Phantom images in 2-channel audio playback versus natural hearing processes

Implications upon loudspeaker, room & recording design for “accurate” capture and reproduction of an auditory scene

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Hearing happens between the ears

We use:

- Intensity differences
- Time differences
- Frequency analysis
- Stream segregation
- Pattern recognition
- Prioritizing Learning
Sensing threads to life in different scenarios

Sound - Sight - Touch - Smell - Taste

Sound source
- Direction
- Distance
- Size
- Reflections

versus

Acoustic background

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Drift thresholds for one and two reflections

Fig. 2.6. Drift threshold (DT) of a second reflection $R_2$, continuous speech

Peter Damaske, Acoustics and Hearing, Springer 2008
Binaural recording & reproduction

Phantom images are
- inside the head when in front
- too close when on side
- behind when above
- volume dependent for distance
- turning with head
- without skin vibration
“Accurate” recording & reproduction of an auditory scene

A phantom image with minimal room influence

A natural perspective for the recording

MICROPHONES

EARS

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Direct signals, crosstalk, reflections

Phantom image spread & diffuseness
Room reflections & perceived frequency response

Direct & reflected sounds determine in-room response at the listener

L - R symmetry of reflections for phantom image positioning

Loudspeakers >3 feet from reflecting surfaces (>6 ms delay)

Each reflection with same spectral content as the direct sound (= delayed copies)

Listener’s brain can safely blank out the room & focus on the direct sound !!!

Below 150 Hz use dipole bass
A few room modes can be equalized parametrically

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Acoustically hiding L & R loudspeakers

Flat on-axis response in free-field

Frequency independent polar response

Acoustically small size
($\lambda = 13$ inch @ 1kHz)

Low cabinet edge diffraction

Low stored energy (resonances)

Low non-linear distortion
(new sounds, intermodulation)

Large dynamic range, high SPL

Hide loudspeakers visually

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Stereo recording & reproduction

Phantom image placement between loudspeakers & not L or R crowding

Recording angle

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Imaging between L & R loudspeakers vs. sound incidence angle

\[ \text{Time } \Delta t = \frac{500 \times \sin \beta}{c} \]  
\[ \text{Phase } \Delta \phi = 180 \times \frac{\Delta t}{\text{time}} \times \sin \beta \text{ [degree]} \]
Concert hall to living room mapping

Phantom images between loudspeakers
Soundfield recording for stereo

Cardioid main microphones for clarity & image placement

Omni microphones in rear for decorrelated spatial pickup

Listener’s brain for assembling a believable illusion of sounds in their spatial context

Combining main & ambient microphone outputs by using a trustworthy loudspeaker/room setup
“Accurate” stereo recording & reproduction

Microphones

Loudspeakers & setup for minimal room contribution

Recordings with a natural perspective

Ears

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Thank you for your attention

QUESTIONS?

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