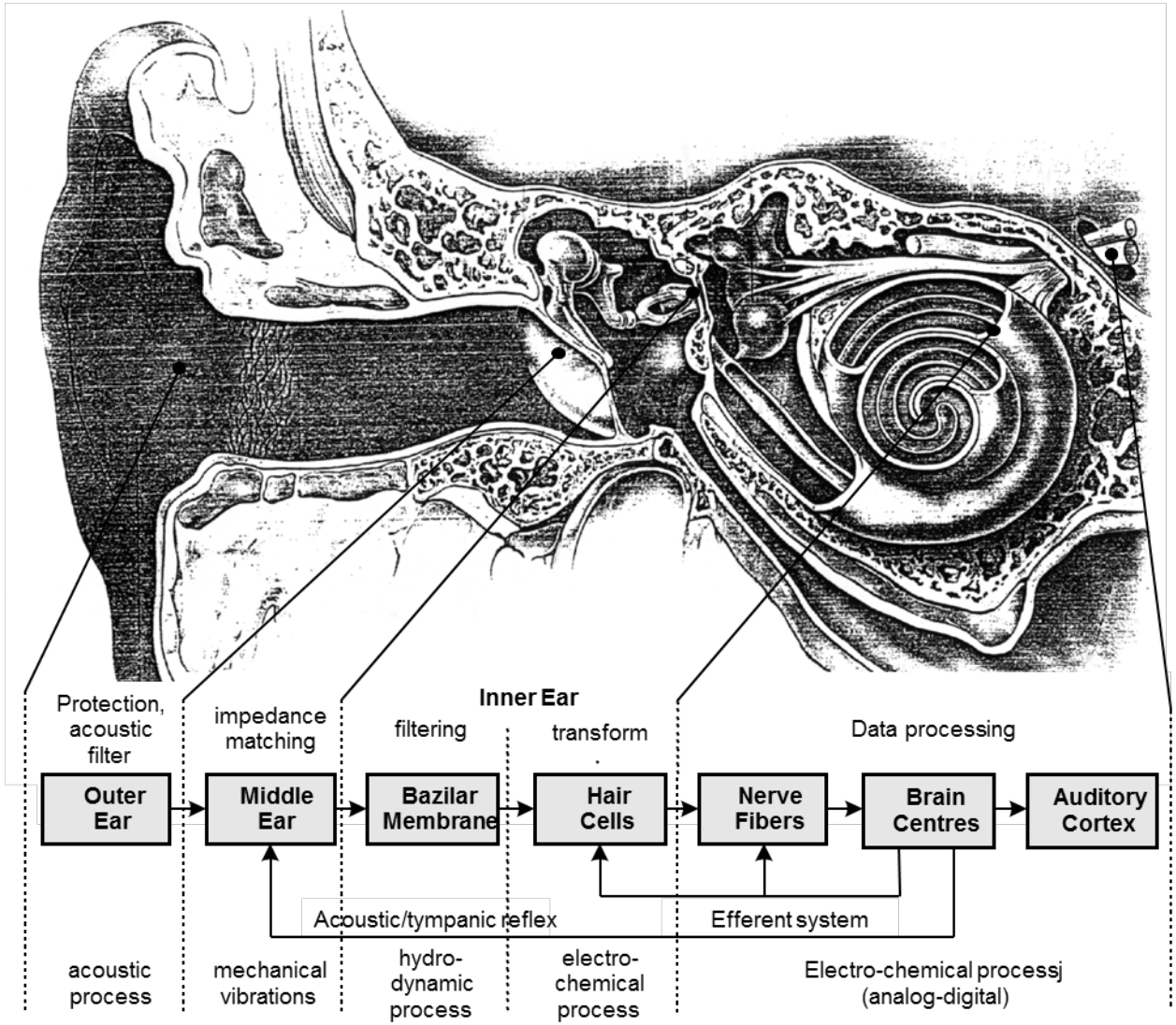
- **Libor Husník**
  - Digital transducers
  - Spatial sound synthesis
  - (subjective) quality of archive records
- **František Rund**
  - Auditory models and measurement
  - (objective) quality of archive records
- **Thomas Lavergne + Zdeněk Škvor**
  - Omnidirectional ultrasound PVDF transducer
  - Optoacoustic transducer

Auditory models project team

- **MMTG staff**
  - **František Rund**
  - Stanislav Vítek
  - Petr Maršálek
- **Ph.D. students**
  - Dominik Štorek
  - Václav Vencovský
  - **Jaroslav Bouše**
- **M.Eng. students**
  - *Tomáš Lindner*
  - Jan Stuchlík
  - Jan Štemberg
  - Ondřej Šupka
  - Sanyia Dyussekenova

Human hearing system

External, middle and inner ear



Auditory models

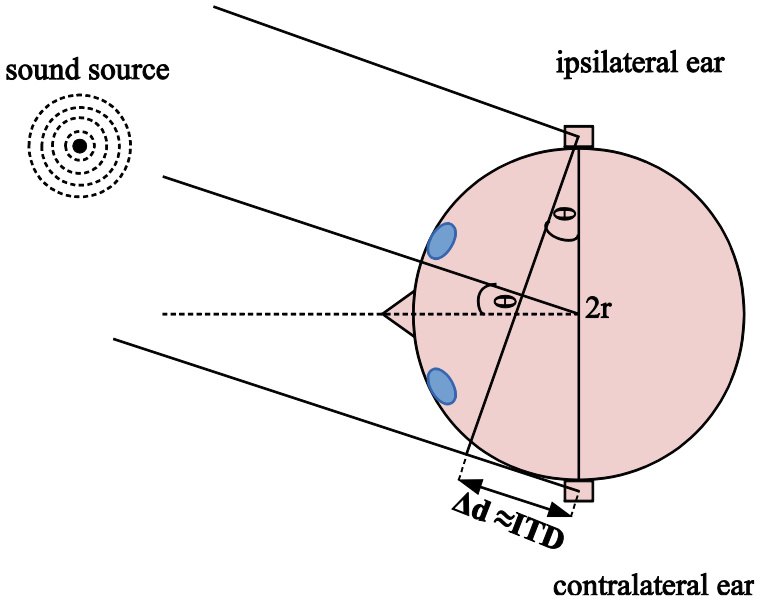
- **External and middle ear**
  - Cascade of simple filters
- **Inner ear – filterbank**
  - Transmission line model
  - Gamatone filters
  - Gamachirp filters
  - Biophysical models
  - …

