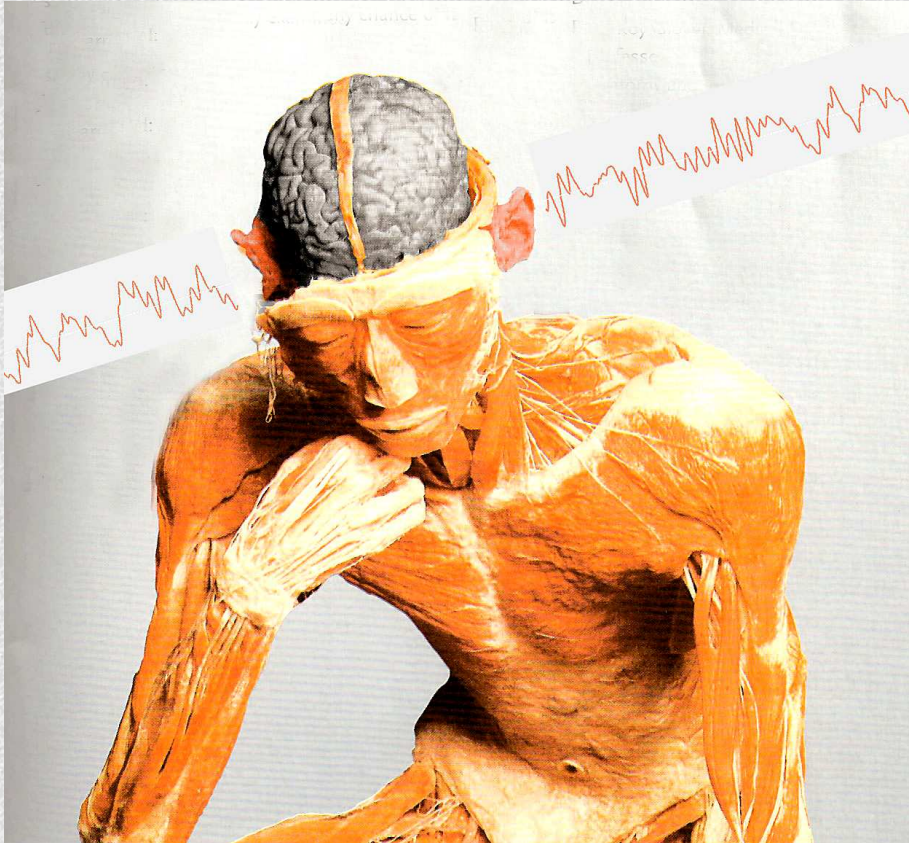# Phantom images
in 2-channel audio playback
versus natural hearing processes

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

Siegfried Linkwitz

LINKWITZ LAB

Hearing happens between the ears

We use:

Intensity **differences**
Time **differences**
Frequency **analysis**

Stream **segregation**
Pattern **recognition**
Prioritizing
Learning

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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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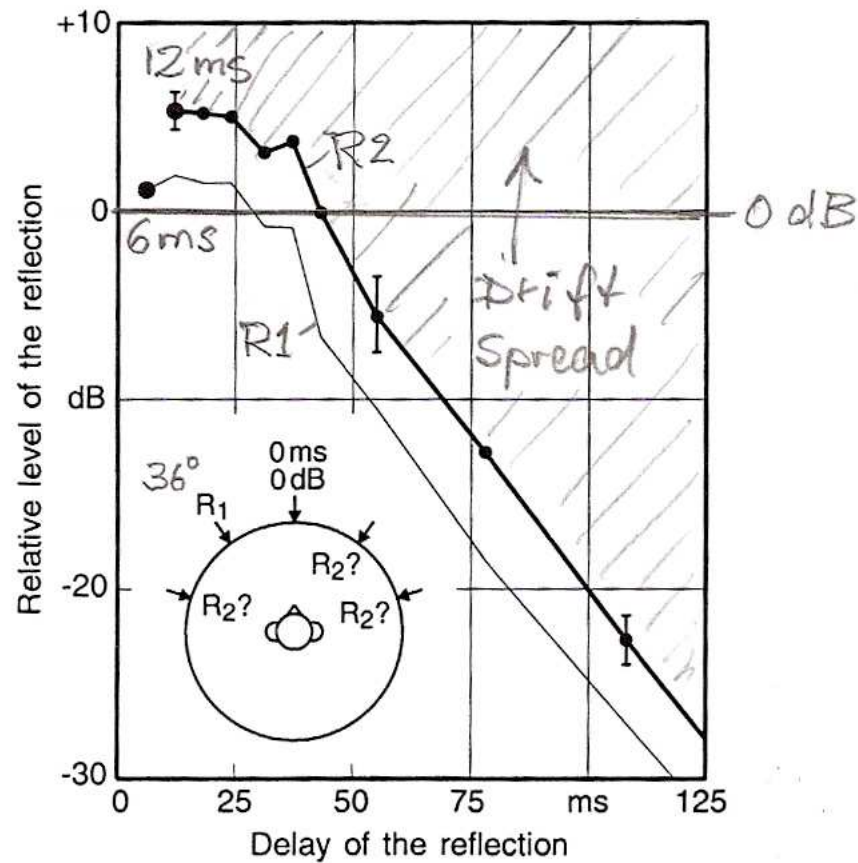
Drift thresholds for one and two reflections

