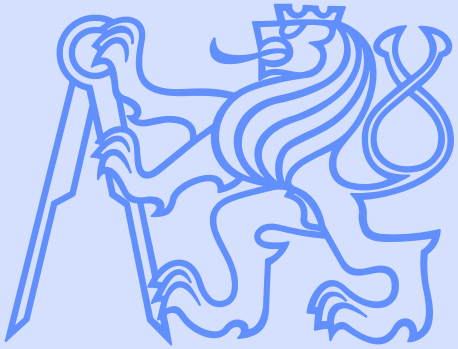
Multimedia Technology Group

Virtual Acoustic Space as Assistive Technology



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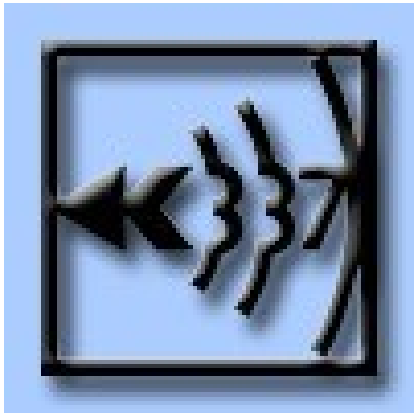
Outline

- **Introduction of MMTG FEE CTU and CAT CTU**
  - MMTG
  - CAT
  - MMTG projects under CAT
  - Idea of Perseus
- **Virtual Acoustic Space as Assistive Technology**
  - Idea of VAS
  - VAS Project team
  - VAS problems and areas
    - VAS algorithms
    - HRIR measurement
    - Implementation (matlab, pd, chameleon)
    - HRIR interpolation
    - HRIR synthesis – structural model, personalization
    - Listening tests organization and interpretation
    - Binaural models for verification and testing

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

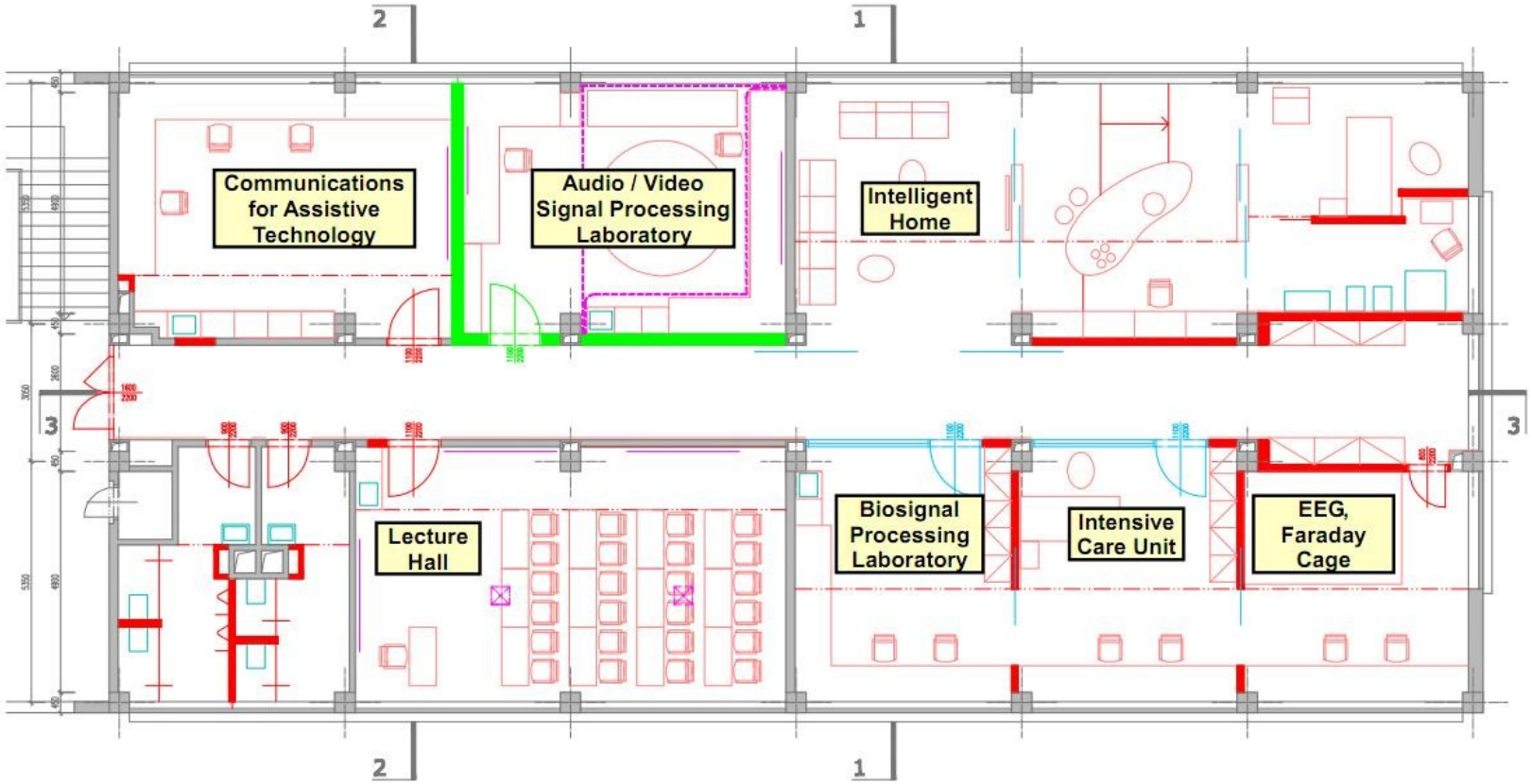
Broadcast Technology and Measurement Group

CAD for RF circuits

RF Embedded Systems

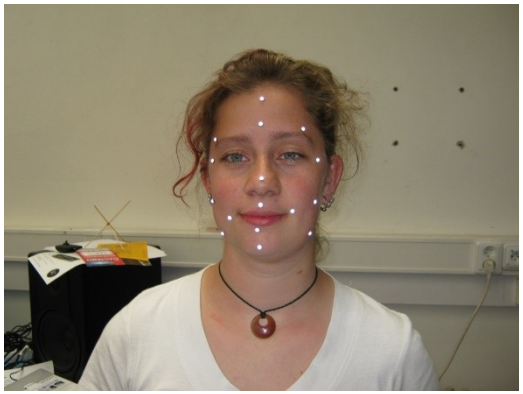
Center of Assistive Technology

- ***Joint project***
  - Faculty of Electrical Engineering, CTU in Prague
  - 1st Faculty of Medicine, CUNI in Prague



Center of Assistive Technology

- ***MMTG projects***
  - ***Effect of stereoscopic system configuration on subjective perception***
  - ***Czech Sign Language as a Supplement to Television Broadcasting***
  - ***Personal Assistant for Blind Users (PERSEUS)***

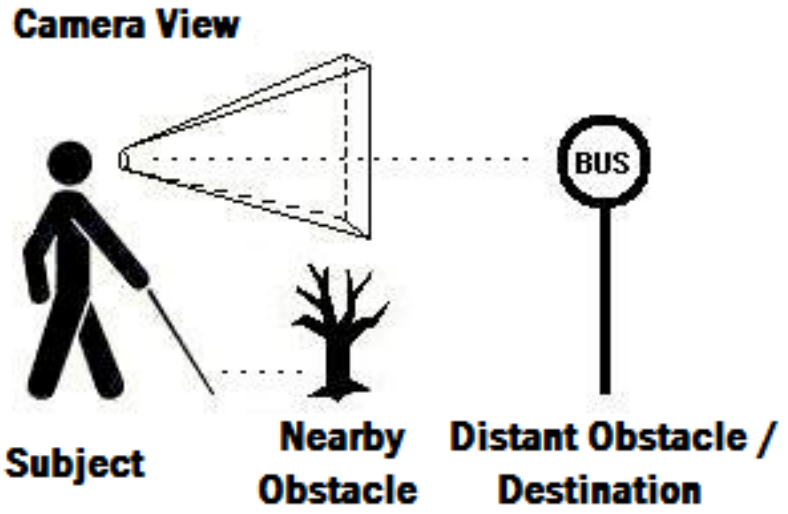


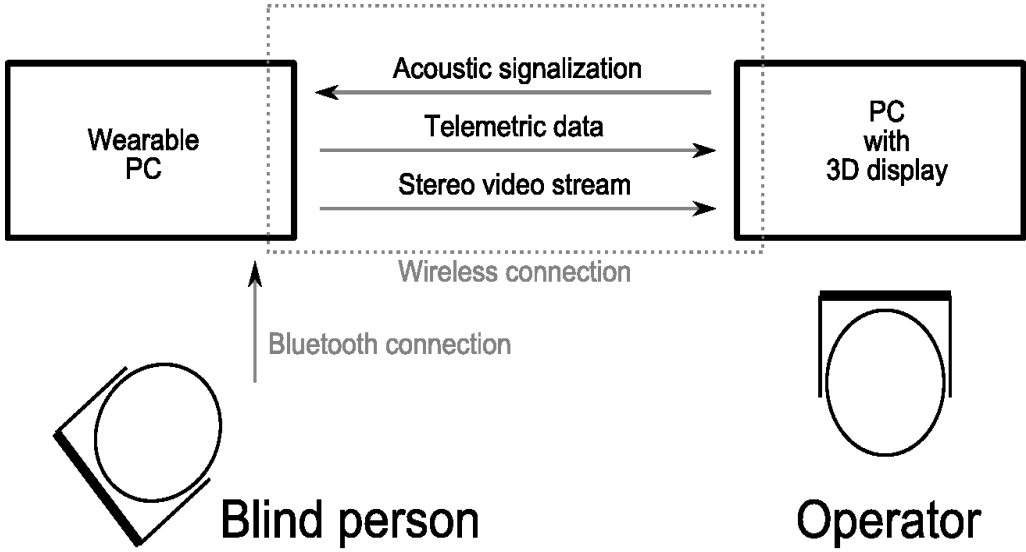
Idea of PERSEUS

- **Assistive call center for visually impaired people at department of Telecommunication Engineering of FEE CTU**
  - In case they get lost
  - Operator sees position of the user on a map
- **Problems:**
  - Unusual or unexpected situation (road work) not mentioned in the map
  - Communication with the operator blocks hearing sense
- **How to effectively navigate blind persons in unknown natural environment (e.g. streets, public transport, shopping centers, etc.) in such situations?**
- **How to arrange the communication between the subject and the operator without using direct speech?**

Idea of PERSEUS

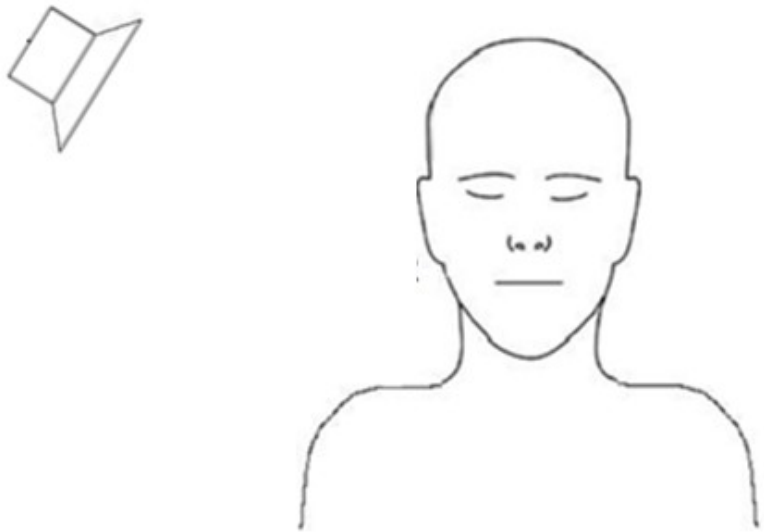
- Personal Assistant for Blind Users (PERSEUS)
- Stereoscopic video transmitter and stereo audio receiver
- Joystick-based operating interface
- The subject follows path according to virtually positioned stimuli





