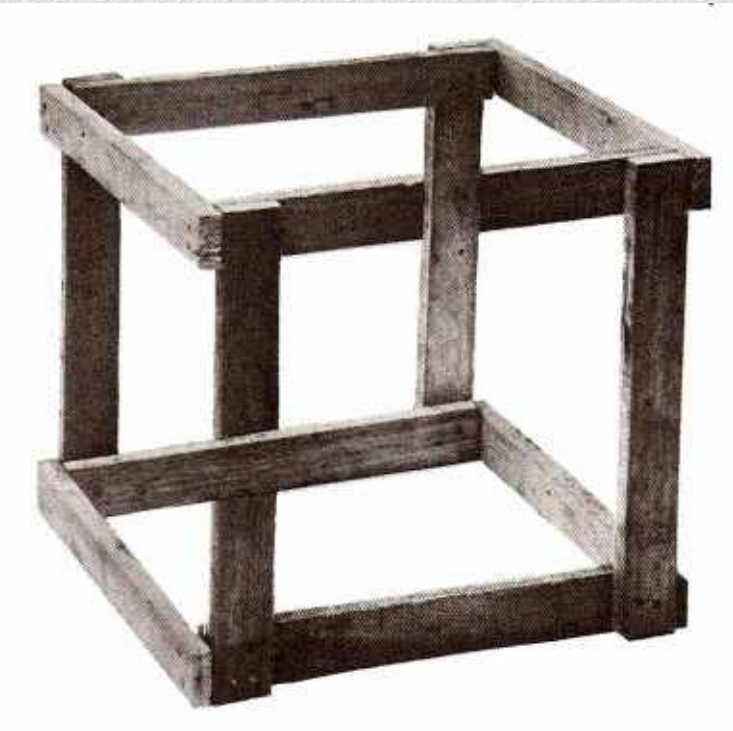
Accurate sound reproduction from two loudspeakers in a living room

Siegfried Linkwitz


D
M
A
B
Visual Scene

What object is this?



Perception of sound

The Ear-Brain-Processor

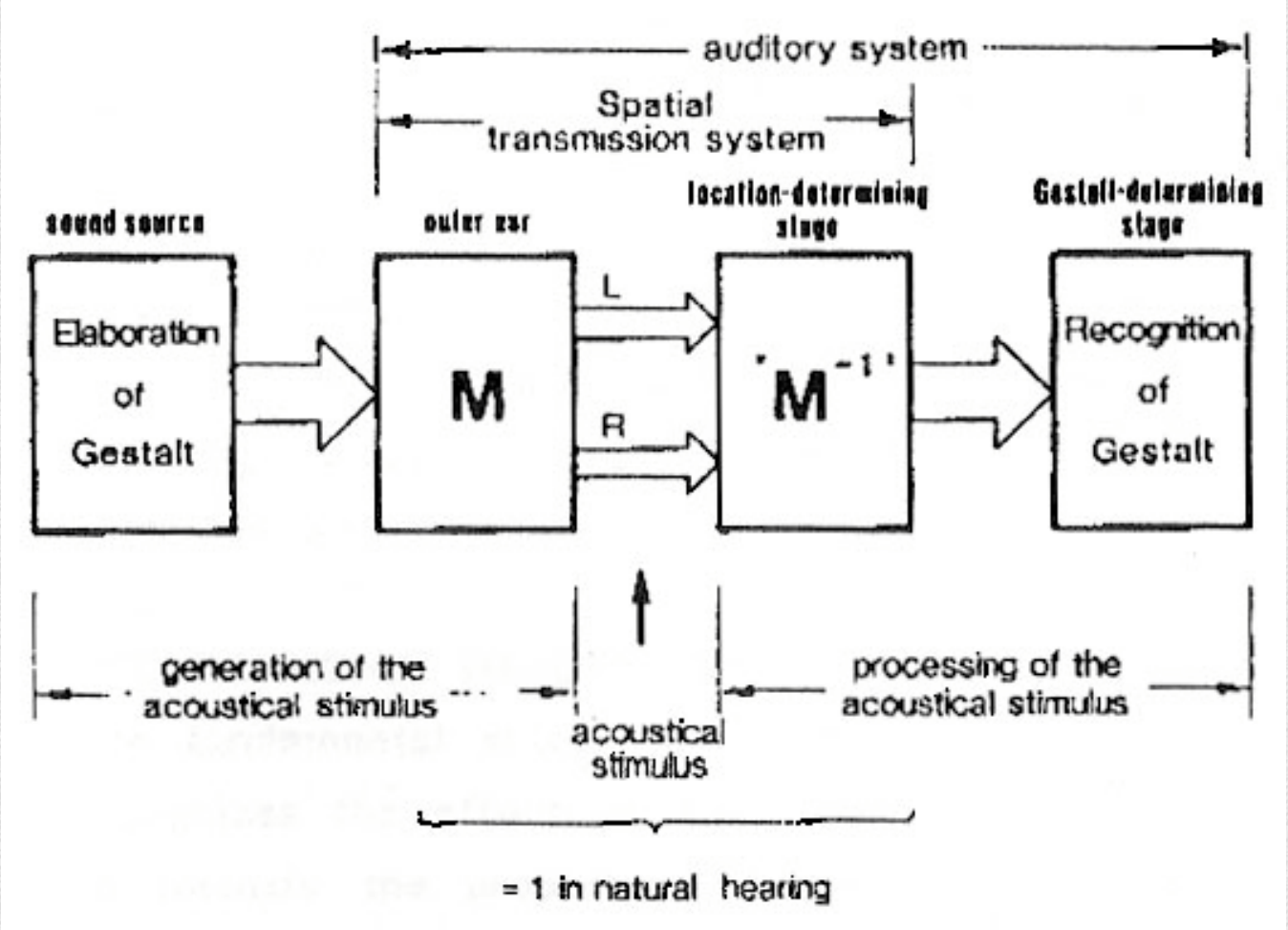
- Sound stream segregation & integration using sound onset, timbre, duration, envelope, loudness, direction cues

- Precedence effect

- Head movement, HRTF

- Our perceptual “acoustic horizon” is variable and adapts by attention

Association Model of Perception



Guenther Theile in Perception of Reproduced Sound, 1987

Visual & Auditory Scene

Accurate sound reproduction = creating an auditory illusion of the original auditory scene

Misleading auditory cues in Playback and Recording must be minimized to strengthen the illusion of "Being There"

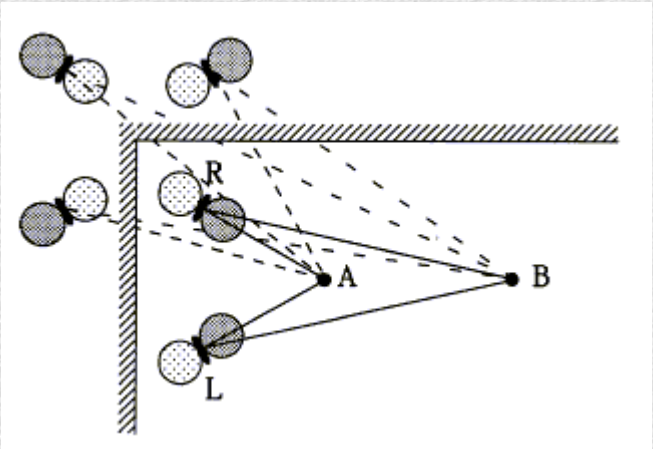
Misleading cues from the loudspeaker

- On-axis frequency response variations
- Frequency dependent directivity
- Resonances / stored energy
- Non-linear distortion
- Cabinet edge diffraction