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**

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"Accurate" recording & reproduction of an auditory scene

A phantom image with minimal room influence

Microphones

Ears
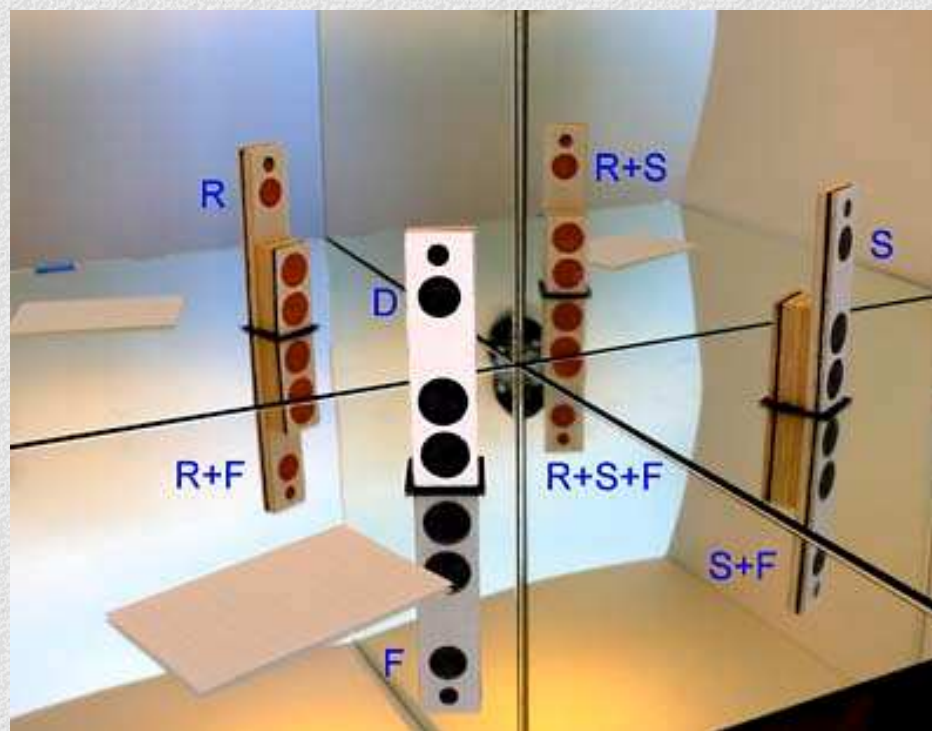
A natural perspective for the recording

