



APPLICATION OF THE HEAD RELATED TRANSFER FUNCTIONS IN ROOM ACOUSTICS DESIGN USING BEAMFORMING

¹**Mojtaba NAVVAB, PhD.**

Taubman College of Architecture and Urban Planning TCAUP, Bldg. Tech. Lab
UNiversity of Michigan - 2000 Bonisteel Blvd, Ann Arbor MI 48109-2069 USA, E-
mai:moji@umich.edu

Andy MEYER, Dipl. -Ing. & , Gunnar HEILMANN, Dipl. -Wi. -Ing.

Gfai Tech GmbH, Rudower Chaussee 30,
12489 Berlin-Adlershof, Germany

ABSTRACT

Head Related Transfer Function (HRTF) describes how a given sound wave input is filtered by the diffraction and reflection properties of the body, before the sound reaches the eardrum. HRTF measurements of a population of US - American troops in the 1960s provided the data and knowledge of the measurement technology for various acoustic application including artificial head. The use of Acoustic camera allows to perform very complex functions in room acoustic evaluation in real time and examine the room acoustic characteristics under different sound sources and room acoustic conditions. The real time data provides the designers and audio engineer to fine tune or calibrate their sound system for a given standard associated to architectural design. The data obtained through this system also provides the fundamentals to validate the latest software in acoustic design and or audio engineering. The process establishes new room acoustic indexes for pre and post design evaluations.

This paper describes the process in obtaining the HRTF and its conversion to Spatial Frequency Response Surfaces through the format used by MATLAB data files of compensated Head-Related Impulse Response (HRIR) measurements. The measurements were made using Acoustic Camera with its' various settings and capabilities under real room acoustic conditions. Hearing with both ears is defined as binaural hearing. It provides the ability in hearing the sound naturally and accurately. The sound that is received from both ears allows to locate the direction and true spatial perception of sounds. The geometrical parameters of the human body have a major impact on binaural hearing. The application and the analysis of the latest room acoustic measurements by Acoustic Camera allows to examine this concept and new development in the creation of a possible new room acoustic index. This approach will include an improved representation of the current indexes used in architectural design. and contributes to the upgrading of the current standards for room acoustics.

24 & 25 February 2010



Berlin Beamforming Conference

Application of the Head Related Transfer Functions In Room Acoustics Design Using Beamforming

Mojtaba NAVVAB, Ph.D.

Taubman College of Architecture and Urban Planning TCAUP, Bldg. Tech. Lab
University of Michigan - 2000 Bonisteel Blvd, Ann Arbor MI 48109-2069 USA,

E-mail: moji@umich.edu

Andy MEYER, Dipl. -Ing. & , Gunnar HEILMANN, Dipl. -Wi. -Ing.

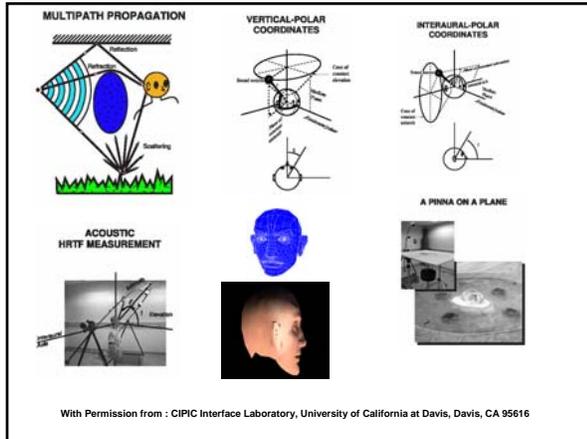
Gfai Tech GmbH, Rudower Chaussee 30,
12489 Berlin-Adlershof, Germany

Abstract: Application of the Head Related Transfer Functions In Room Acoustics Design Using Beamforming

Head Related Transfer Function (HRTF) describes how a given sound wave input is filtered by the diffraction and reflection properties of the body, before the sound reaches the eardrum. HRTF measurements of a population of US - American troops in the 1960s provided the data and knowledge of the measurement technology for various acoustic application including artificial head. The use of Acoustic camera allows to perform very complex functions in room acoustic evaluation in real time and examine the room acoustic characteristics under different sound sources and room acoustic conditions. The real time data provides the designers and audio engineer to fine tune or calibrate their sound system for a given standard associated to architectural design. The data obtain through this system also provides the fundamentals to validate the latest software in acoustic design and or audio engineering. The process establishes new room acoustic indexes for pre and post design evaluations.