Idea of Virtual Acoustic Space

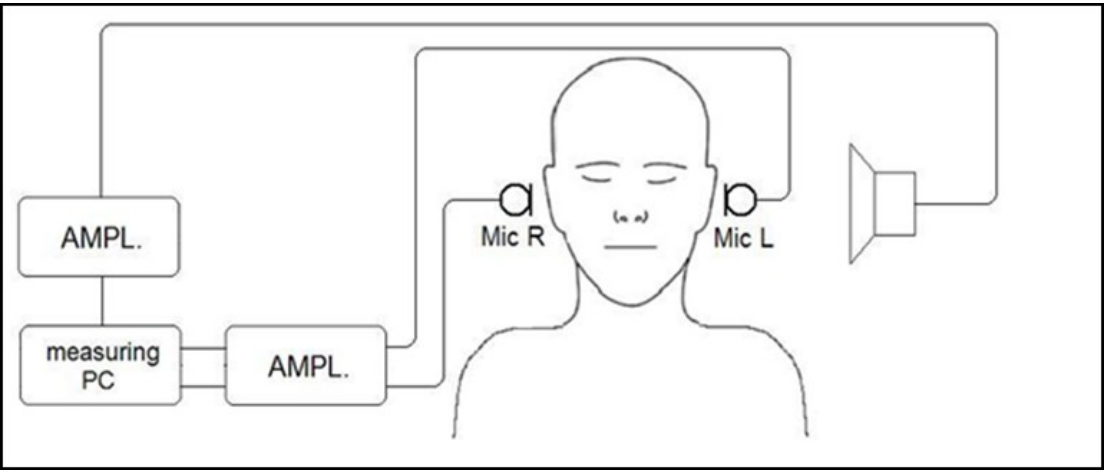
- **Real source**

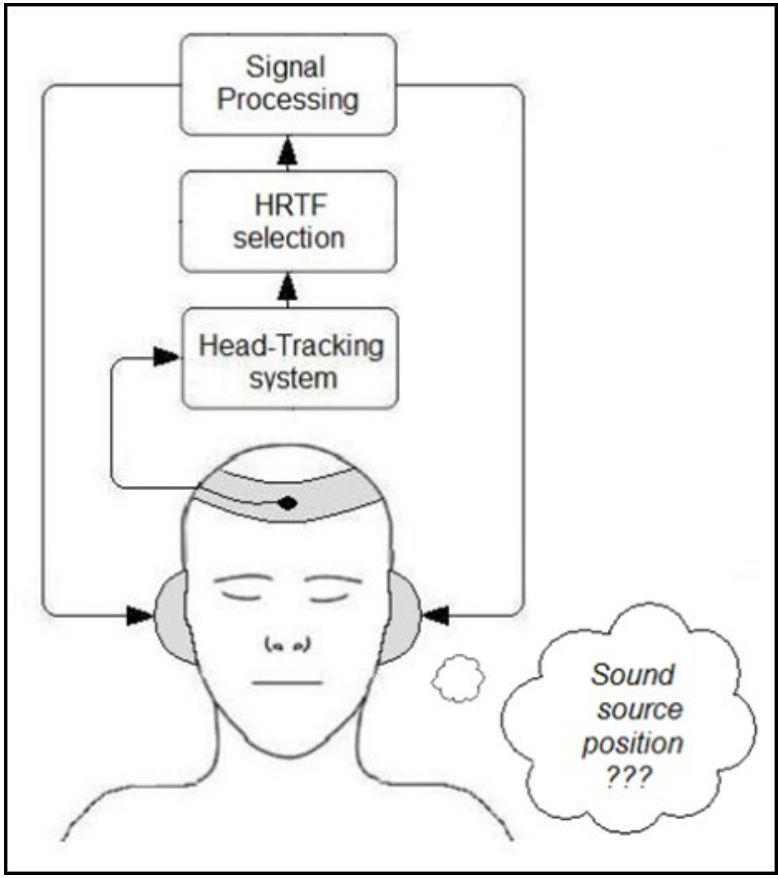


- **Virtual source**

Idea of VAS

- **Virtual Acoustic Space and HRTF**





VAS project team

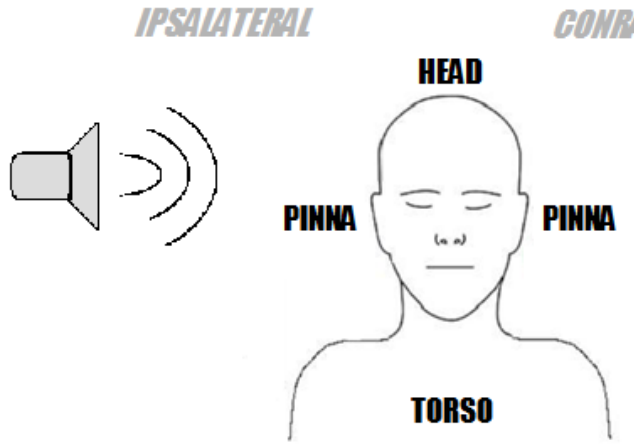
- **MMTG staff**
  - **František Rund**
  - Stanislav Vítek
  - *František Kadlec*
- **Ph.D. students**
  - Dominik Štorek
  - Václav Vencovský
  - **Jaroslav Bouše**
- **M.Eng. students**
  - *Jaroslav Bouše*
  - *Richard Suchan*
  - *Jiří Kotzot*
  - *Filip Saturka*
  - *Tomáš Baráth*
  - **Alan Štolc**
  - *Martin Švejda*
  - Václav Punda
  - *Martin Strachota*
  - **Tomáš Lindner**

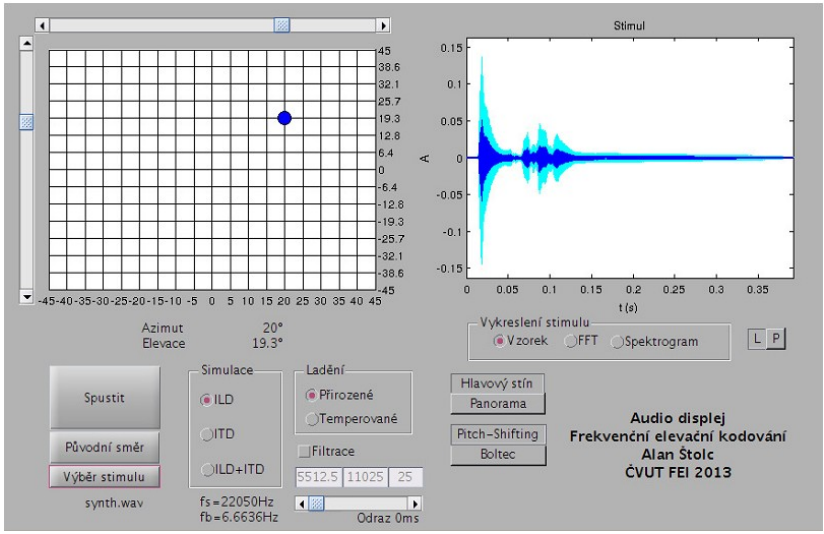
Areas

- VAS algorithms (virtual or augmented reality?)
- HRIR/HRTF measurement
- HRIR/HRTF interpolation
- HRIR/HRTF synthesis – structural model, personalization
- Implementation (matlab, pd, chameleon)
- Listening tests organization and interpretation
- Binaural models for verification and testing

VAS algorithms

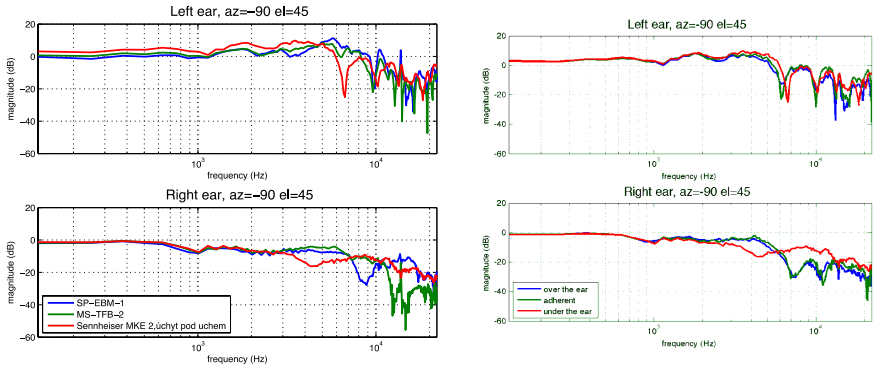
- **Simple**
  - Amplitude panning (ILD)
  - Time/phase delay (ITD)
  - Room (floor) reflections simulation
- **HRTF based**
  - Measured HRTF/HRIR
  - DHRTF
  - HRTF personalization
  - Structural models – HRIR decomposition
- **Head tracking**
- **Sonification approach**
  - Code?

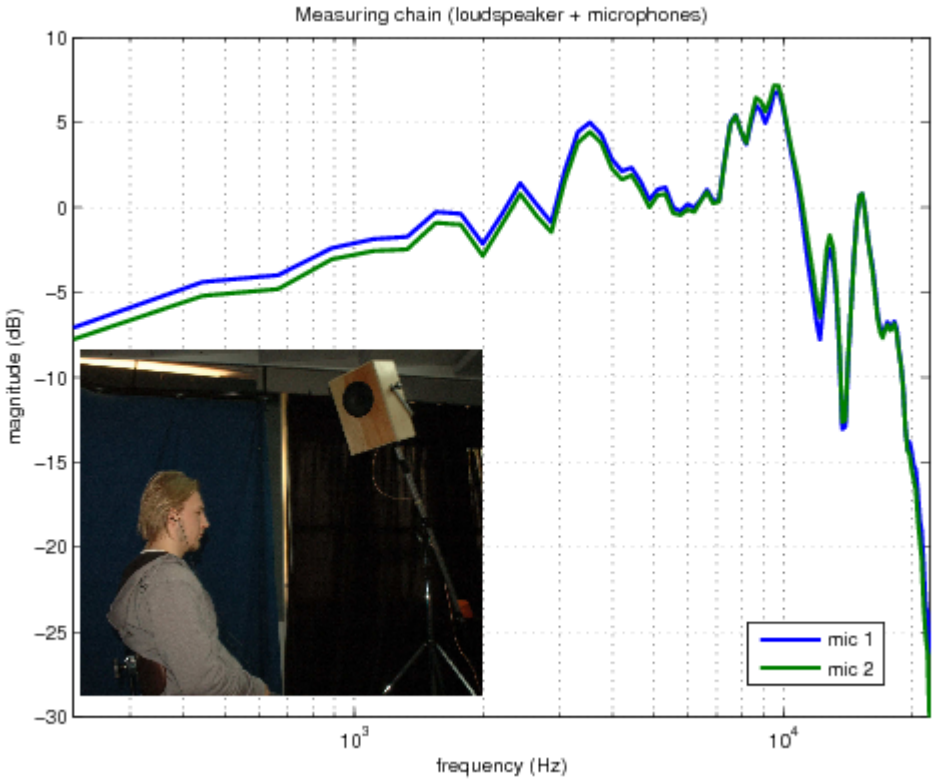




HRTF measurement

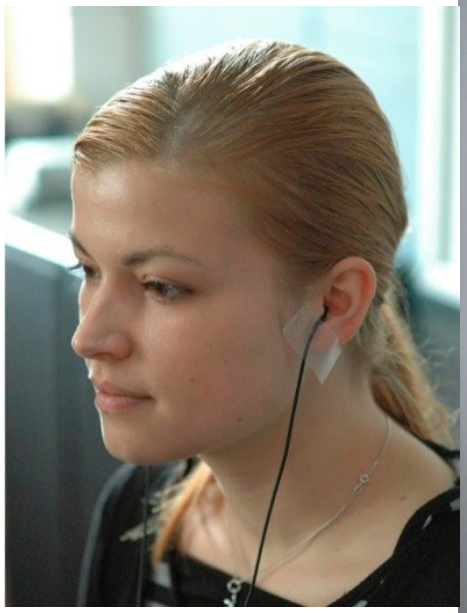
- **Measurement chain**
  - A method for IR/TF measurement
  - Loudspeaker
  - Microphones
  - Azimuth & elevation