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Direct signals, crosstalk, reflections
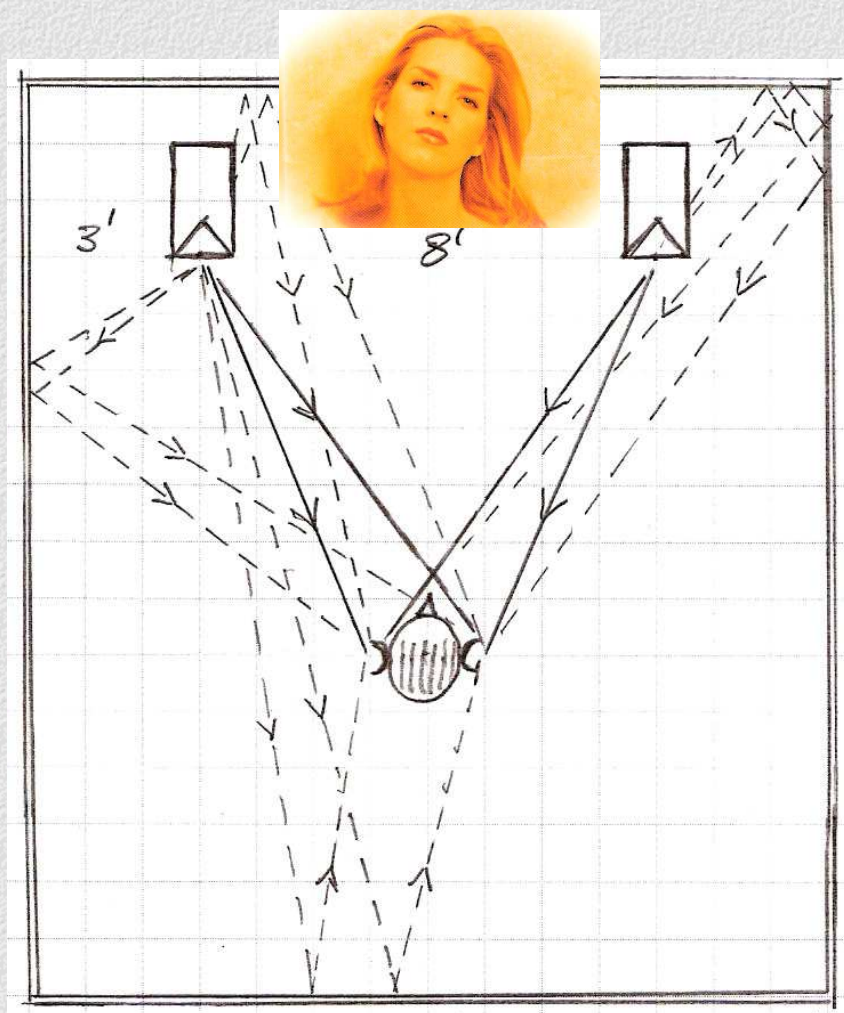
Phantom image spread & diffuseness

Room reflections & perceived frequency response

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

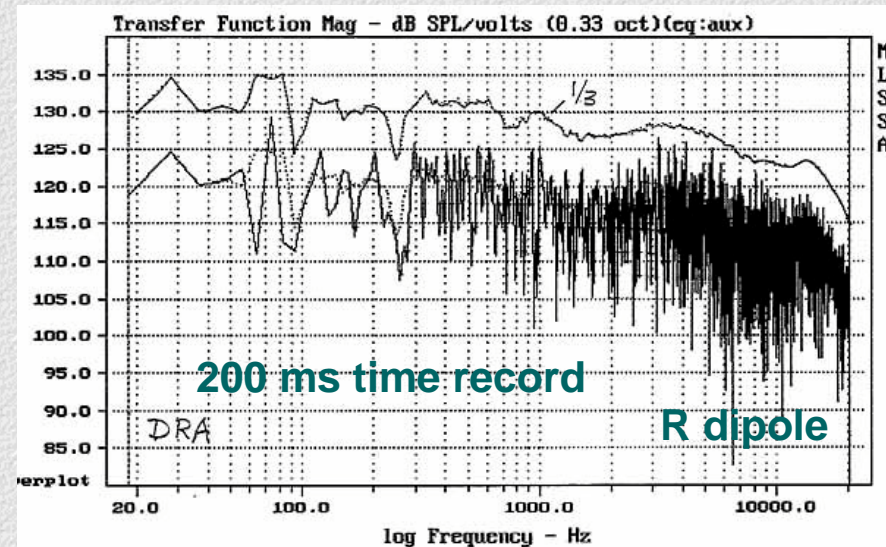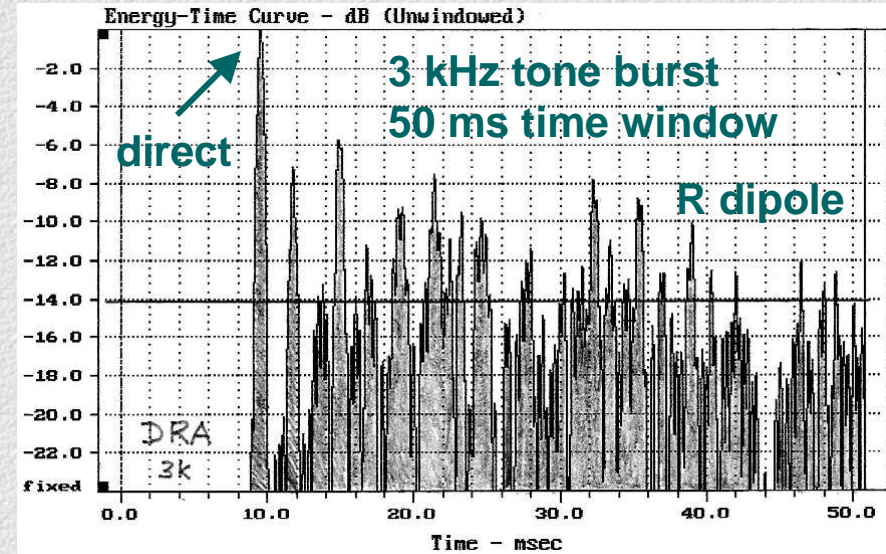**L - R symmetry of reflections for phantom image positioning**

