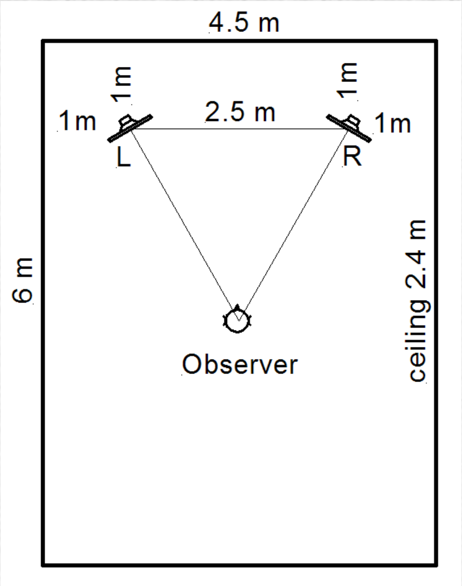
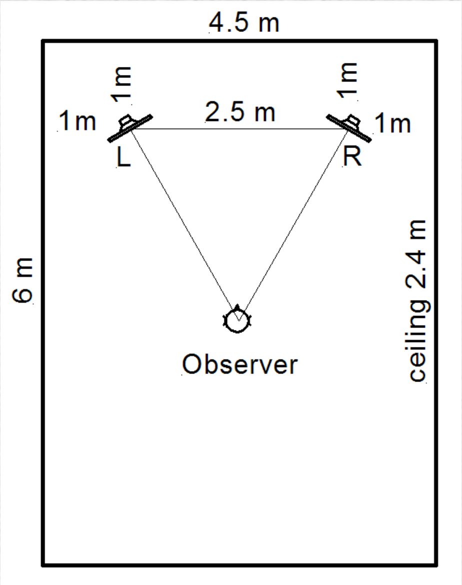
The challenge to find the optimum radiation pattern and placement of stereo loudspeakers in a room for the creation of phantom sources and simultaneous masking of real sources



Do we know the optimum way to reproduce 2-channel sound?



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.

The optimum radiation pattern

for a loudspeaker and

the optimum placement of

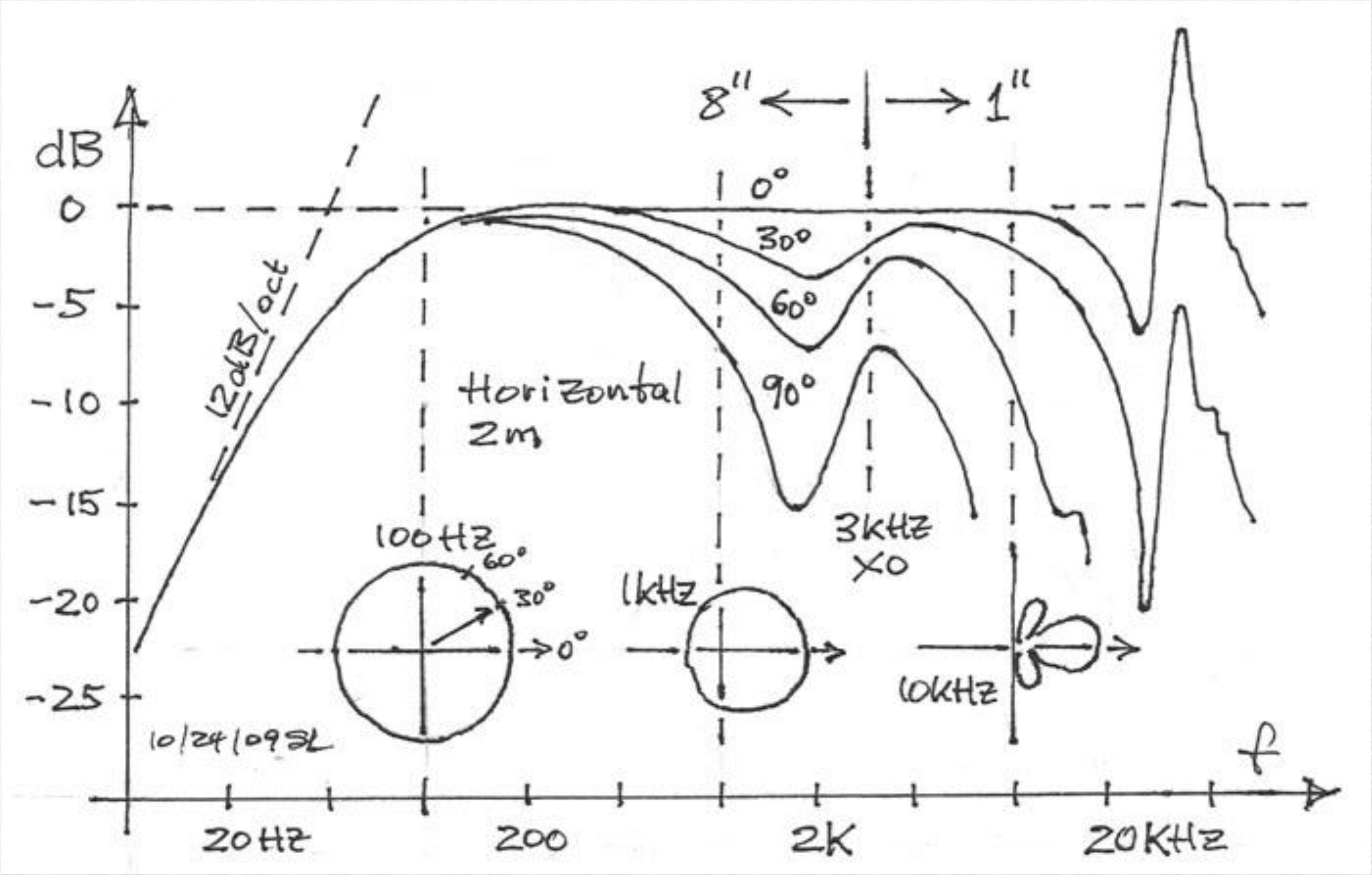
two loudspeakers in a room

are not generally known and

understood

Radiation Pattern

Sealed box, 2-way



Audio/Video Showroom

Radiation patterns are omni, dipole, bipole, directional and non-directional, or combinations thereof

Loudspeakers are placed in corners,
on shelves, into the wall, against the wall,
on stands, out in the room, etc.

Rooms are treated with absorbers, diffusors,
are lively, dead, or in between

It all works to some degree

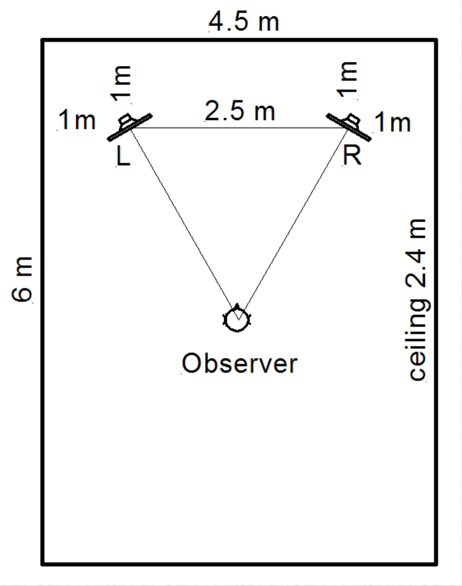
There is no clear choice, but agreement that:

A symmetrical loudspeaker setup is best
for sound stage balance & phantom imaging

Electrostatic loudspeakers often excel in
sonic detail, clarity and openness
though they have dynamic range
and placement problems

Rooms are problematic

The room is not the problem!
The loudspeaker's off-axis response is the problem!



Stereo is about creating an **Auditory ILLUSION**

Anything that distracts from creating the illusion must be minimized

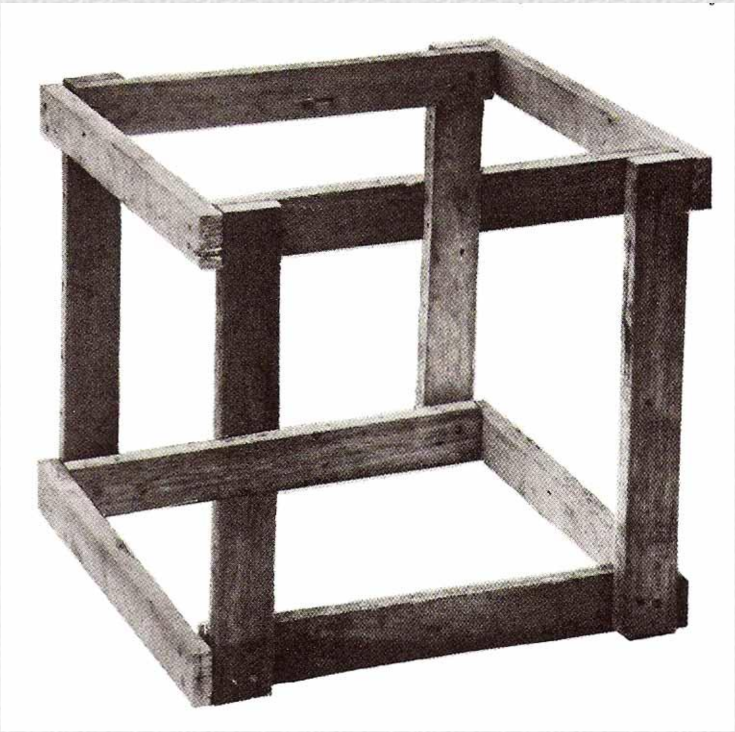
How do we perceive the REALITY of an **Auditory Scene?**

How do we perceive the REALITY of a

Visual Scene?

Depth in a 2-dimensional Visual Scene

What is this?



