

ECS614U/ECS749P: Sound Recording and Production

Michael Terrell

`michael.terrell@eecs.qmul.ac.uk`

`http://qmplus.qmul.ac.uk/course/view.php?id=3243`

Centre for Digital Music
School of Electronic Engineering and Computer Science
Queen Mary University of London

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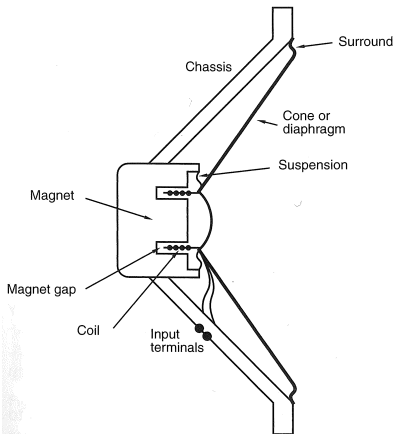
Sound Reproduction

Sound reproduction

- Our perception of a mix is affected by the sound system it is reproduced on.
- This includes both the **loudspeakers** and the **room**.

Loudspeakers

Moving coil loudspeaker



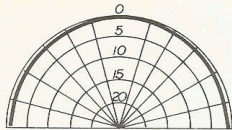
- Reverse process of a dynamic microphone.
- Coil of wire is wrapped around a cylindrical former, mounted in the gaps in a permanent magnet.
- Audio signal is passed through the coil, which induces motion.
- Coil is attached to a cone or diaphragm, and its movement causes compressions and rarefactions in the air (i.e. sound).

Loudspeaker directivity

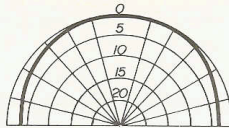
- The polar directivity pattern of a loudspeaker is analogous to the polar response pattern of a microphone.
- It describes how the sound is radiated by the loudspeaker as a function of angle and frequency.
- The angle of dispersion is often referred to as the Q-factor (like an EQ filter). A high Q means a narrow angle.
- Loudspeakers are either variable Q, or constant Q (most studio speakers are variable Q).

Idealised directivity pattern (a single radiating piston mounted in an infinite baffle)

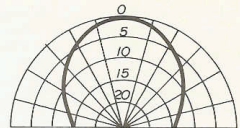
- Directivity is dependent upon frequency; high frequency is more directional.



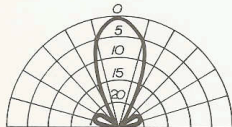
DIAMETER = $1/4 \lambda$



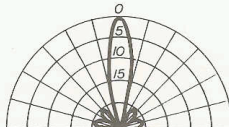
DIAMETER = $1/2 \lambda$



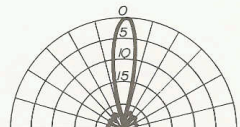
DIAMETER = λ



DIAMETER = 2λ

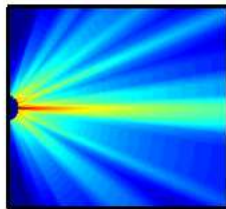
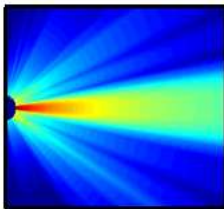
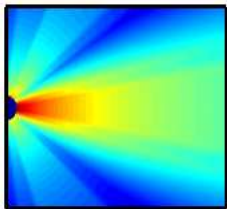
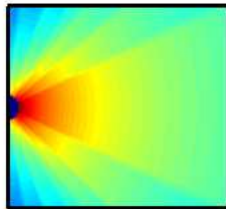
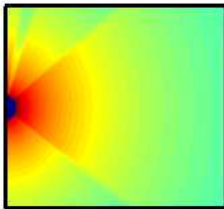
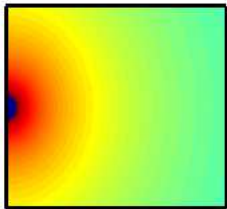


DIAMETER = 4λ

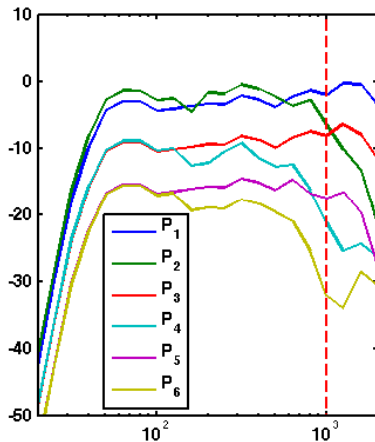
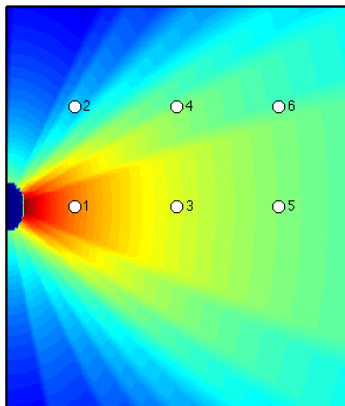


