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sense and simplicity

ENSEA

Ecole Nationale
Supérieure
de l'Electronique
et de ses Applications

ENSEA conference

Small acoustics

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January 8, 2000

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Introduction

Listening to loudspeakers

The difference which comes when comparing how headphones and loudspeaker produce sound is

- With loudspeaker, listener is **immersed** in a propagating sound field

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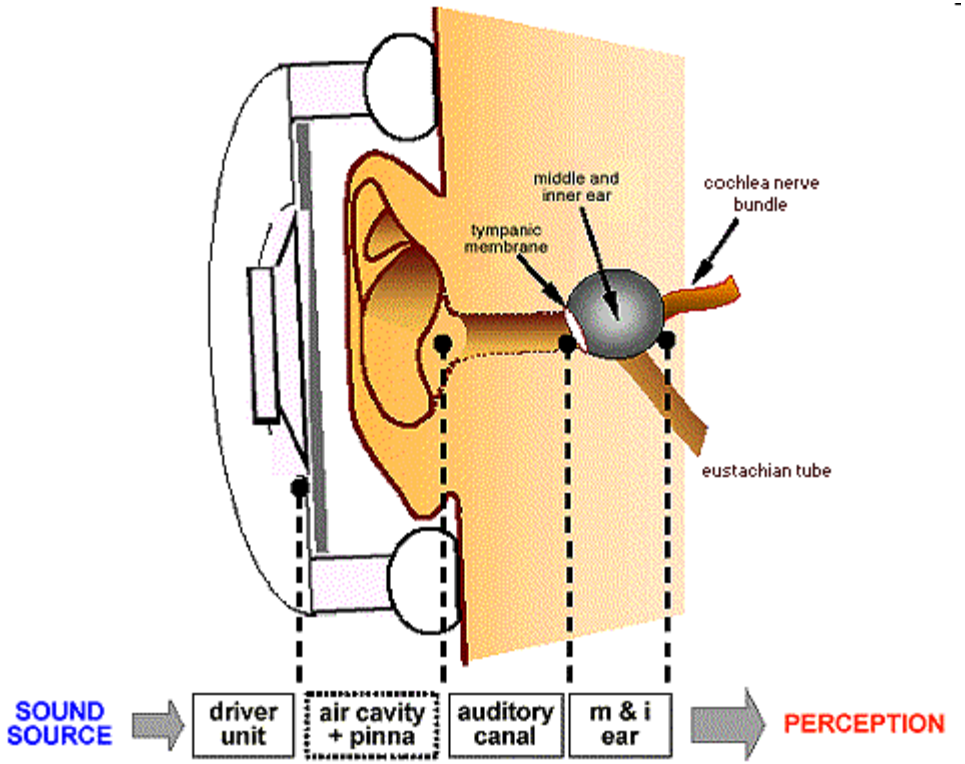
Introduction

Listening to headphones



From the sound source to the perception

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Introduction

- Loudspeaker is made to reproduce a sound stage recorded during a concert or a studio session
- What about headphones?

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Introduction

We have to split the question into two:

1. Frequency response (timbre,…)
2. Sound image (localization,…)

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Headphones frequency response

- In front of the headphones driver there is a cavity (see slide 3)
- Up to 2kHz where the wavelength is still large compare to the cavity dimensions, the **sound pressure is distributed uniformly in the volume**
  Pressure is in phase with the volume displacement and **its amplitude is propositional to it.**
- **Leaks** influence low frequencies

→ Acoustics phenomena are different from the loudspeakers ones

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Headphones frequency response

- For a loudspeaker the aim is to get a flat frequency response
- What could be the “ideal” headphones frequency response?