Potentially misleading cues from the room

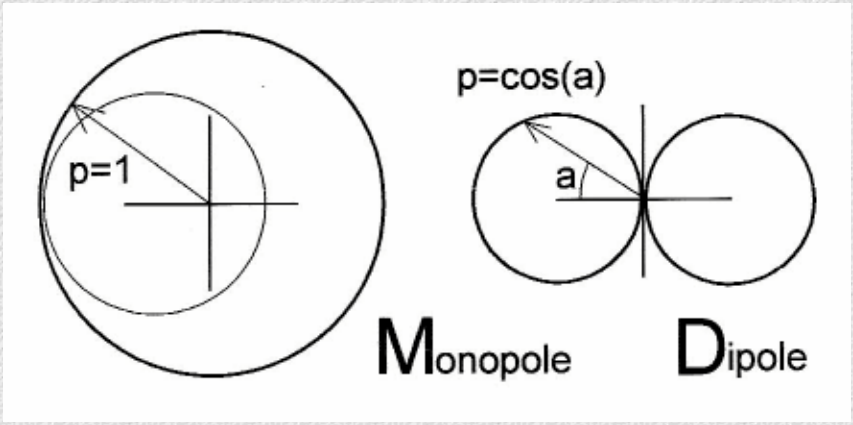
- Low frequency modes / resonances
- Reverberation / RT60
- Reflections
- Left-Right setup symmetry

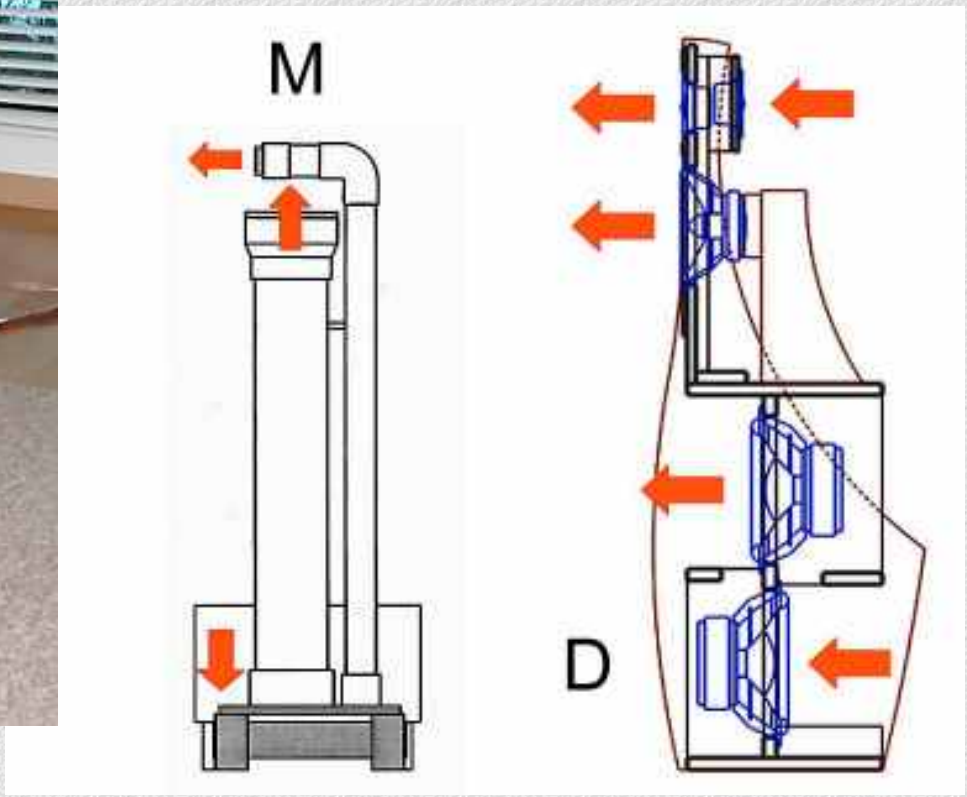
The room becomes engaged in the reproduction of an auditory scene via the directional behavior of the loudspeakers