DIAMETER = 6λ

Directivity Pattern of a real loudspeaker



Frequency response at different locations



Moving Coil Design Considerations 1

- **HF limit:** a small diaphragm radius increases the HF limit, but is inefficient and has poor sensitivity.
- **LF limit:** a heavy diaphragm and soft suspension decreases the LF limit, but a heavy diaphragm is inefficient with poor sensitivity, and soft suspension is mechanically fragile.
- **Efficiency:** a large and light diaphragm improves efficiency, but it is hard to have both large and light.

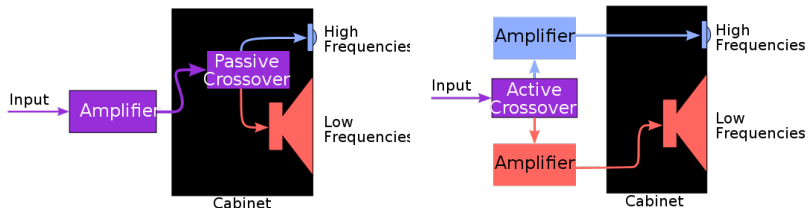
Moving Coil Design Considerations 2

- **Linearity:** we want the frequency response to be the same at any signal level.
 - If coil and magnet gap are the same length, there is less of the coil in the magnetic field when it is displaced, so velocity becomes displacement-dependent.
 - Solve by making either the coil or gap longer, but this reduces efficiency.
 - Non-linearity also caused by non-perfect spring behaviour of the suspension.

Crossovers

- The efficiency of good quality loudspeakers is around 5%.
- It is impossible to design an efficient (moving coil) drive unit with a flat frequency response over the full range.
- The strategy is to split the audio signal into frequency bands using a **crossover**, and to send each part to a separate driver that is tuned to work in a specific frequency range.
- For standard two-way speakers the drivers are referred to as “woofers” and “tweeters”.

Passive and Active Crossovers



<http://commons.wikimedia.org/wiki/User:Iainf>

Passive and Active Crossovers

Type	Passive	Active
Advantages	<ul style="list-style-type: none"> • One amp per speaker • Easy to realise cheaply • HF drive unit protected from switch-on 	<ul style="list-style-type: none"> • Easy to design accurate and sophisticated filters • Components are cheap • Direct connection of power amp to drive unit: good control • Easy adjustment for different drive unit sensitivities • Can use power amps with different power outputs • Can easily incorporate EQ to compensate for drive-unit
Disadvantages	<ul style="list-style-type: none"> • Hard to design accurately • Components large and expensive for high power systems • Harder for amp to control drive unit at resonance • Difficult to match drive units of different sensitivities • Must have same LF and HF power output • Components can saturate at high drive levels 	<ul style="list-style-type: none"> • At least two power amps per speaker (expensive) • More cabling • Amp switch-on can damage tweeters.

Other Loudspeaker Types

- Other transducers used include:
 - Electrostatic
 - Ribbon
 - Distributed mode
 - Piezo-electric
- These are very rare. They are generally capable of very high sound quality, but with low power. They are also difficult and expensive to manufacture.

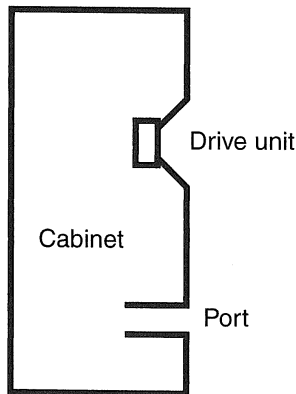
Cabinets

- In free air the cone would radiate sound forwards and backwards in a figure-of-eight pattern with the lobes out of phase.
- This causes cancellation for wavelengths greater than the dimensions of the drive unit (bass frequencies).
- Drive units are usually mounted in closed cabinets to prevent cancellations.
- Cabinet design can have a great impact on the speaker performance.