- Torso, shoulder, head, external ear, … influence the sound propagation by creating diffractions and reflections

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Headphones frequency response

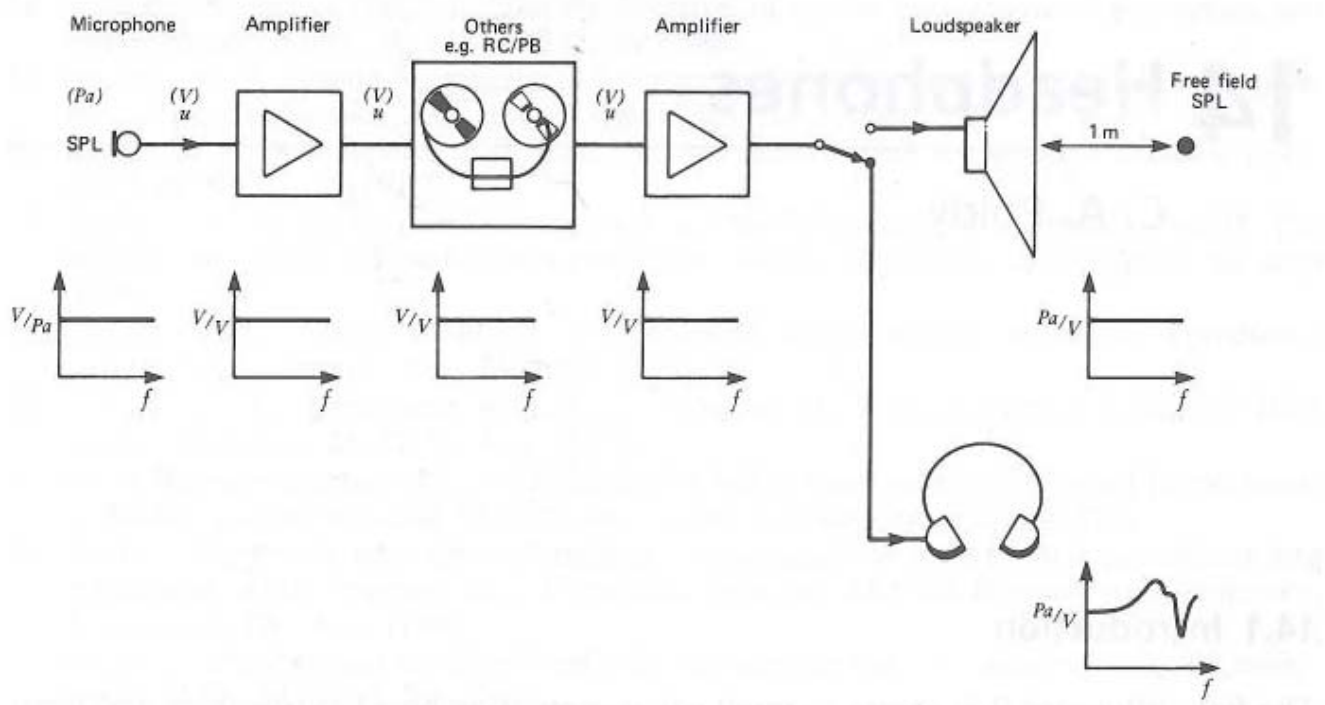

Figure 14.1. Block diagram comparing headphones with other components in the hi-fi chain.

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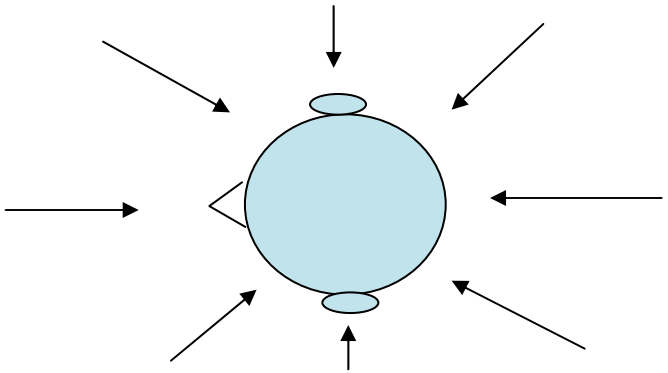
How to equalized the frequency response

- Free field response
  “anechoic environment”

- Diffuse field response
  “reverberant environment”