Binaural hearing

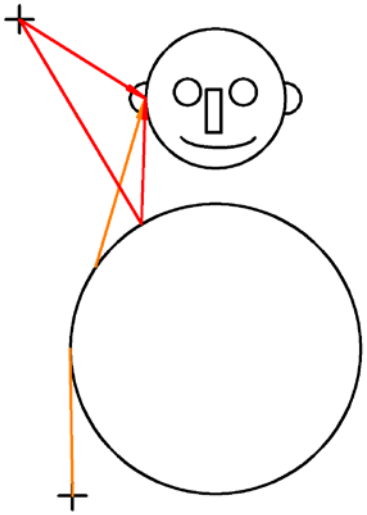
- **Binaural summation**
- **Binaural masking**
  - Coctail party effect
- **Extraction of a signal in reverberant environment**
- **Localization of sound source**

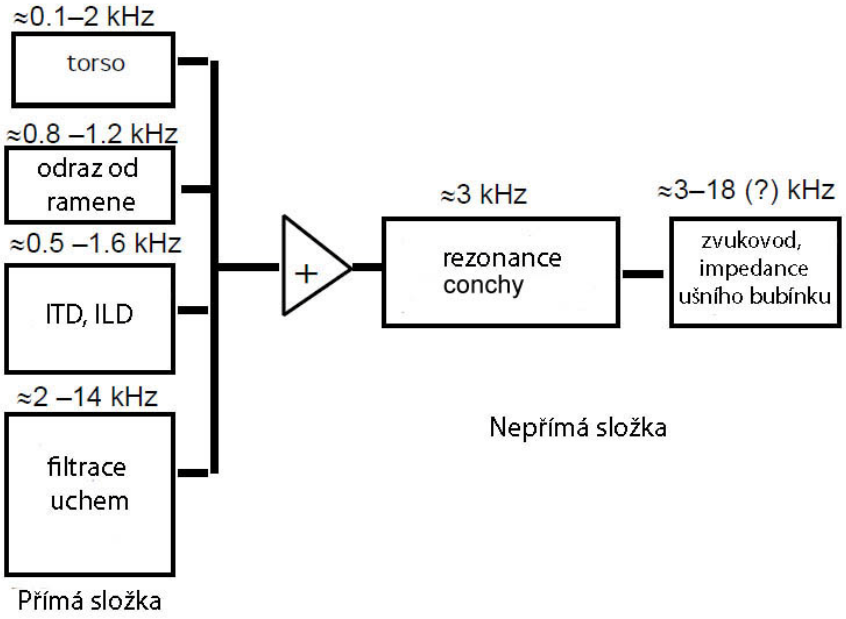
Basic localization cues

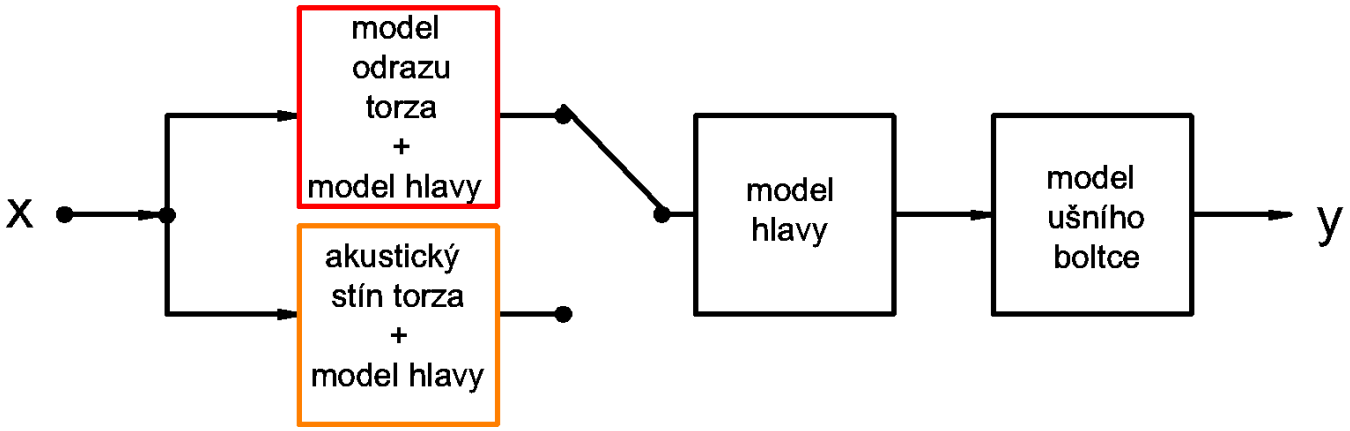
- **Interaural differences**
  - Time (phase) – ITD/IPD
  - Level – ILD
- **Lateralization**
- **Filtration cues (HRTF)**
- **Head movement**
- **Experience (memory)**
- **Visual information**



HRTF modeling







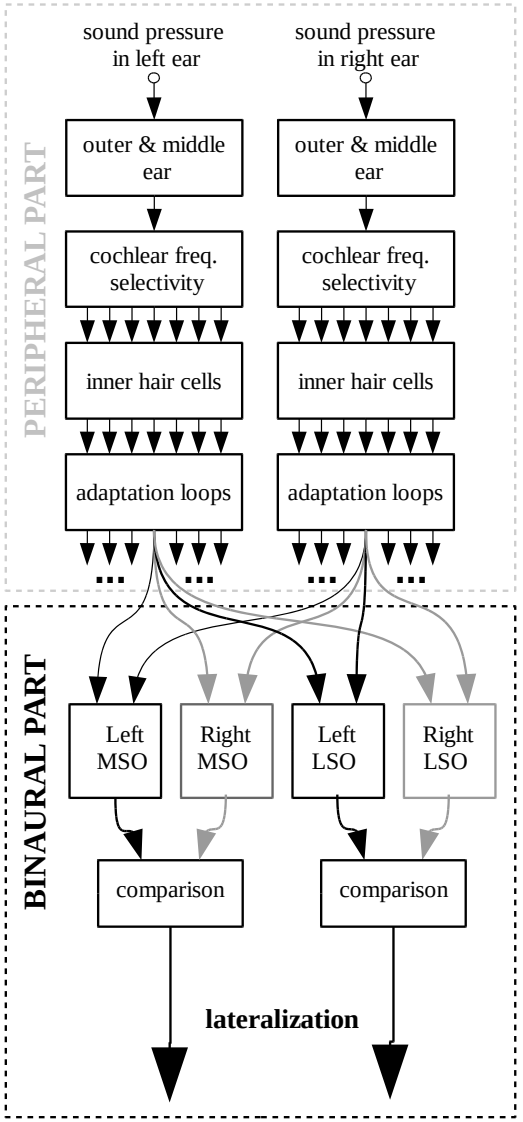
Olivary complex

- **Decoding of spatial information**
- **Lateral superior olive (LSO)**
  - ILD
- **Medial superior olive (MSO)**
  - ITD/IPD

- **Models**
  - Jeffress‘s delay line
  - Equalization-cancelation
  - Count-comparison
  - …