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

L𝐢nkwitz L𝐚b

Acoustically hiding L & R loudspeakers

Flat on-axis response in free-field

Frequency independent polar response

Acoustically small size
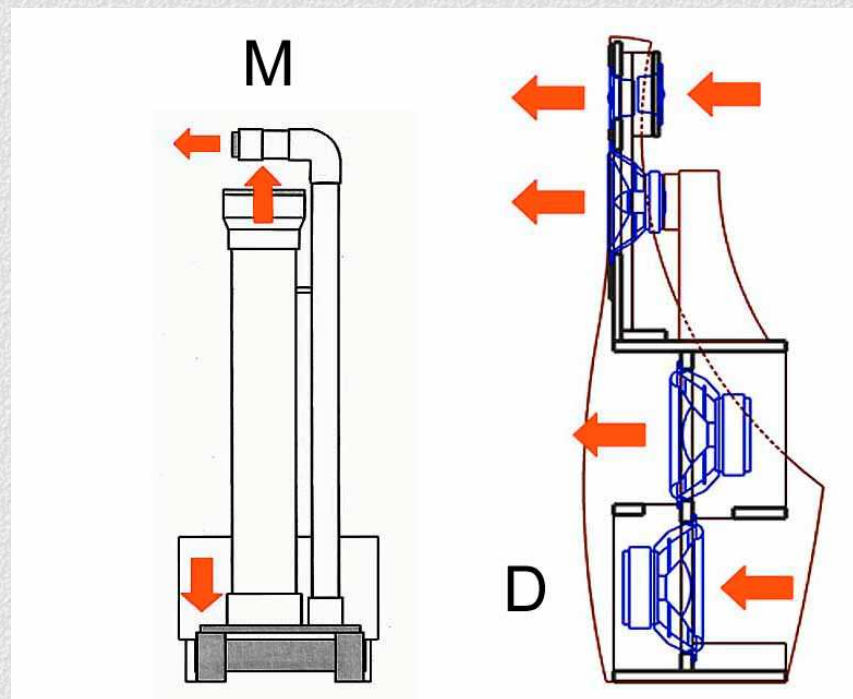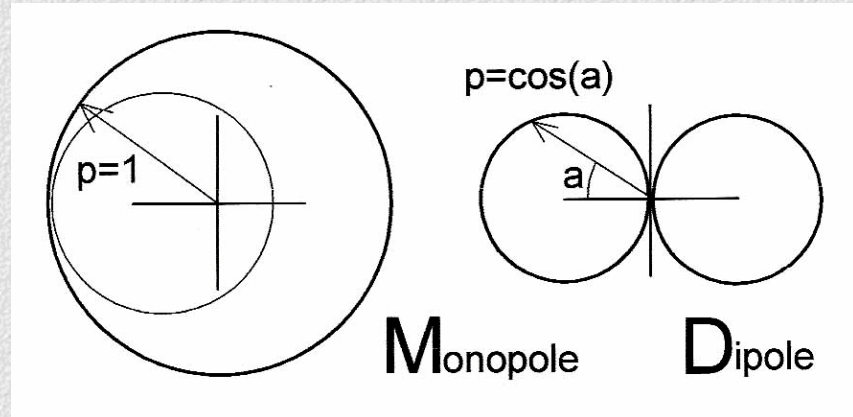(λ = 13 inch @ 1kHz)