This paper describes the process in obtaining the HRTF and its conversion to Spatial Frequency Response Surfaces through the format used by MATLAB data files of compensated Head-Related Impulse Response (HRIR) measurements. The measurements were made using Acoustic Camera with its various settings and capabilities under real room acoustic conditions. Hearing with both ears is defined as binaural hearing. It provides the ability in hearing the sound naturally and accurately. The sound that is received from both ears allows to locate the direction and true spatial perception of sounds.

The geometrical parameters of the human body have a major impact on binaural hearing. The application and the analysis of the latest room acoustic measurements by Acoustic Camera allows to examine this concept and new development in the creation of a possible new room acoustic index. This approach will include an improved representation of the current indexes used in architectural design, and contributes to the upgrading of the current standards for room acoustics.



With Permission from : CIPIC Interface Laboratory, University of California at Davis, Davis, CA 95616



With Permission from : CIPIC Interface Laboratory, University of California at Davis, Davis, CA 95616



With Permission from : CIPIC Interface Laboratory, University of California at Davis, Davis, CA 95616

Wave equation:
$$\frac{\partial^2 p'}{\partial t^2} = c^2 \left(\frac{\partial^2 p'}{\partial x^2} + \frac{\partial^2 p'}{\partial y^2} + \frac{\partial^2 p'}{\partial z^2} \right) = c^2 \nabla^2 p'$$

Fourier Transform from Time to Frequency Domain
$$p'(x, y, z, t) = \int_{-\infty}^{\infty} P(x, y, z, \omega) e^{-i\omega t} d\omega$$

Helmholtz equation:
$$\nabla^2 P + k^2 P = 0$$

Boundary conditions:

Sound-hard boundaries:
$$\frac{\partial P}{\partial n} = 0$$

Sound-soft boundaries:
$$P = 0$$

Impedance boundary conditions:
$$\frac{\partial P}{\partial n} + i\sigma P = g$$

Sommerfeld radiation condition (for infinite domains):
$$\lim_{r \rightarrow \infty} r \left(\frac{\partial P}{\partial r} - ikP \right) = 0$$

With Permission from : CIPIC Interface Laboratory, University of California at Davis, Davis, CA 95616

- **Boundary Element Method**
- Obtain a mesh
- Using Green's function G

$$G(\mathbf{x}, \mathbf{y}) = \frac{e^{i\mathbf{k} \cdot \mathbf{y} - |\mathbf{x} - \mathbf{y}|}}{4\pi |\mathbf{x} - \mathbf{y}|}$$