D
M
A
B
Measurement & listening room

Two types of loudspeakers





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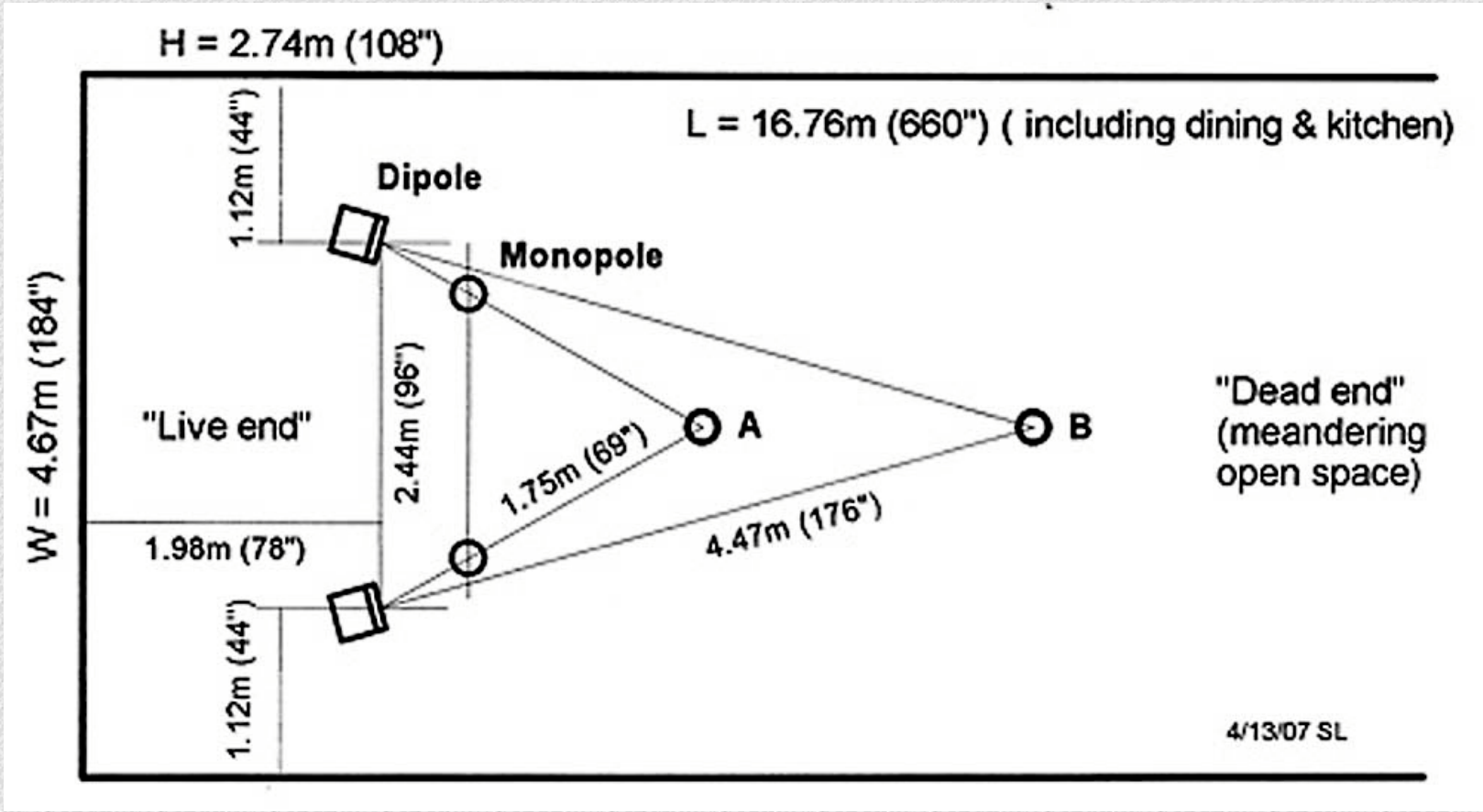
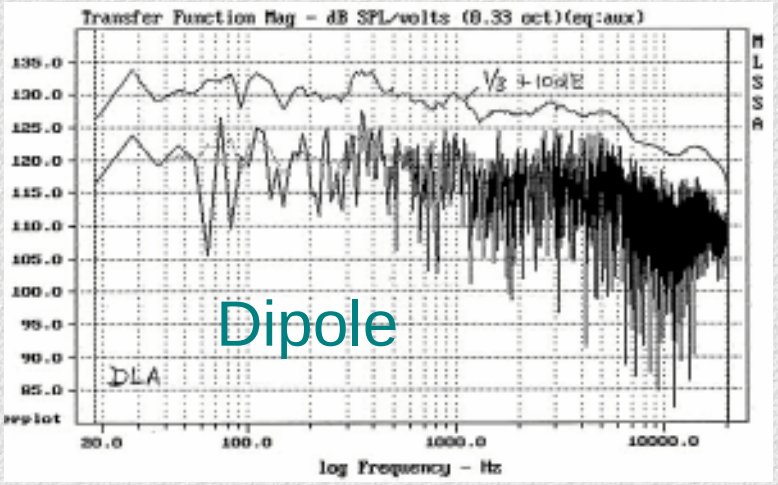
Room-Loudspeaker-Listener layout