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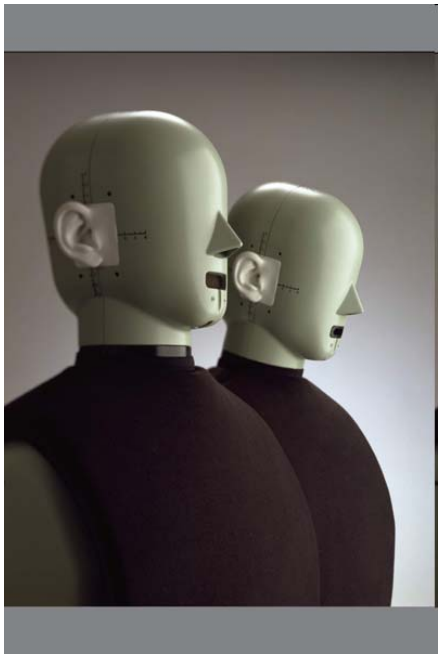
Headphones frequency response
The dummy heads

Kemar



HATS from B&K

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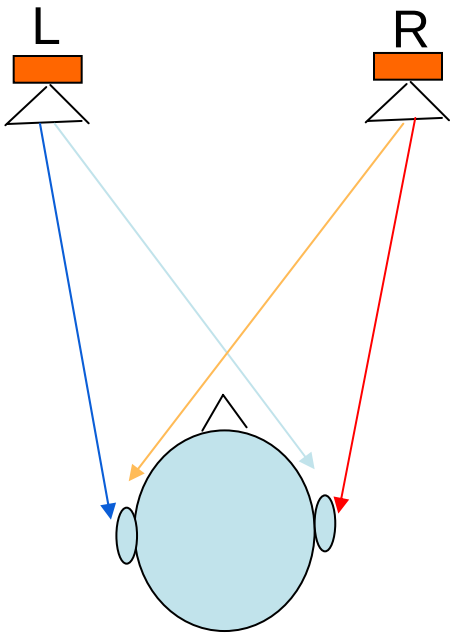
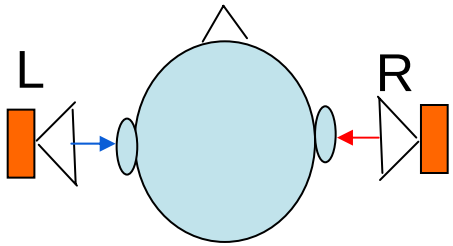
Sound image
Cross-talk

Loudspeakers



Headphones



Part of the signal is missing

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Type of headphones

- Defined by the form factor
  - Circum-aural
  - Supra-aural
  - Ear-bud
  - In-ear

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Type of headphones

- **Circu-maural headphones** have circular or ellipsoid ear pads that fit around the ears. Commonly used in recording studios and among audio enthusiasts.

- **Supra-aural headphones** have pads that sit on top of the ears, rather than around them. (headband, neckband, ear-hook)

- **Earbuds** or **earphones** are headphones of a smaller size that are placed directly outside of the ear canal, but without fully enveloping it. Inexpensive and are favored for their portability and convenience.

- **Canalphones**, also known as **in-ear monitors**, or **IEMs**, are earbuds that are inserted directly into the ear canal.
  They offer portability similar to earbuds, and also act as earplugs to block out environmental

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Driver technologies

- According to the form factor, different type of drivers are needed

- Different driver technologies are available
  - **Electro-dynamic (**from 6mm to 50mm diameter)
  - Electrostatique
  - Electret
  - **Balanced Armature**
  - Ortho-dynamic