Designed binaural model

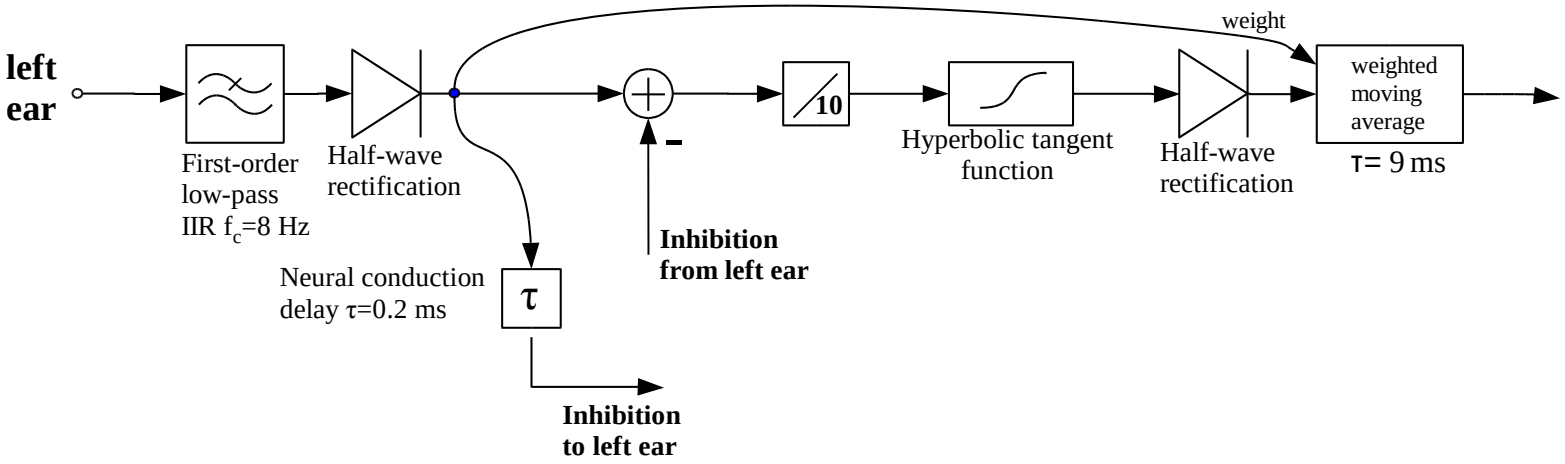
- **Monaural part**
  - Divided into 36 bands(CF 0.1 – 15 kHz)
  - Output: probability of spike firing
- **Designed binaural part**
  - Count-comparison principle
  - Output: Perceived lateralization



Dau et. al..: A quantitative model of the effective signal processing in the auditory system.., ASA 1996

van Bergeijk, W. A.: Variation on a Theme of Bekesy: A Model of Binaural Inter-action. ASA, 1962

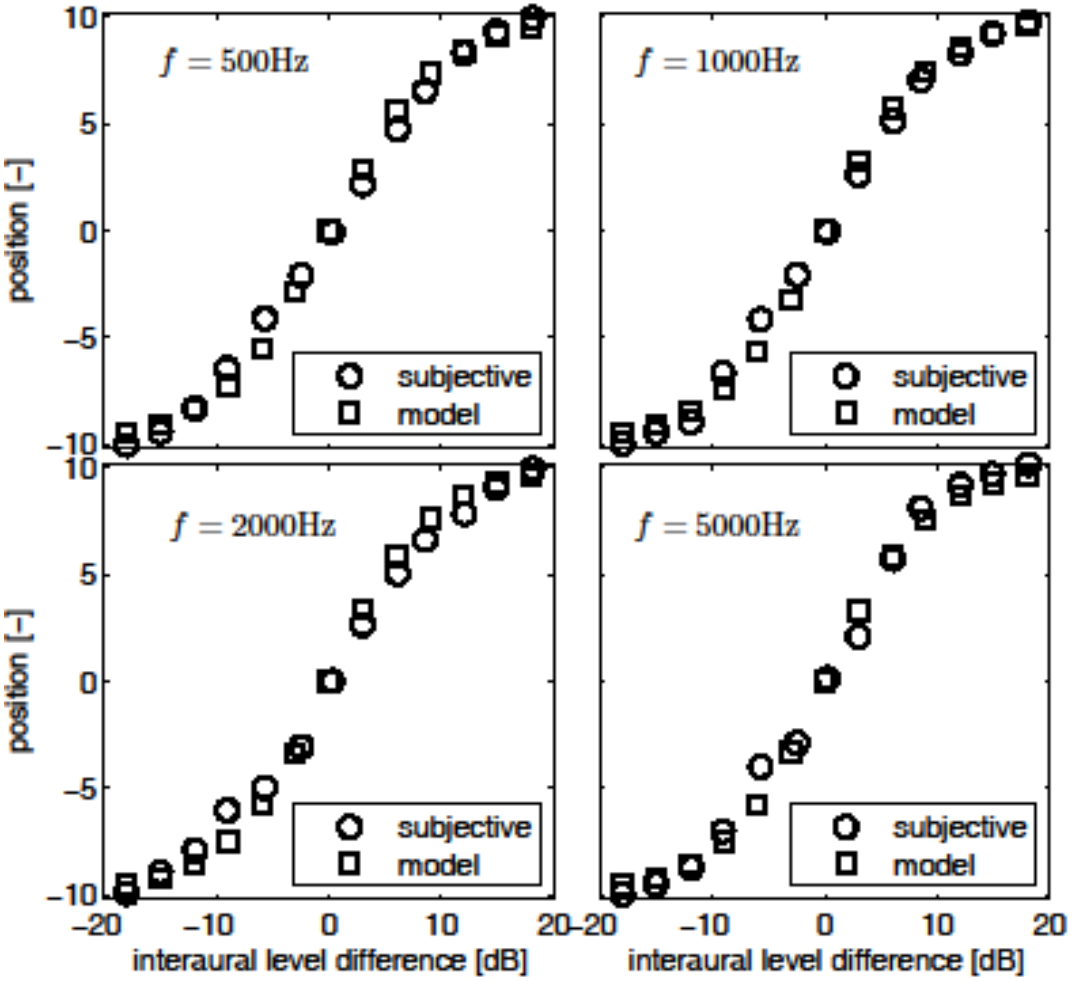
Lateral superior olive (LSO)



- **1 model for each hemisphere**
- **Output -> Count-comparison - subtraction**

Pulkki, V.; Hirvonen, T.: Functional Count-Comparison Model for Binaural Decoding., ACTA acoustica, 2009