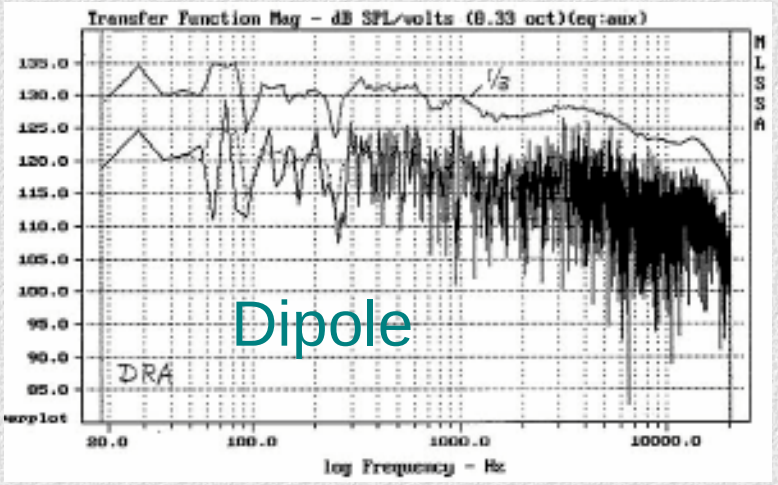


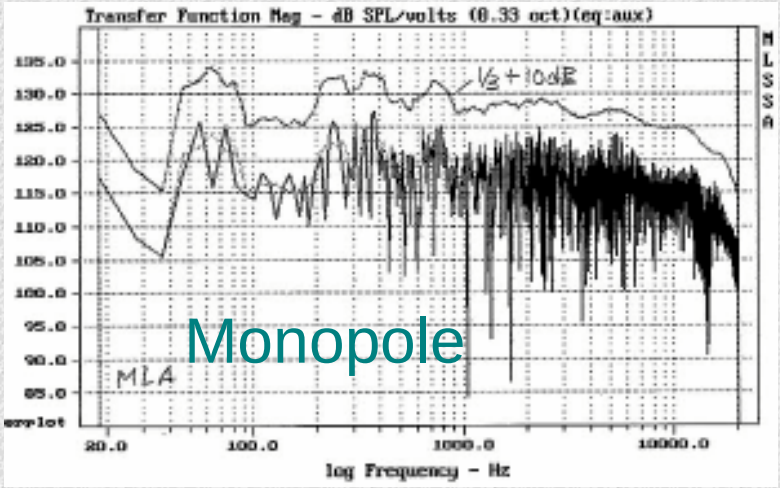
Room response at A

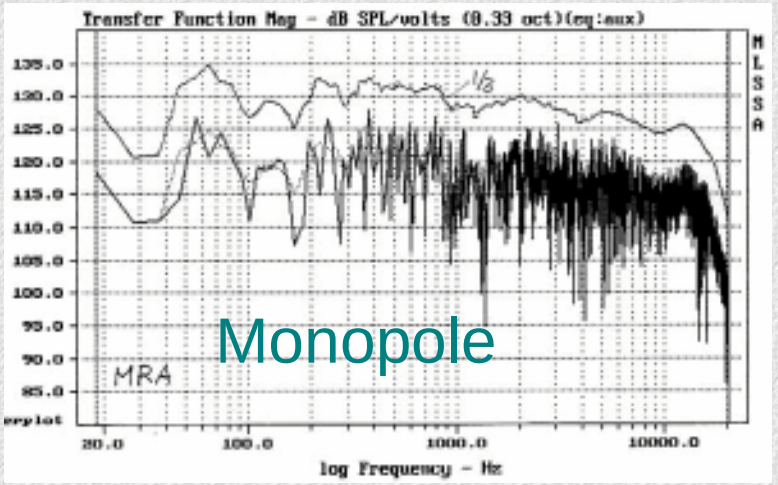
Left speaker

Right speaker



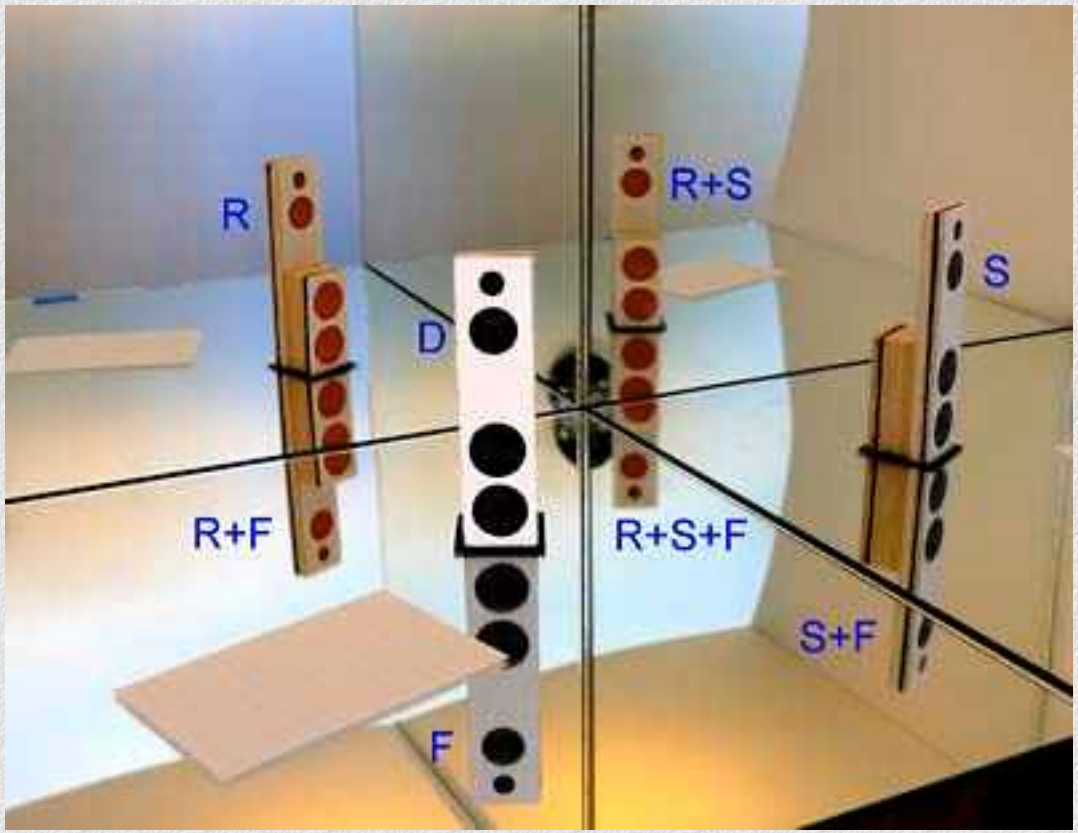


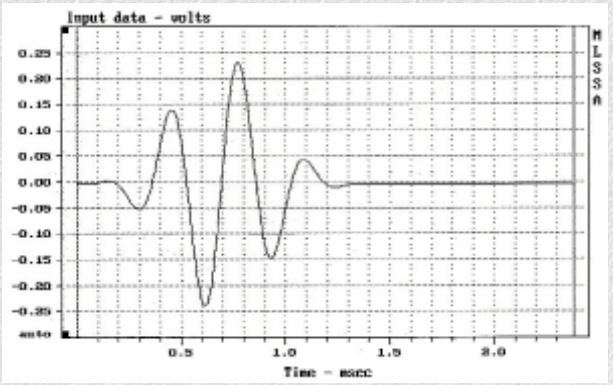


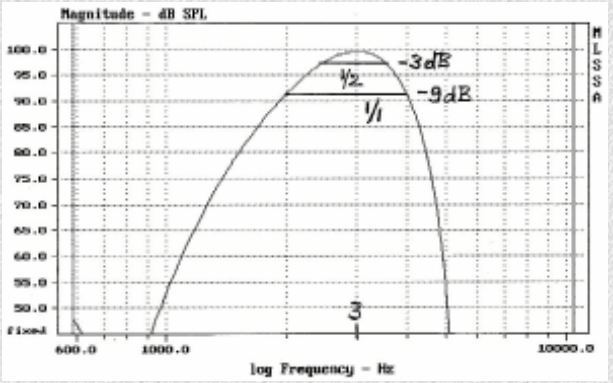


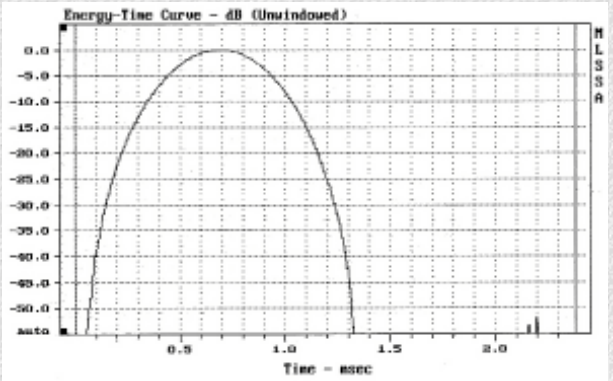
from 200 ms impulse response time record