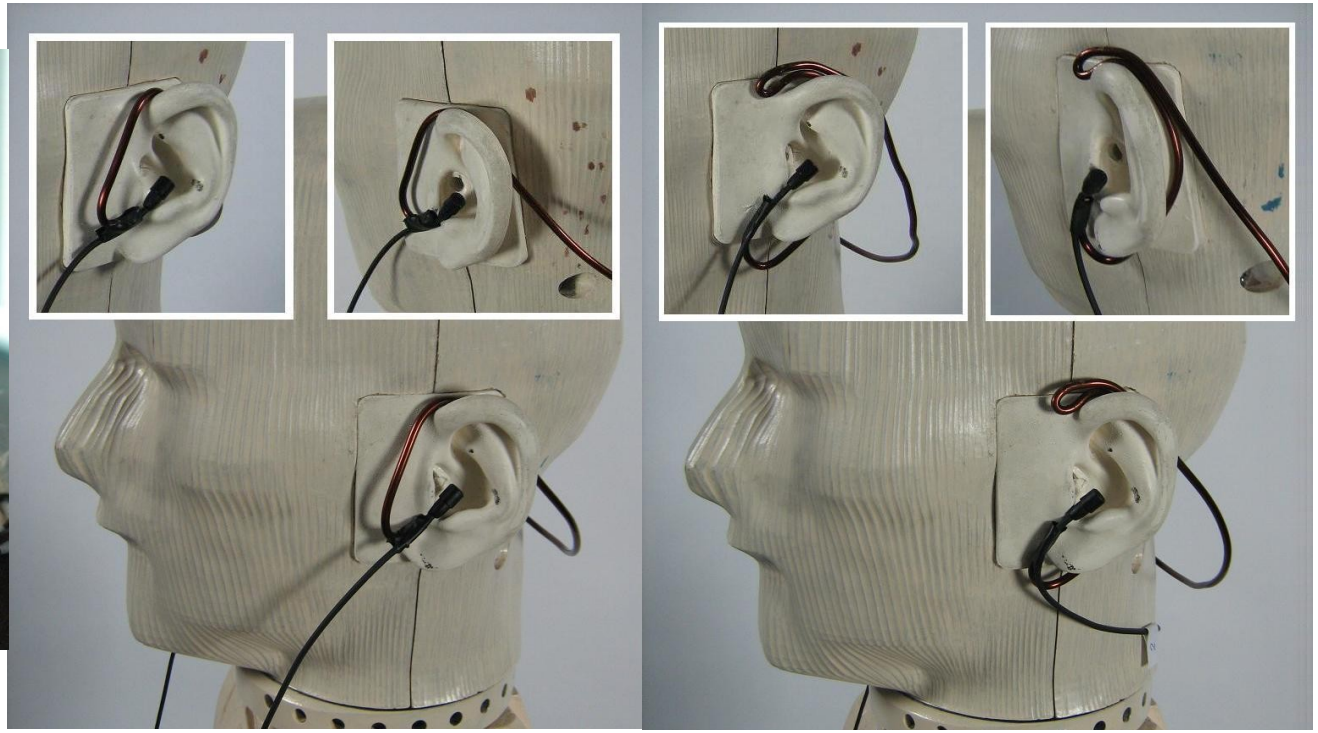


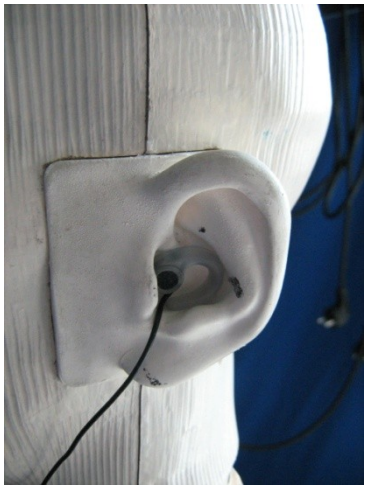


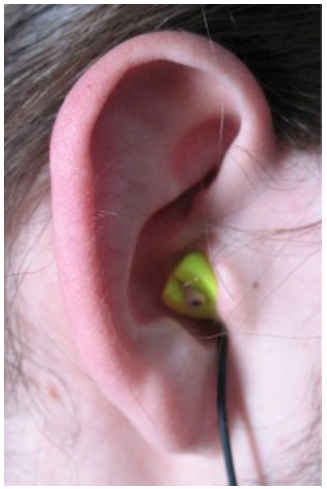
- HRTF – transfer from the source to the ear
- Time & instrument demanding
- Directions:
  - 5 of azimuth
  - 3 of elevation
- Equalization?