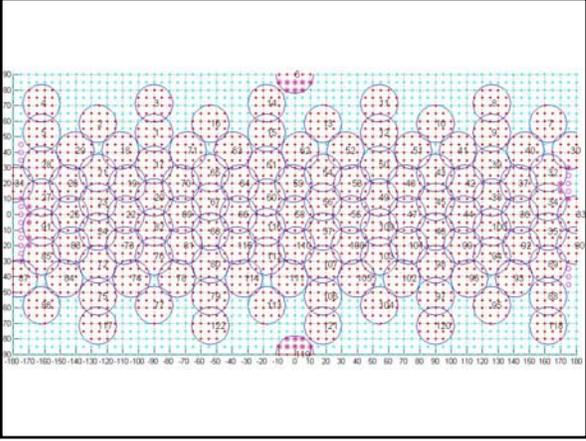
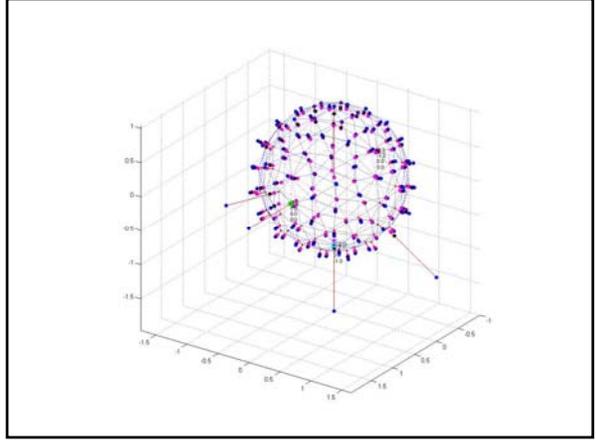
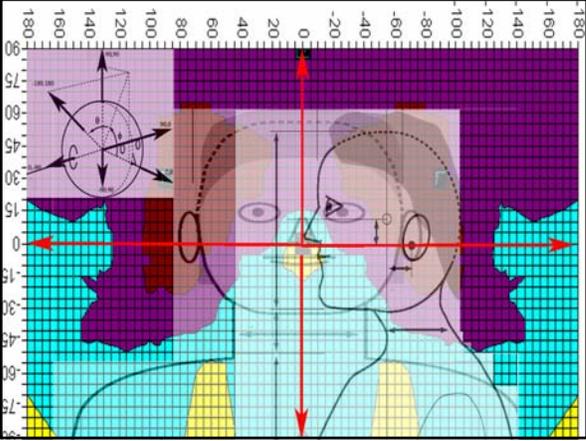
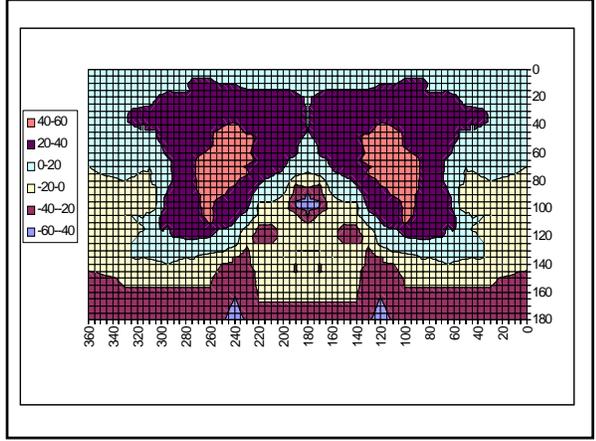
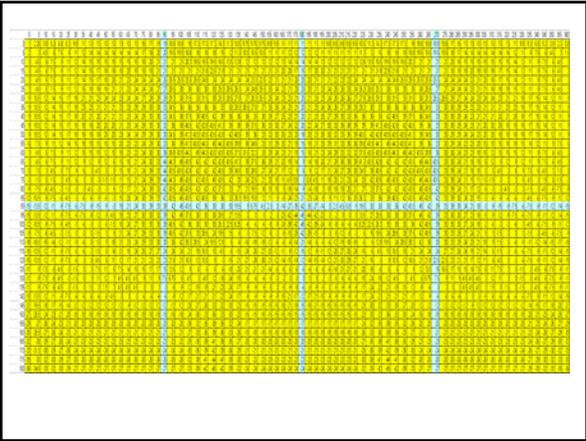
- Convert equation and b.c.s to an integral equation