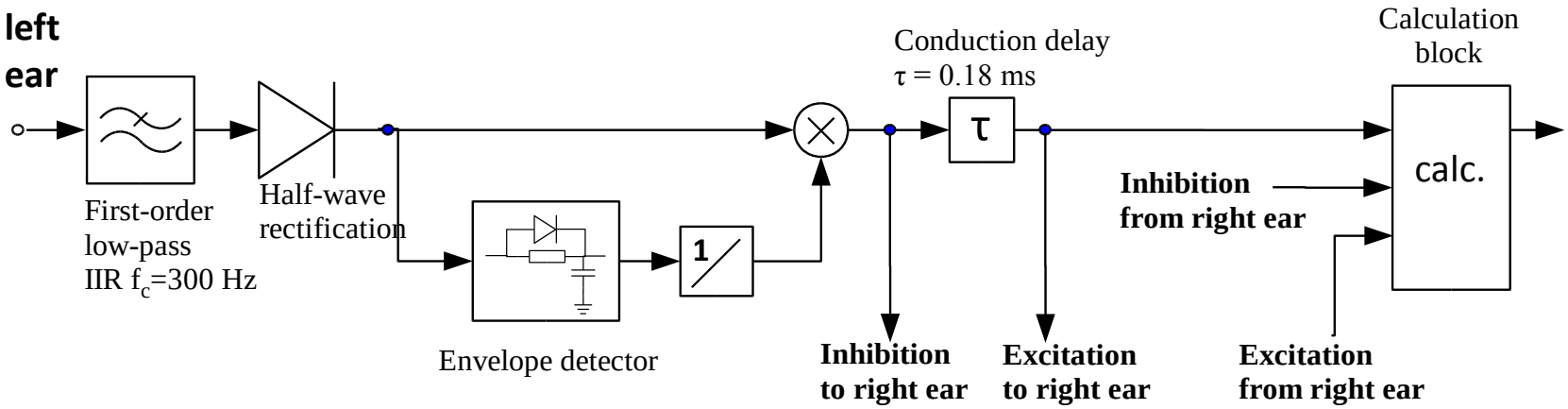
Lateral superior olive (LSO)



Pure tone frequency [Hz]	Correlation score [-]	p-value [-]
500	0.9957	9.7473e-13
1000	0.9960	6.8233e-13
2000	0.9969	1.7756e-13
5000	0.9960	7.1924e-13

Yost, W. A.: Lateral position of sinusoids presented with interaural intensive and temporal differences., JASA 1981

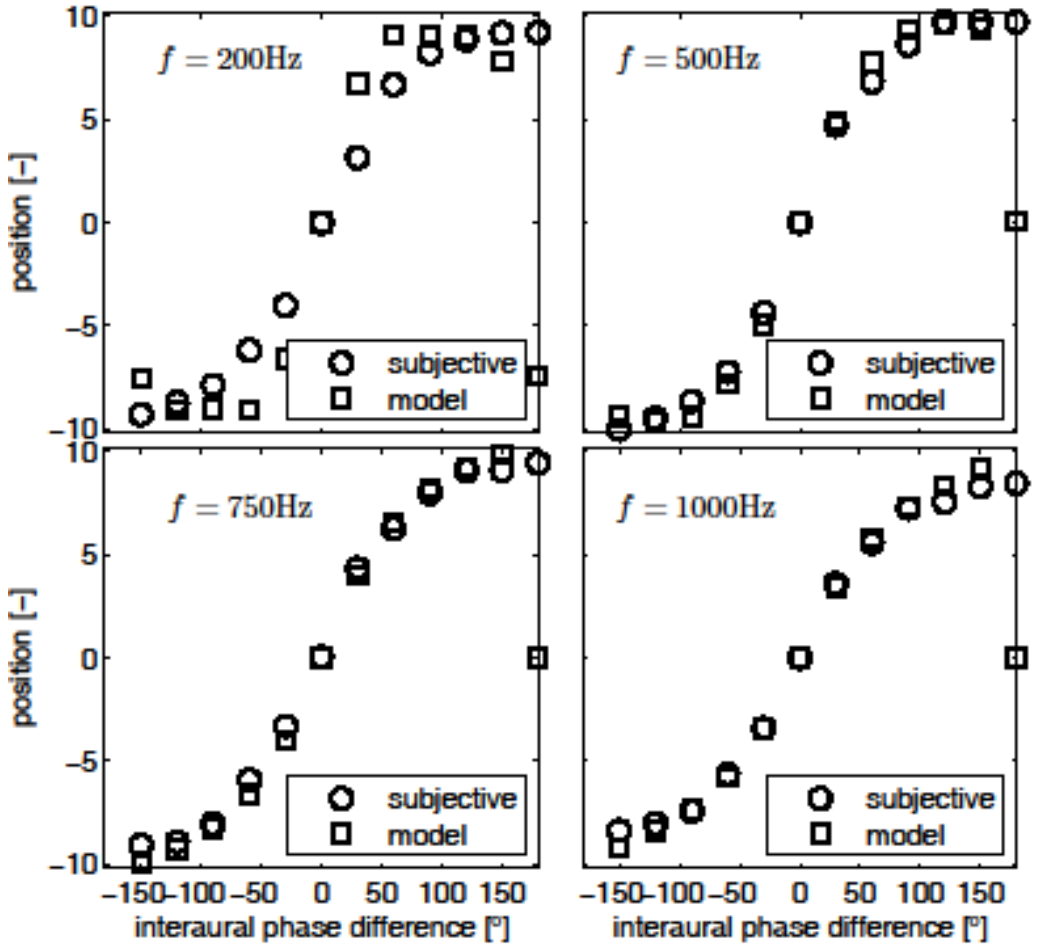
Medial superior olive MSO



- **1 model for each hemisphere**
- **Output -> Count-comparison - comparing ratio**

Grothe, B.: New roles for synaptic inhibition in sound localization. Nature Reviews Neuroscience, 2003