HRTF measurement

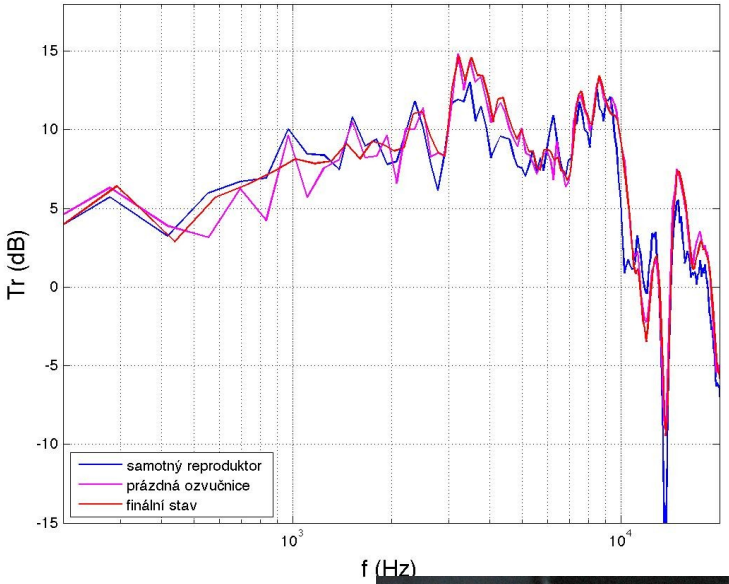


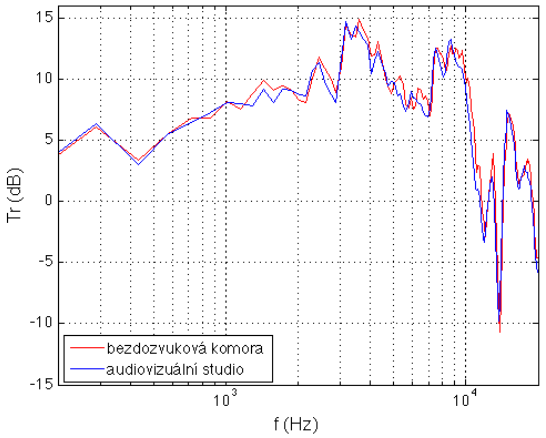


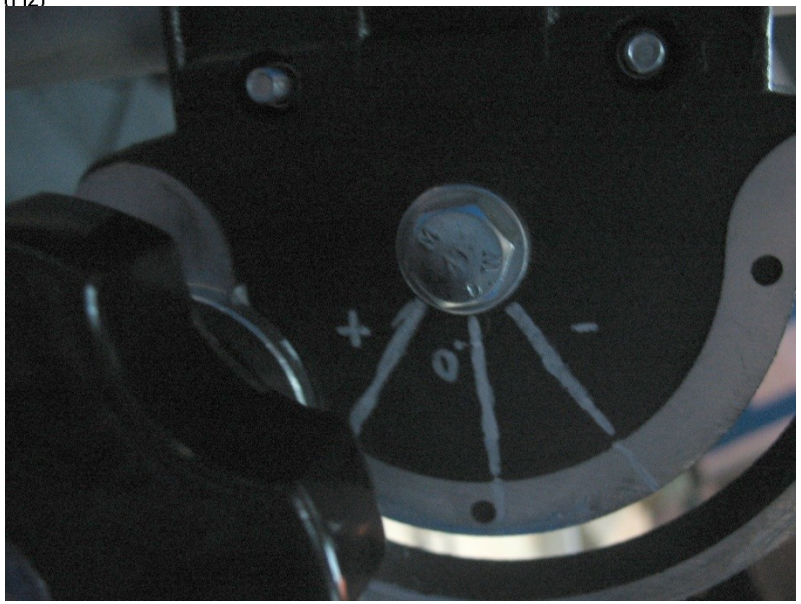




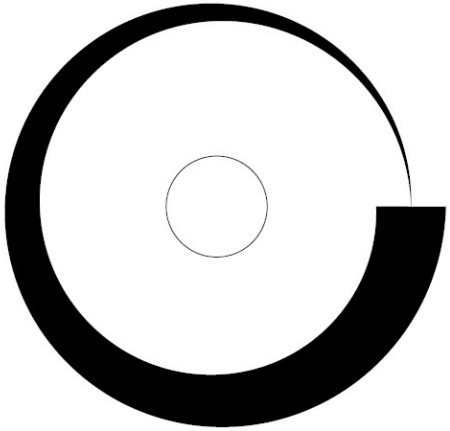
HRTF measurement

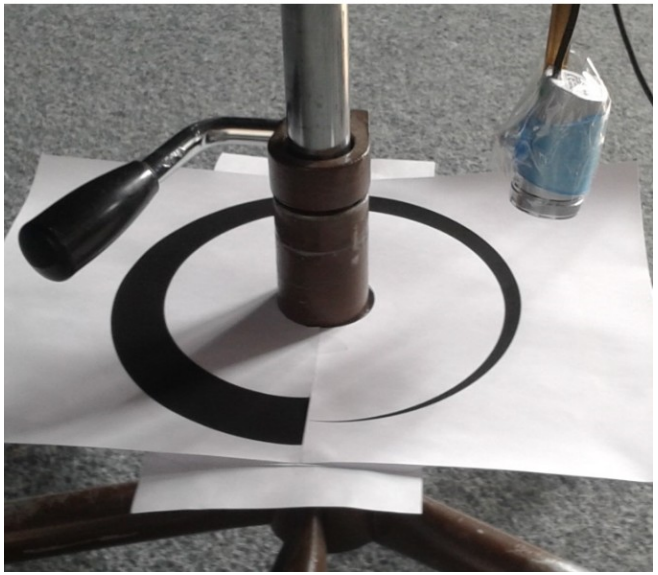


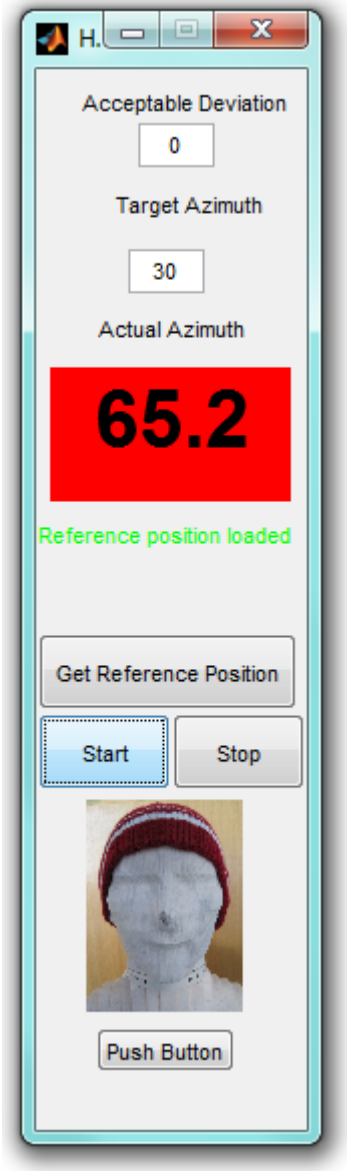




HRTF measurement

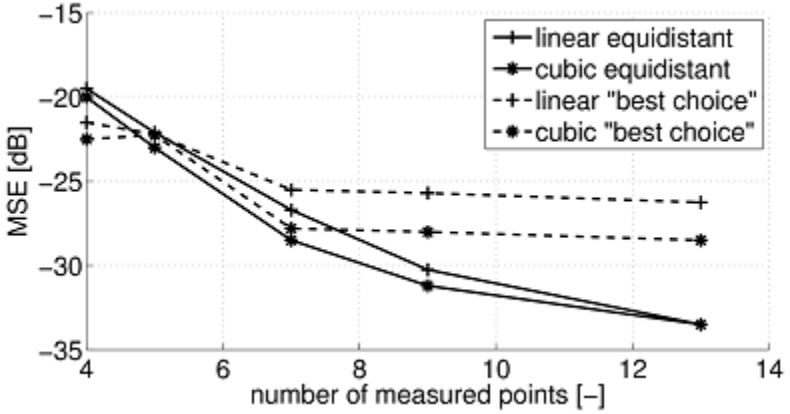




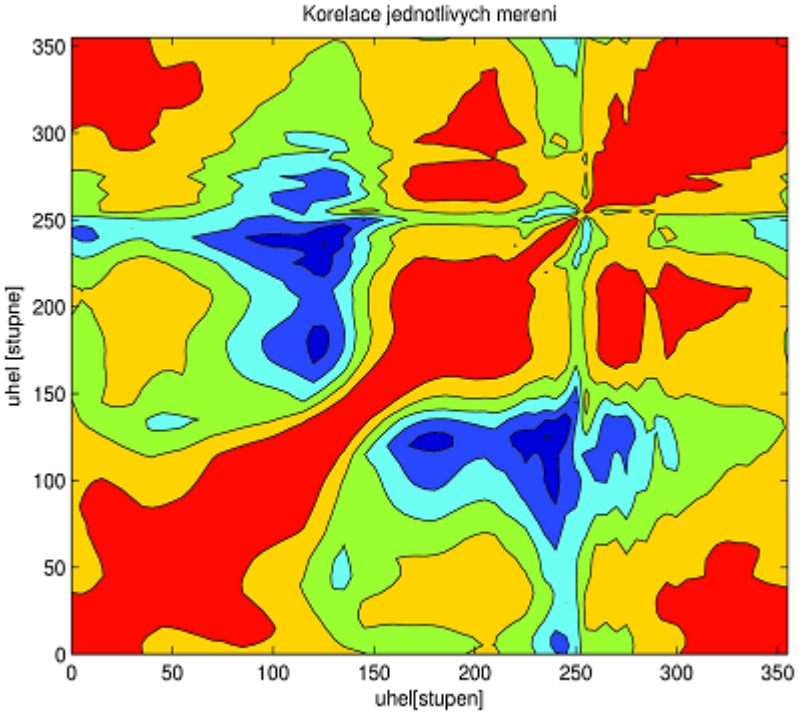


HRTF measurement optimization

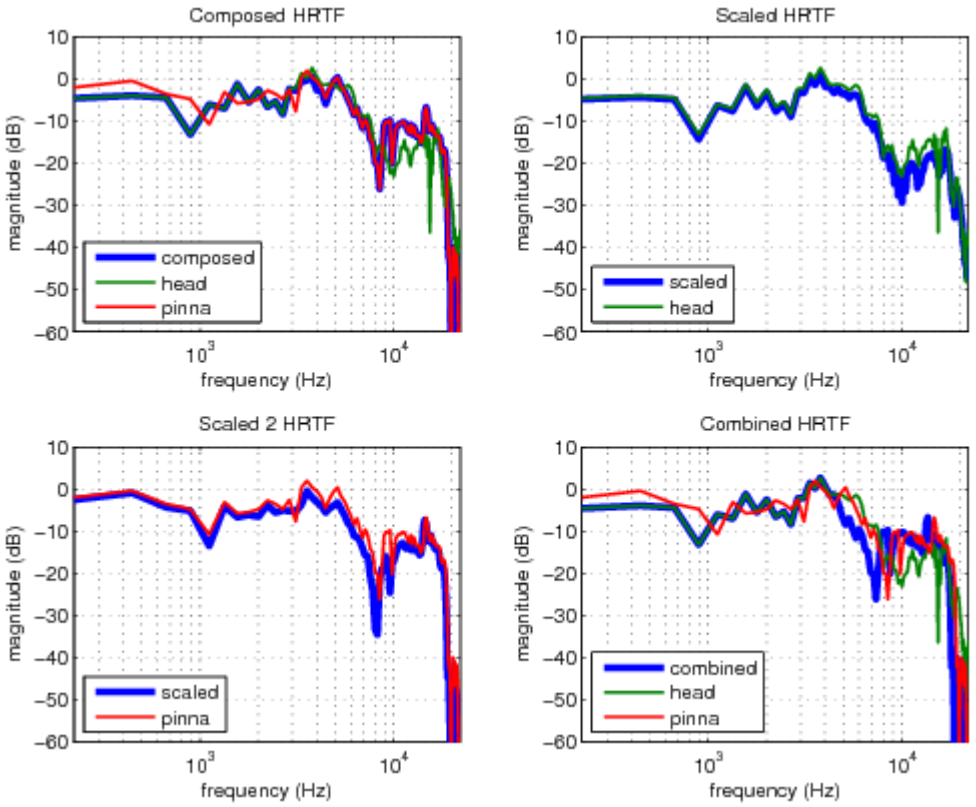
- **Methods of interpolation**
  - Linear
  - Hermite cubic
  - Spherical Fourier series