Closed-Back Cabinets (approx infinite baffle)

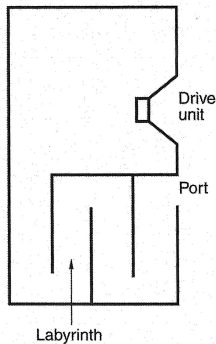
- Drive unit is mounted in one wall of a closed, stiff box.
- At LF the air in the box is a lumped acoustic stiffness. Stiffness is higher for small cabinets and for large cone radii, so large cones require large cabinets.
- At HF standing waves occur inside the cabinet, which can alter the forward radiation, so cabinets are lined and/or filled with a sound-absorbent material.

Ported Cabinets (Bass Reflex)



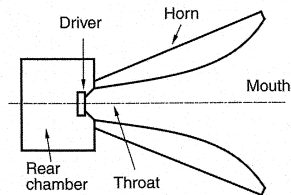
- Air in the hole has a mass and resonates at a particular frequency, reinforcing the forward projected sound from the drive unit.
- Below the resonant frequency the air motion causes sound to be radiated out of phase with the drive unit, so cancellation occurs.
- Above the resonant frequency the air movement is small so the cabinet behaves as if it were closed.
- With careful tuning of the resonant frequency the low frequency limit of the speaker can be extended.

Transmission Line Cabinets



- Another form of bass loading.
- The resonant frequency is determined by the length of the labyrinth.
- Very good bass extension possible.
- Very large cabinet required.
- *Sound wave animation.*

Horn Loading

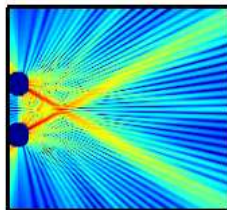
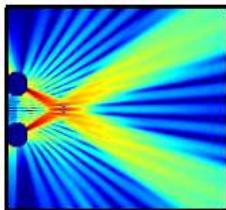
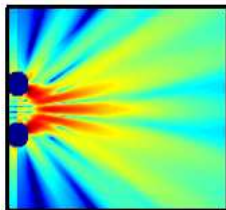
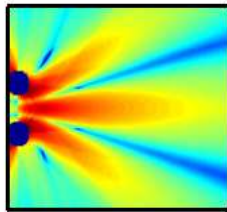
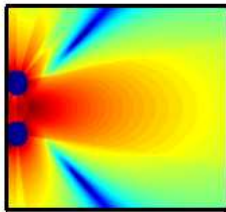
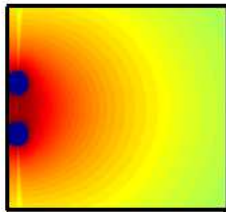


- Horn matches the air impedance at the throat with the impedance of the driver to increase transducer efficiency.
- High pressure / low amplitude sound waves are expanded by the horn into low pressure / high amplitude sound waves at the mouth.
- Horn operates at a limited frequency range, so frequency response is compromised.
- Good when very high sound levels are required.
- Horns tend to be more directional than conventional speakers.

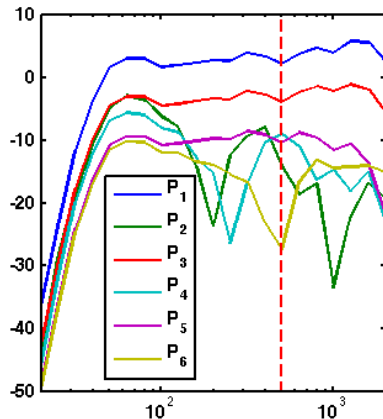
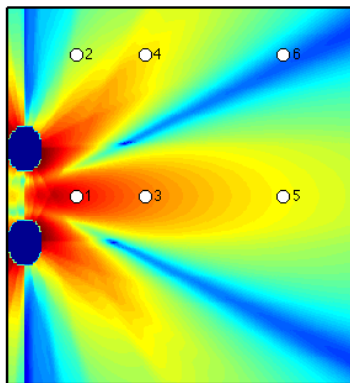
Loudspeaker Interaction

- Most mixing is done on a pair of loudspeakers (left and right).
- The acoustic signals from each of the loudspeakers will interact.
- PHASE! PHASE! PHASE!

Loudspeaker Interaction



Loudspeaker Interaction



Room Acoustics

Room Acoustics

- How do sounds propagate within a space?
- How do sounds travel from their source to a receiver?

Why Study Room Acoustics?

- To improve speech intelligibility, e.g. in a church.
- To improve the quality of music reproduction and performance, e.g. concert hall.
- To control sound in places of work, e.g. noise levels in factories.

