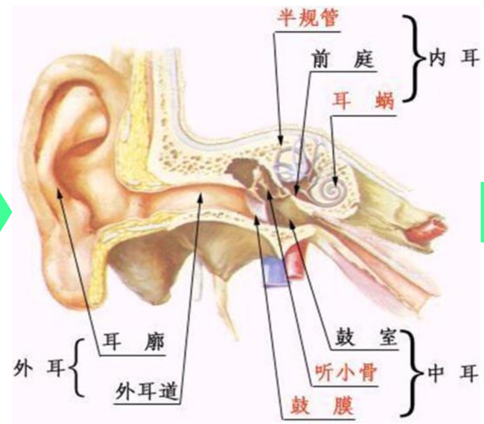
三维音频技术与应用

李军锋

中国科学院声学研究所

三维音频基础

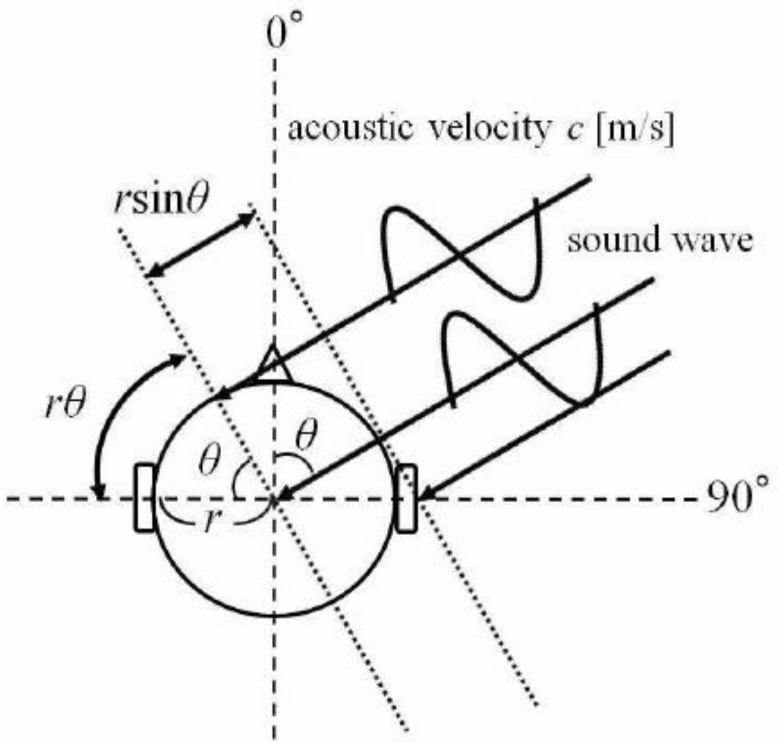
物理过程



生理过程

心理过程

三维音频基础



ITD & ILD

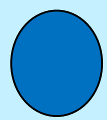
HRTF

三维音频基础

音频信号分类

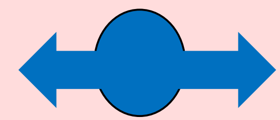
单通道

- 内容可知



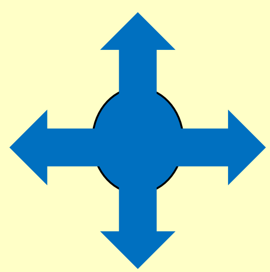
立体声

- 内容可知
- 左右可分



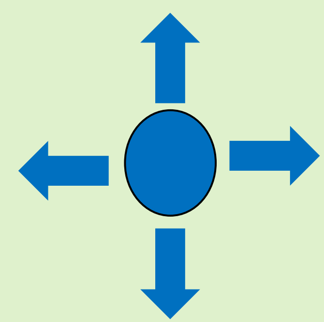
环绕声

- 内容可知
- 左右可分
- 前后可分

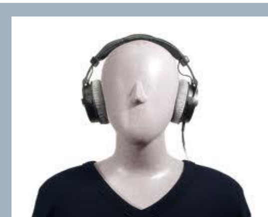
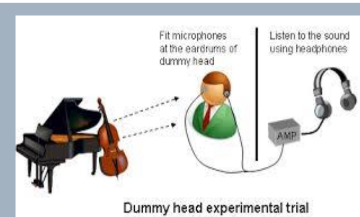
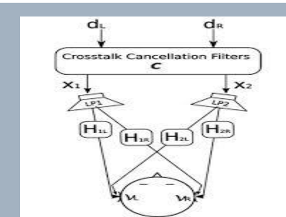
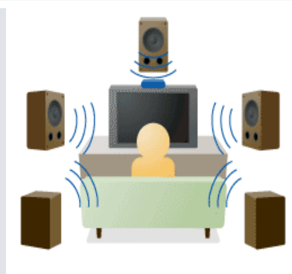
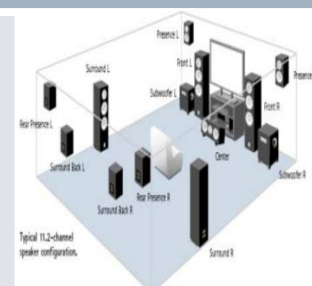
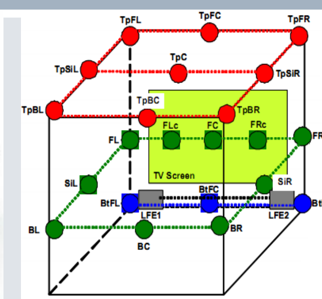
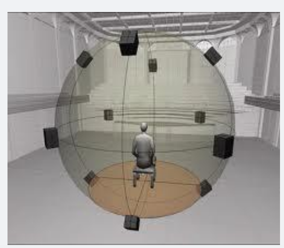
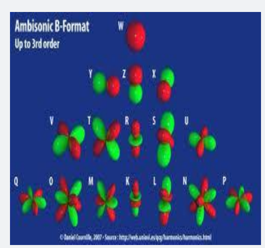
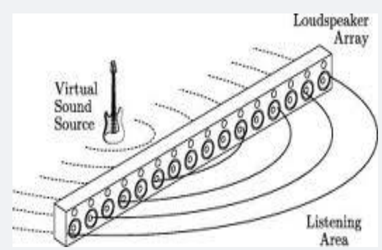


3D

- 内容可知
- 左右可分
- 前后可分
- 上下可分
- 距离可分



三维音频重放技术

基于双耳感知的3D音频重放技术	   Binaural technology
多通路3D音频重放技术	 Dolby 5.1  Yamaha 11.2  Dolby 9.1  NHK 22.2
基于物理声场的3D音频重放技术	  Ambisonics   Wavefield synthesis