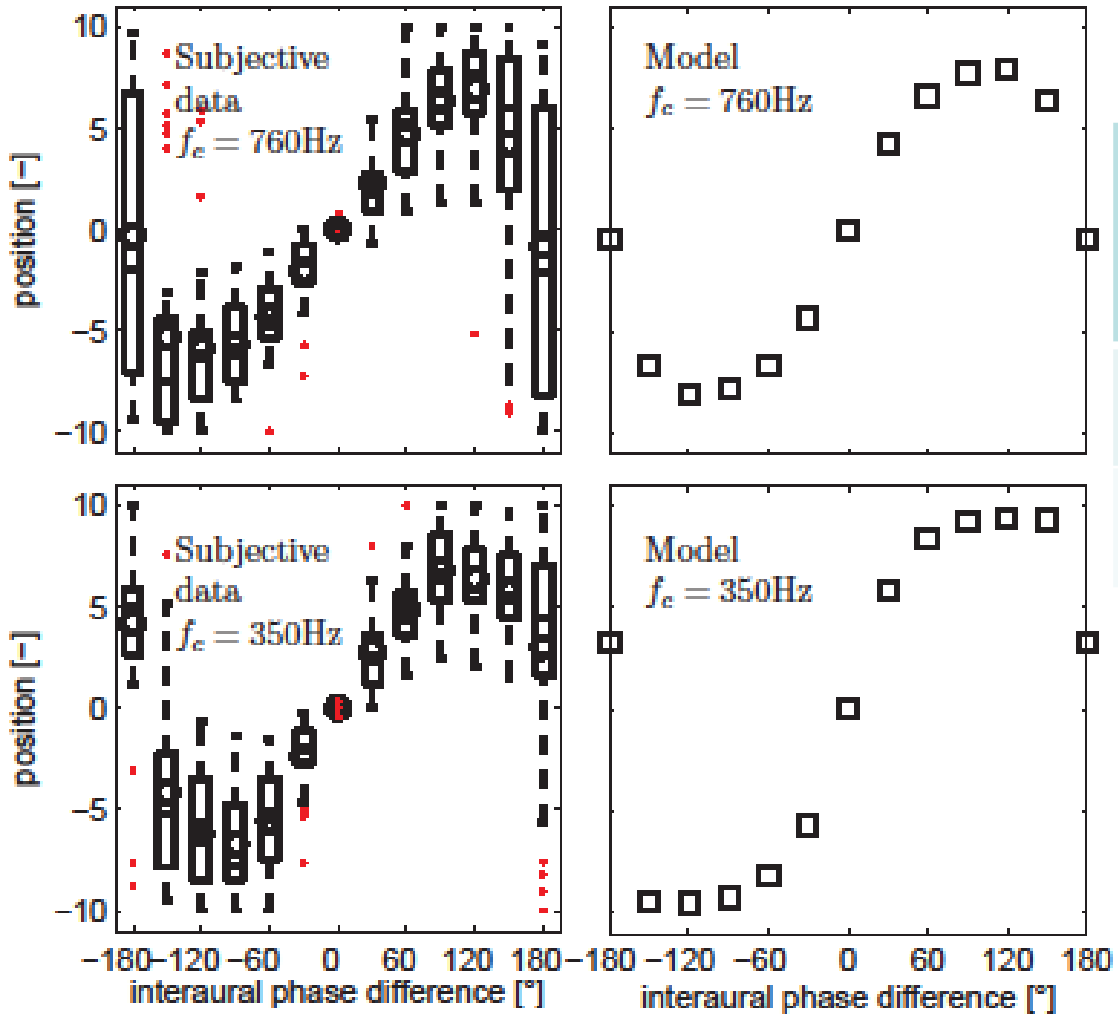
Medial superior olive MSO



Pure tone frequency [Hz]	Correlation score [-]	p-value [-]
200	0.7894	0.0023
500	0.9396	5.7183e-6
750	0.9349	8.2347e-6
1000	0.9330	9.5074e-6

Yost, W. A.: Lateral position of sinusoids presented with interaural intensive and temporal differences., JASA 1981

Medial superior olive MSO

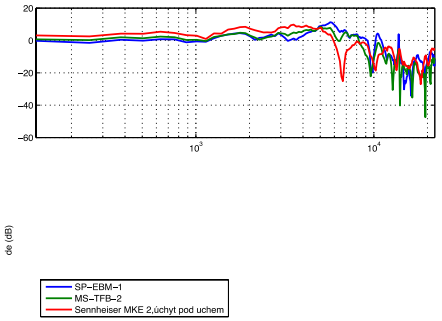


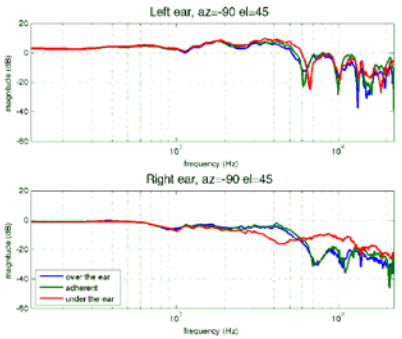
Central frequency [Hz]	Correlation score [-]	p-value [-]
350	0.9809	3.6501e-09
760	0.9626	1.4026e-07

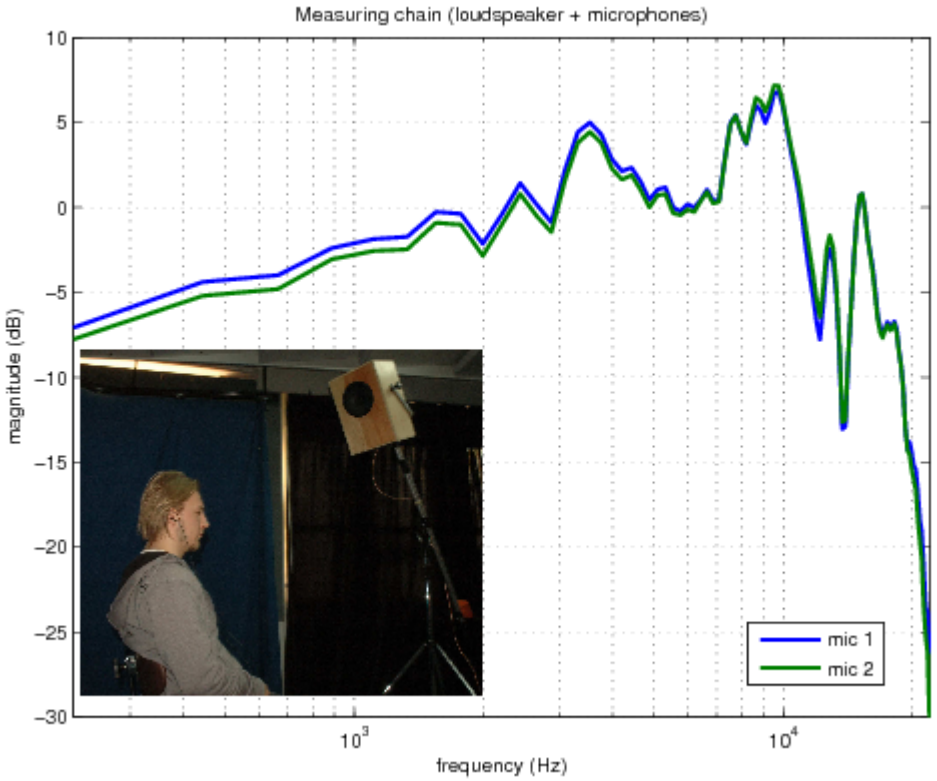
PSYCHOACOUSTIC EXPERIMENTS

HRTF measurement

- **Measurement chain**
  - A method for IR/TF measurement
  - Loudspeaker
  - Microphones
  - Azimuth & elevation