Cues

&

Pattern Recognition

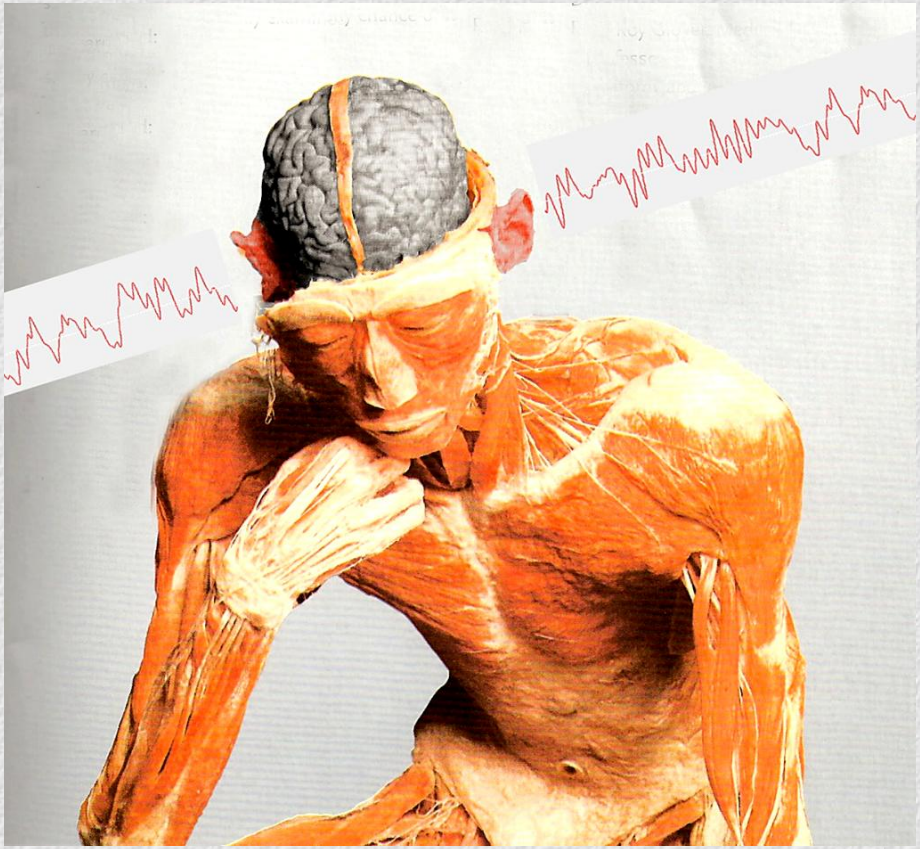
Auditory Scene

Hearing evolved in an environment with multiple sources and reflections

- Direction
- Distance
- Size

- Tracking
- Meaning
- Attention

Hearing happens between the ears, using:

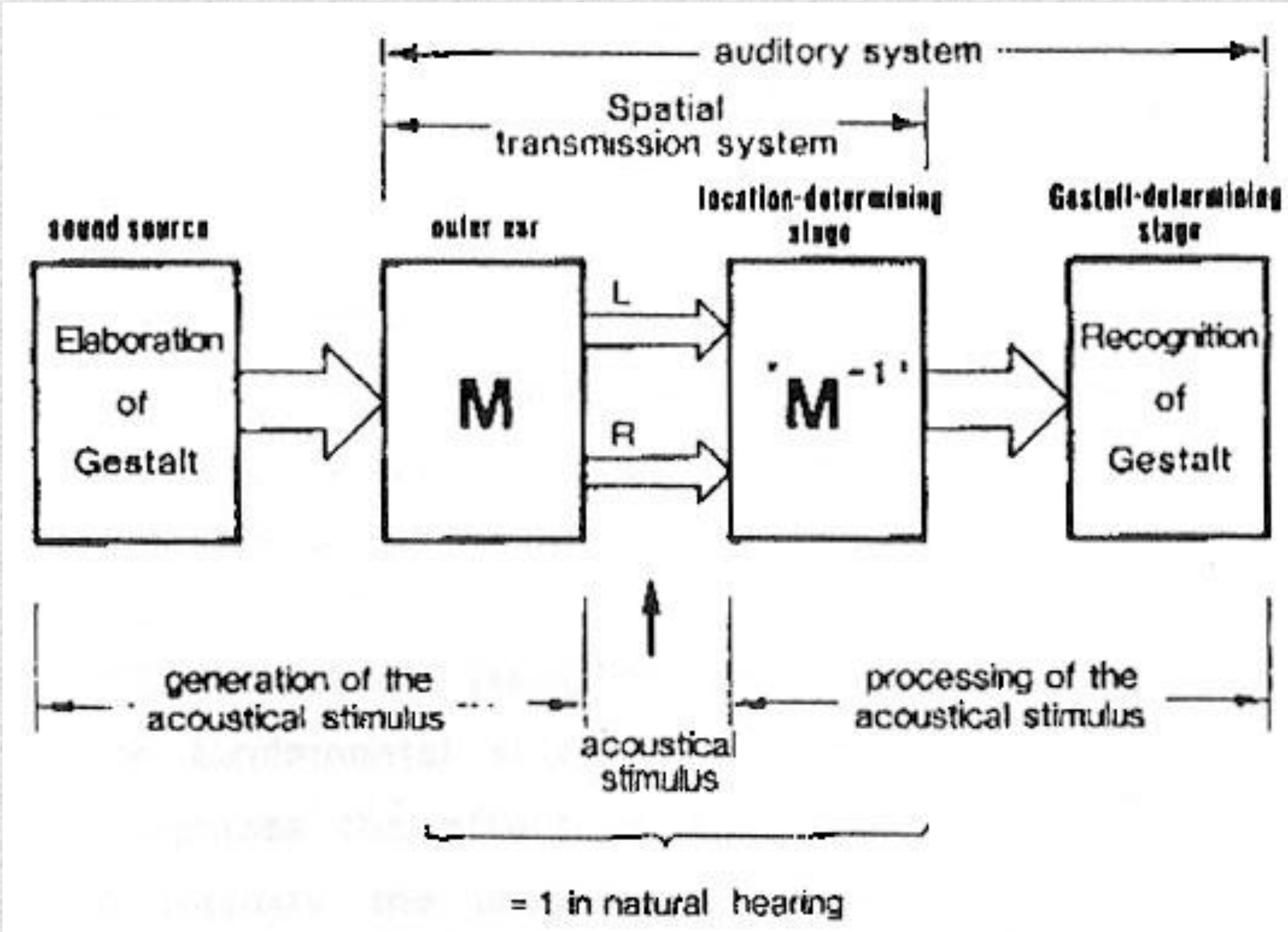


- ❖ Intensity differences
- ❖ Arrival time differences
- ❖ Envelope variations
- ❖ Spectrum masking