三维音频基础理论与方法—传统方法

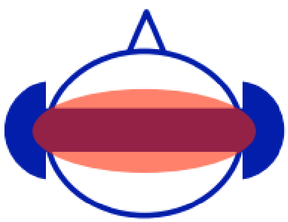
- 电话
  - 单通道
  - 0.3~3.4kHz

- 立体声
  - 双通道
  - ~22.05kHz

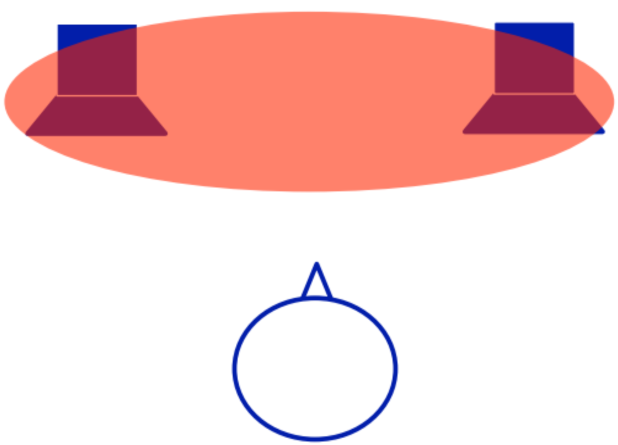
- 5.1环绕声
  - 5.1通道
  - ~48kHz

三维音频基础理论与方法—传统方法

立体声



耳机重放



扬声器重放

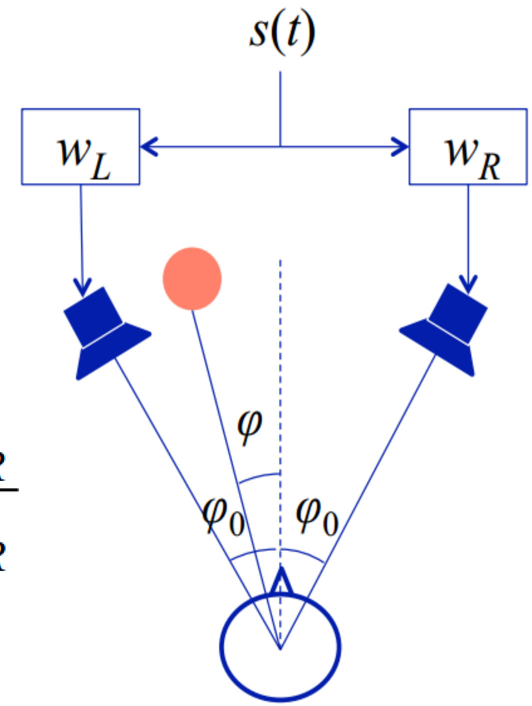
立体声原理

- 正弦法则

$$\frac{\sin\varphi}{\sin\varphi_0}=\frac{w_L-w_R}{w_L+w_R}$$