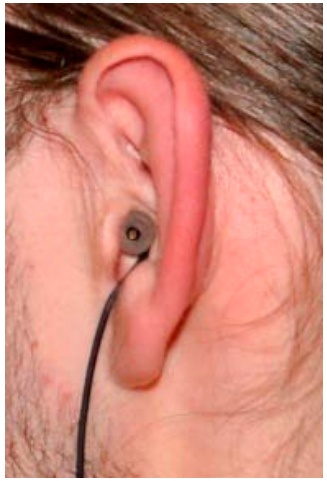


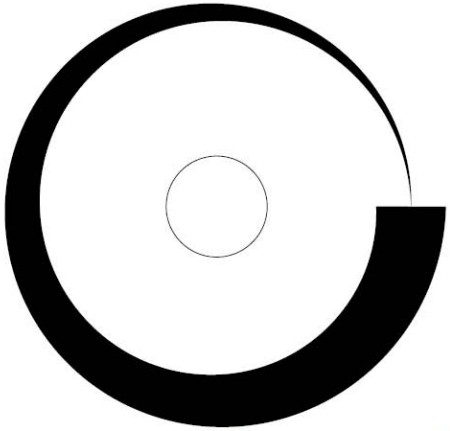


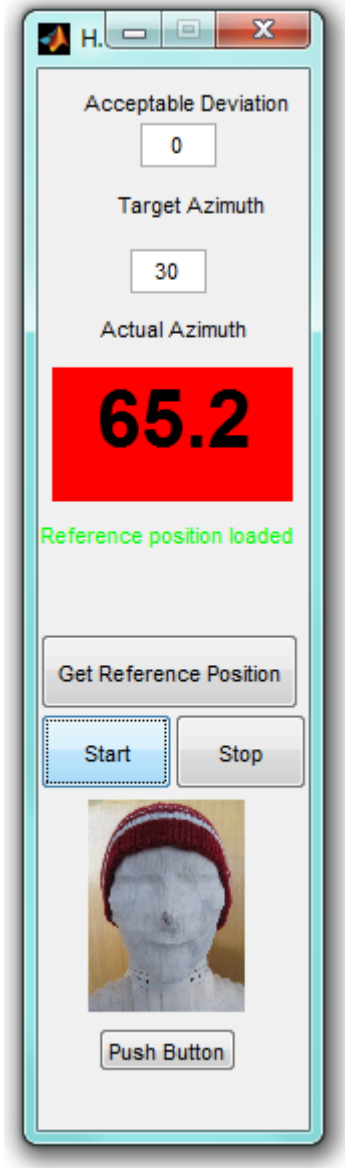


- HRTF – transfer from the source to the ear
- Time & instrument demanding
- Directions:
- Equalization

HRTF measurement

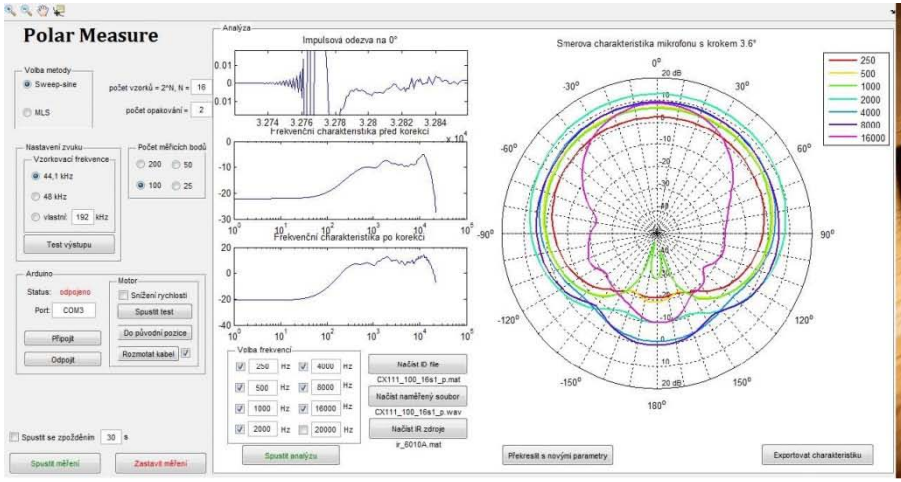


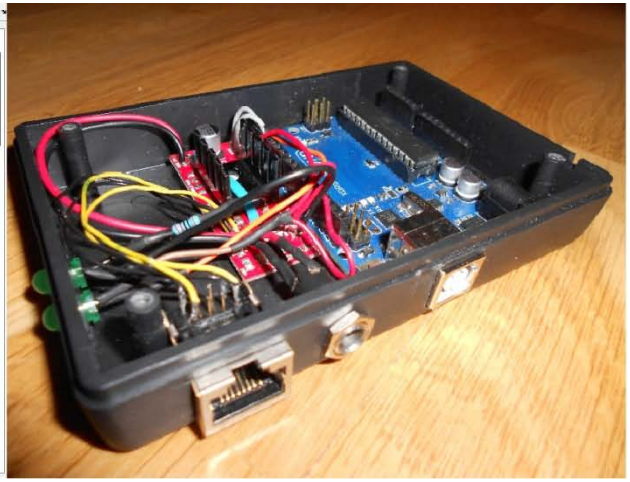




HRTF measurement optimization

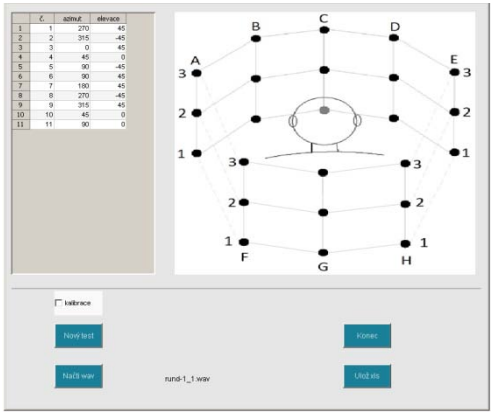
- **Automatized system for measurement**
- **Computer controled rotation of the chair**
  - Matlab, Arduino, step motor driver
- **IR/TF measurement method implemented in Matlab**
  - Sweep sine method
  - MLS based method
- **Testing implementation – microphone polar pattern measurement**