Low cabinet edge diffraction

Low stored energy (resonances)

Low non-linear distortion
(new sounds, intermodulation)

Large dynamic range, high SPL

Hide loudspeakers visually
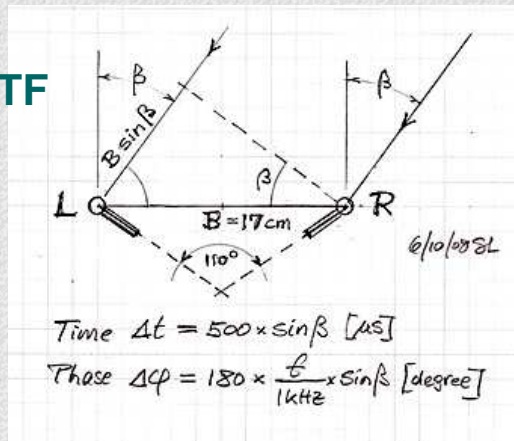
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Stereo recording & reproduction

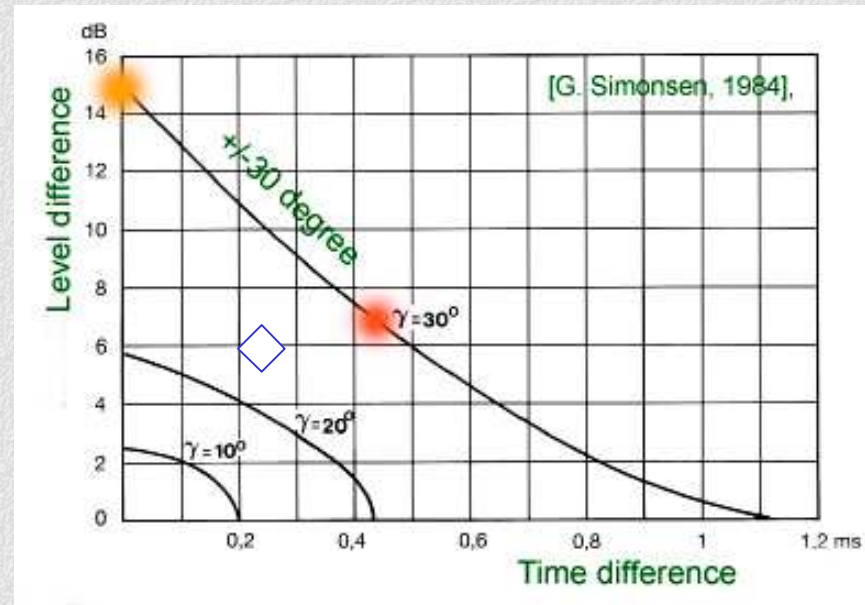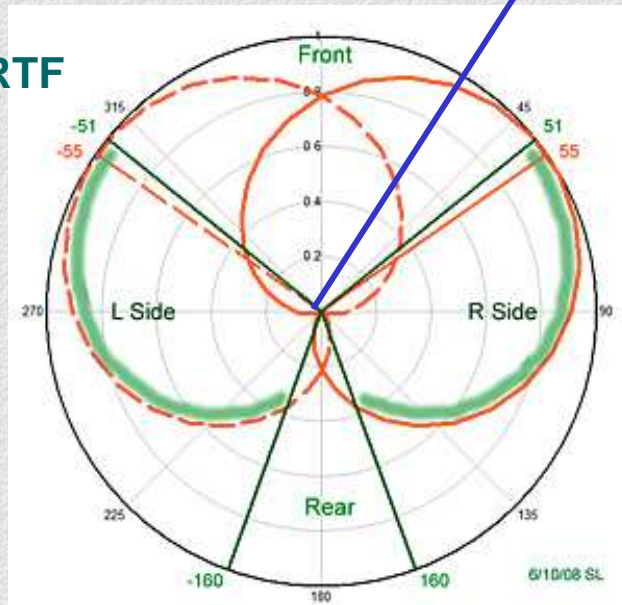**Phantom image placement between loudspeakers & not L or R crowding**