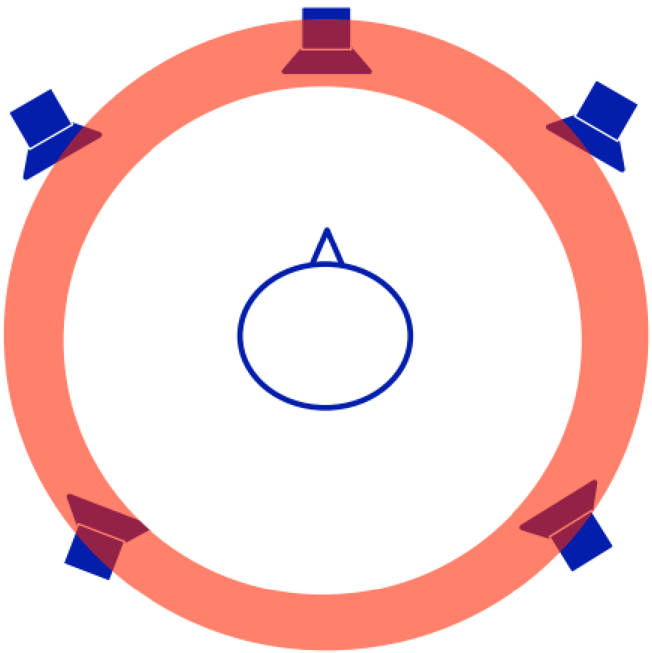
- 正切法则

$$\frac{\tan\varphi}{\tan\varphi_0}=\frac{w_L-w_R}{w_L+w_R}$$

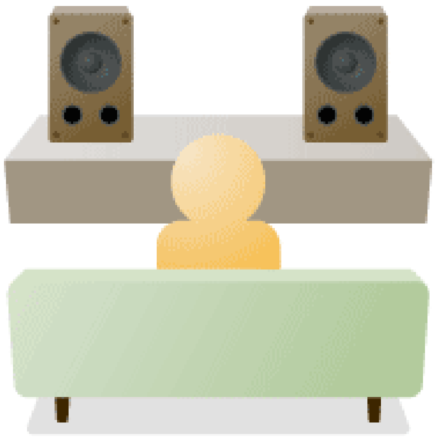


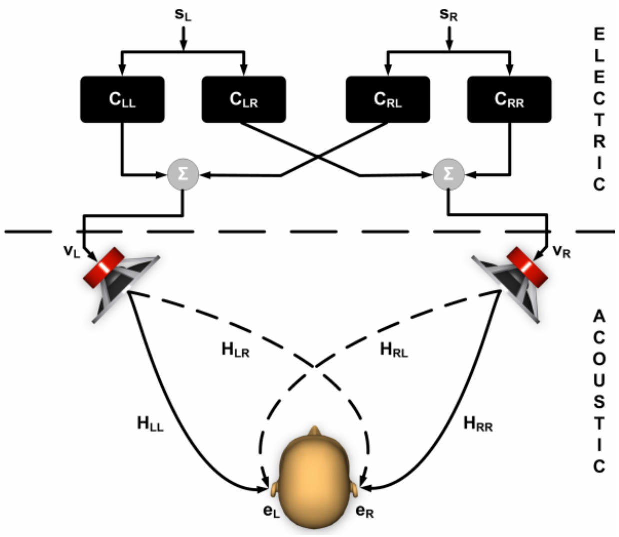
三维音频基础理论与方法—传统方法

- 5.1环绕声
  - 前后左右声像（√）
  - 上下声像（×）



三维音频基础理论与方法—双耳技术

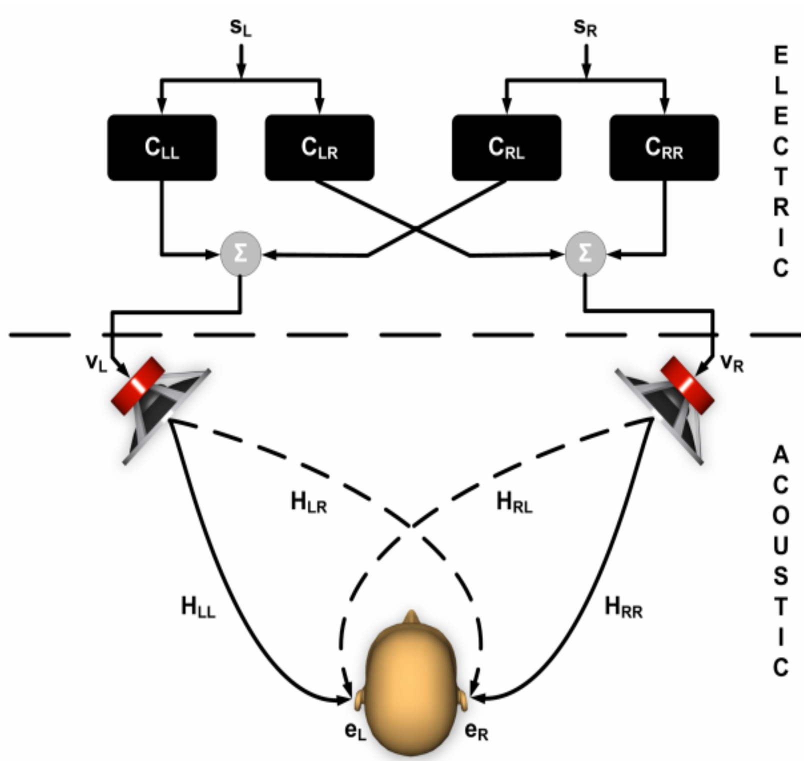




串声消除

三维音频基础理论与方法—双耳技术

问题描述



Assume:

$$e_L(z) = H_{LL}(z)s_L(z) + H_{RL}(z)s_R(z),$$
$$e_R(z) = H_{LR}(z)s_L(z) + H_{RR}(z)s_R(z),$$
$$\boldsymbol{e}(z) = \begin{bmatrix} e_L(z) & e_R(z) \end{bmatrix}^T;$$
$$\boldsymbol{s}(z) = \begin{bmatrix} s_L(z) & s_R(z) \end{bmatrix}^T$$
$$\boldsymbol{H}(z) = \begin{bmatrix} H_{LL}(z) & H_{RL}(z) \\ H_{LR}(z) & H_{RR}(z) \end{bmatrix},$$

Then:

$$\boldsymbol{e}(z) = \boldsymbol{H}(z)\boldsymbol{C}(z)\boldsymbol{s}(z).$$

$$C(z) = H^{-1}(z)e^{j\omega\Delta}.$$

三维音频基础理论与方法—双耳技术

串声消除方法

- Least-Squares Approximation
- Stereo Diploe & OSD (Southampton)
- RACE (Ambiphonic)
- BACCH (Princeton)

英国南开普敦大学
Nelson教授

Takeuchi博士

http://www.marantz.jp

美国ambiophonics公司
Ralph Glasgal

http://www.ambiophonics.org/index.html

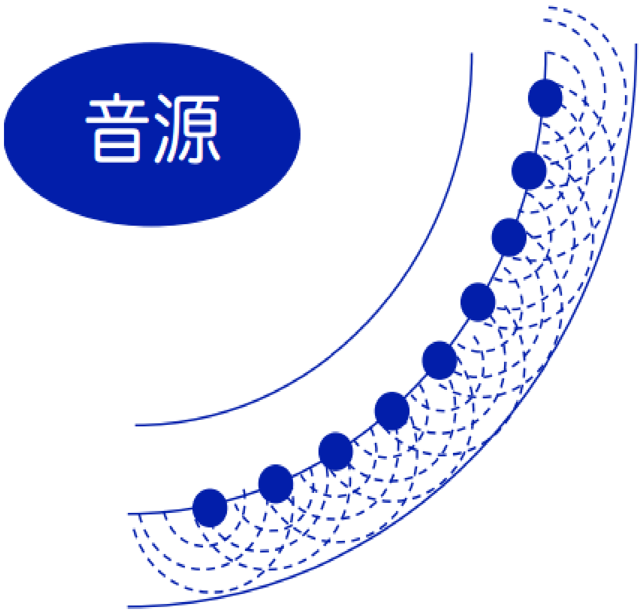
美国普林斯顿大学
Choueiri教授

http://www.cambridgemechatronics.com/

三维音频基础理论与方法——波场合成

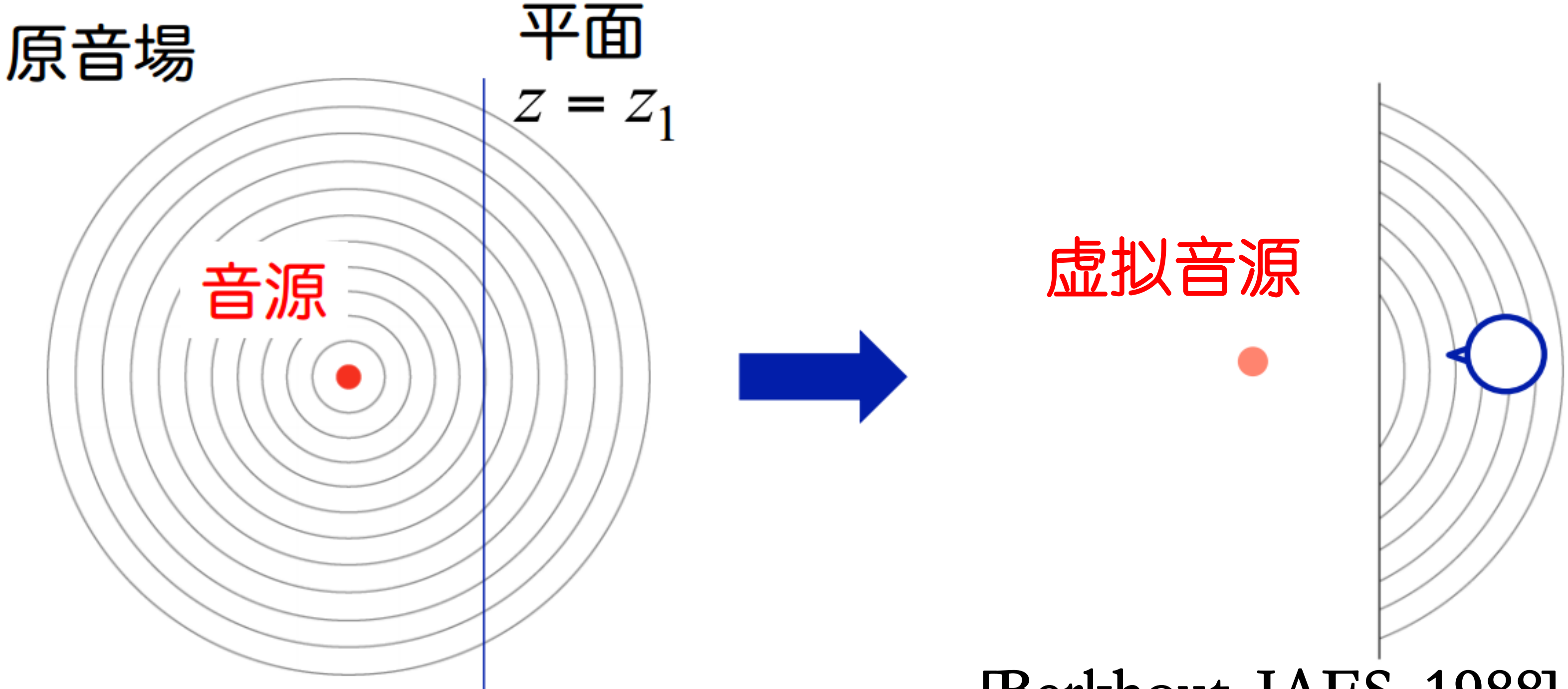
- 惠更斯（Huygens）原理

当波行进时，波前上的每一点都可视为新的点波源，以其为圆心或球心，各自发出圆形波或球面波。



三维音频基础理论与方法—波场合成

$$p(\mathbf{s}) = |z - z_1| \iint_S p(\mathbf{r}) \frac{1 + jk|\mathbf{r}-\mathbf{s}|}{2\pi|\mathbf{r}-\mathbf{s}|^3} \cdot e^{-jk|\mathbf{r}-\mathbf{s}|} dS$$