- ❖ Stream segregation
- ❖ Pattern recognition
- ❖ Attention
- ❖ Learning

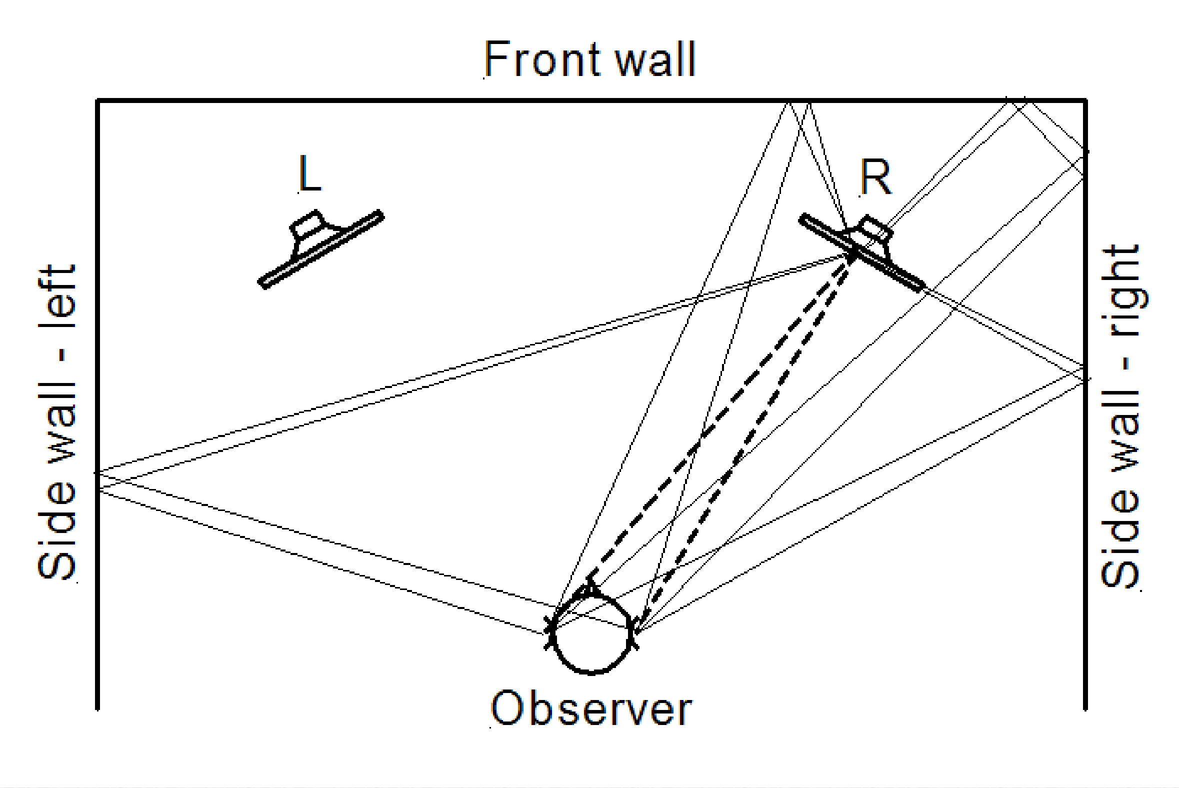
Head movements
Tactile & visual inputs

Association Model of Perception



Guenther Theile in Perception of Reproduced Sound, 1987

A single loudspeaker in the room: A real source



Drift thresholds for one and two reflections

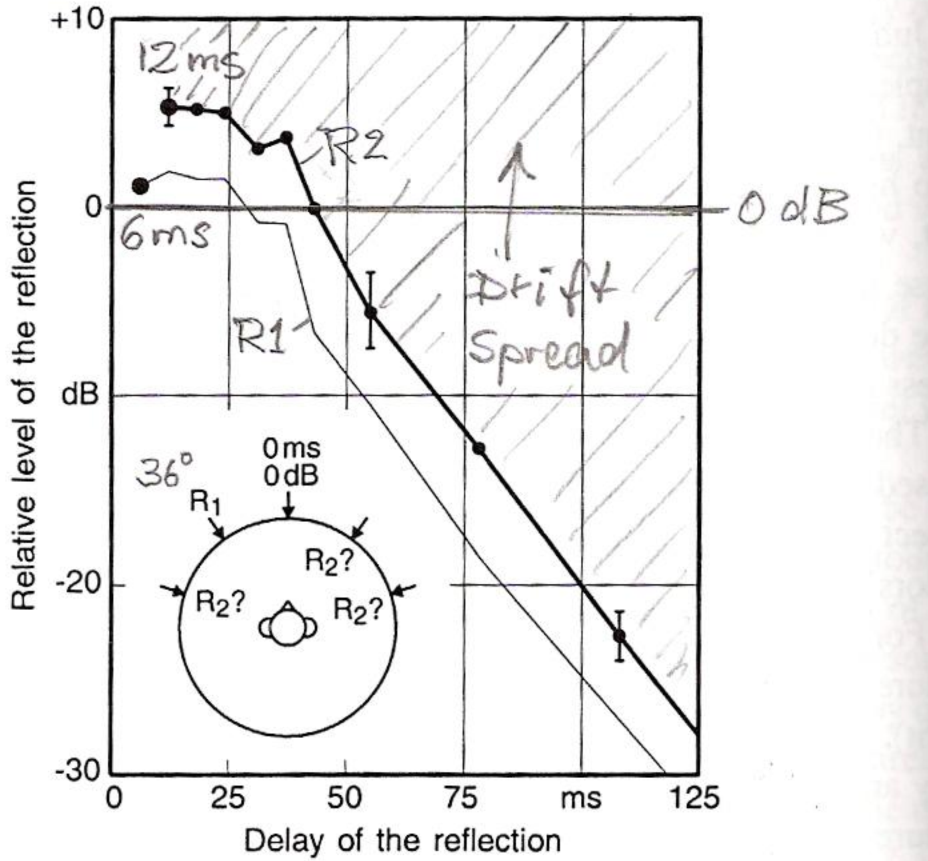
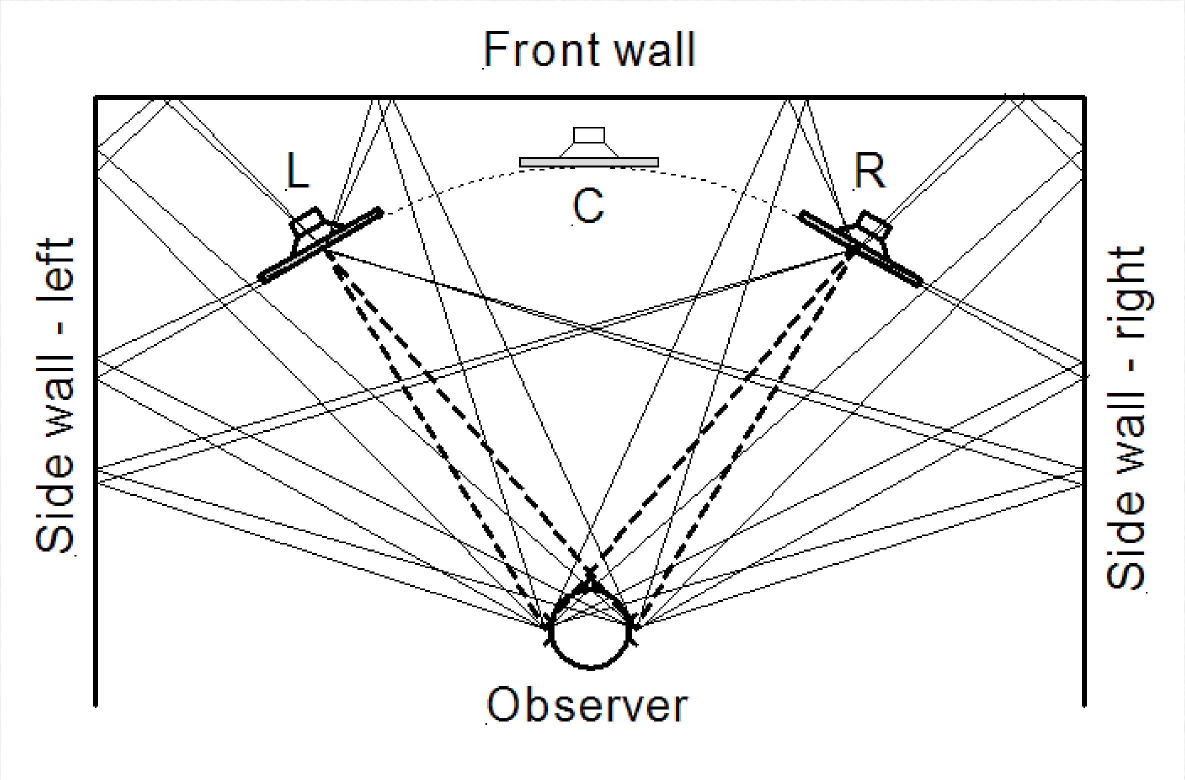


Fig. 2.6. Drift threshold (DT) of a second reflection R_2, continuous speech

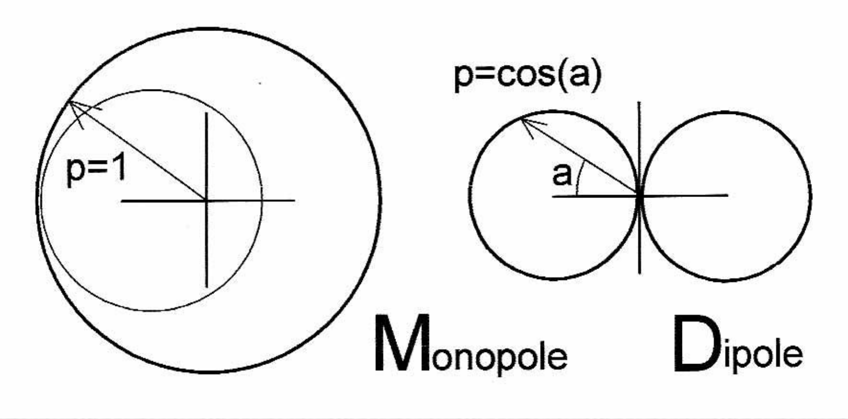
Peter Damaske, Acoustics and Hearing, Springer 2008

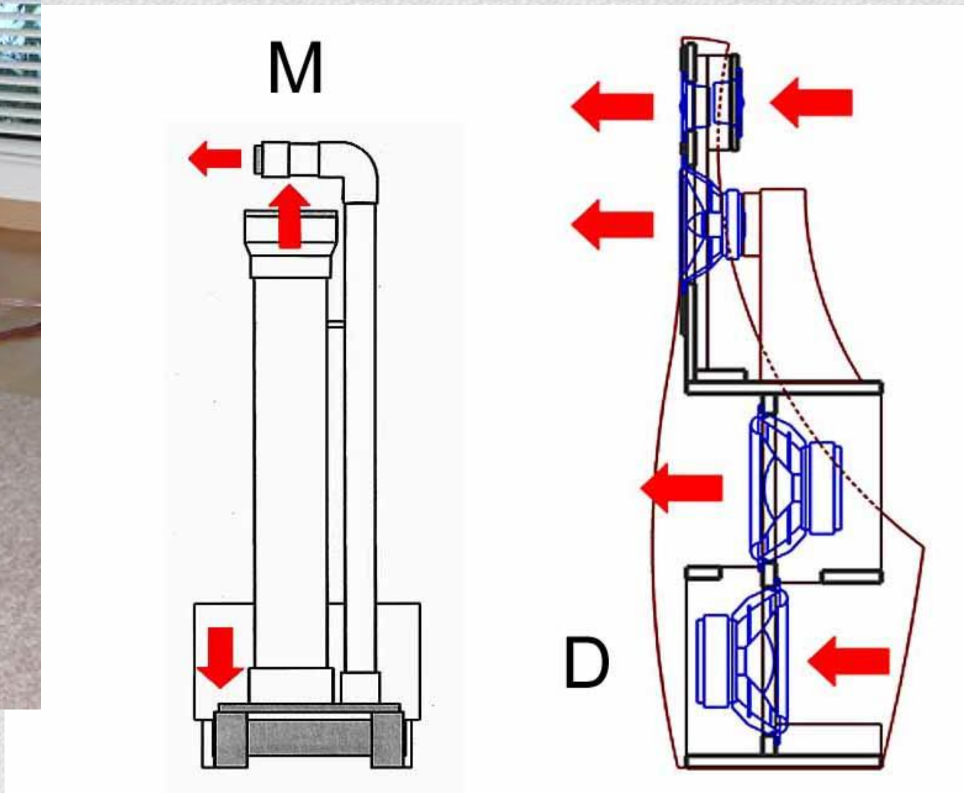
Two loudspeaker in the room: Real and phantom sources