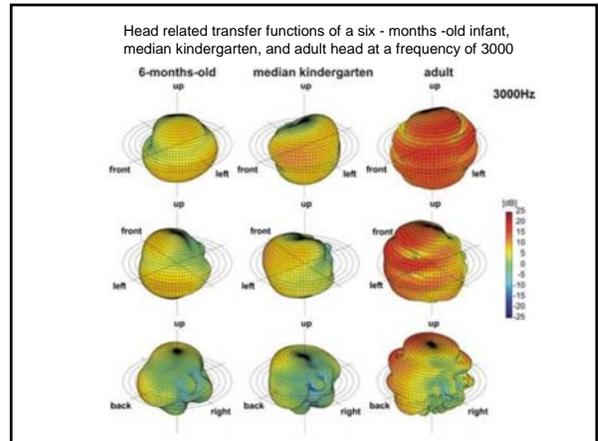
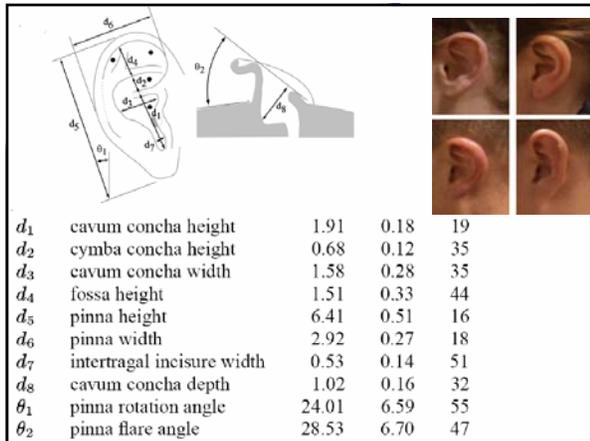
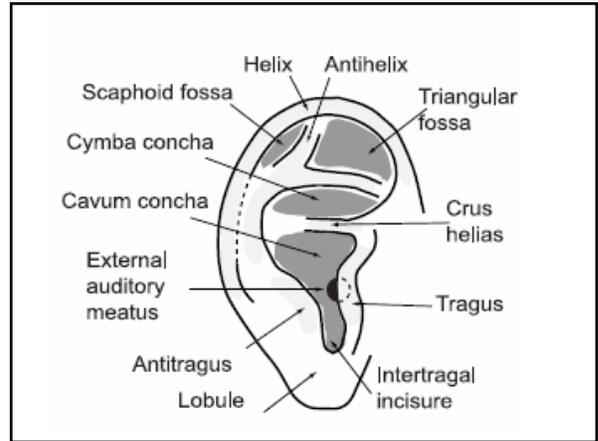
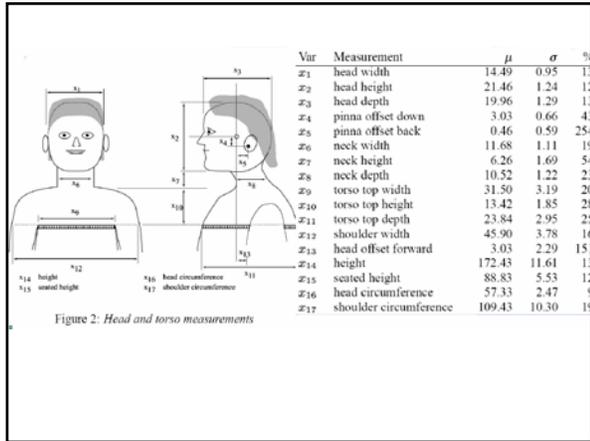
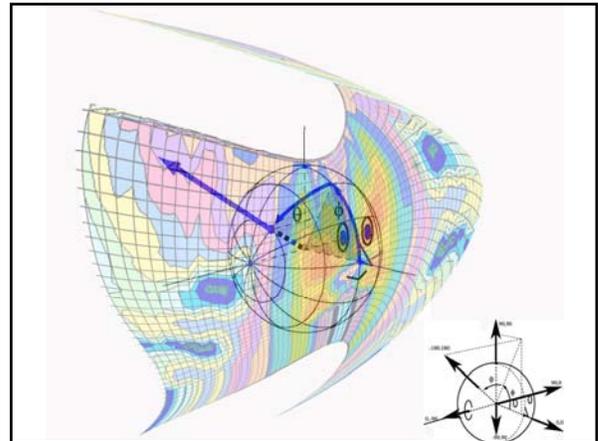
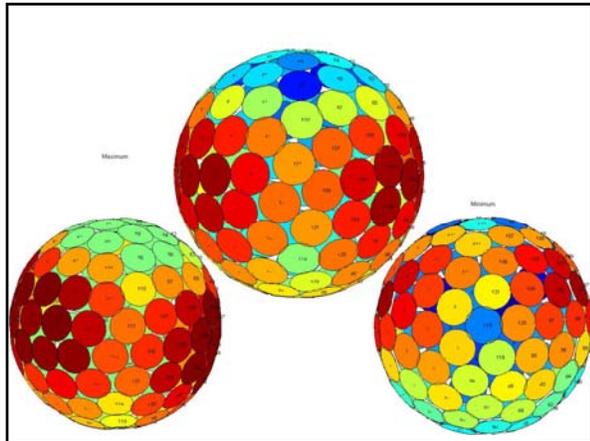
$$C(x)p(x) = \int_{\Gamma_y} \left[G(x, y; k) \frac{\partial p(y)}{\partial n_y} - \frac{\partial G(x, y; k)}{\partial n_y} p(y) \right] d\Gamma_y$$