- **Selection of directions for measurement**

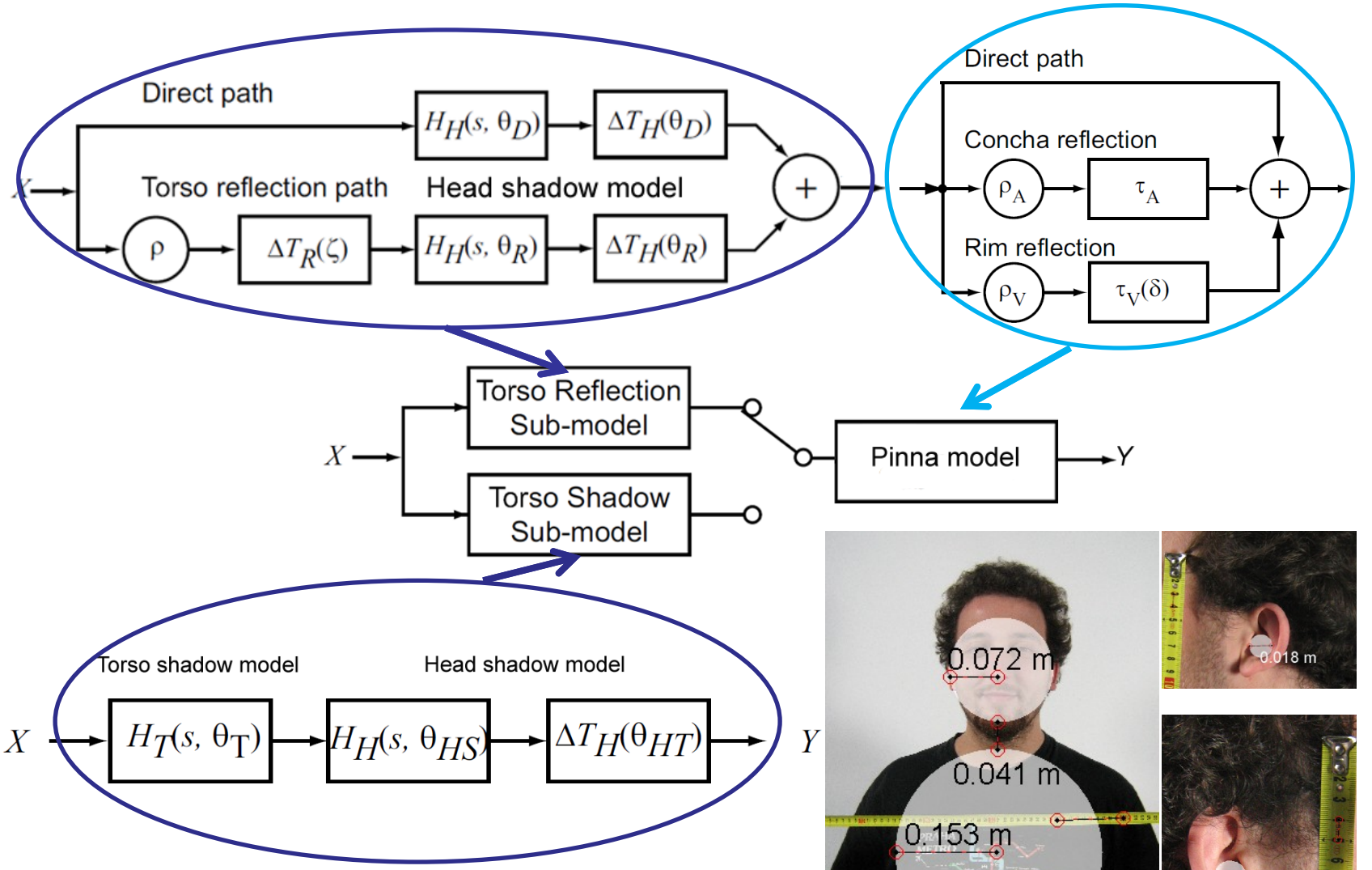


HRTF personalization

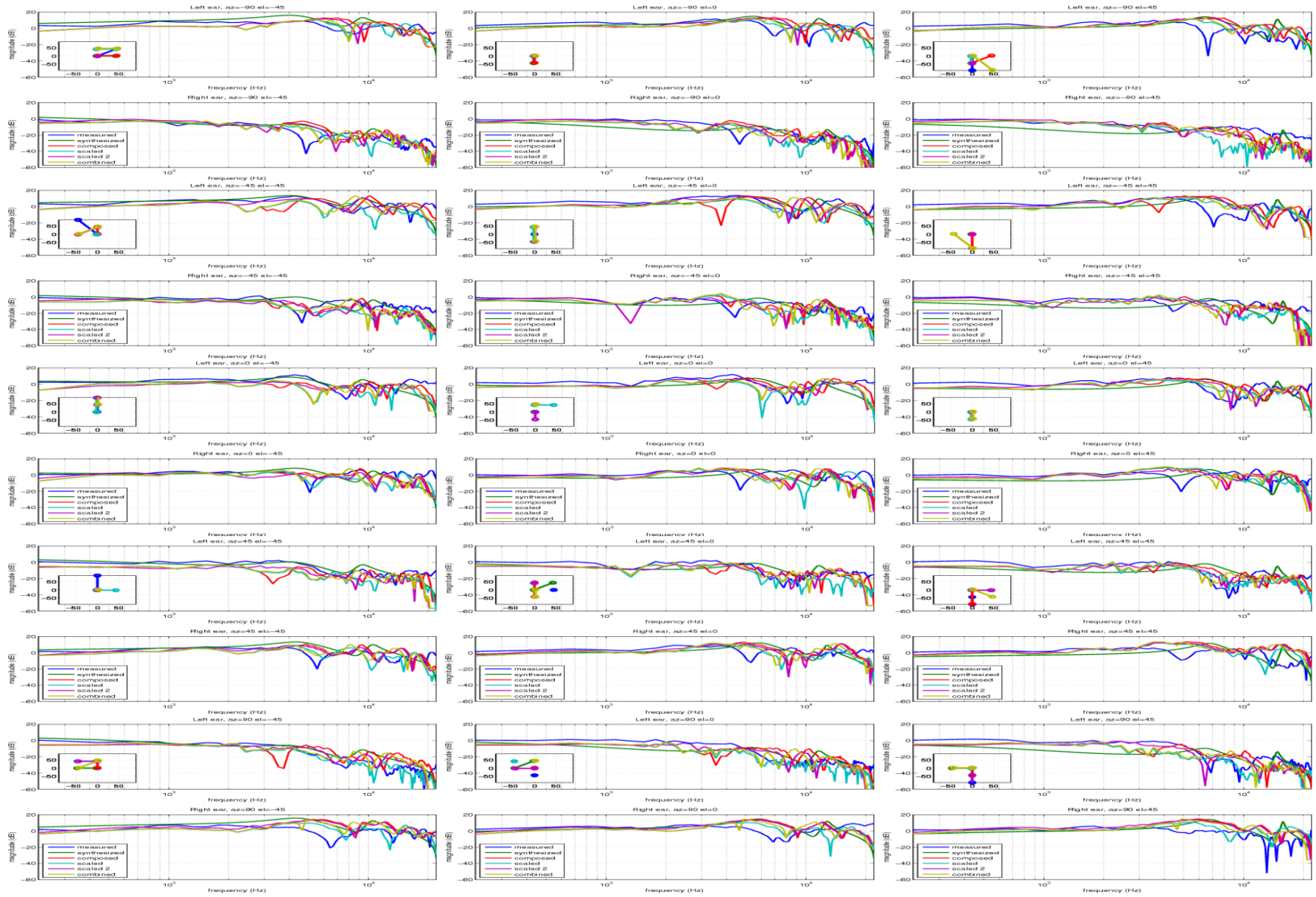


- HRTF – influenced by anthropometry
- Database HRTF
- Methods:
  - Cut & past – compose
    - Head + pinna
  - Scaling
    - Head based
    - Pinna based
  - Combination
    - Head + pinna
    - Pinna scaled

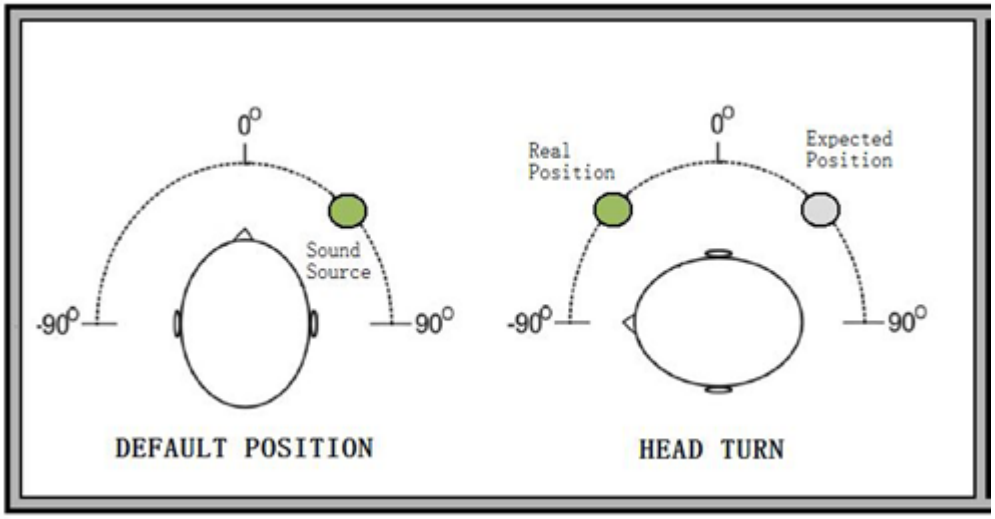
Structural model



HRTF comparison



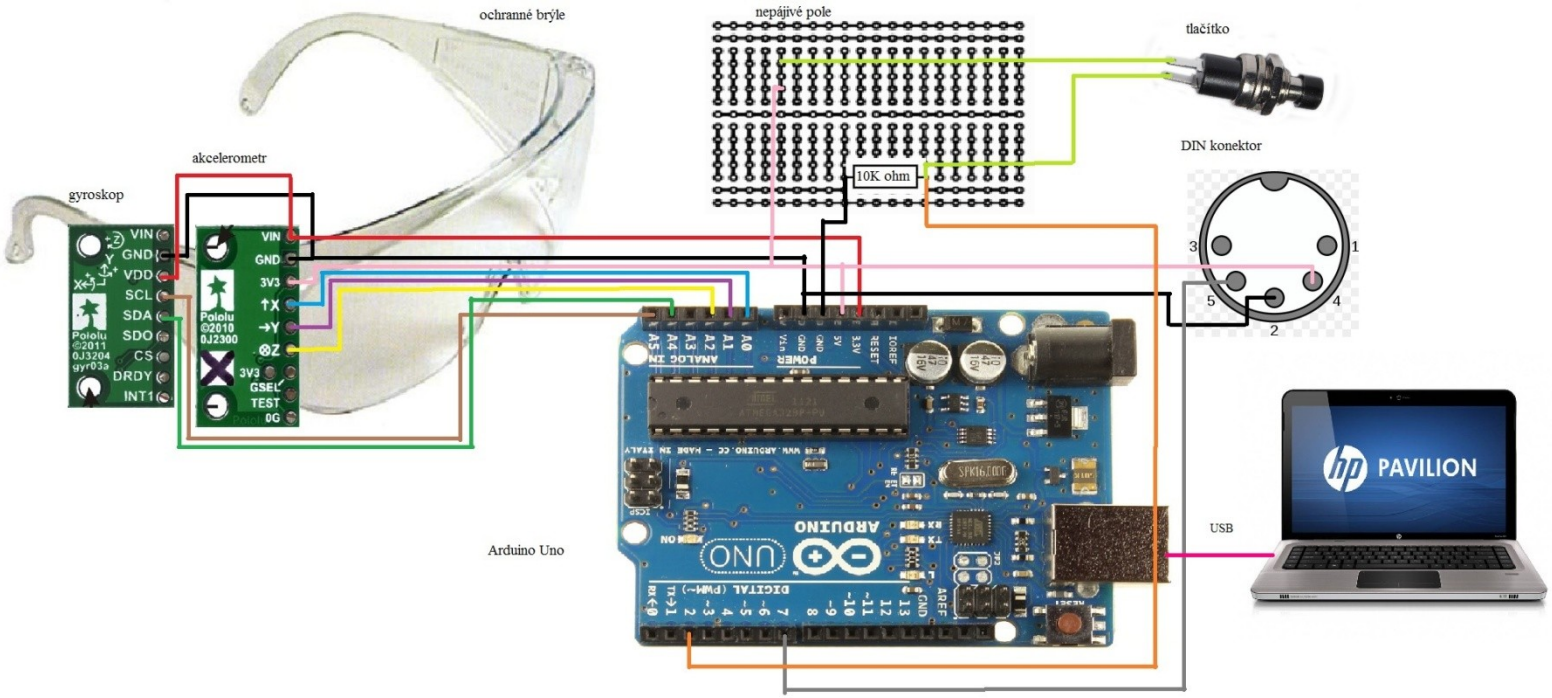
Head tracking



- **Optical head-tracking**
- **Hardware headtracker**
  - Accelerometer + gyroscope
  - Arduino
  - MIDI output

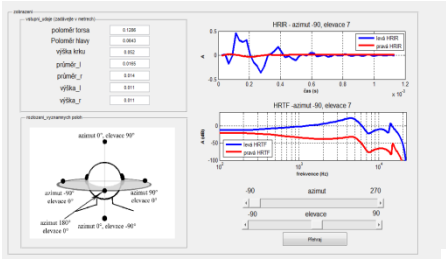
Head tracking

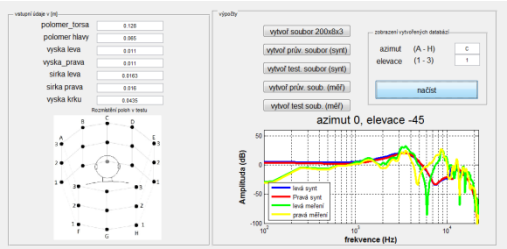
- **MIDI head-tracker**
  - MEMS gyroscope
  - MEMS accelerometer

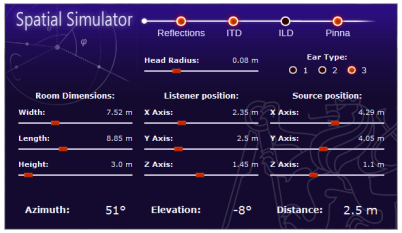


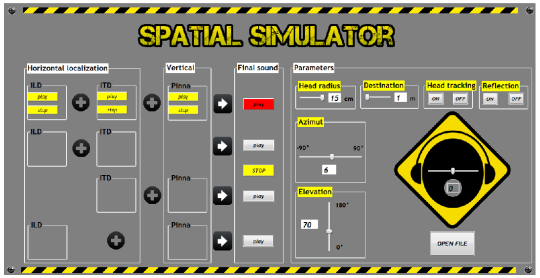
VAS implementation

- **Simple Matlab GUIs**
  - ITD, ILD, structural models, …
  - Perseus testing implementation
  - Auditory display
- **VST plug-ins – real time**
  - Structural model or HRTF bank
  - Structural model + room reflections
- **Pure data – real time**
  - Structural model + floor reflections
  - Head-tracking (MIDI or optical)
- **Chameleon DSP – real time**
  - HRIR convolution
  - DHRIR convolution
  - Amplitude panning
  - Head-tracking (MIDI)