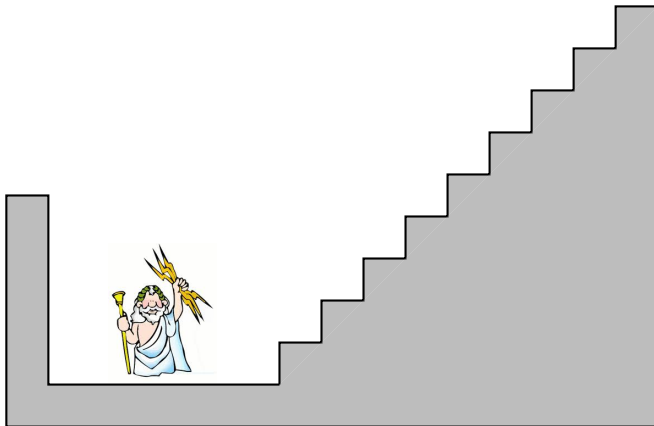
Why Study Room Acoustics?

- Modifying the acoustics of a room is incredibly expensive.
- Rooms are designed with their acoustics in mind:
 - Engineering rules of thumb.
 - Computational modelling.

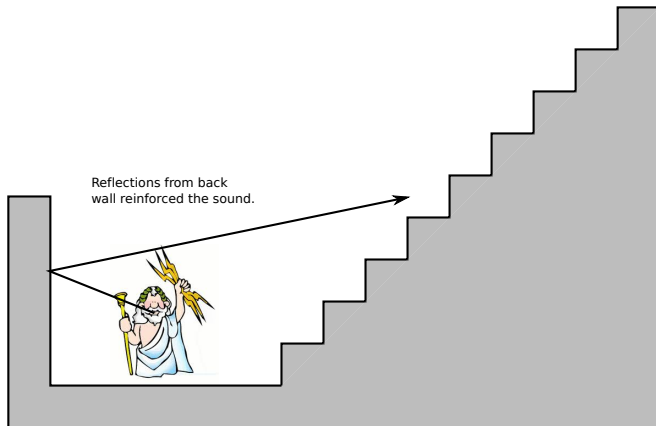
Greek Amphitheatres



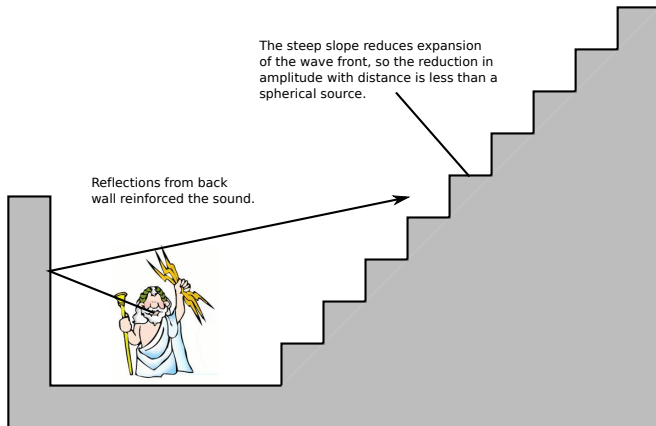
Greek Amphitheatres



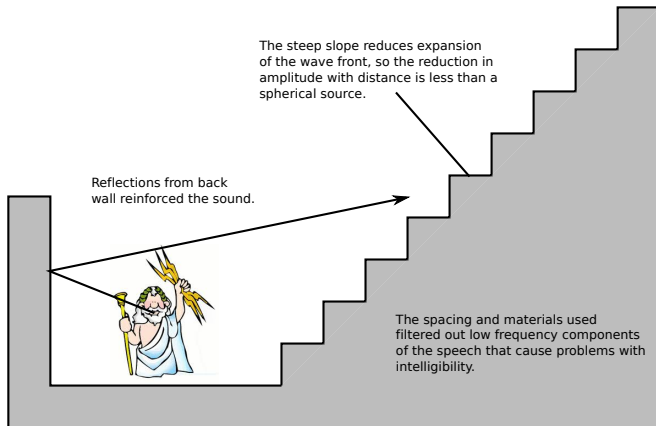
Greek Amphitheatres



Greek Amphitheatres



Greek Amphitheatres



Room Resonance

- A room can be thought of as a large box of air.
- Standing waves can form in a room, and are referred to as room resonances (or room modes).

<http://www.walter-fendt.de/ph14e/stwaverefl.htm>.