Observations after 30+ years of designing loudspeakers to please myself

Two types of loudspeakers



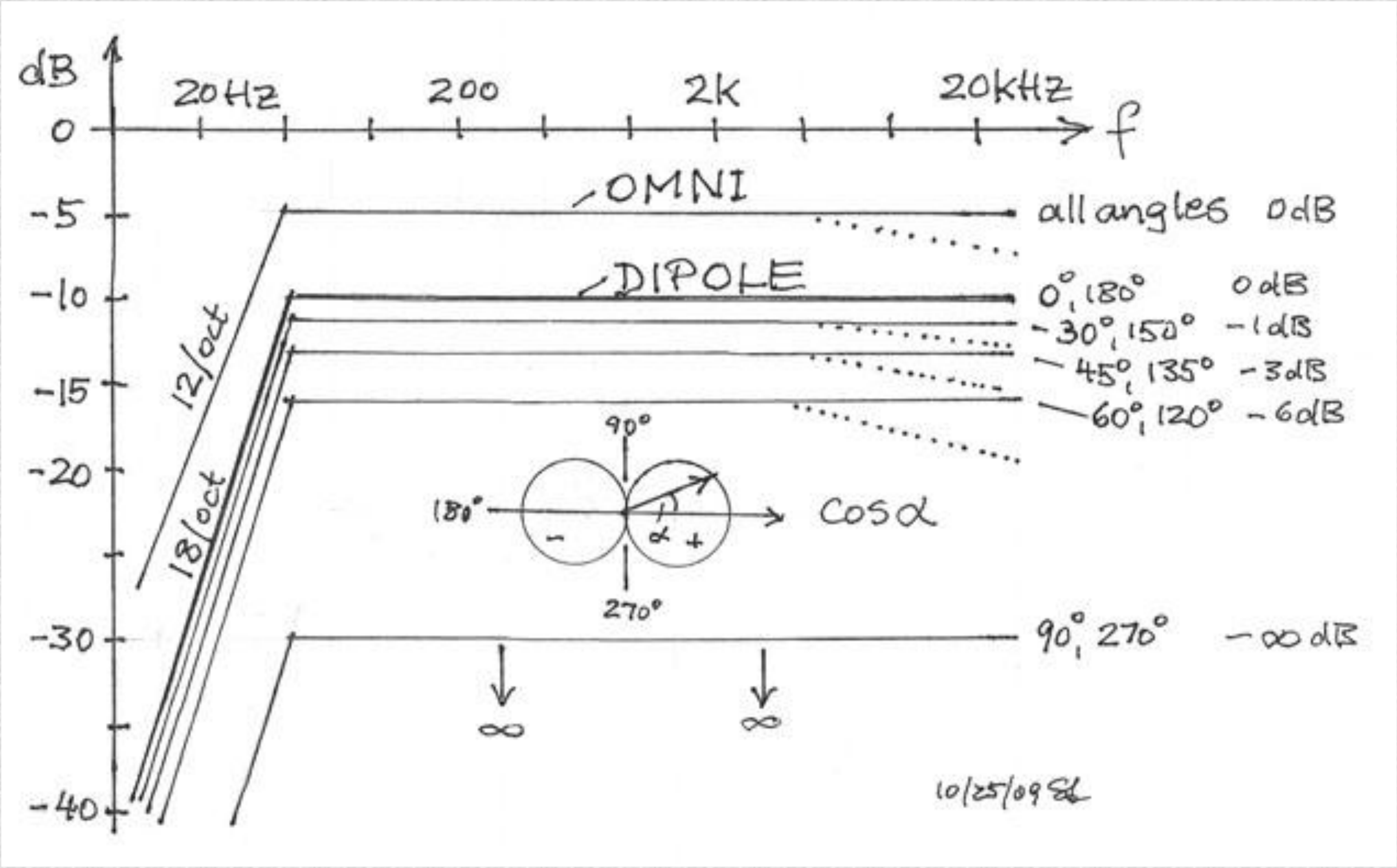


These dipolar and monopolar loudspeakers sound almost identical in spectral balance and clarity despite their differences in measured room response and burst response.

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

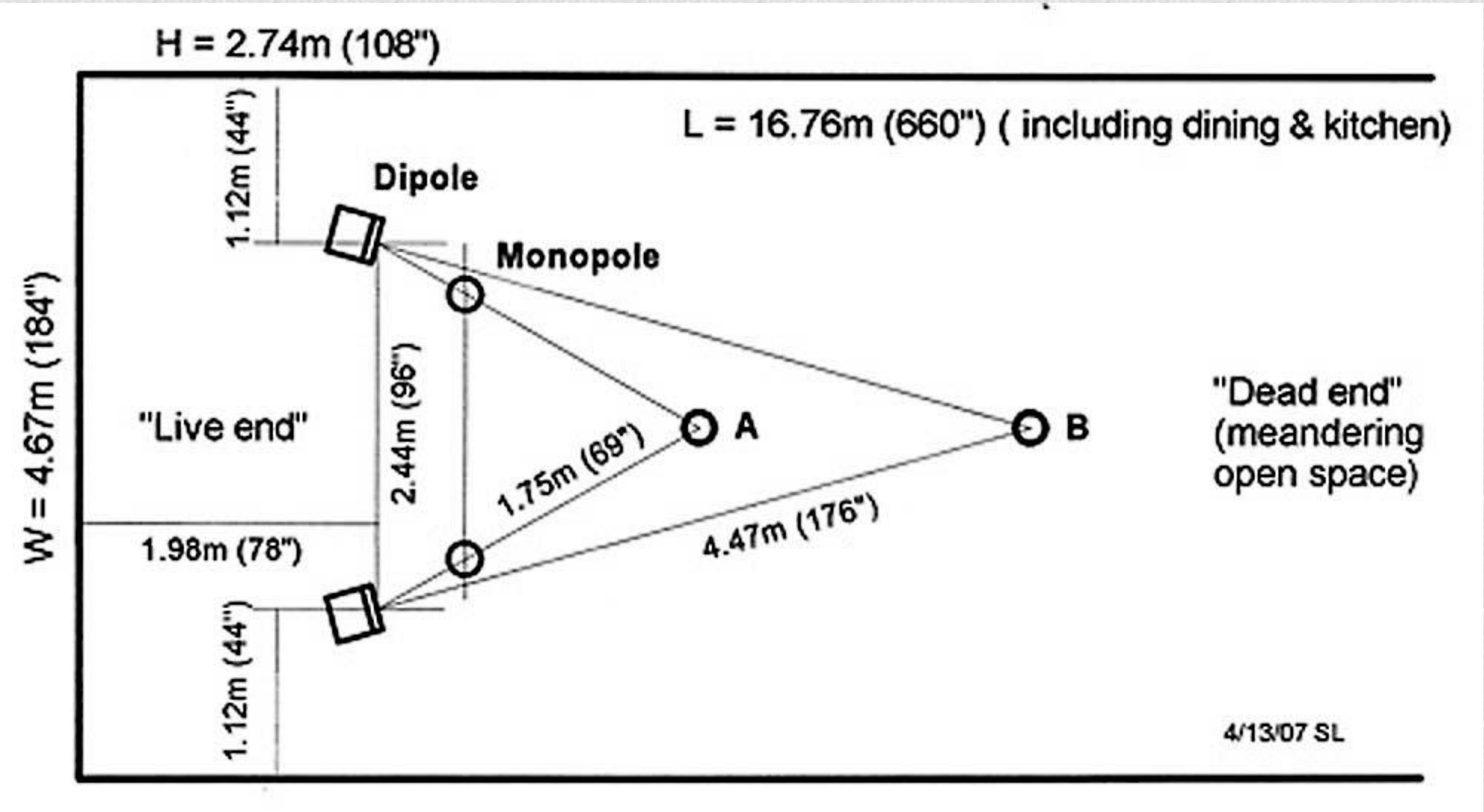
Loudspeakers and room “disappear”

Radiation Pattern



My Living Room

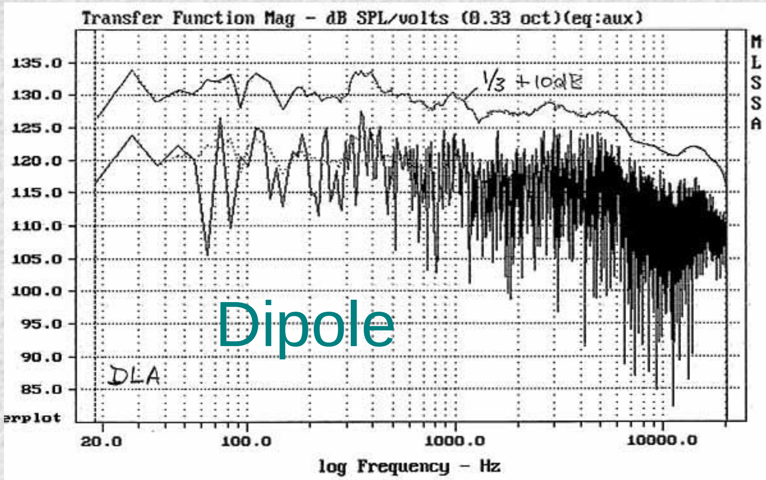
- Loudspeaker & listener setup symmetrical and >1 m from walls
- Lively acoustics (RT60 around 500ms above 200 Hz)