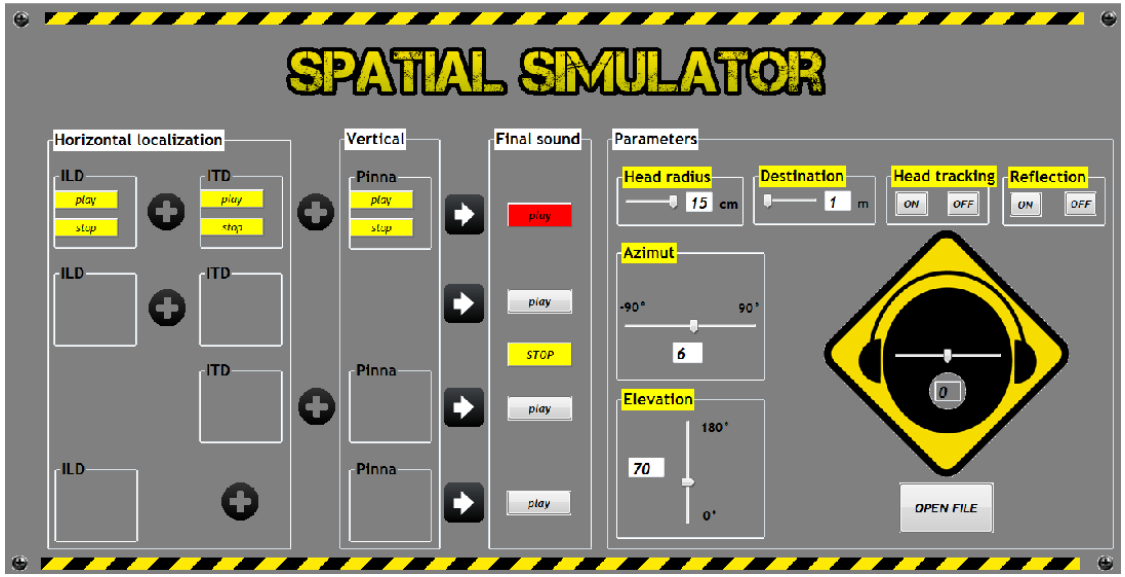


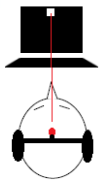


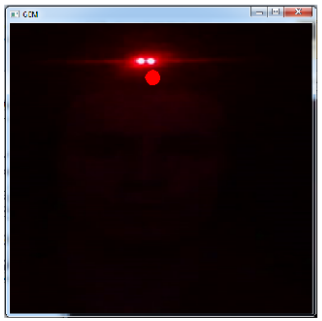


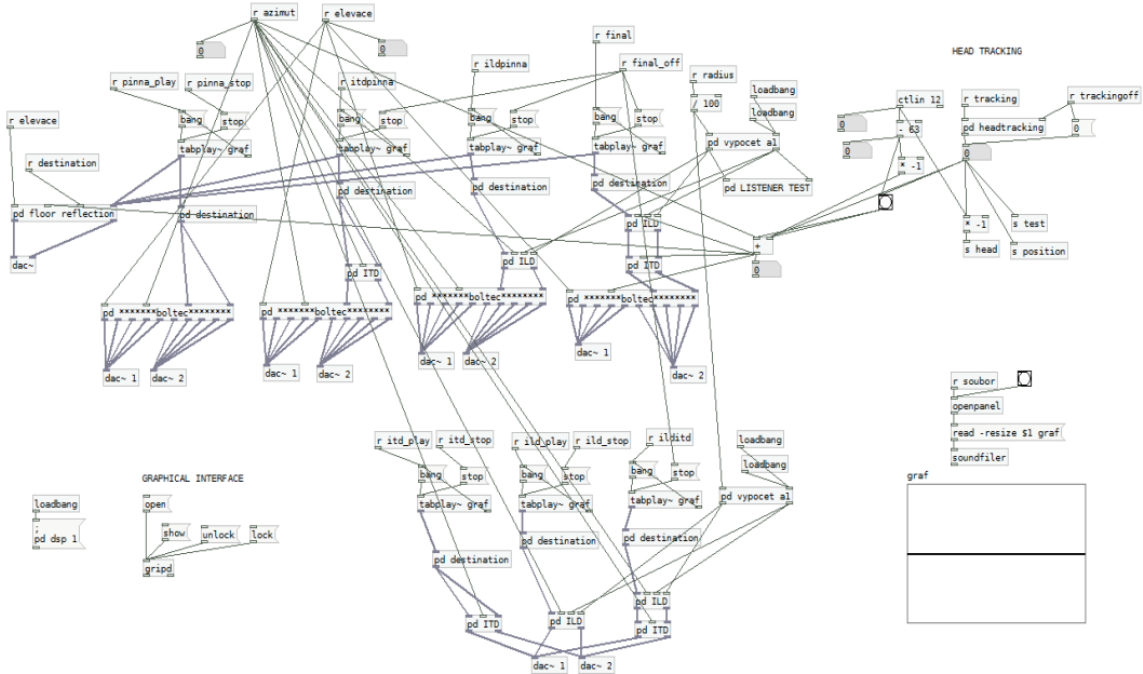
pd

- Real-time processing
- GUI
- Structural model
- Floor reflections
- Head tracking
  - Optical
  - MIDI









DSP chameleon

- **Real-time processing**
- **Algorithms**
  - HRTF (interpolated bank)
  - DHRTF (interpolated bank)
  - Amplitude panning
- **MIDI head tracker enabled**
- **MIDI remote control**
- **Matlab support for HRIR bank change**

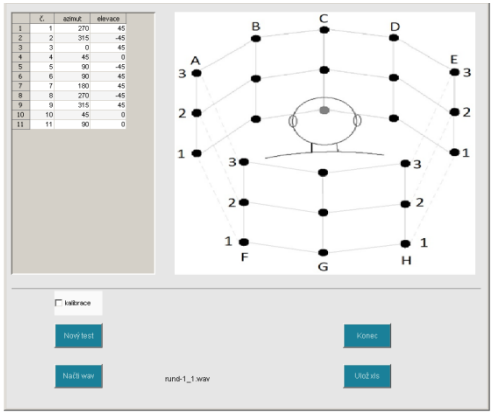
Problems

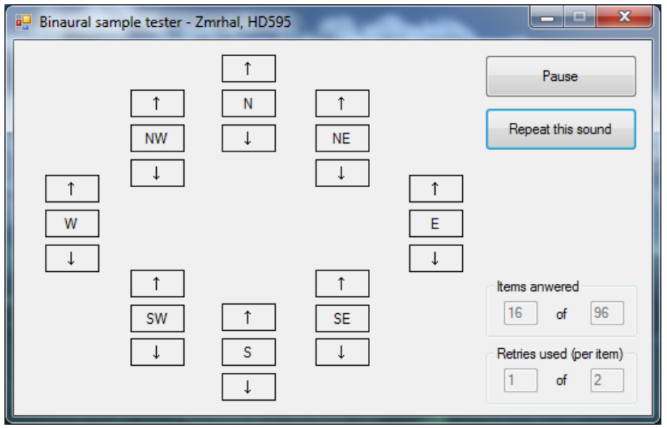
- How to obtain well-positioned stimuli?
- Which positioning method is the best one?
- How to test it?

- Subjective (listening test)
- Objective (binaural models)

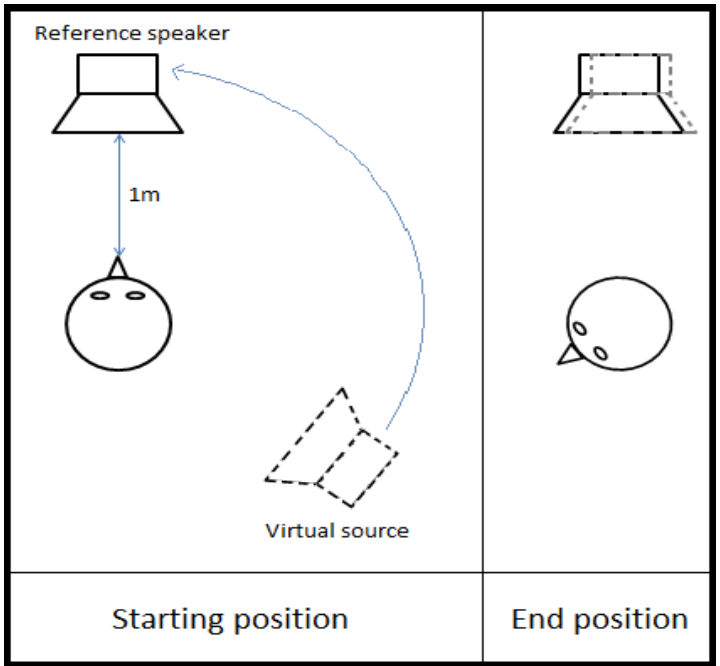
Testing

- **How to test function of the VAS?**
  - Standard method



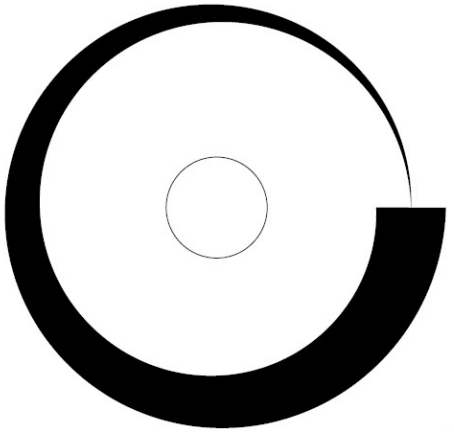


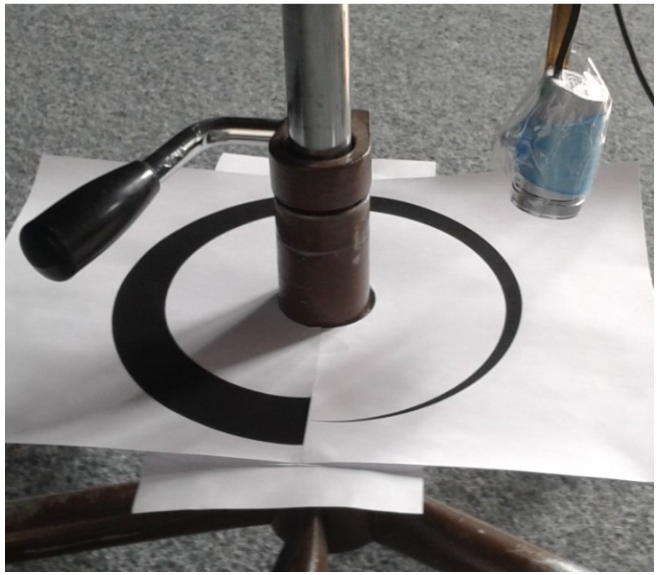
  - New method
    - This method provides good results and subjects are more comfortable with understanding and completing the task
    - The task is to turn the head until the two sources overlap



Testing

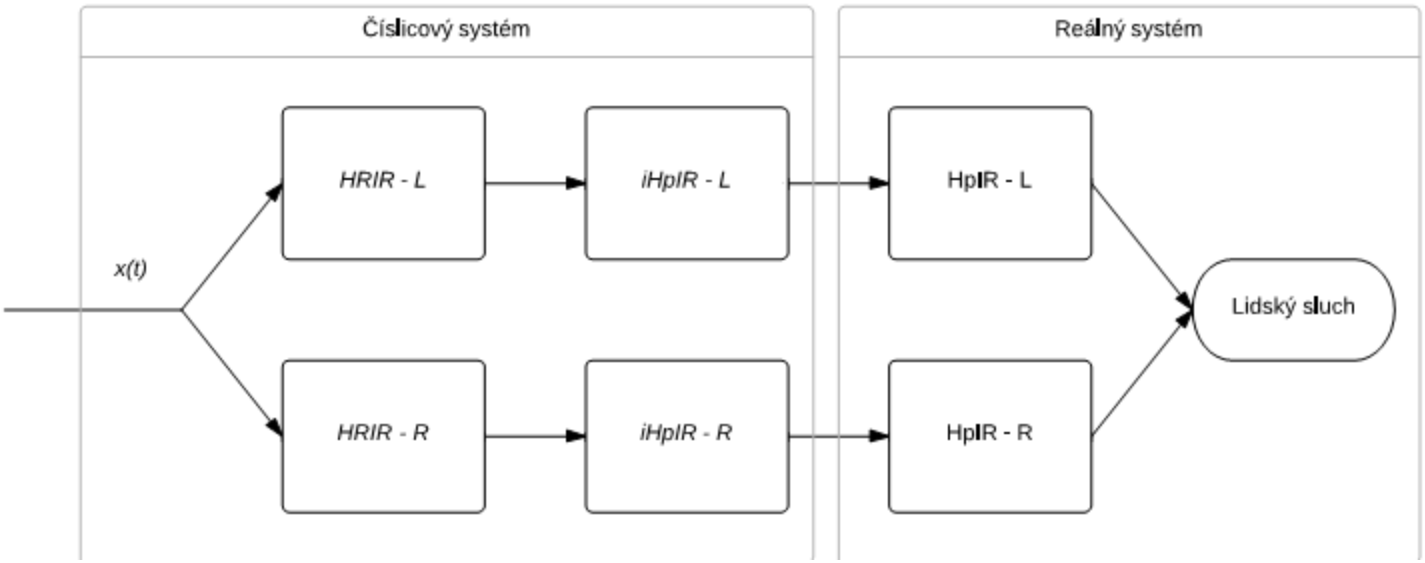
- The same setup as for HRTF measurement
- Horizontal plane (azimuth)
- User switches real and virtual sources