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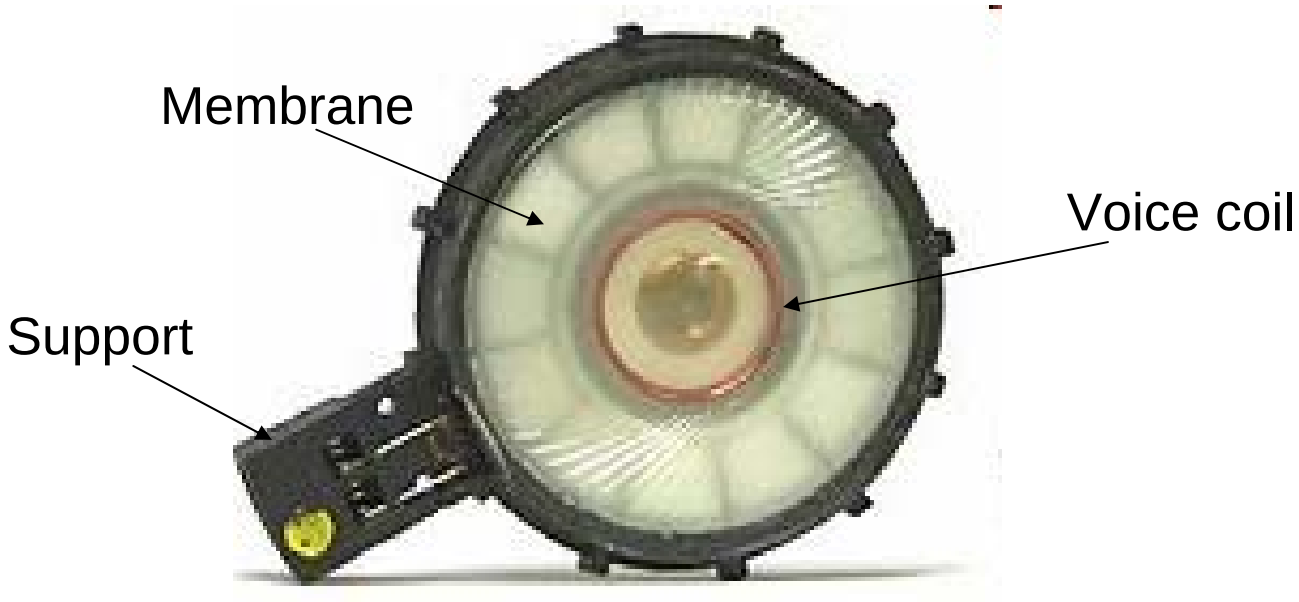
Electro-dynamic driver

- Same principle as the loudspeakers
  - Moving mass
  - Motor
  - **No Suspension,** the membrane takes care of that



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Balanced armature driver

- Electro-dynamic principle
- Transducers used by the hearing aids brands
- In-ear application
- More and more popular: Shure, Etymotic Research, Philips, Apple, …

Philips SHE9850

Apple in ear (2 transducers per ear)

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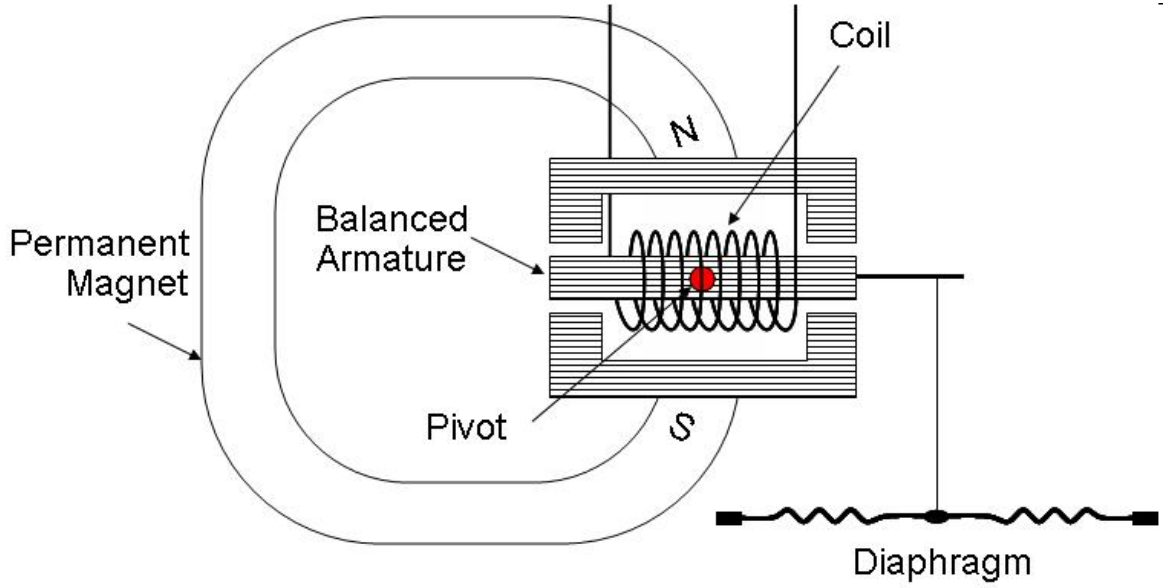
How does it work?