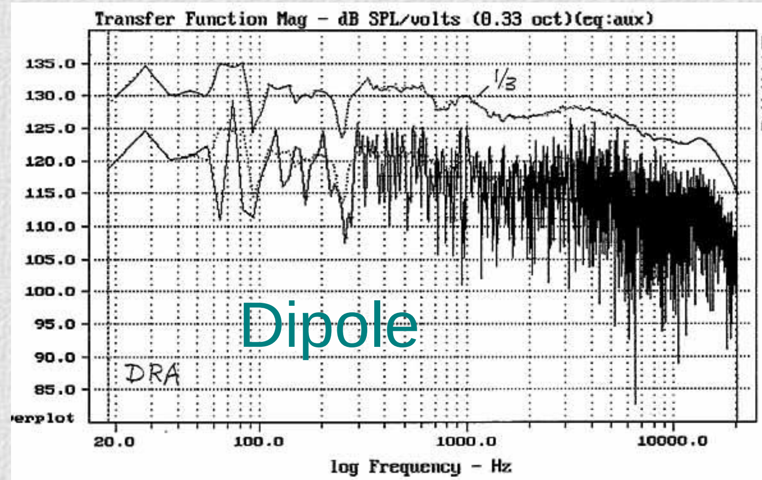


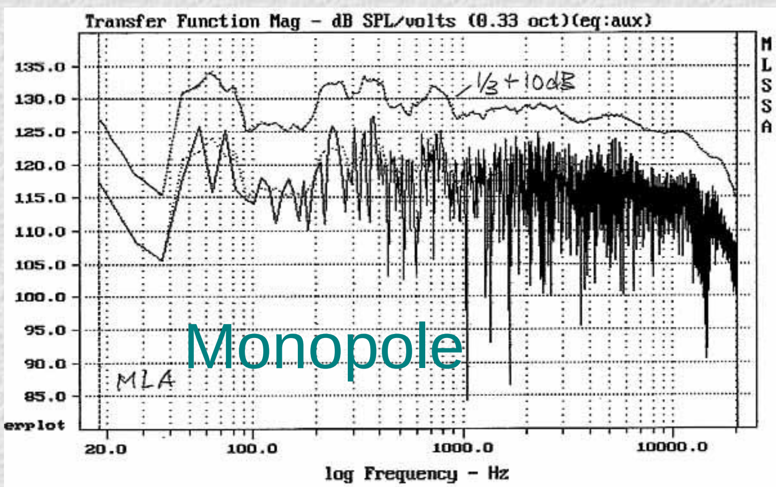
Room response at A

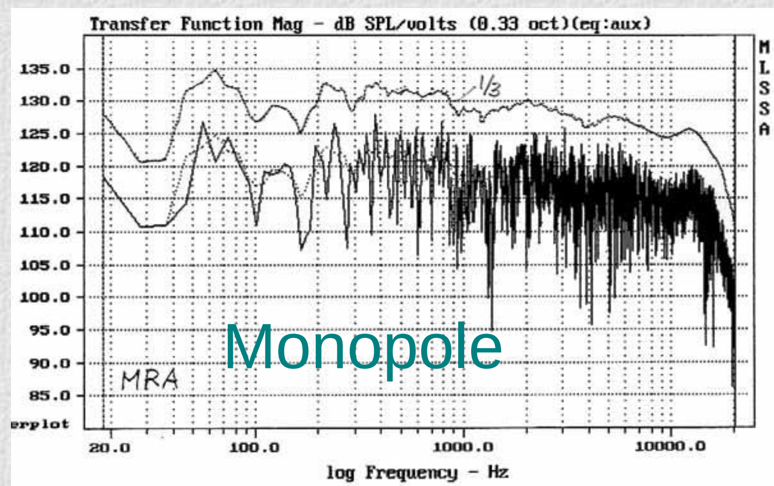
Left speaker

Right speaker



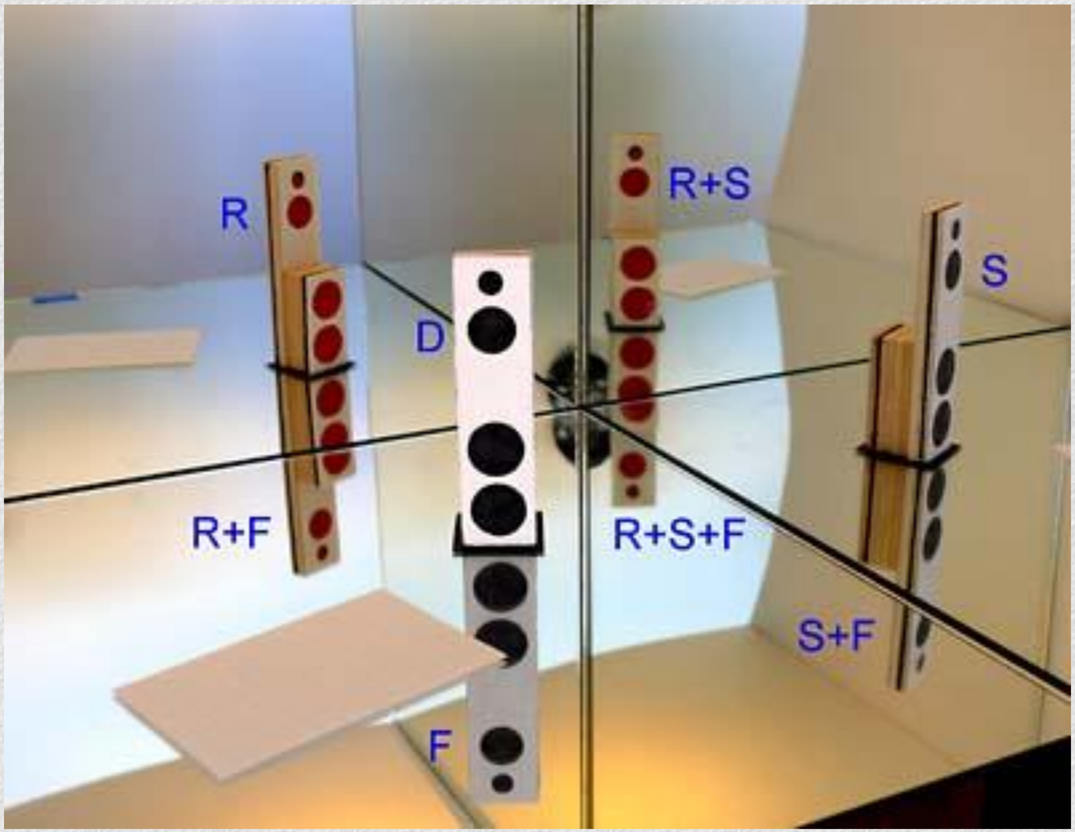


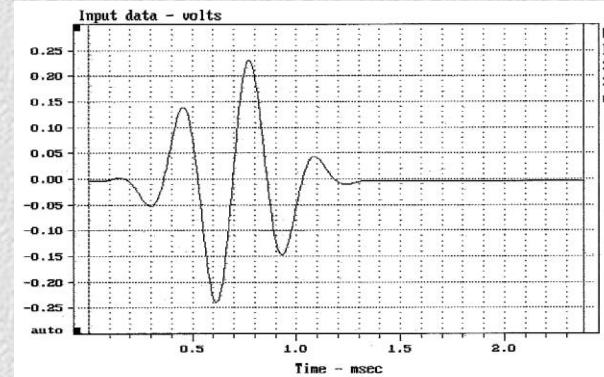


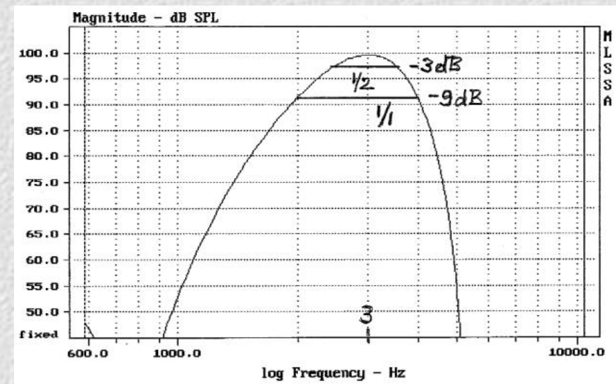


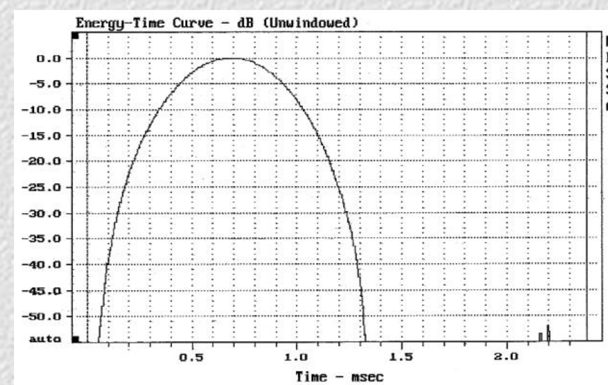
from 200 ms impulse response time record