Room reflections and their measurement



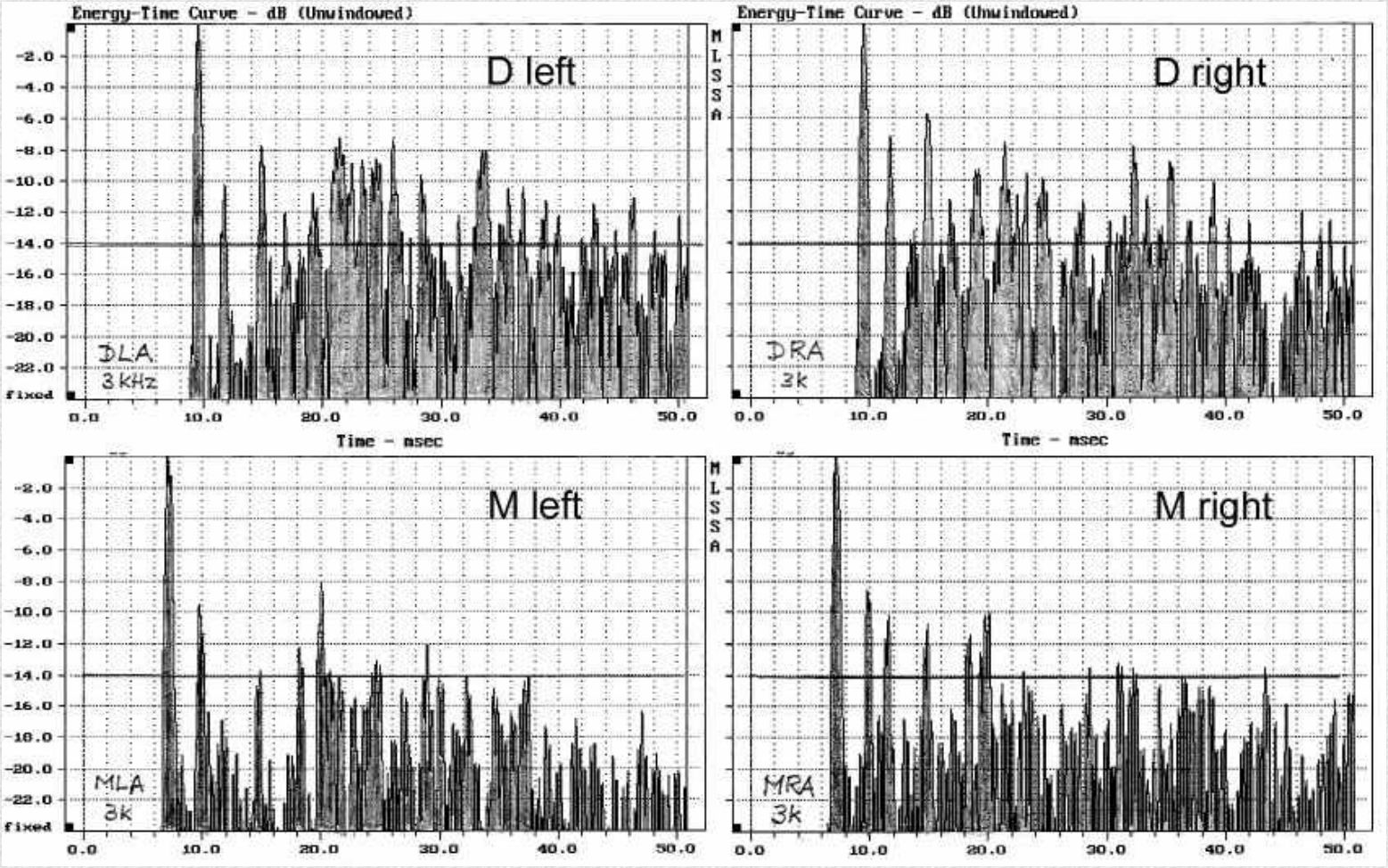




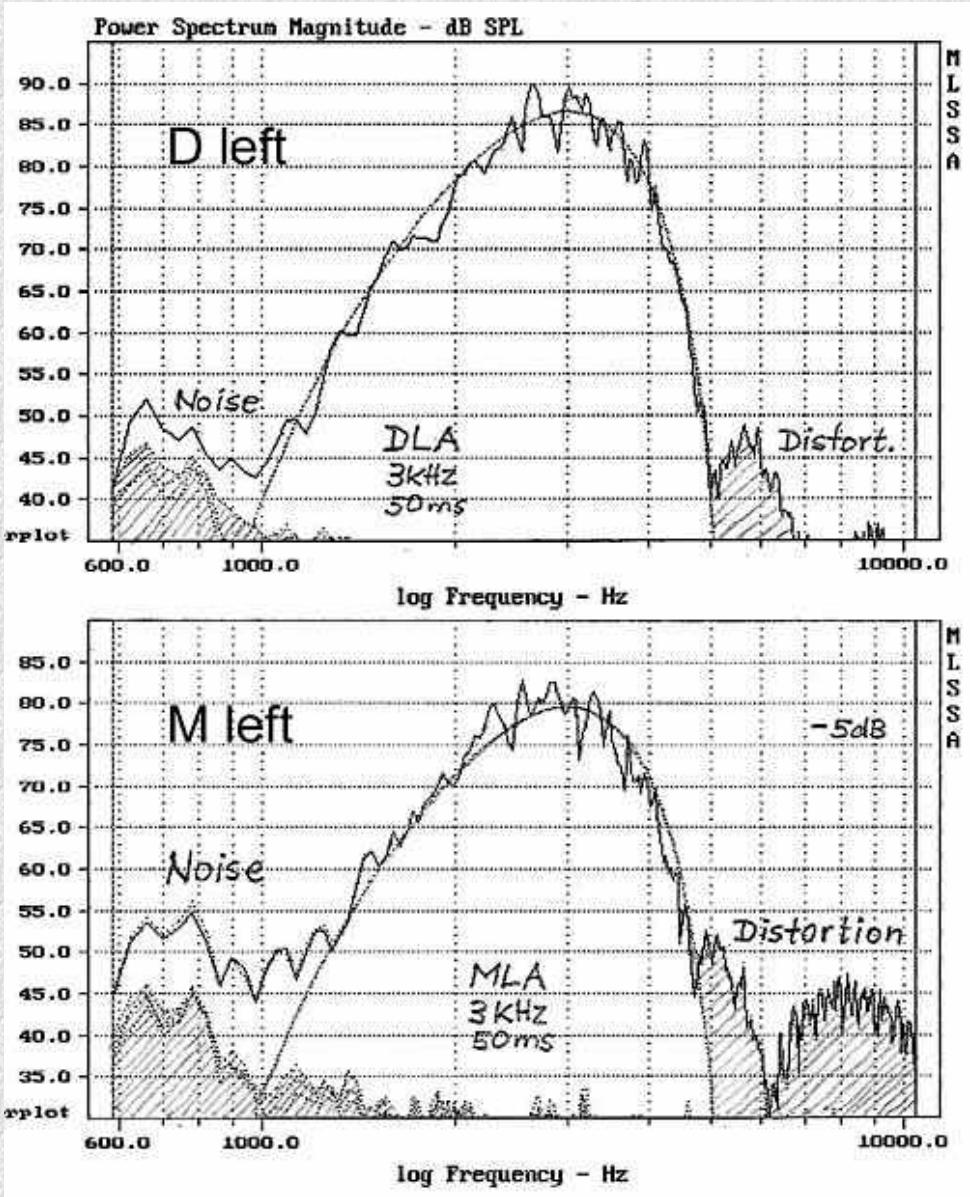


Tone burst test signal

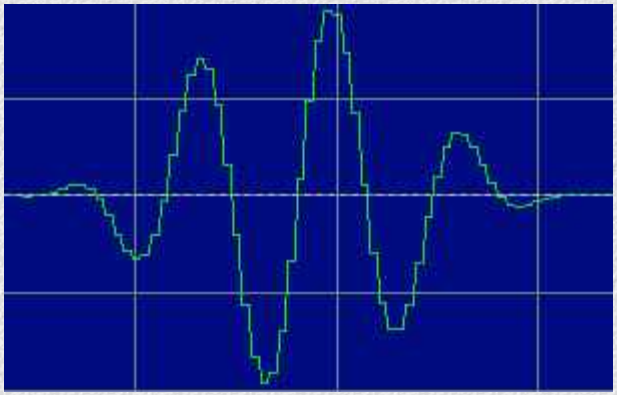
3 kHz burst response at A during 50 ms

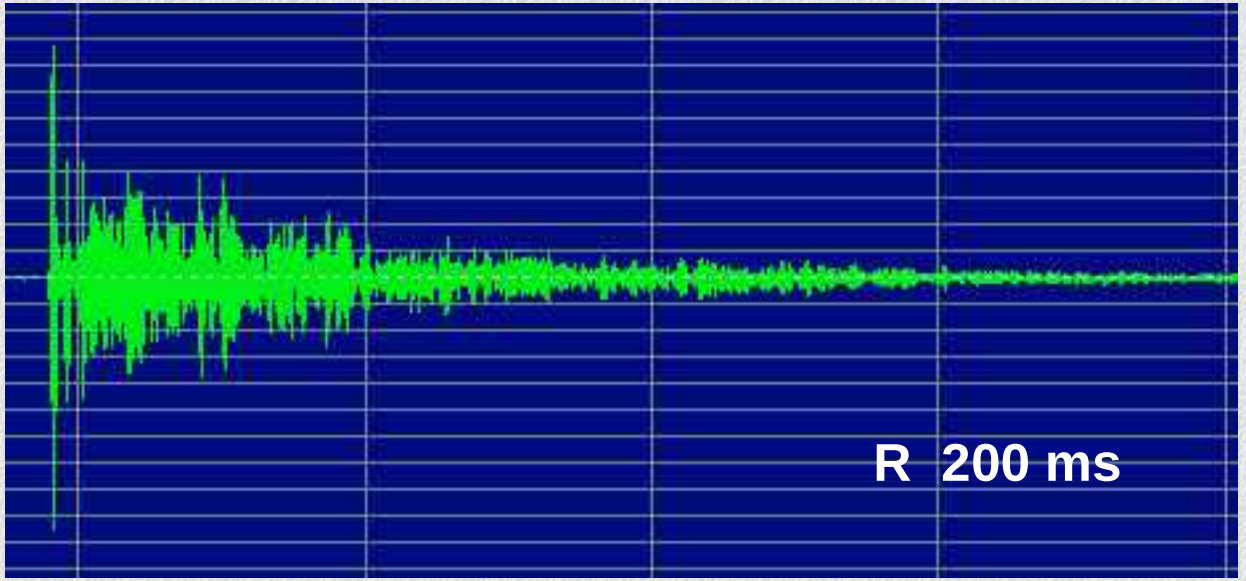


Power spectrum during 50 ms of 3 kHz burst



3 kHz burst with room reflections





OBSERVATION

The dipolar and monopolar loudspeakers
sound almost identical in
spectral balance and clarity
despite their differences in measured
room response and burst response.

Phantom imaging is very similar, precise,
but with greater depth for the dipole.

Loudspeakers and room “disappear”

POSTULATE

To minimize misleading cues from the room requires:

- Spectrum of reflections = direct sound
- Delay of reflections >6 ms ($\Delta l > 6$ ft)