- The resonant frequencies are dependent on the room geometry.

Shroeder Frequency

- What happens to the room modes as the frequency is increased?

Shroeder Frequency

- At high frequencies the density of the standing waves increases, and the spacing between nodes and anti-nodes decreases.
- This has a chaotic, randomising effect on the formation of standing waves, and they become less prominent and perceptible.
- The transition from discrete to randomised standing waves occurs at the Shroeder frequency.

Shroeder Frequency

- What happens to the room modes as the volume of the room is increased?

Shroeder Frequency

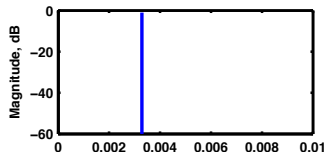
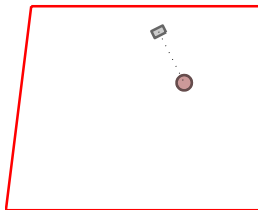
- In large rooms the first mode (the fundamental) has a much lower frequency
- The density of standing waves will reach the transition state at a lower frequency, i.e. Shroeder frequency is lower.
- In large rooms there may be no discrete room modes in the audible frequency range.
- In small rooms many discrete room modes will exist in the audible frequency range.

Room Resonance

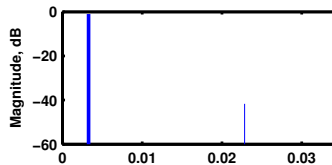
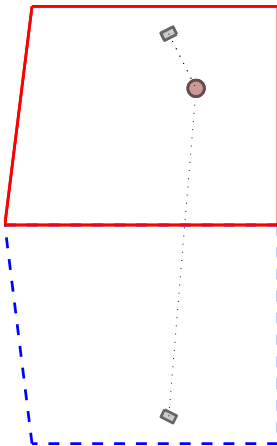
- What happens when a room is full of “stuff”, e.g. tables, chairs, people?
- What happens when a room geometry is non-symmetrical?

Room Reflections

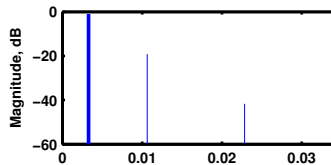
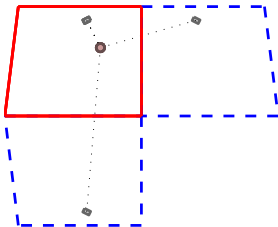
How can we model the signal path from loudspeakers to the listener, including the effect of reflections?



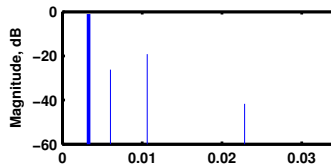
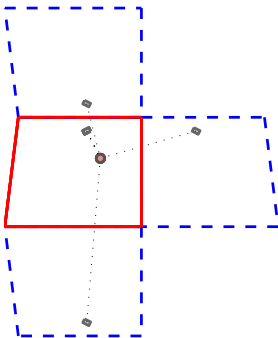
Room Reflections



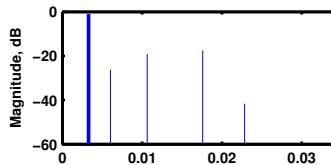
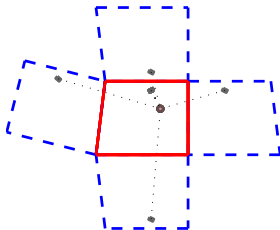
Room Reflections



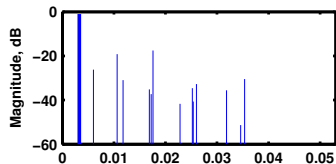
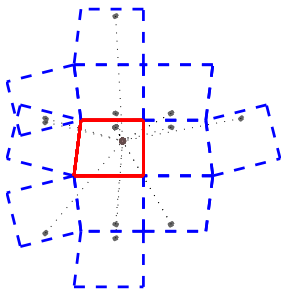
Room Reflections