Room reflections and their measurement



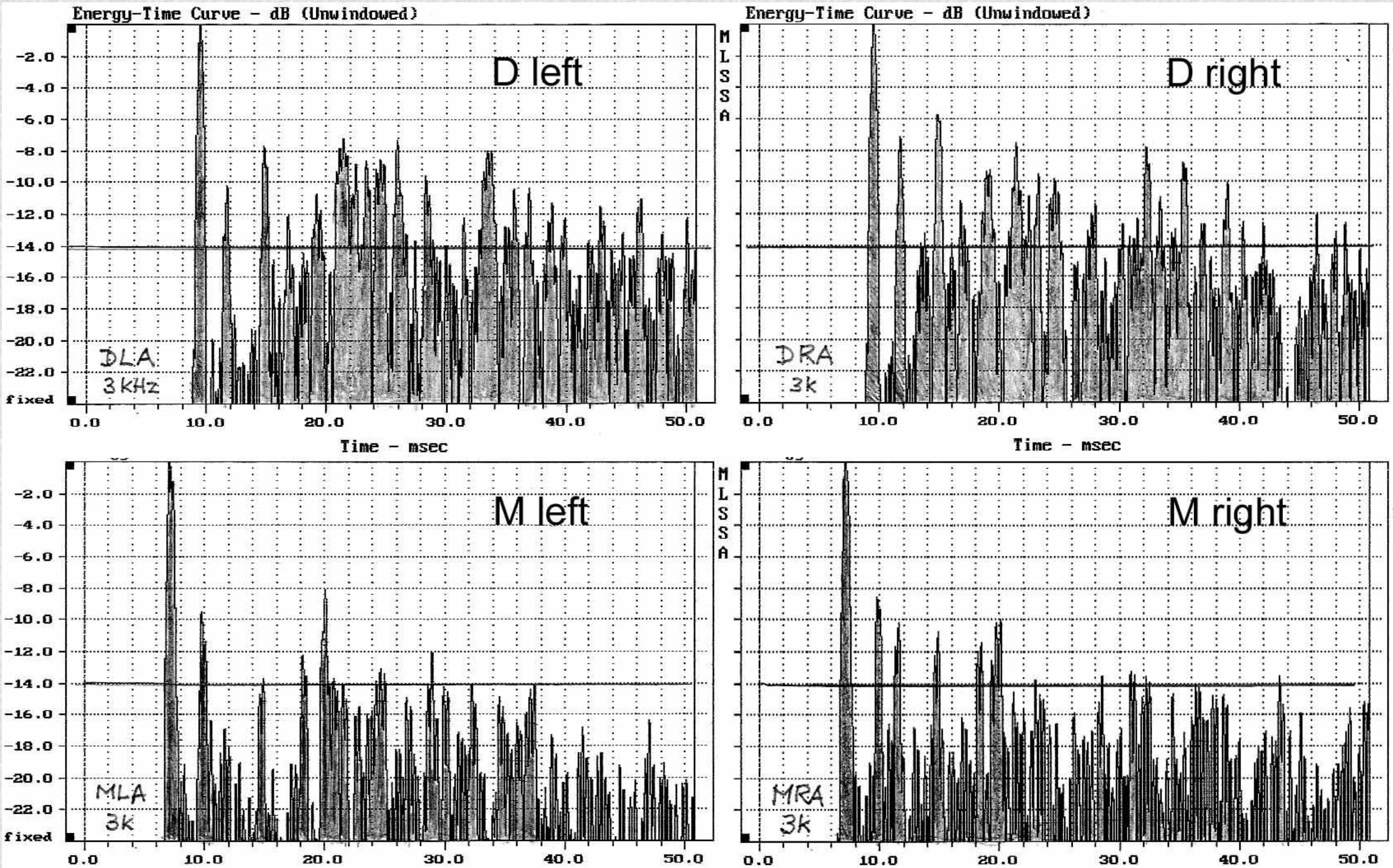






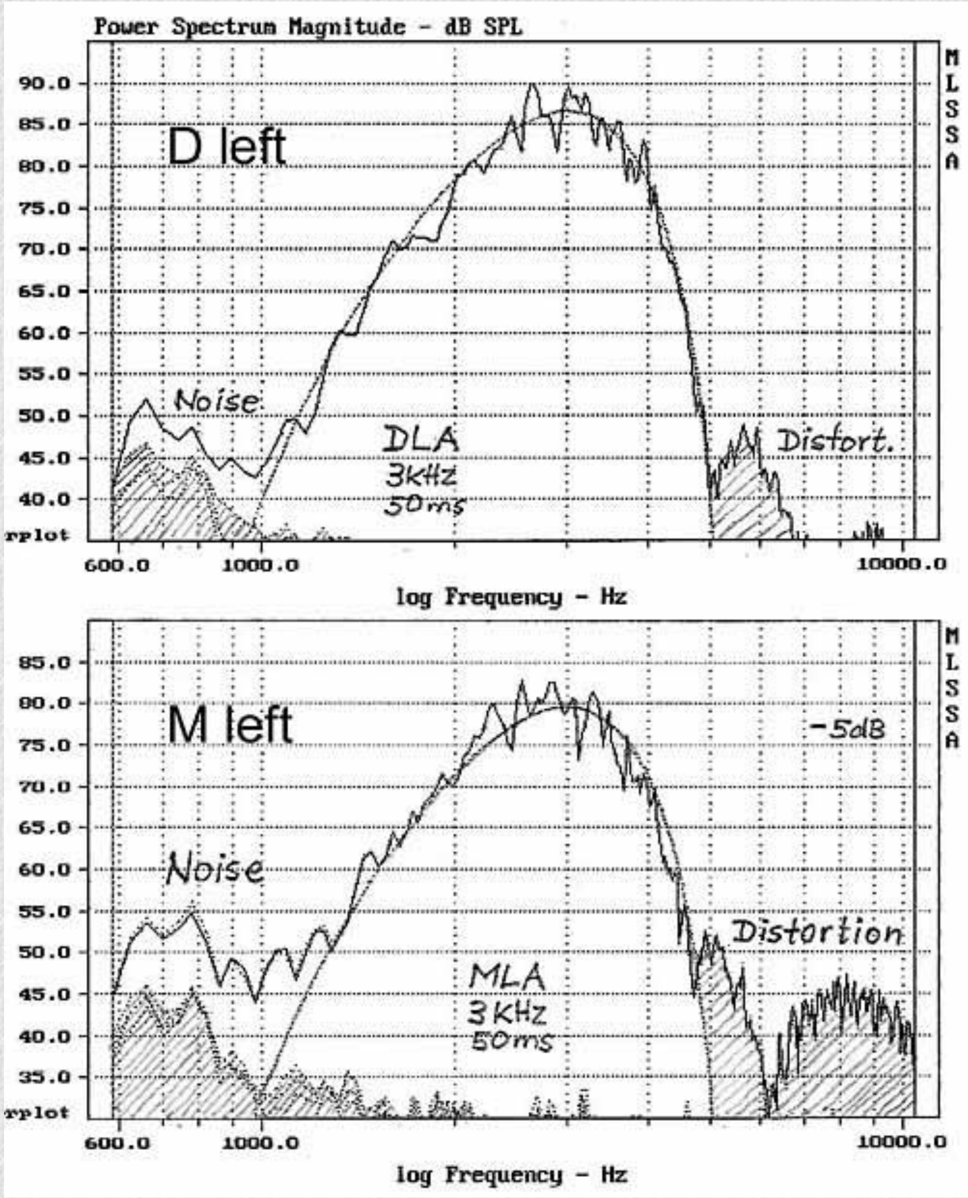
Tone burst test signal

3 kHz burst response at A during 50 ms



LINKWITZ LAB

Power spectrum during 50 ms of 3 kHz burst



POSTULATE #1

To minimize misleading cues from the room requires:

- Spectrum of reflections = direct sound
- Delay of reflections >6 ms (Δl > 6 ft)
- Symmetry of reflections rel. to direct sounds

POSTULATE #2

To optimally illuminate the room requires a frequency-independent polar response as from:

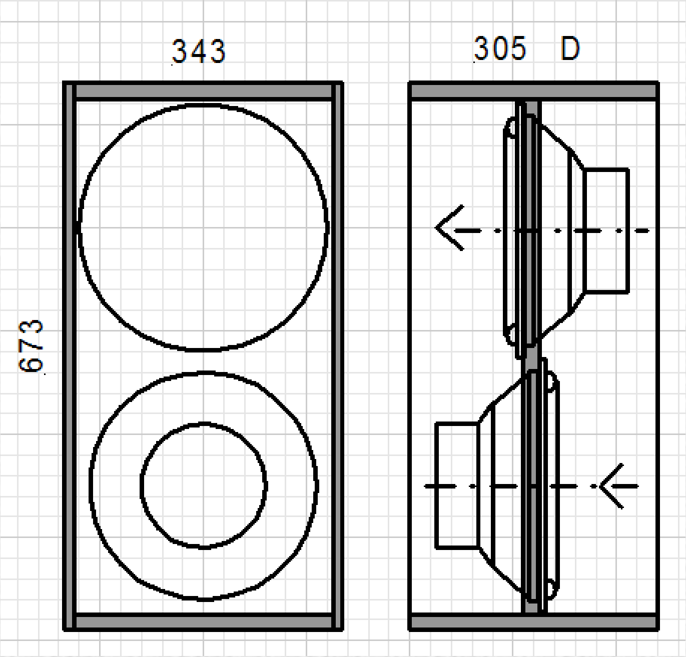
- ❖ Omni-directional loudspeakers
- ❖ Bi-directional, dipolar loudspeakers
- ❖ Uni-directional, cardioid loudspeakers

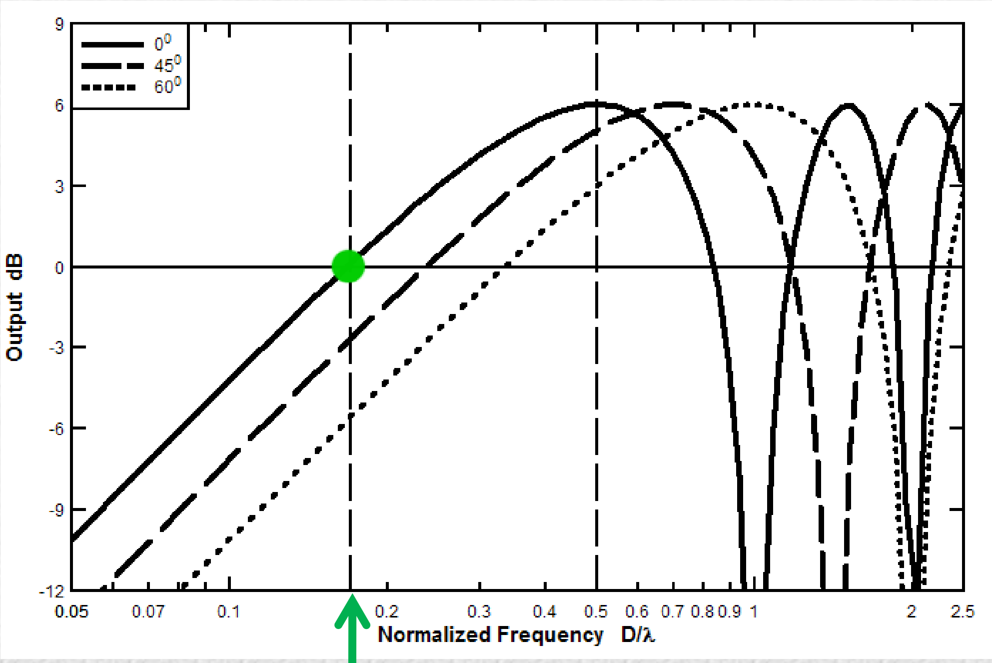
The task of building a dipole loudspeaker with:

- ❖ Flat on-axis response in free-field (20 Hz – 20 kHz)
- ❖ Frequency independent polar response
- ❖ Acoustically small size (λ = 34 cm @ 1kHz)
- ❖ Low cabinet edge diffraction
- ❖ Low stored energy (resonances)
- ❖ Low non-linear distortion (new sounds, intermodulation)
- ❖ Large dynamic range, high SPL

Practical dipole source

- Bass frequency range -

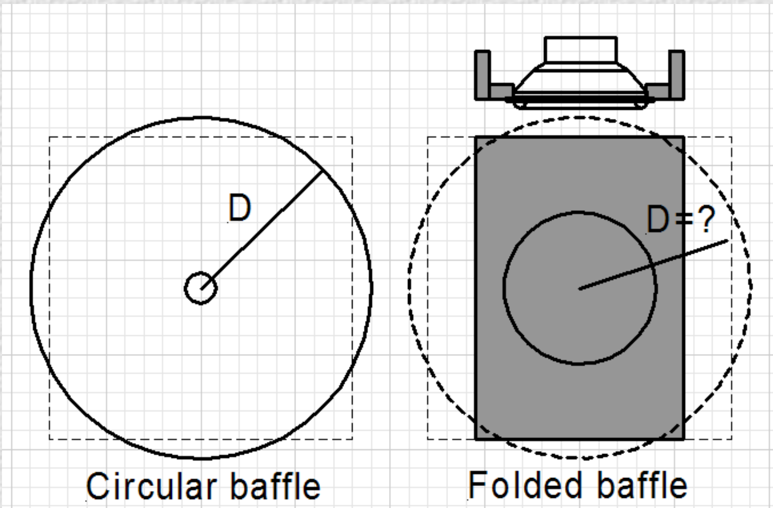


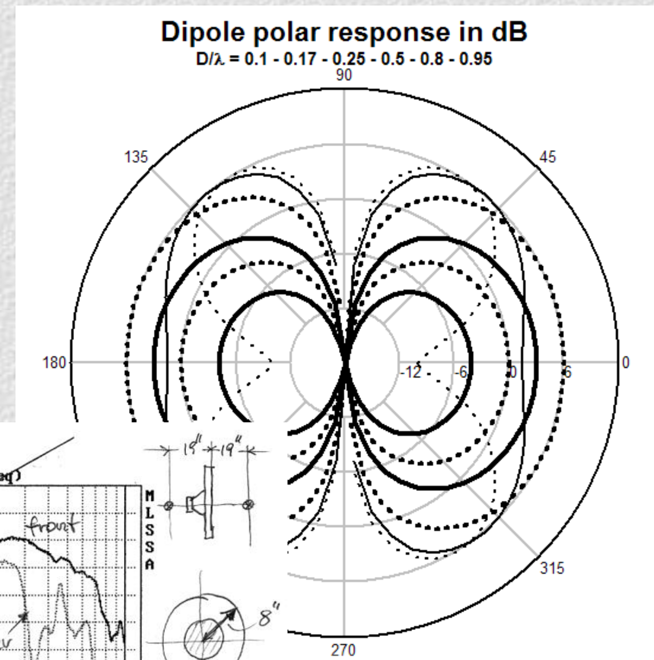


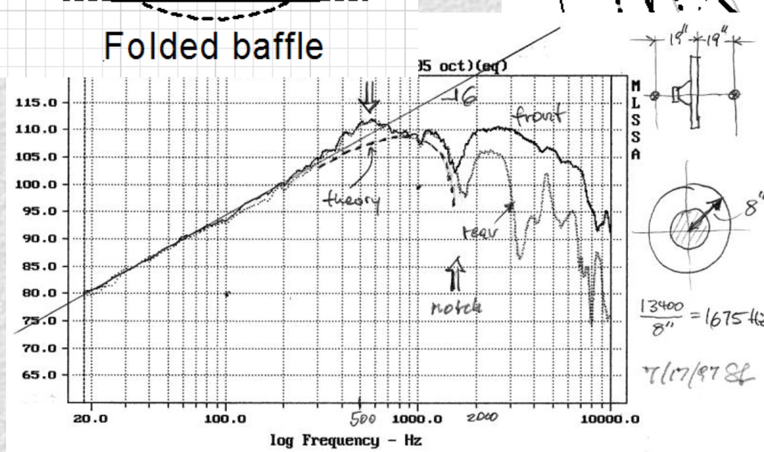
Fequal @ D = λ/6

Practical dipole source

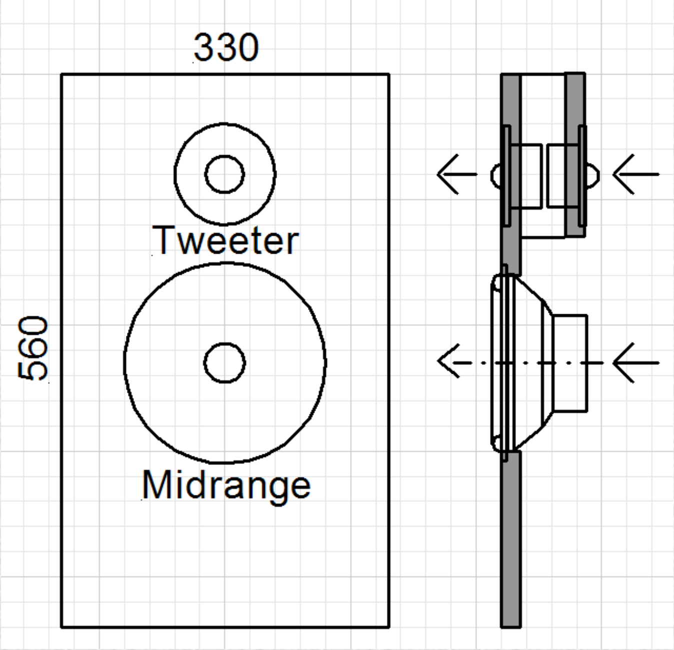
- Mid frequency range -

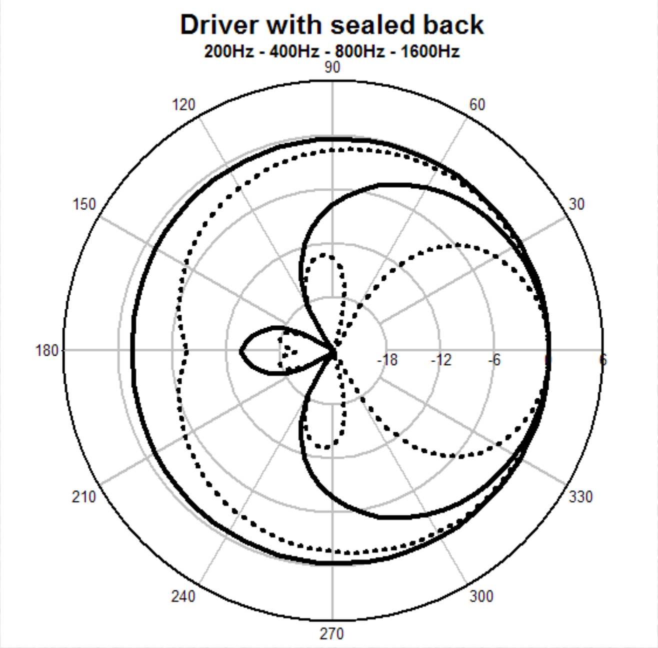




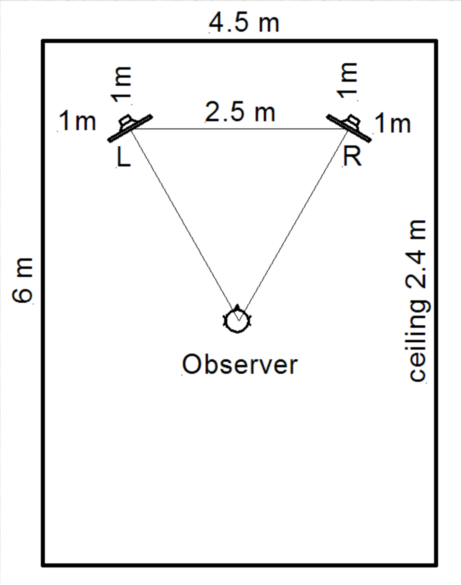


Practical dipole source
- Tweeter frequency range -





Have we found the optimum way to reproduce 2-channel sound?



My Conclusions

❖ Natural hearing processes must be respected to optimally create auditory illusions in the absence of physically accurate wavefield reproduction

❖ Loudspeakers should be designed to illuminate the listening room with equal timbre for all horizontal and vertical angles

❖ Loudspeakers should be placed at least 1 m from the walls

❖ Loudspeakers and listener should be set up symmetrically relative to adjacent room boundaries

❖ The loudspeaker is far more problematic than the room in creating a believable auditory illusion

Compared to surround sound:

What am I missing in stereo?