- Symmetry of reflections rel. to direct sounds

Loudspeaker requirements

Frequency-independent polar response

- Omni-directional
- Bi-directional, dipolar
- Uni-directional, cardioid

Consistent acoustic illumination
of the room at all frequencies

Room requirements

- Symmetrical loudspeaker-listener setup
- Loudspeakers >3 ft from large surfaces
- Frequency-independent absorption/diffusion

THE PRECEDENCE EFFECT IN A ROOM

Localization

Direct and reflected sound are heard as a single entity from the location of the direct sound.

The Haas effect

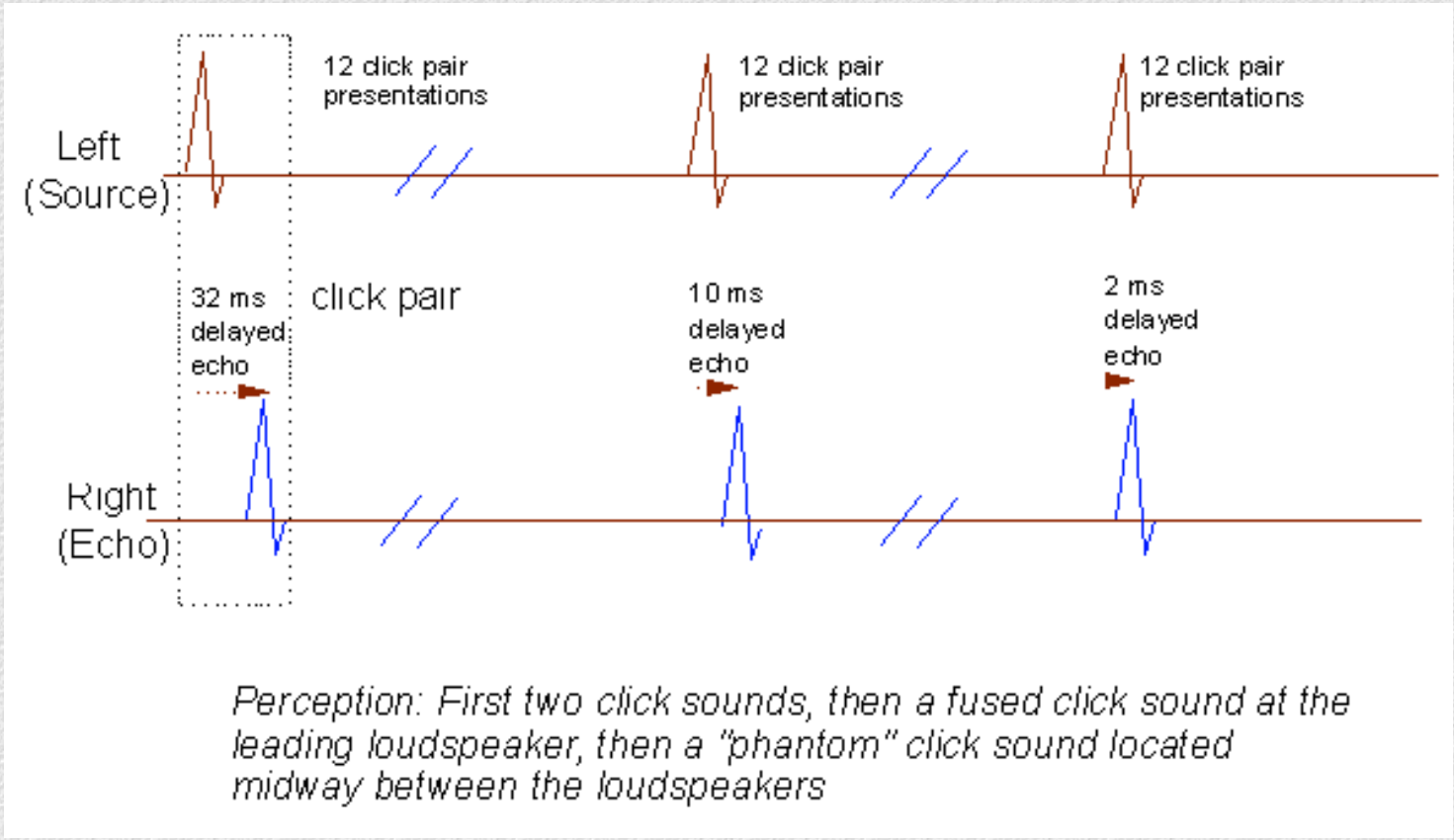
Integration of a direct sound with a delayed sound adding loudness

De-reverberation

We are not normally much aware of reverberated sound even when its energy is larger than that of the direct sound