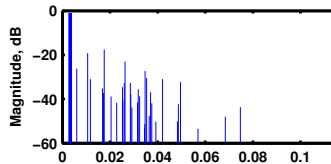
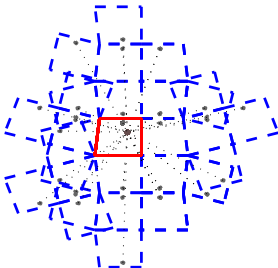
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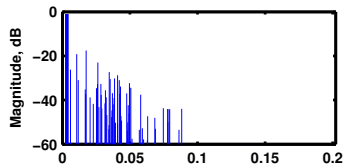
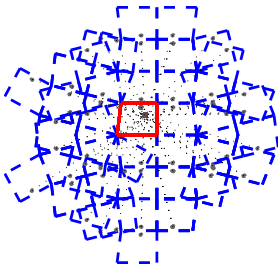
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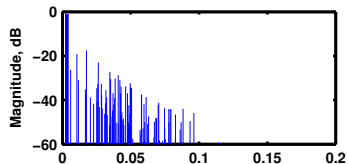
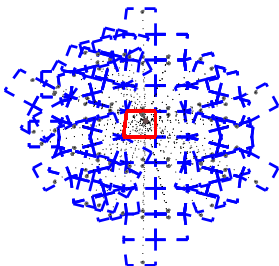
Room Reflections



Room Reflections

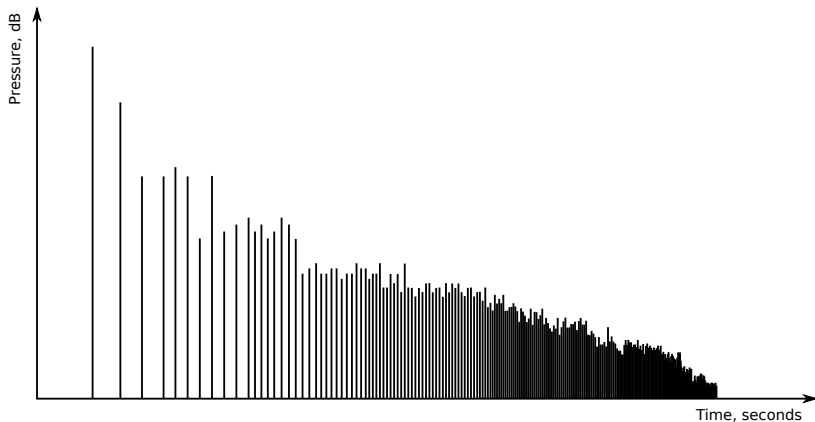


Room Reflections



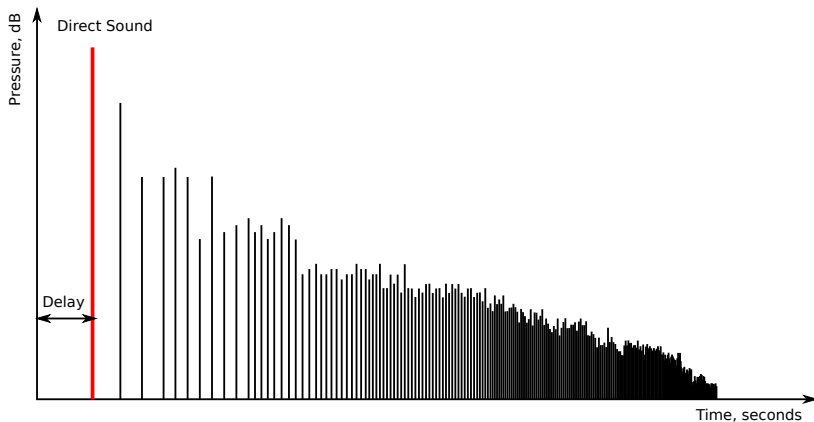
Room Impulse Response

If my source produces an impulse, what does my receiver measure?