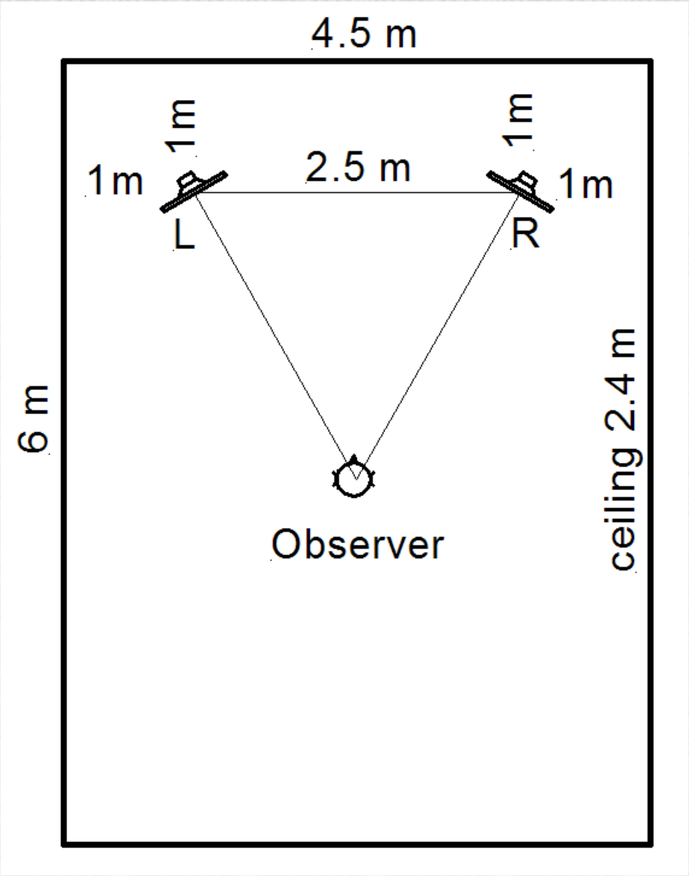
❖ Complete Envelopment

What am I gaining?

❖ Frontal spatial realism
❖ Believability
❖ Satisfaction
❖ Simplicity

I challenge the audio engineering community to scientifically verify, dismiss or refine what has been observed about the perceptual effects of radiation pattern and loudspeaker room placement

Prerequisites for the Tests



1. Room of at least 6 x 4.5 x 2.4 m
2. Tweeter at least 1 m from walls
3. Dipole & box loudspeakers
4. Listeners familiar with acoustic sounds in spaces

Listener Qualifications

Able to listen for the naturalness of sounds rather than for particular preferences

Having auditory memory/experience of unamplified sounds

Able to recognize the naturalness of sounds in space (direct-reflected-reverberant in 3D)

The Task

For the specified setup and for the two loudspeaker types:

1 - Characterize the differences in phantom image creation and loudspeaker/room masking

2 – Determine the sensitivity of the results to loudspeaker placement closer to, or further away from the walls

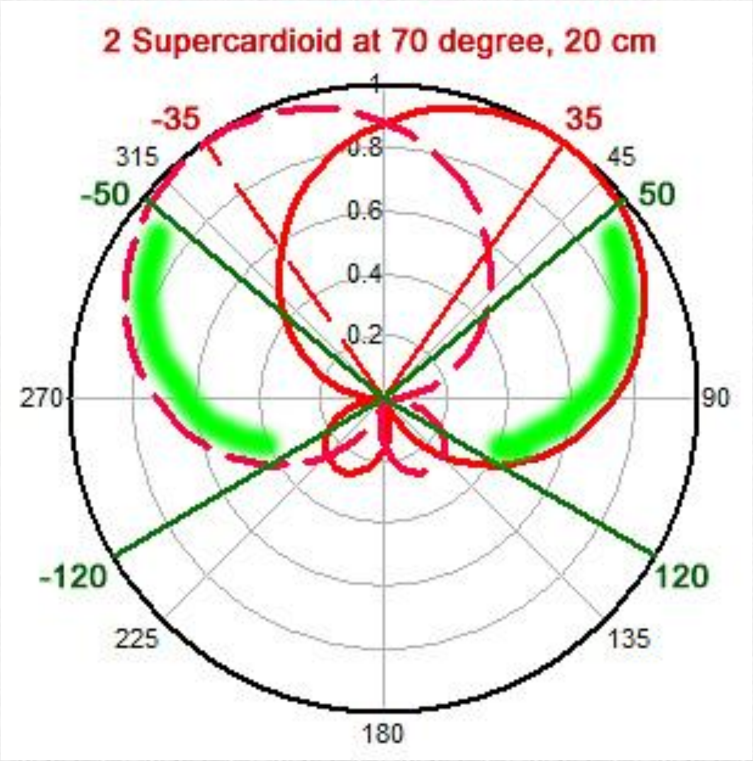
3 – Explain the results in psycho-acoustic terms

4 – Suggest improvements in the radiation pattern, implement them and verify their effectiveness

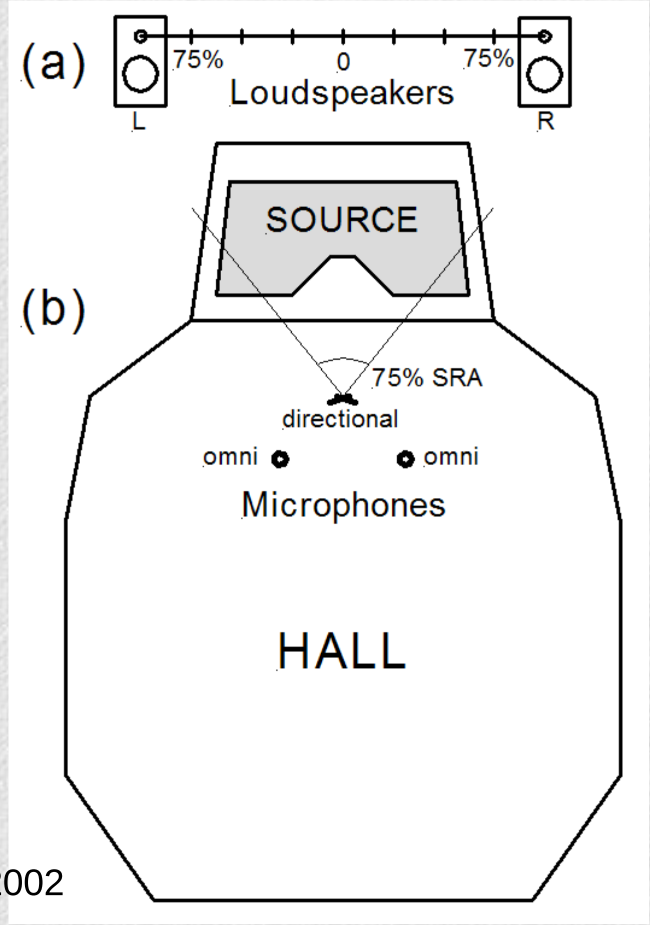
The need for sound recordings from a realistic perspective

Spatial cues about venue and orchestra

Mapping from Concert Hall to Loudspeakers

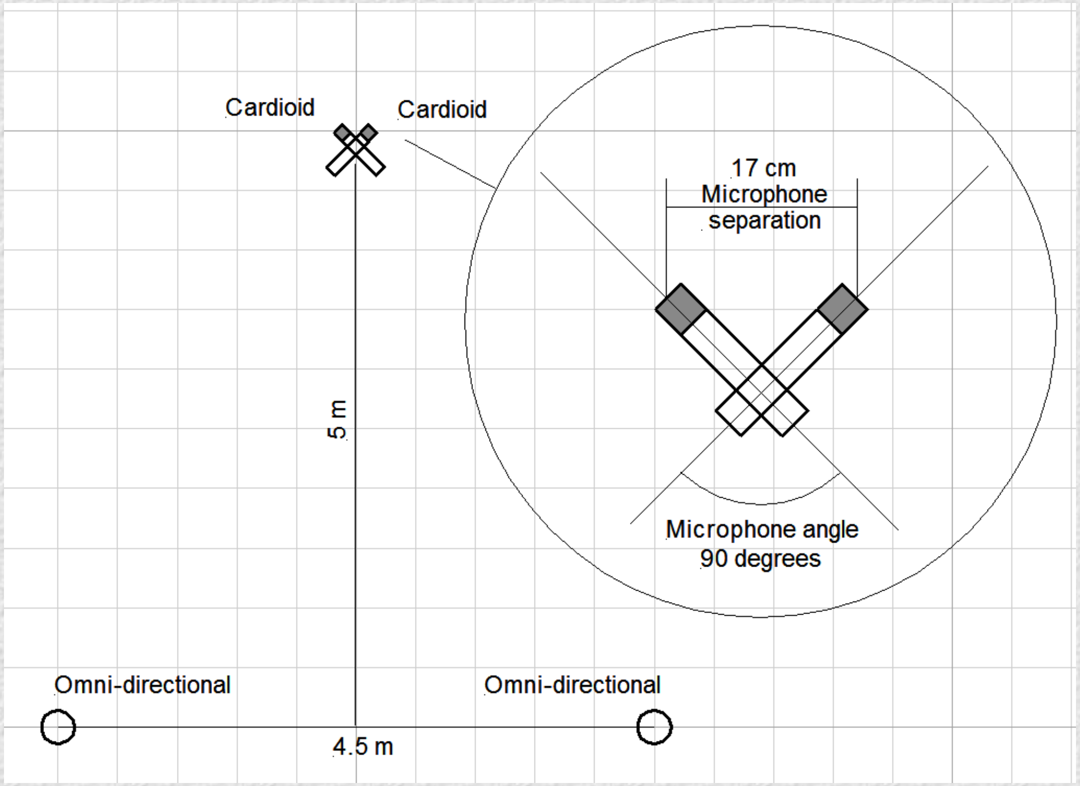


Stereo Recording Angle



H.Wittek, G.Theile, Munich AES, 2002

Source + Response microphone array



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Thank you for your attention

Questions?

www.linkwitzlab.com
Publications