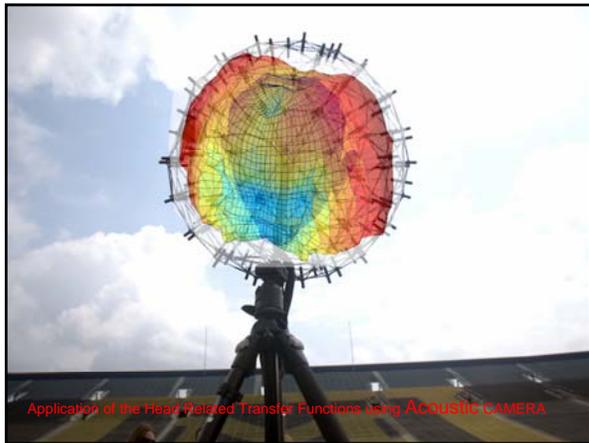
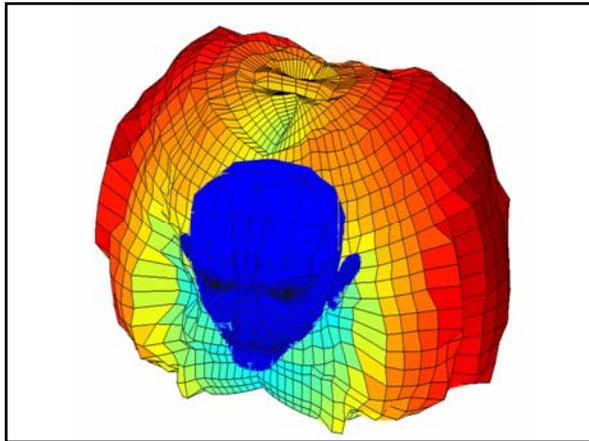
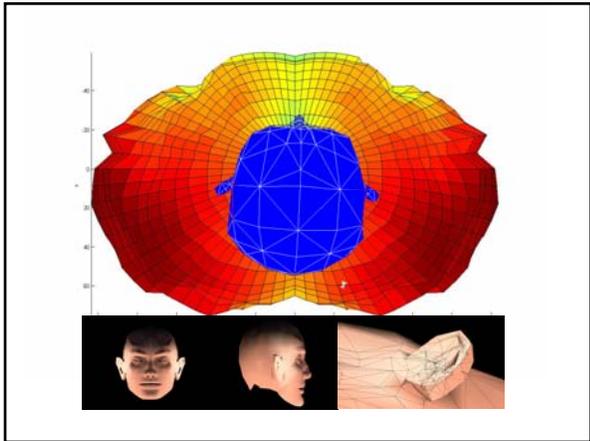
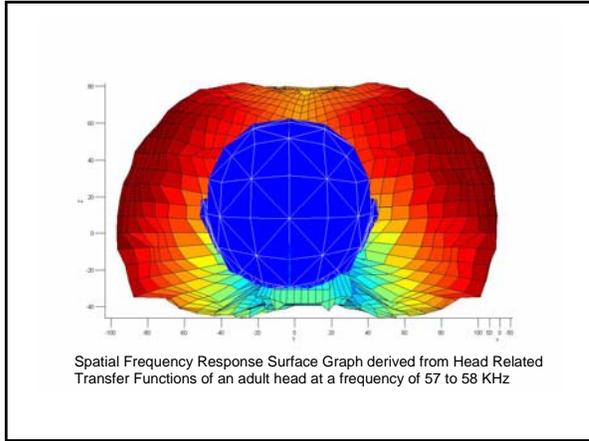
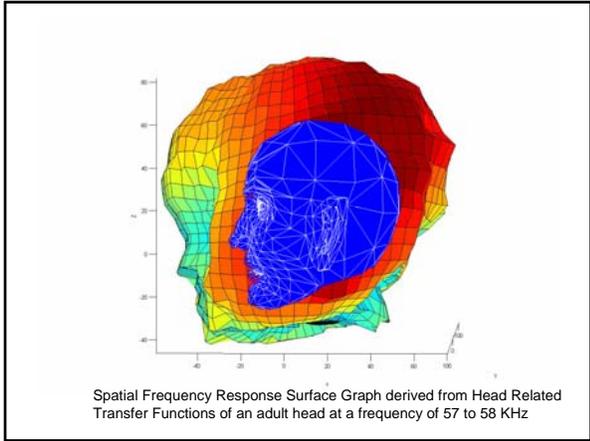
- Need accurate surface meshes of individuals