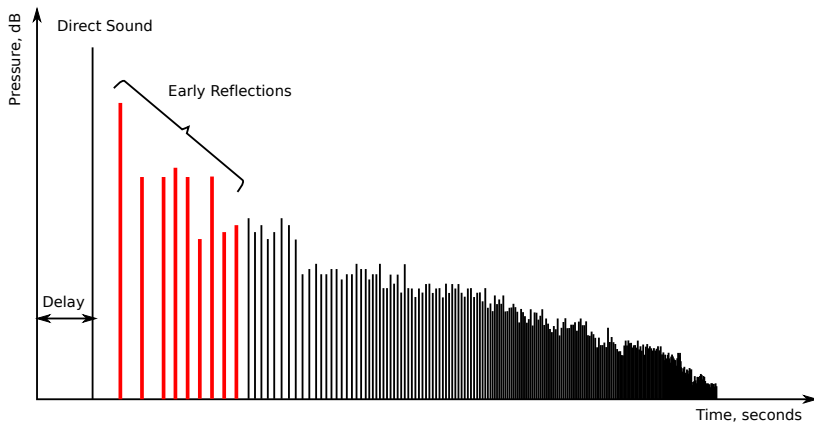
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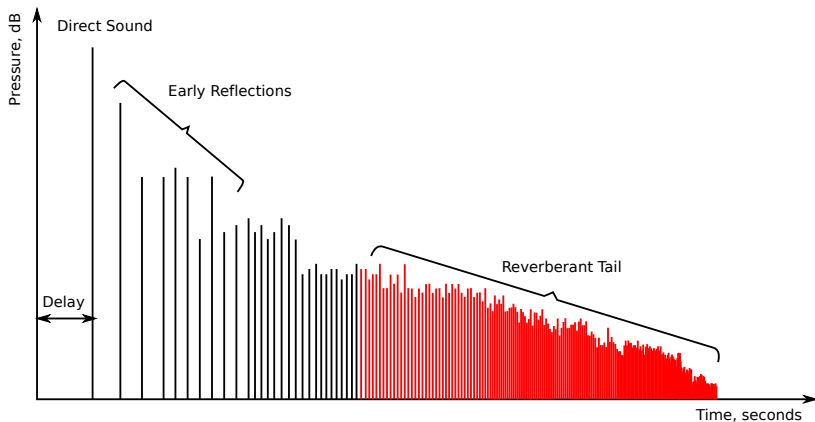
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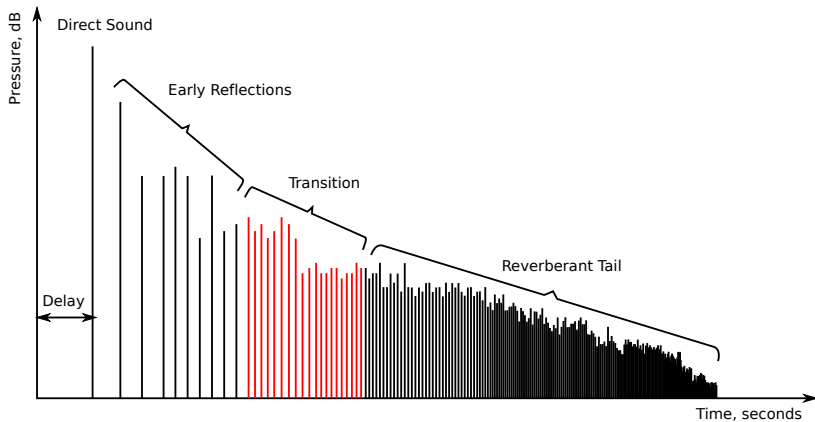
Room Impulse Response

If my source produces an impulse, what does my receiver measure?



Room Impulse Response

If my source produces an impulse, what does my receiver measure?



Room Acoustic Terms

- **Direct sound:** the sound reaching the receiver via a direct path from the source, i.e. no reflections.
- **Indirect sound:** the sound reaching the receiver from all reflected paths.
- **Early reflections:** discrete low order reflections.
- **Reverberant tail:** high density, high order reflections.
- **Transition phase:** region where the impulse response changes from early reflections to the reverberant tail.

Room Acoustic Metrics

- **RT_{60} (RT_{30}):** the time it takes for the energy in the impulse response to drop by 60 (30) dB.
- **Direct to reverberant ratio:** the ratio of energy in the direct sound versus the reverberant tail.
- **Frequency response:** the effect that the room has on the frequency spectrum of a signal.

Reflections

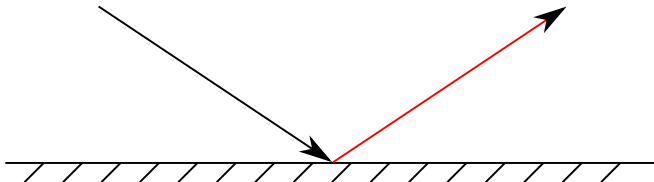
- Sound energy is invariably absorbed by the reflecting surface → the reflected sound wave has a lower magnitude compared to the incident wave.
- The phase of the sound wave can also be altered by the reflection.
- The effect on both magnitude and phase can be frequency dependent.

Reflections

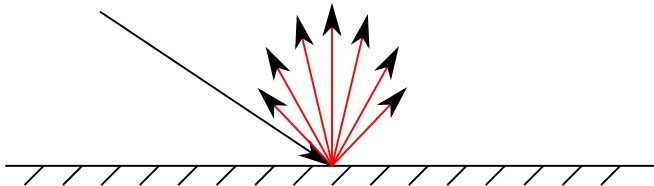
- The directional distribution of sound energy after a reflection will lie between two extremes:
 - **Specular** - the energy is reflect at an angle equal to the angle of incidence.
 - **Diffuse** - the energy is smeared in many directions and is independent of the angle of incidence.