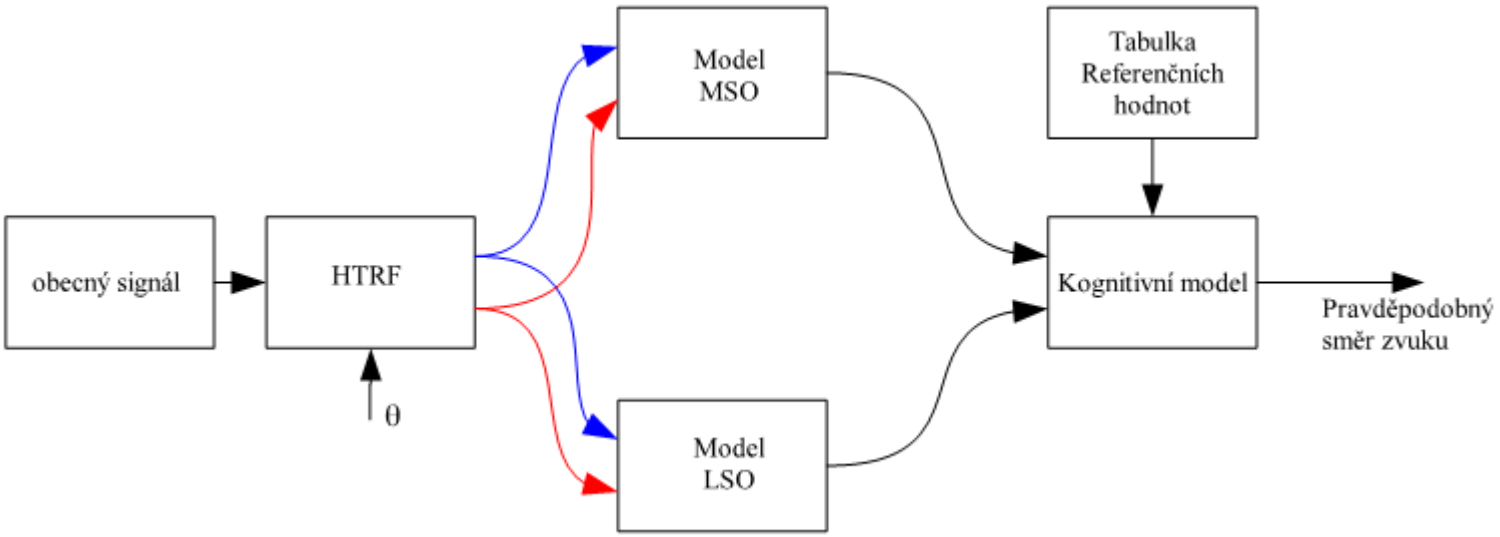
Headphones influence

- **How the headphones influences test results?**

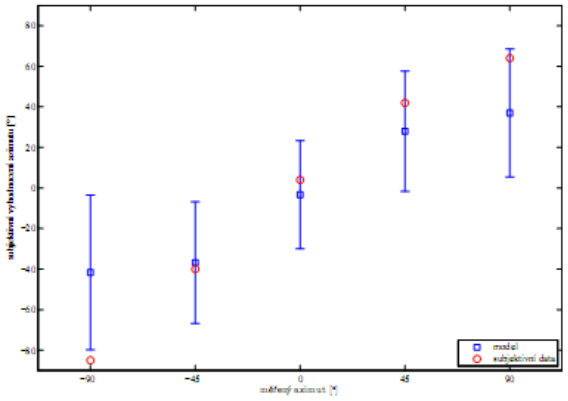


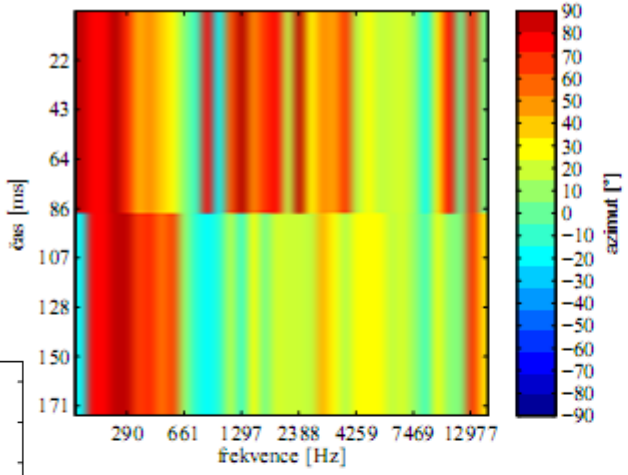
Models

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

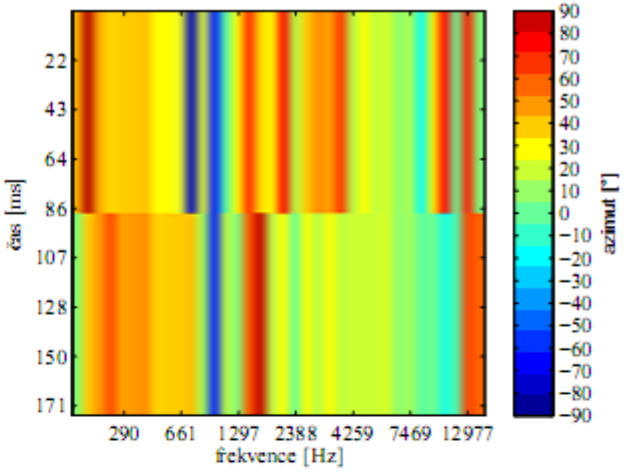


Models

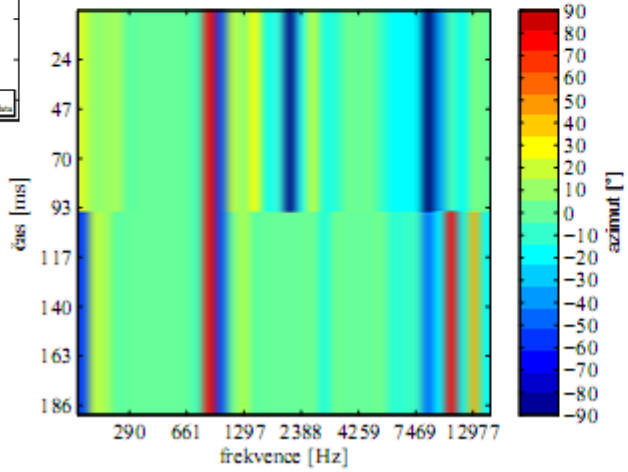




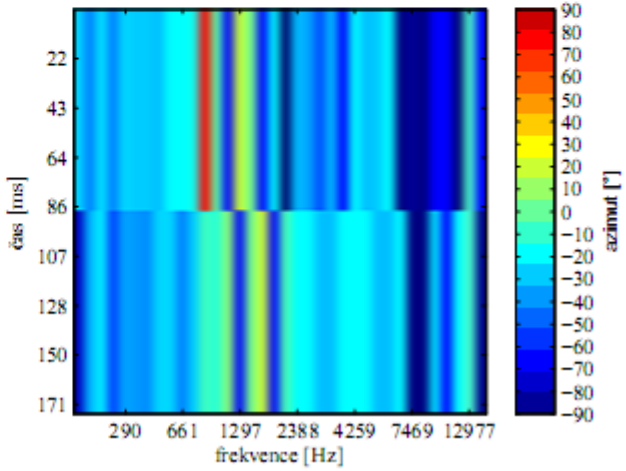
(a) azimut 90°



(b) azimut 45°



(c) azimut 0°



(d) azimut -45°

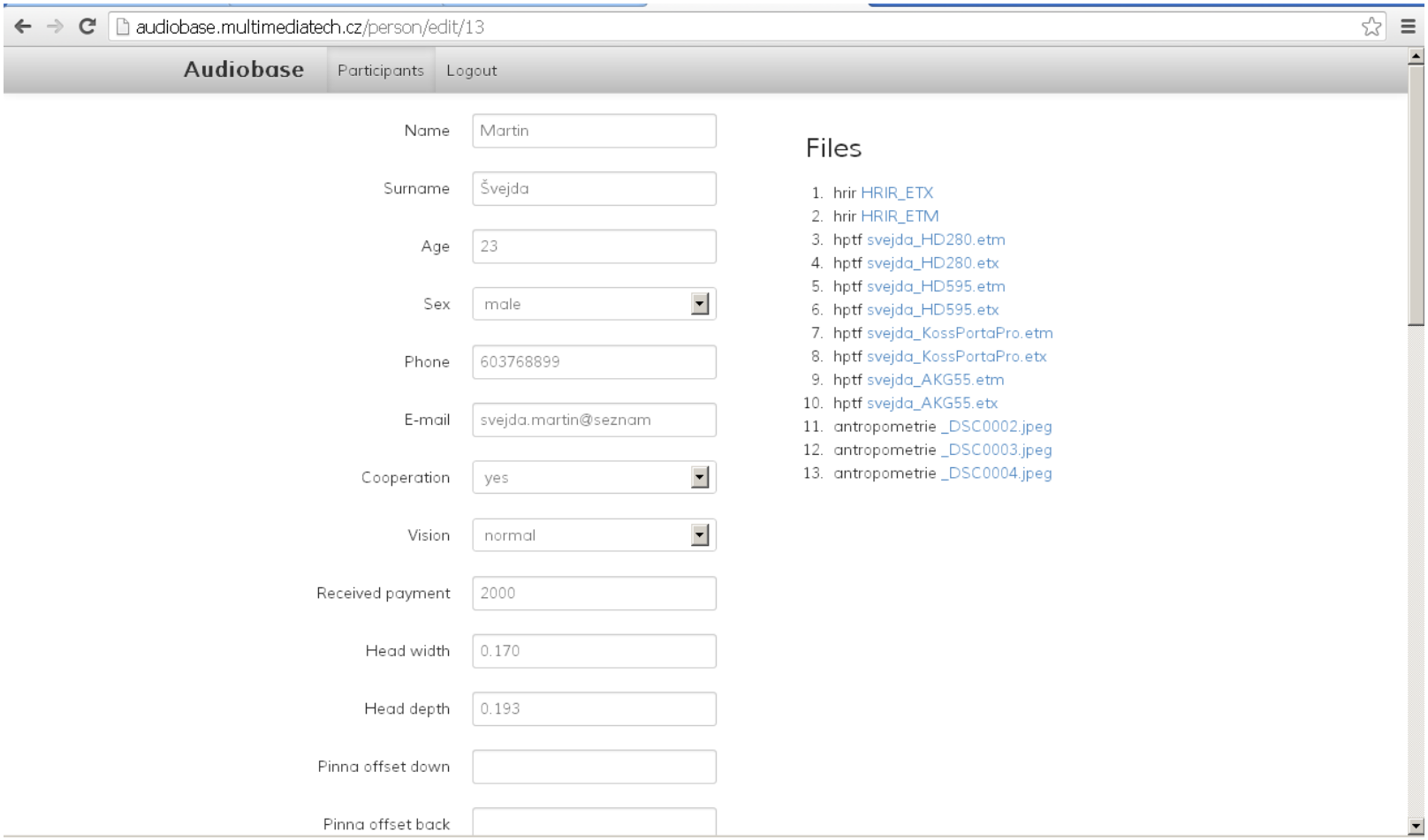
Conclusions

- **VAS for assistive technology?**
- **Virtual or augumented reality?**

- **Testing of VAS**
  - New method for testing
  - Binaural models for VAS algorithms verifications

Audiobase

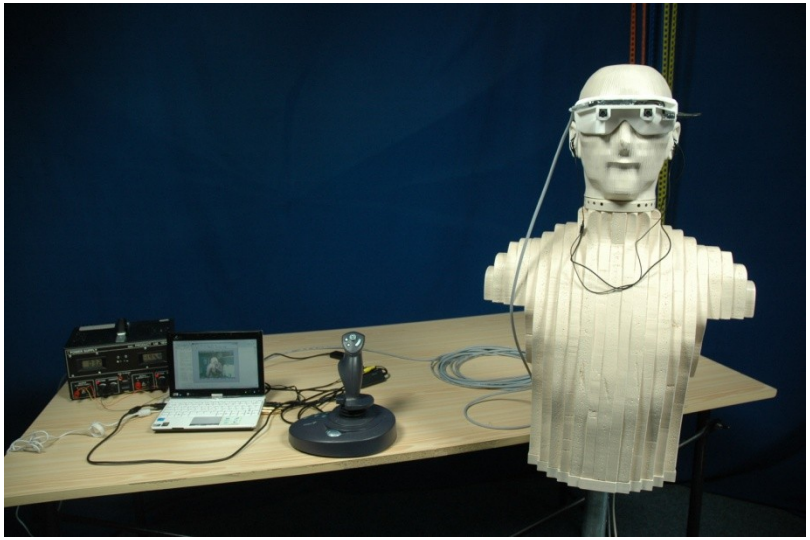
- http://audiobase.multimediatech.cz/



Thank you for your attention

QUESTIONS?