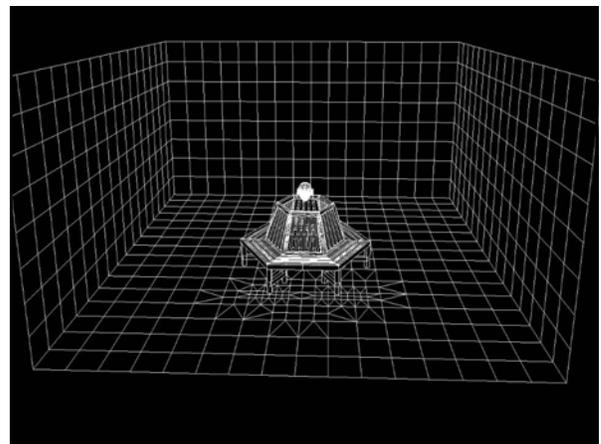
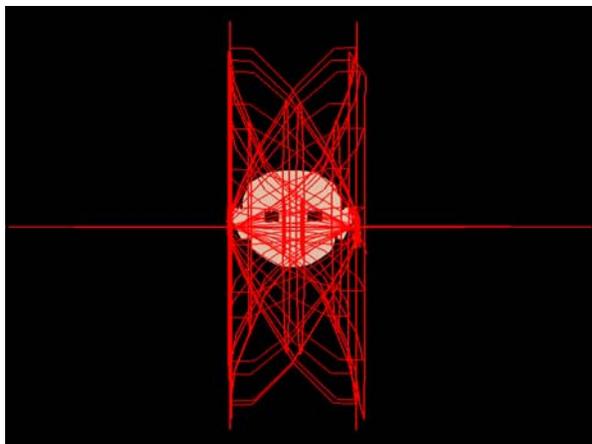
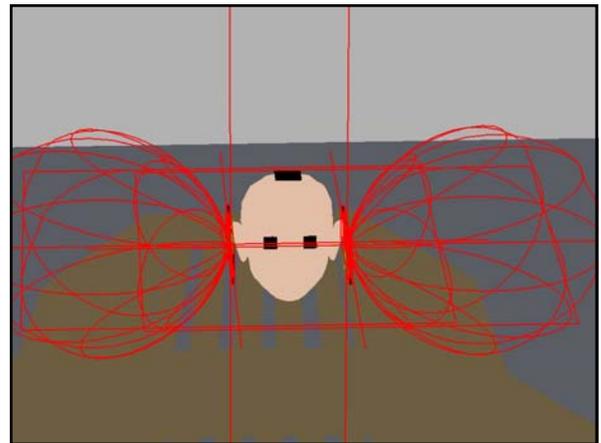
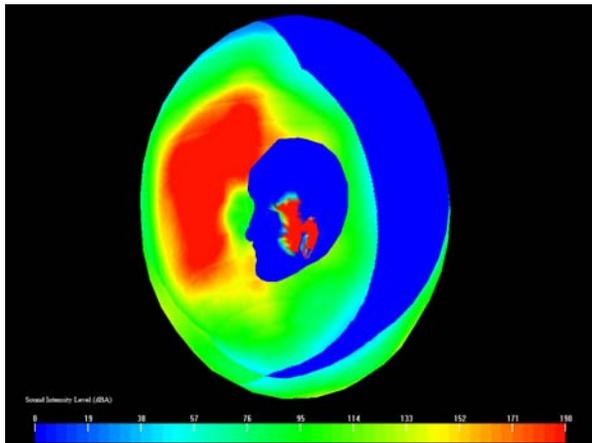
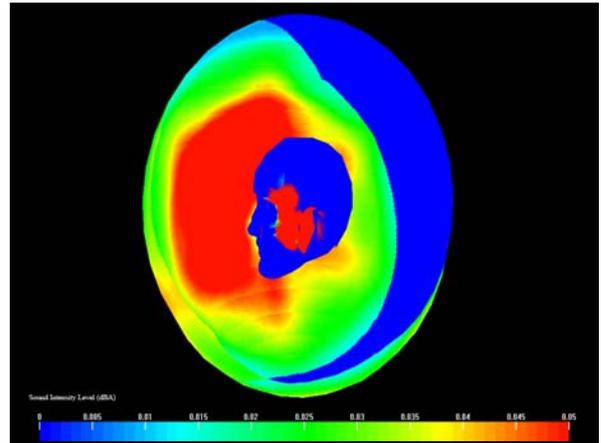
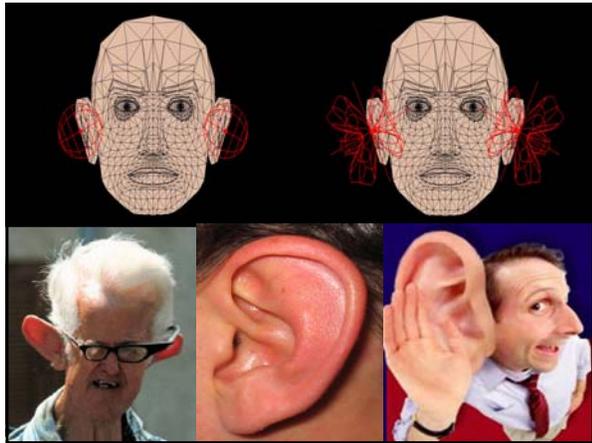