Microphones

Ears

Recording angle

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10-17-08 (10)

ORTF

Imaging between
L & R loudspeakers vs.
sound incidence angle
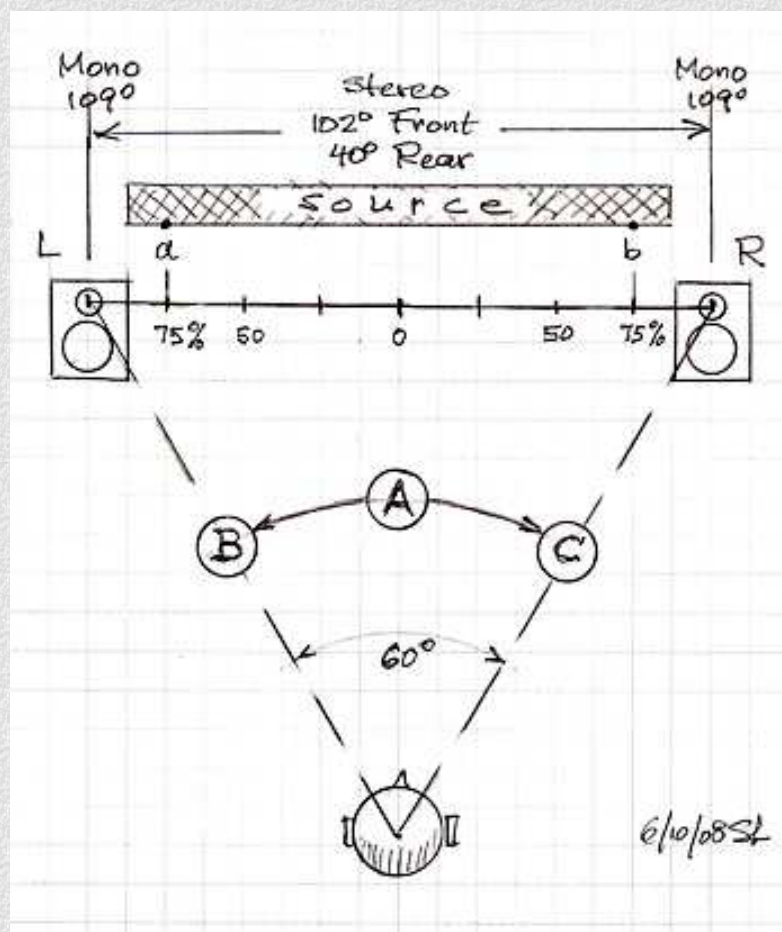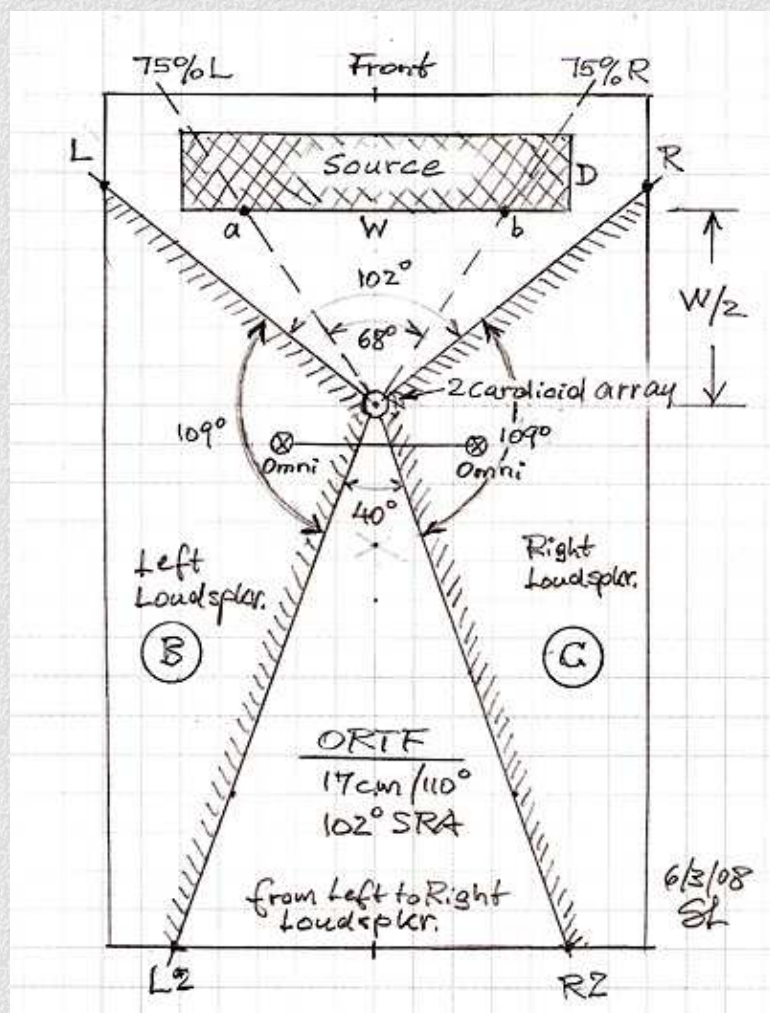
ORTF