William M. Hartmann, 1997

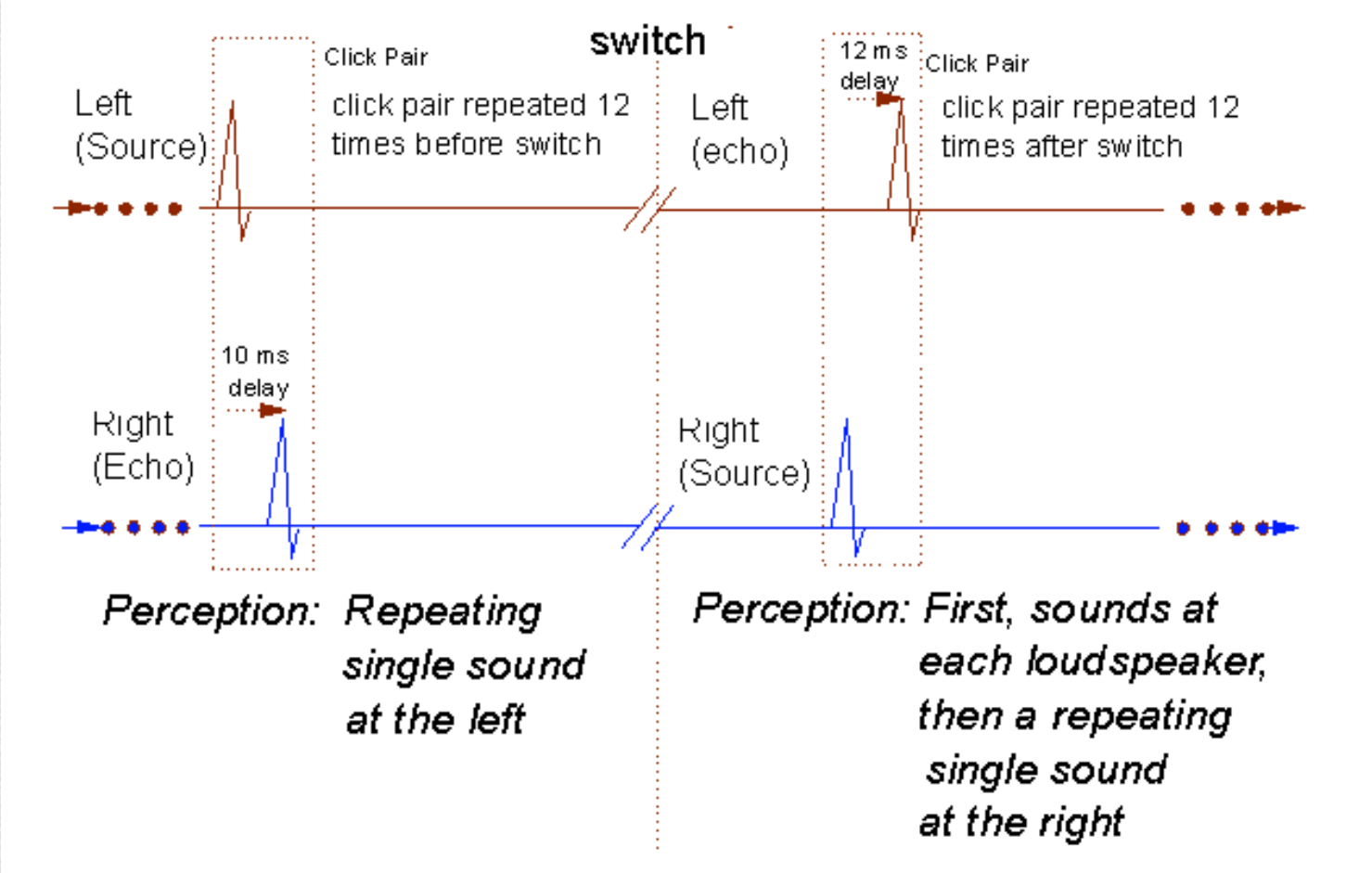
Precedence Effect



Perception: First two click sounds, then a fused click sound at the leading loudspeaker, then a "phantom" click sound located midway between the loudspeakers

Parmly Hearing Institute

Clifton Effect



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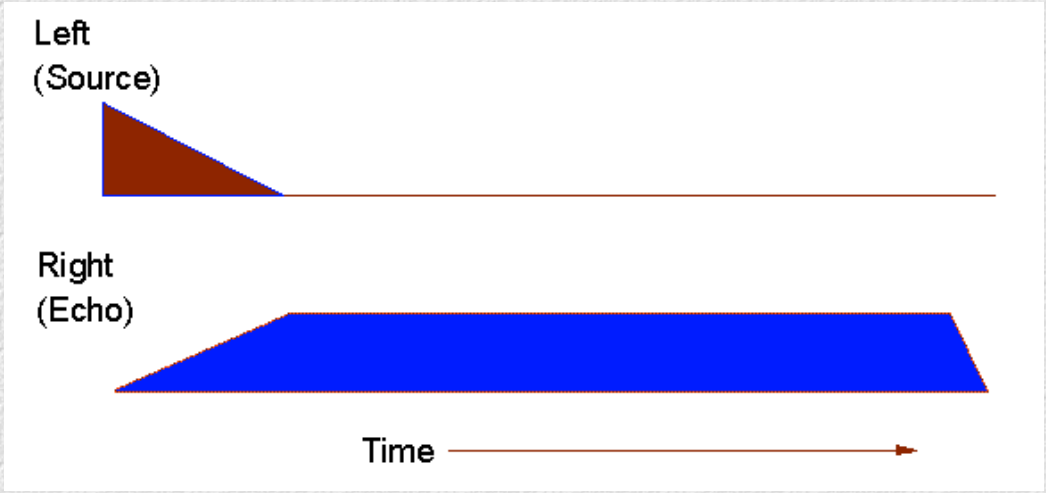
Franssen Effect