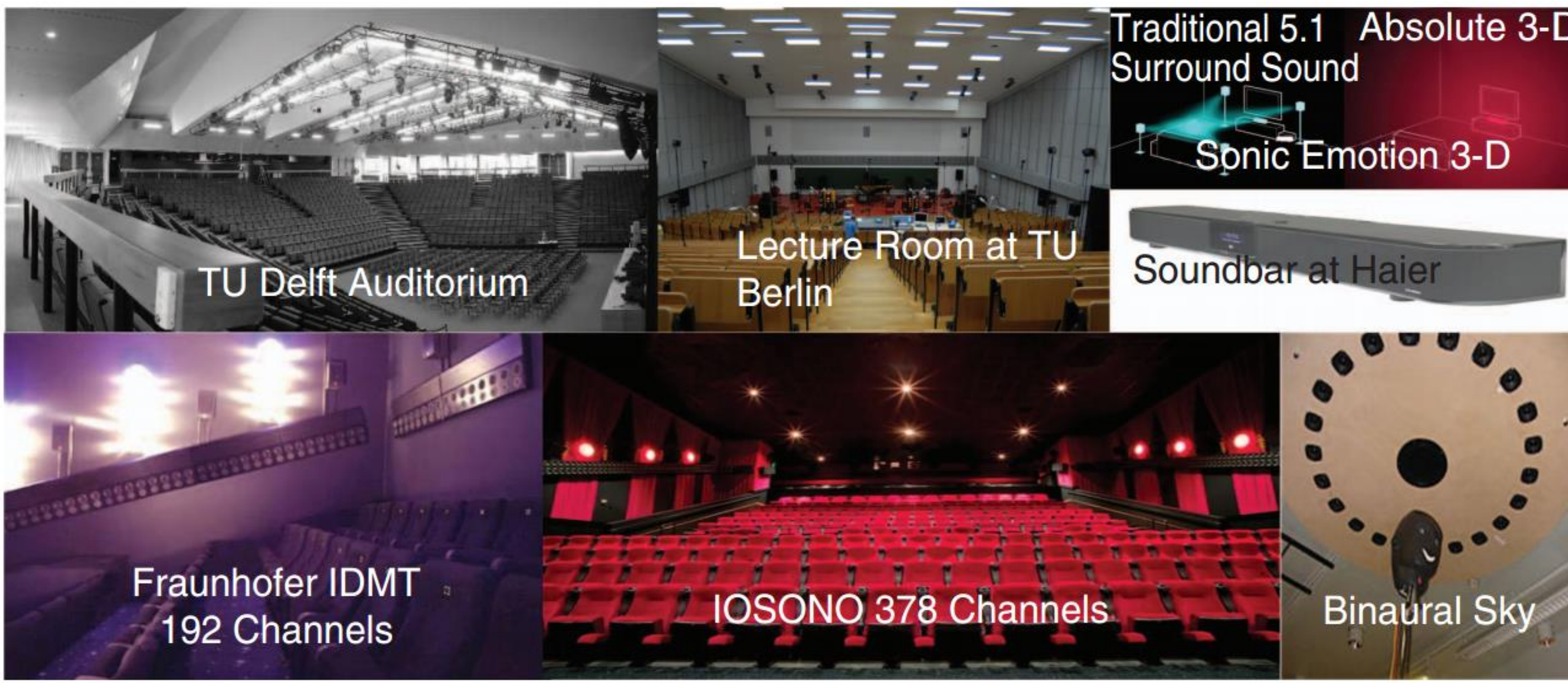


[Berkhout, JAES, 1988]

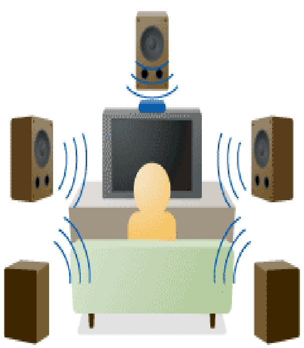
三维音频基础理论与方法—波场合成

EU项目（CARROUSO)

Sonic emotion 公司（http://www2.sonicemotion.com/）
IOSONO公司（http://www.iosono-sound.com/home/)