Concert hall to living room mapping

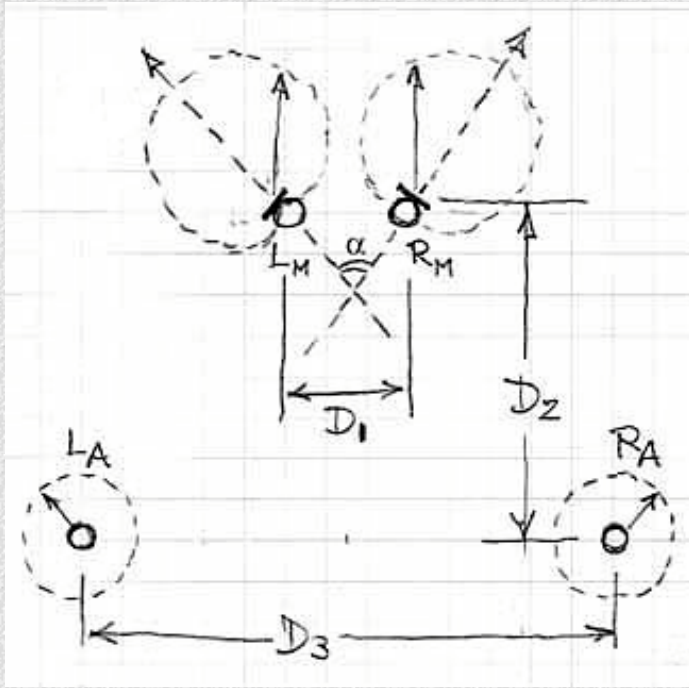**Phantom images between loudspeakers**

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
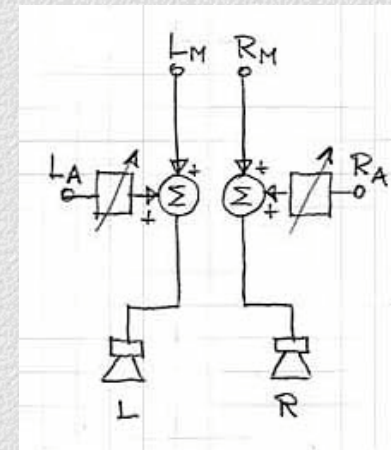
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"Accurate" stereo recording & reproduction

Loudspeakers & setup for minimal room contribution

Microphones

Ears

Recordings with a natural perspective

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Thank you for your attention

QUESTIONS?

www.linkwitzlab.com