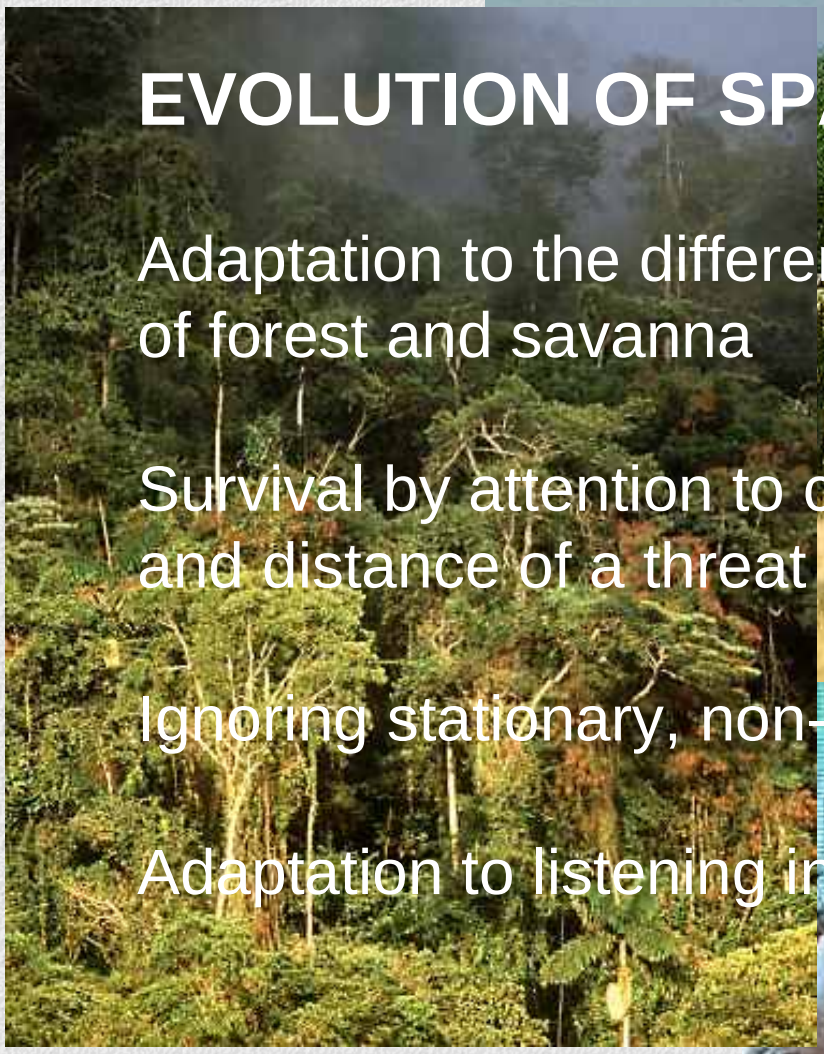


Effect with 1 kHz tone

Effect with noise

1 kHz L&R

EVOLUTION OF SPATIAL HEARING

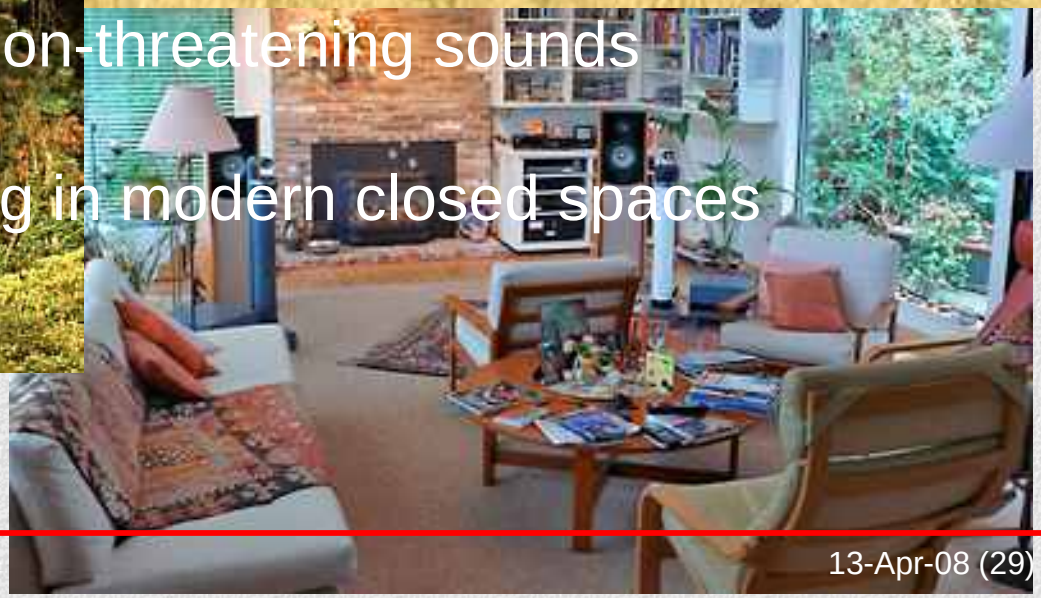


Adaptation to the different acoustic properties of forest and savanna

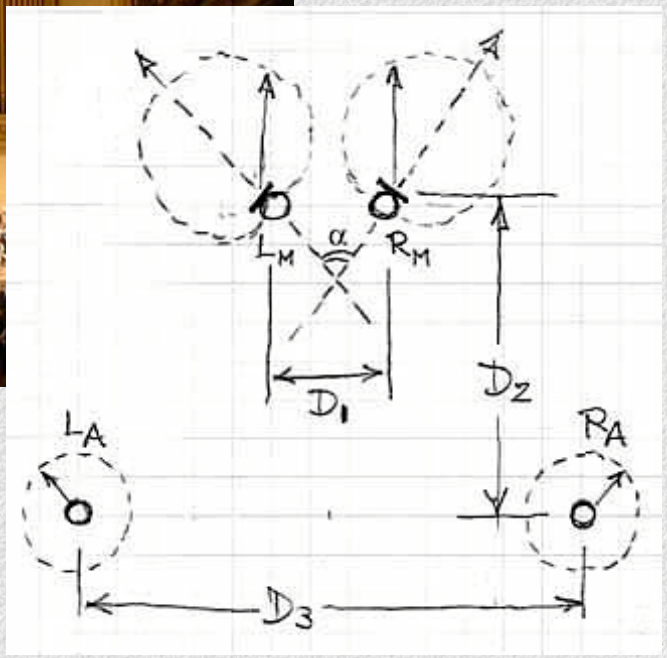
Survival by attention to cues for direction and distance of a threat

Ignoring stationary, non-threatening sounds

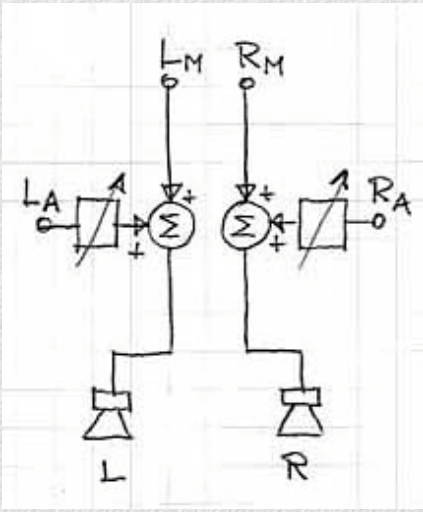
Adaptation to listening in modern closed spaces



Auditory Scene Recording



ORTF+A



Impediments to recreating an auditory scene

- Inadequate polar response of typical box loudspeakers
- Loudspeaker placement too close to and non-symmetrical to the room walls
- Room treatment with absorbers and diffusers which change the spectral content of reflections
- Electronic room equalization above bass frequencies
- Insufficient dynamic range of the loudspeaker
- Recordings with too many microphones and in separated acoustic spaces. "Clothes line" recordings

Two-channel Stereo vs. Surround sound

What am I missing?

- Complete Envelopment

What am I gaining?

- Believability
- Satisfaction
- Simplicity


Two-channel playback in a normal
living space can provide an
experience that is fully satisfying.
Loudspeakers and room
disappear and the illusion of listening
into a different space takes over.

Thank you for your attention

Questions?

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