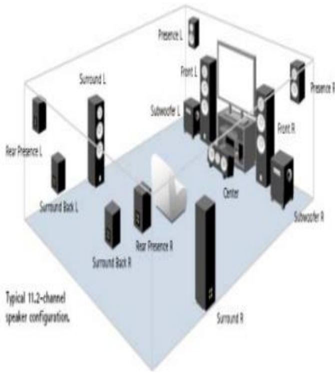


三维音频基础理论与方法——多通道方法

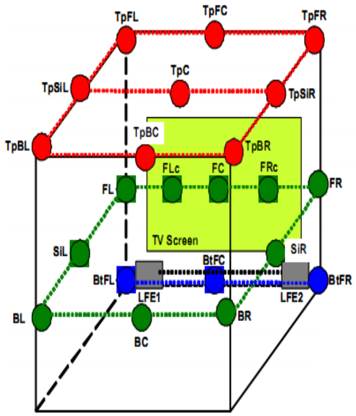


Dolby 5.1

Dolby 9.1



Yamaha 11.2



NHK 22.2

三维音频基础理论与方法——多通道方法

三维音频@中科院声学所

耳机重放

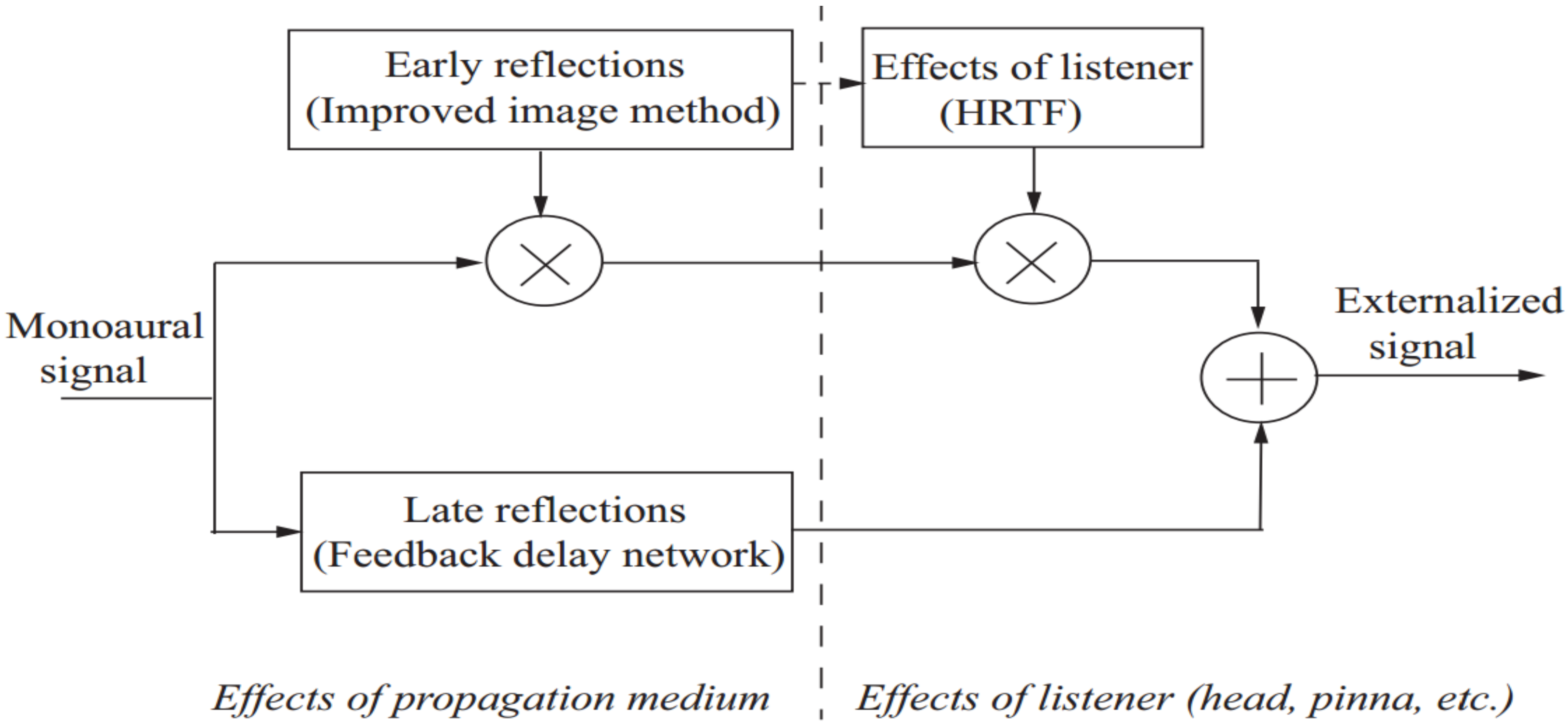
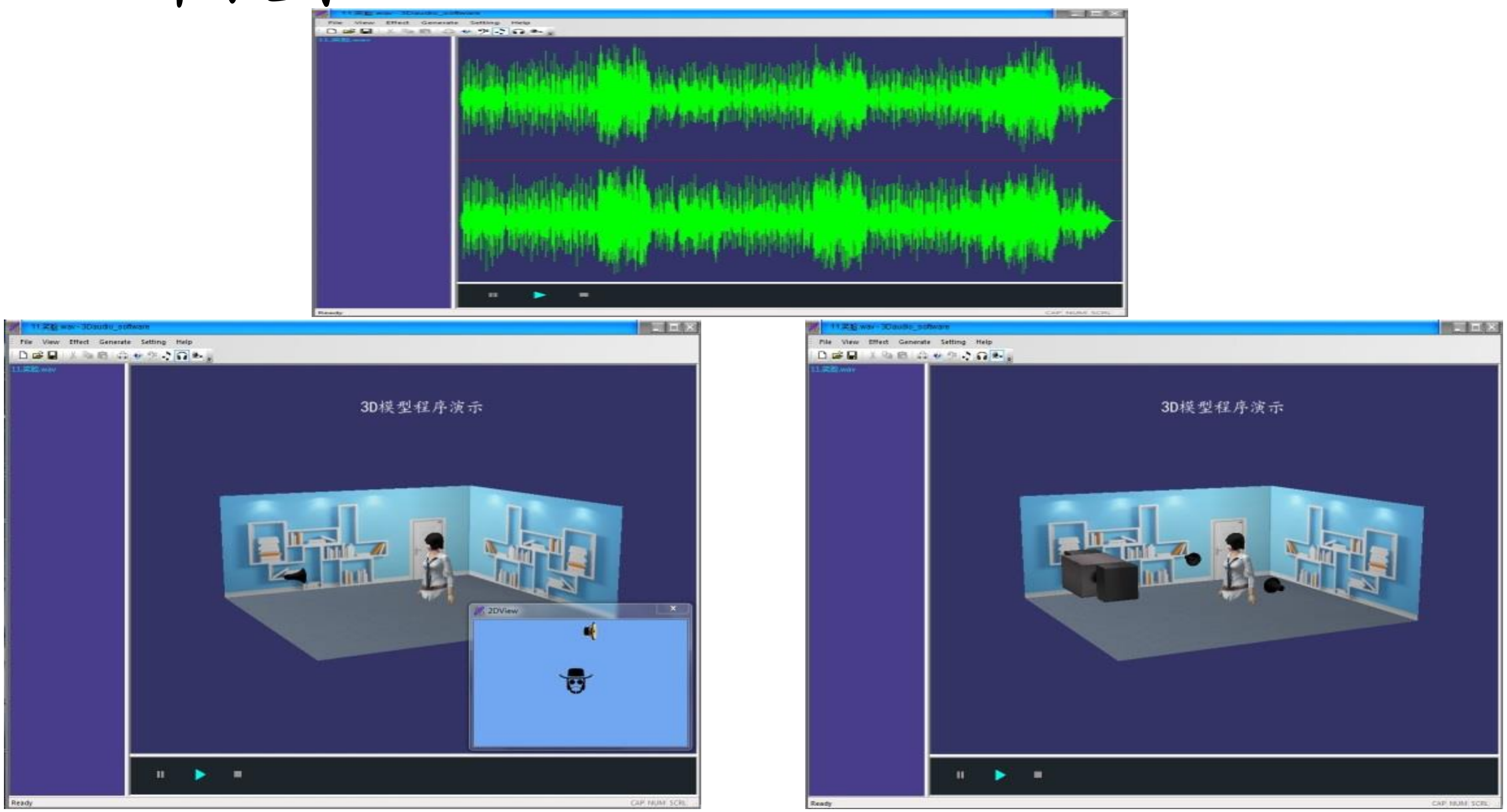