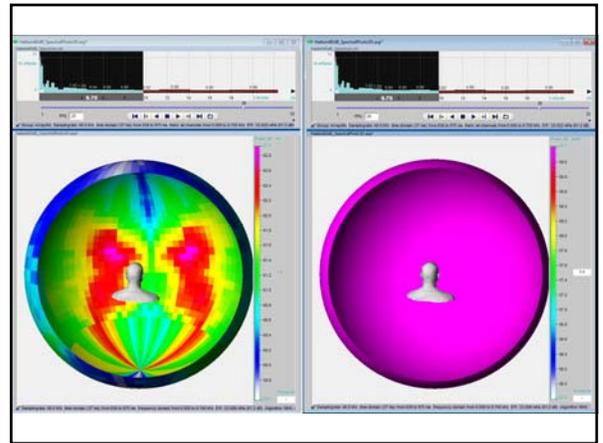
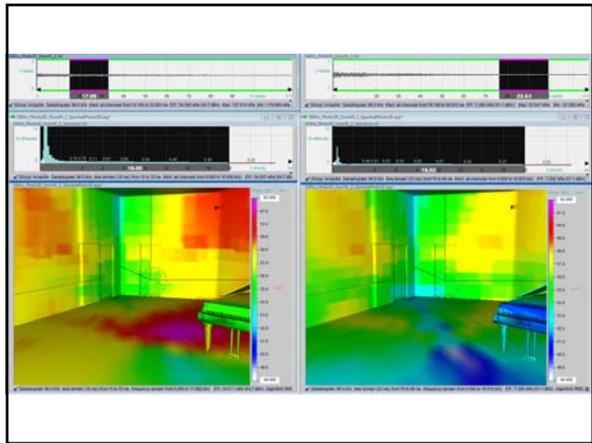
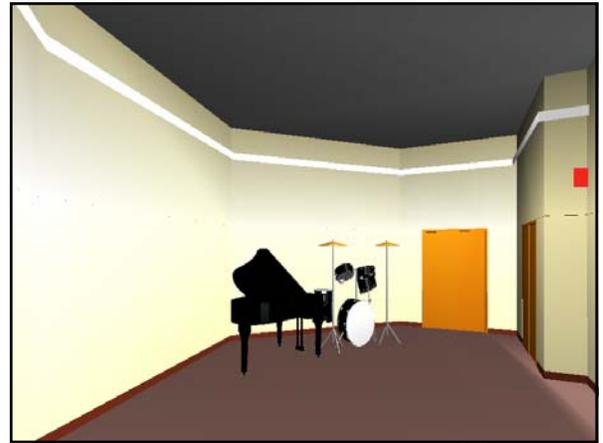
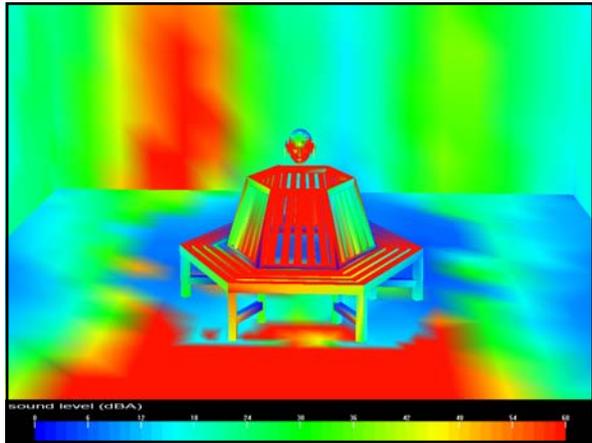
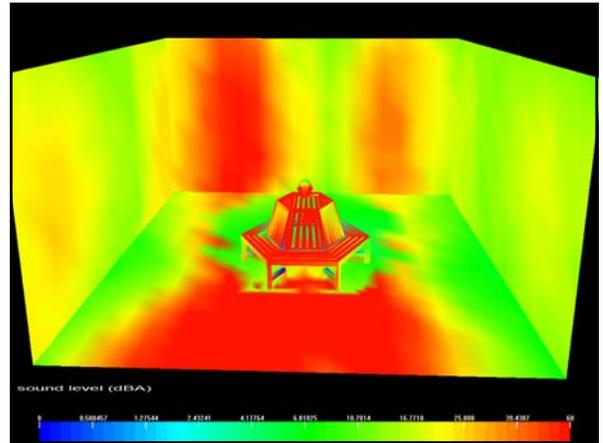
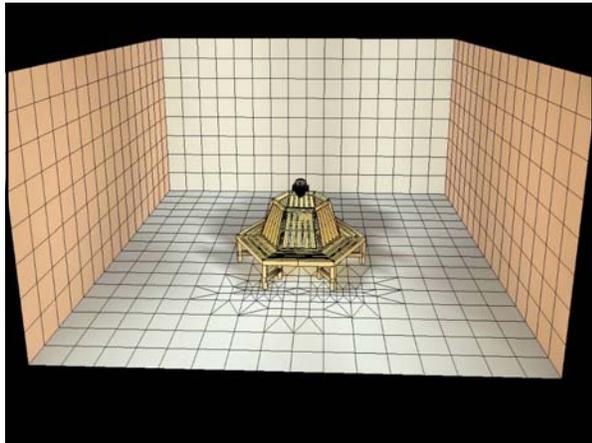
With Permission from : CIPI Interface Laboratory, University of California at Davis, Davis, CA 95616

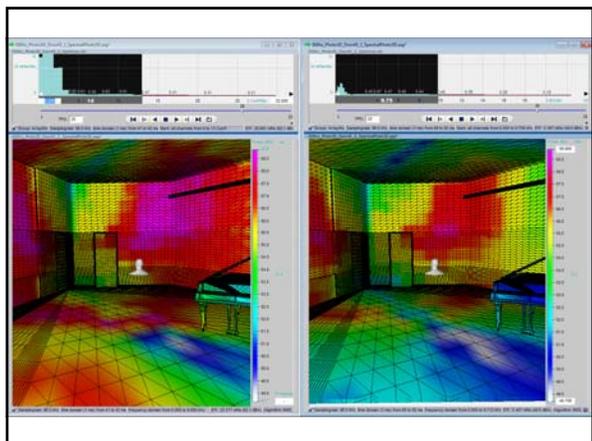












Application of the Head Related Transfer Functions

1. Auto Industry
2. Classrooms / Lecture Hall
3. Indoor sport arena (Basketball)
4. Outdoor sport (American Football)
5. Recording studio

Application of the Head Related Transfer Functions

Within

Virtual Reality laboratory

Recording studio