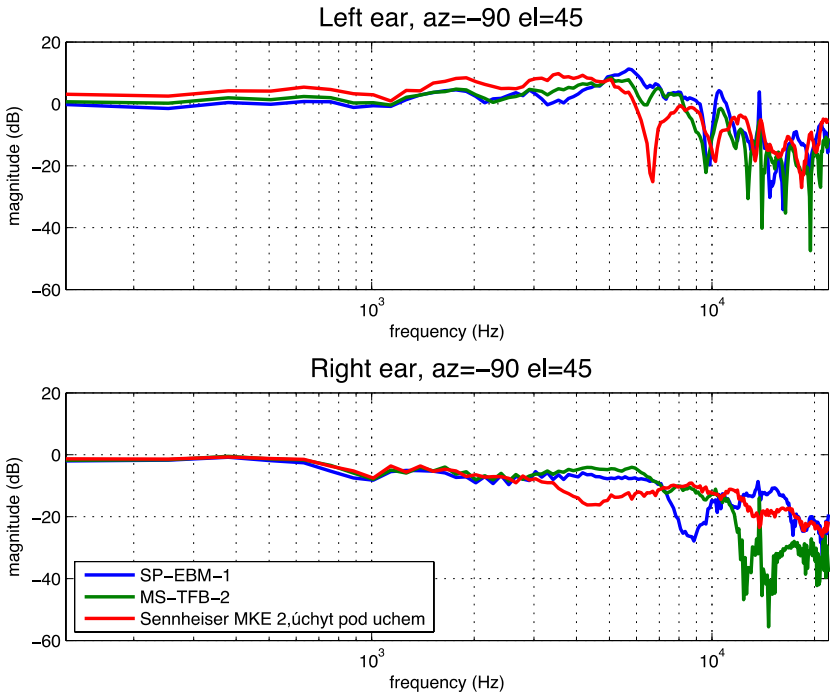
Idea of PERSEUS

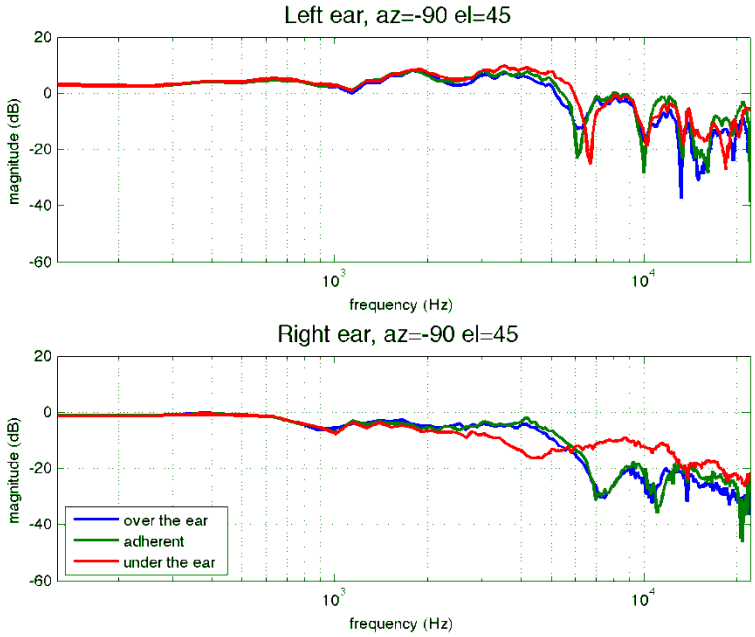


HRTF measurement

- **Microphones**

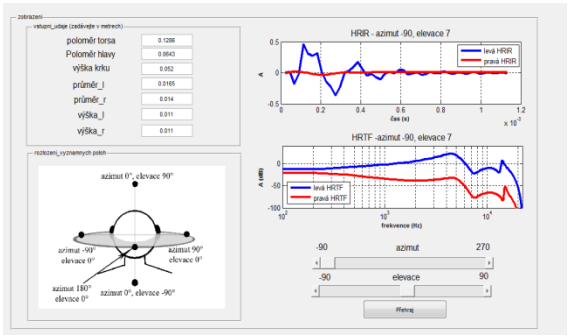
HRTF measurement

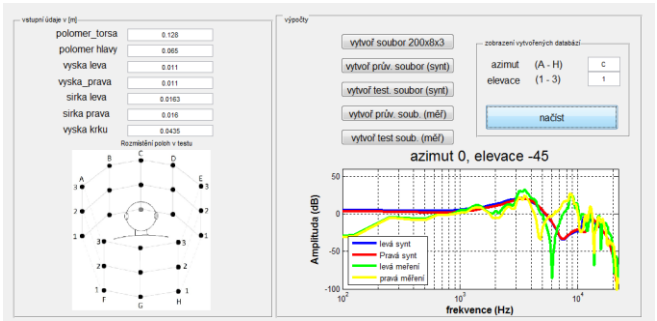


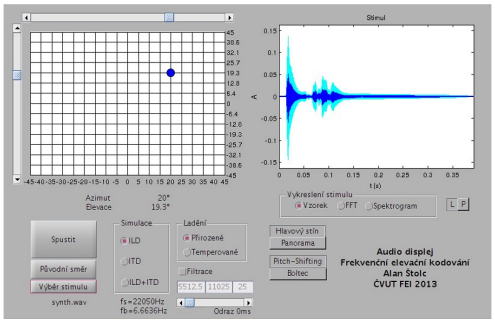


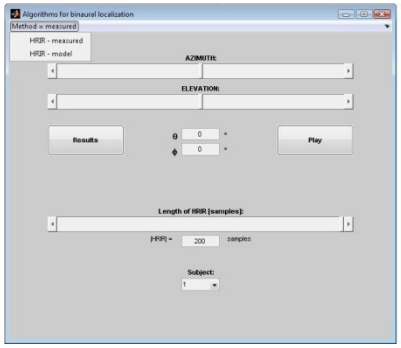
Matlab

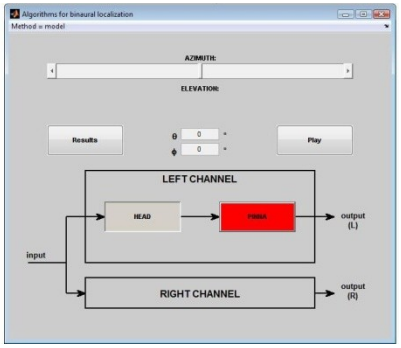
- **Various scripts and GUIs**

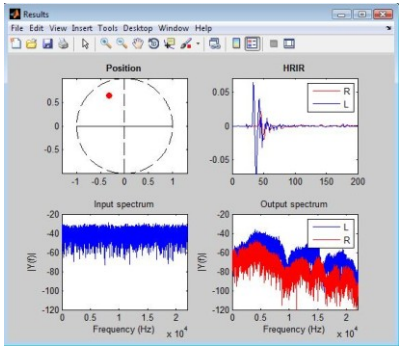


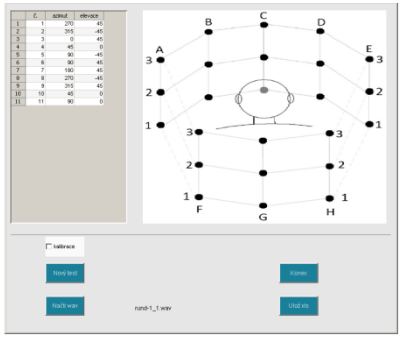


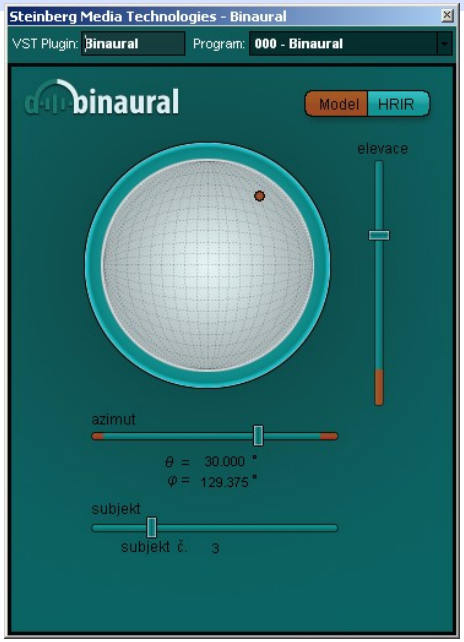
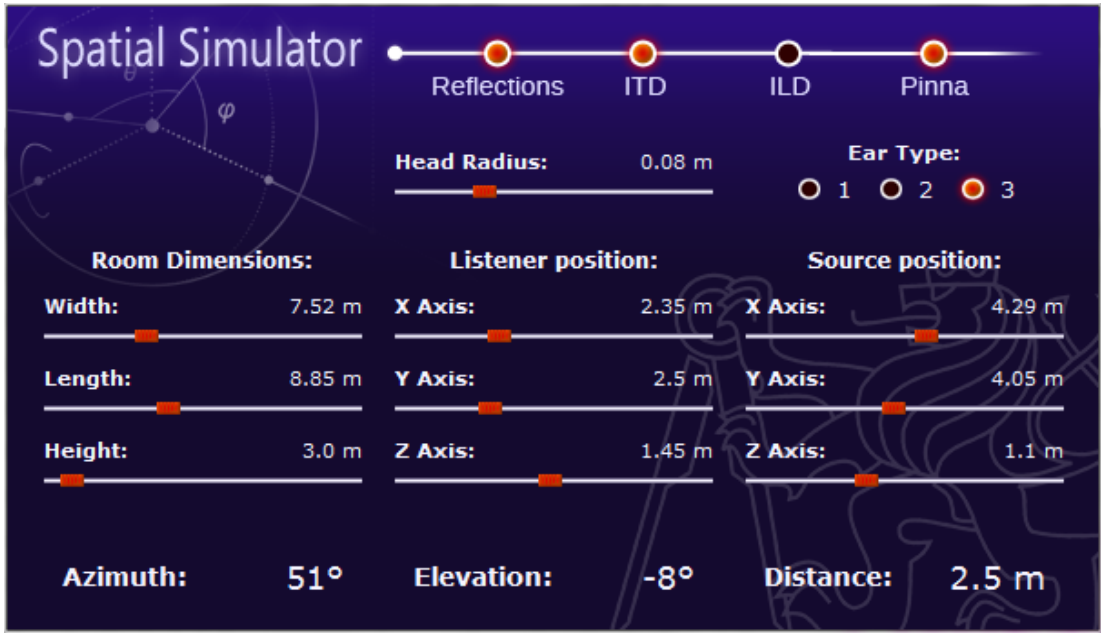










VST

- **Binaural**
  - HRIR from database
  - Simple structural model
- **Spatial Simulator**
  - Simple structural model
  - Room reflections