Reflections

SPECULAR REFLECTION

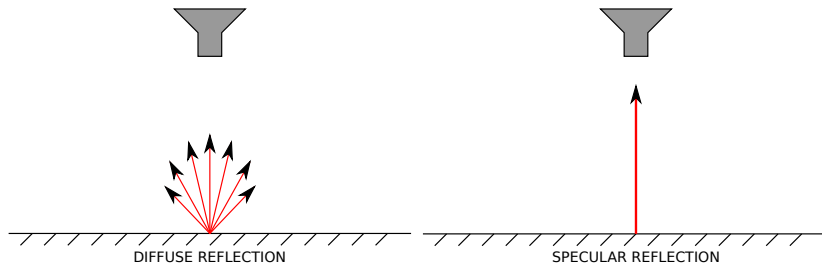


DIFFUSE REFLECTION



Reflections

- Diffuse reflections scramble the sound wave so it is a less perfect copy to the original.
- A specular reflection is a perfect copy of the original sound.
- How does this effect sound reinforcement and cancellation due to a reflection?



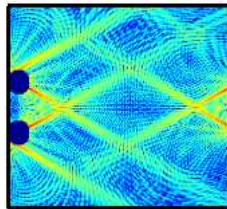
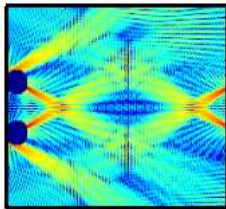
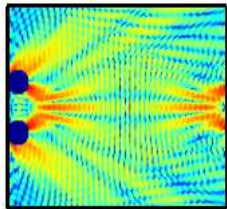
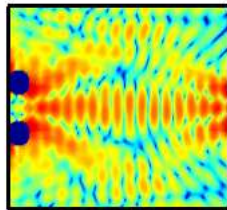
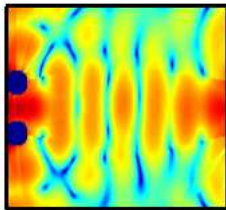
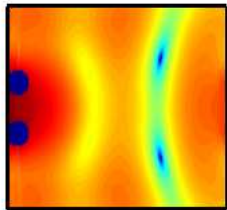
Absorbers and Diffusers

- **Absorbers** are placed in rooms to remove sound energy from reflected waves. They are generally tuned to specific frequencies.
- **Diffusers** are used to scatter the energy and randomise the phase of a reflected sound. This reduces the comb filter effect compared to specular reflections.

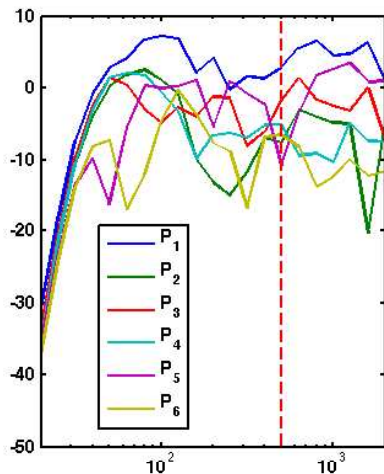
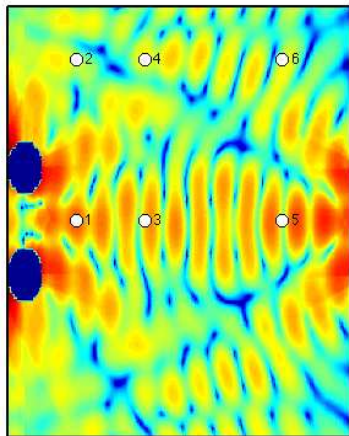
Frequency Response

- The room **impulse response** tells us how reflections affect our source sound as a function of time.
- The room **frequency response** tells us how reflections affect our source sound as a function of frequency.
- These terms are used for any system, not just for rooms.

(Loudspeaker Pair + Room) Response



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Measure System Responses

- To measure a loudspeaker + room (+ microphone + interface) response:
 - Play a test signal through a loudspeaker (noise or sine sweep).
 - Record the signal using a microphone.
 - Compare the two signals to extract the impulse and frequency response.
- A 30 day trial of Smaart can be download from *www.rationalacoustics.com*.