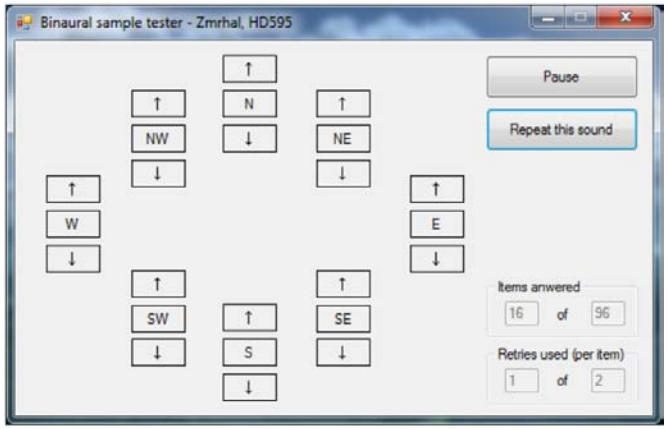




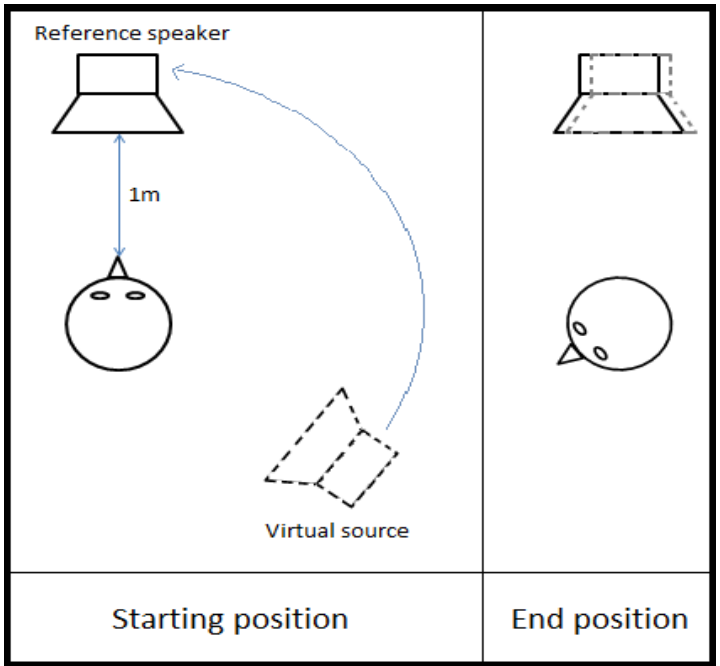
HRTF test

- **How to test orientation in 3D?**
  - Standard method



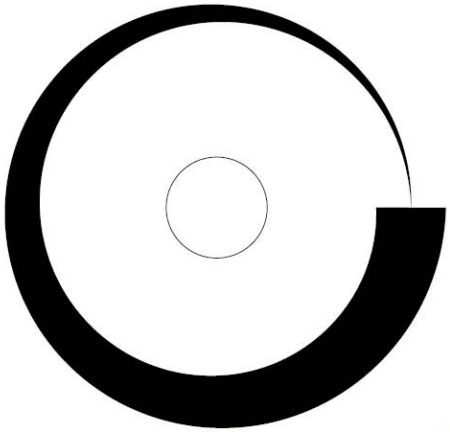


  - New method
    - This method provides good results and subjects are more comfortable with understanding and completing the task
    - The task is to turn the head until the two sources overlap



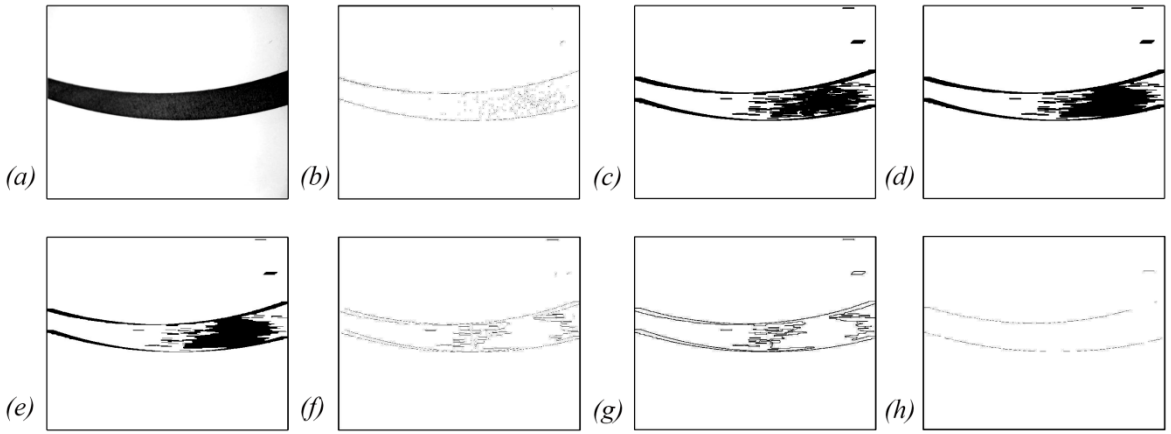
HRTF test

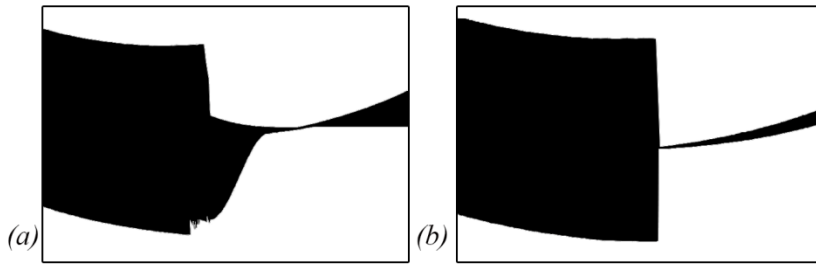
- The same setup as for HRTF measurement
- Horizontal plane (azimuth)
- User switches real and virtual sources