Fig.1 Block diagram of the proposed sound image externalization system for headphone reproduction.

三维音频@中科院声学所

□ 双耳技术



基于双耳技术的重放系统

声像距离重建

- 声像距离重建是三维声信号重放的重要部分。将基于镜像法的混响合成融入波长合成技术中，实现了声像感知距离的重建

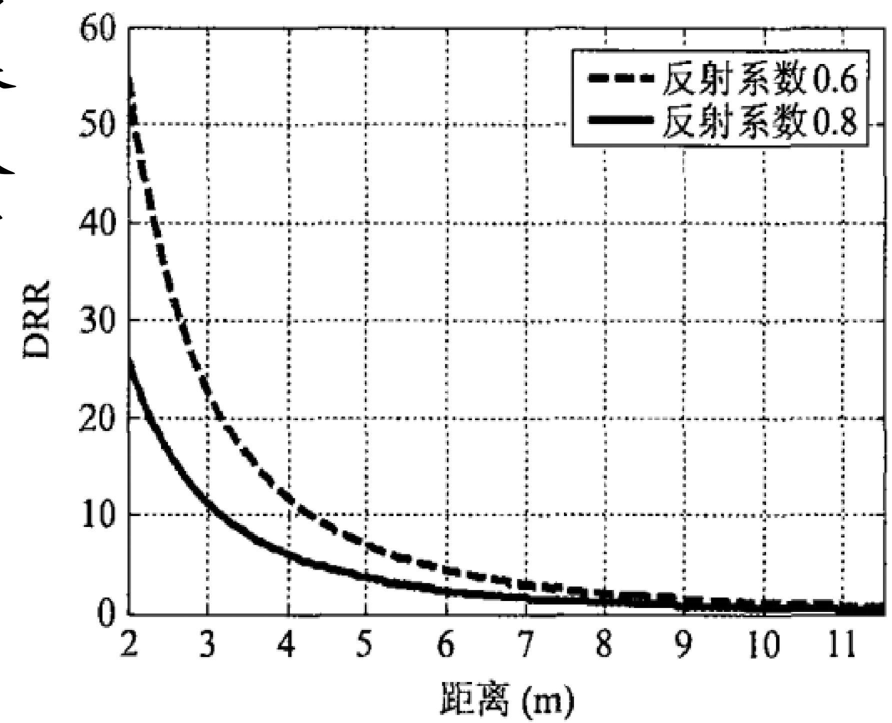


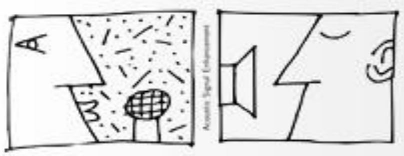
图 DRR 与距离和反射系数之间的关系

三维音频@中科院声学所

- WFS重放

24通道WFS重放系统

三维音频



- Home
- Committees
- Call for Papers
- Program
  - Keynote Talks
  - Papers and Authors
  - Tuesday, Sep. 4th
  - Wednesday, Sep. 5th
  - Thursday, Sep. 6th
  - Social Events
  - Satellite Workshop

Keynote Talks

Tue., Sep. 4th 09:15	Peter Kroon Media Signal Processing in Cell Phones – What is so Smart about it?
Tue., Sep. 4th 10:45	Peter Jax Signal Enhancement for Future High-Resolution Spatial Audio Formats
Tue., Sep. 4th 14:00	Jan Skoglund Interactive Audio in a Web-Based World
Tue., Sep. 4th 16:30	Bernd Geiser Paths toward HD-Voice Communication
Wed., Sep. 5th 09:00	Patrick Naylor Acoustic Signal Processing in Noise: It's Not Getting Any Quieter
Thu., Sep. 6th 09:00	Richard Heusdens Distributed Signal Processing: Application to MVDR Beam-Forming
Thu., Sep. 6th 11:00	Henning Puder Optimized Directional Processing in Hearing Aids with Integrated Spatial Noise Reduction

谢 谢！