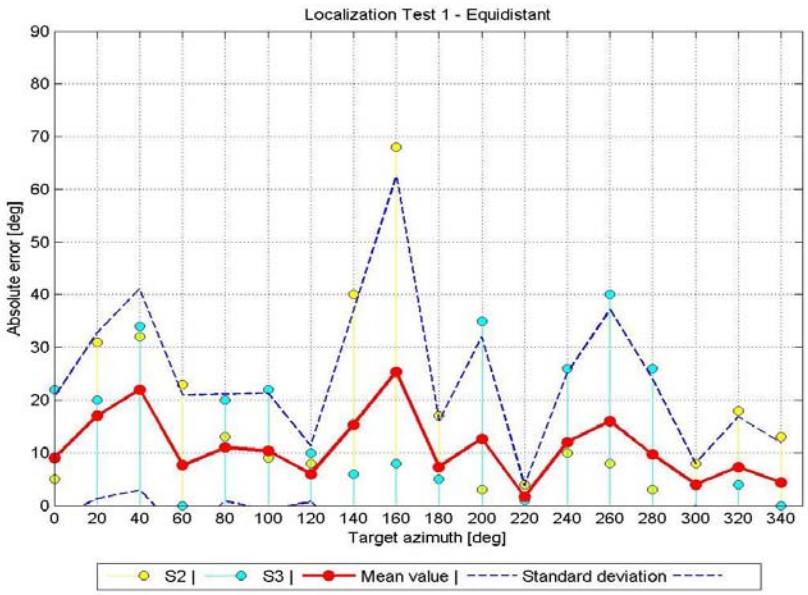


HRTF testing

- Improved azimuth detection algorithm
- Automatized data export

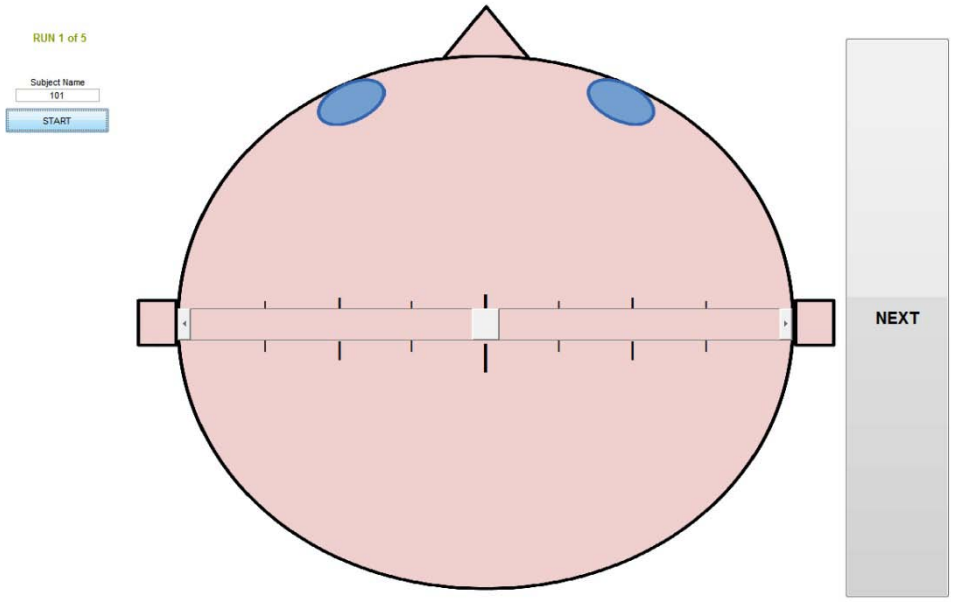






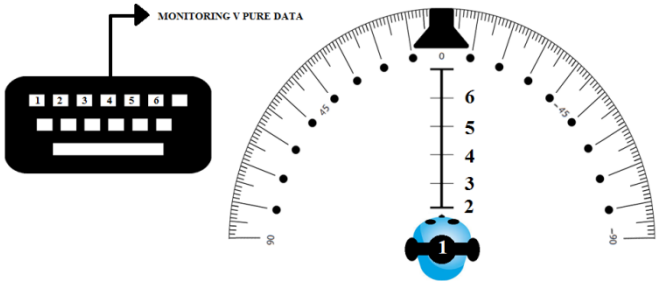
Psychoacoustic experiments

- Pure tone lateralization
- Narrow-band noise (1 ERB) lateralization
- Influence of headphones transfer function to lateralization
- Headphones calibration – audiology
- Dichotic pitch lateralization
- Lateralization – ITD vs IPD



Externalization experiment

- **Augmented reality – mixed real and virtual**
- **Binaural earphones-microphones**
- **Set of experiments**
  - Real source
  - Real source with mic-earphones
  - Recorded real source
  - Virtual source
  - …
- **With/without visual control**



AUDITORY MODELS APPLICATION

Auditory models applications

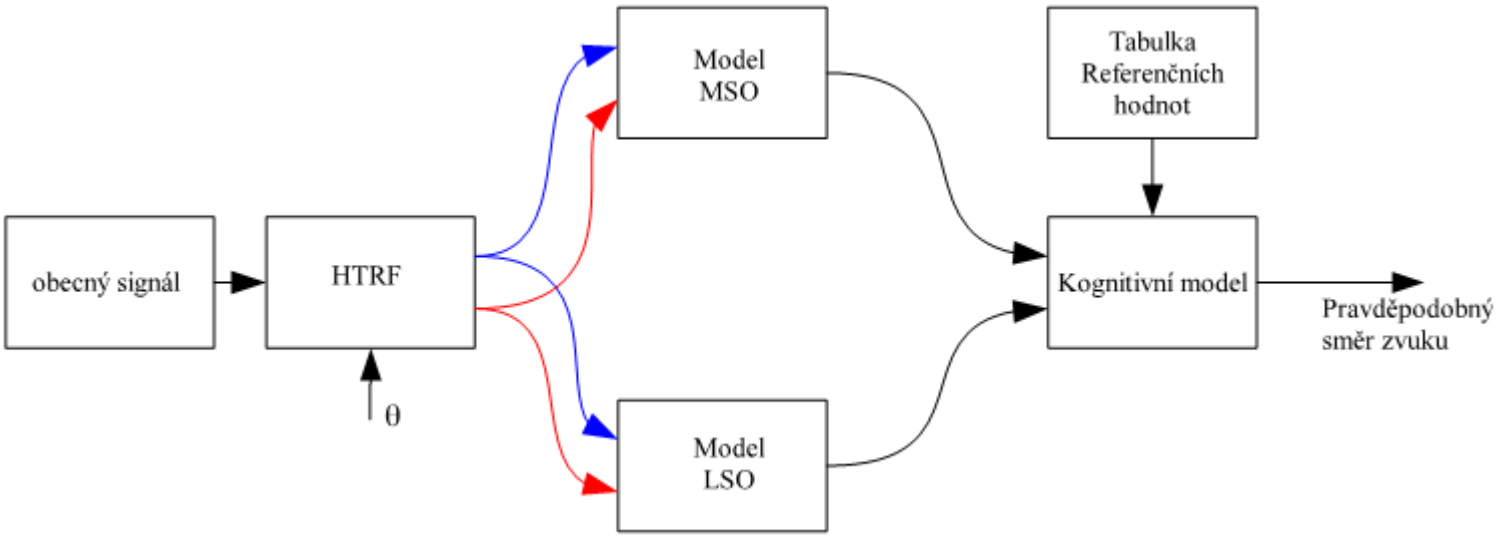
- Lossy compression
- Quality assessment
- Virtual reality, augmented reality
- Room acoustics,
- Cochlear implants,
- …

Archive records quality assessment

- **Digitalization and restoration of archive records**
- **Necessary to assess the quality**
  - Comparison with (old) standards – if the original tests are available
  - Calculation of a measures from the signal
    - Bandwidth
    - Number of clicks
    - Dynamical range
    - …
  - Using of auditory models
    - Summation of the artifacts – is not linear
    - E.g. masking takes place
    - Algorithms like PEAQ, PEMO-Q is not optimized for archive records

VAS test

- Testing is complicate and time demanding
- Verification of VAS algorithms using models?



Conclusions

- Human hearing and auditory models
- New findings necessary to implement (binaural hearing)
- Auditory models are used for wide range of applications
- Simple models, not accounting for some effects (e.g. binaural)

Thank you for your attention

QUESTIONS?