- Electro-dynamic principle but optimized in term of size



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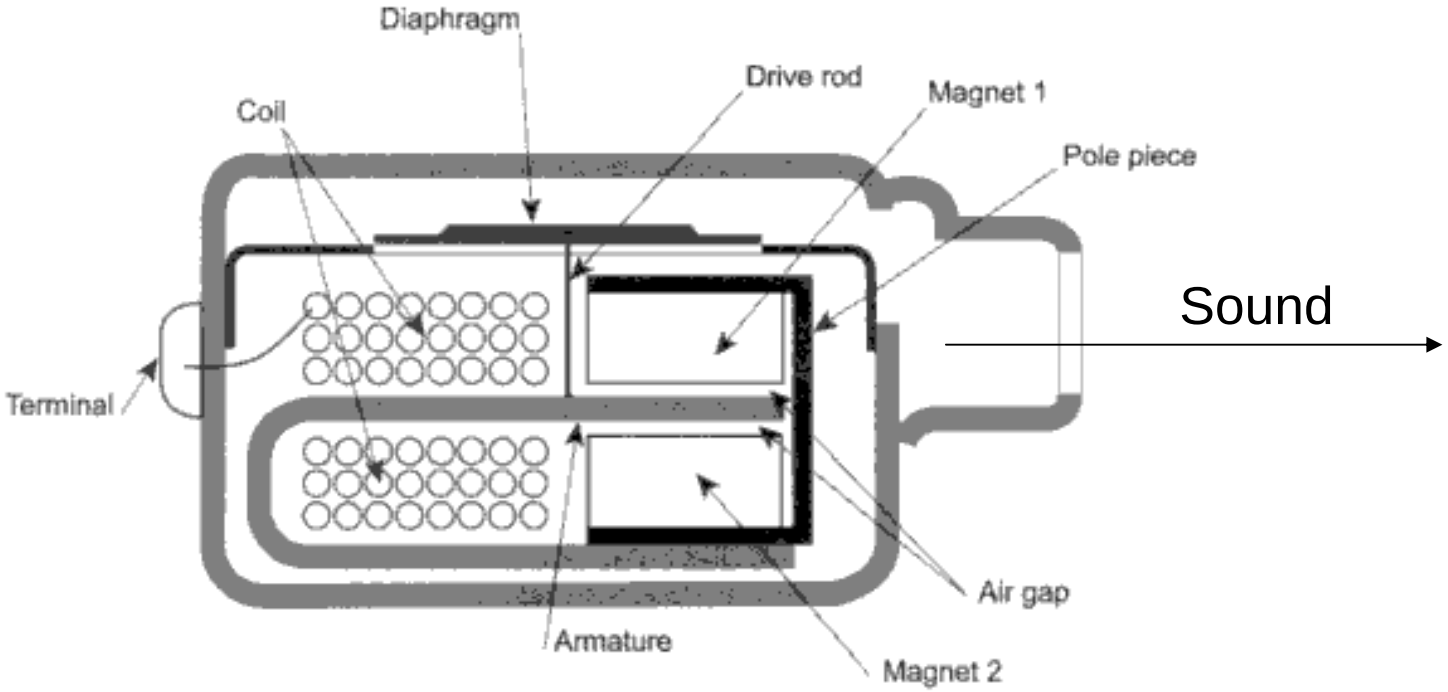
Balanced armature driver architecture



Dimensions are about 5mm x 2mm x 3mm

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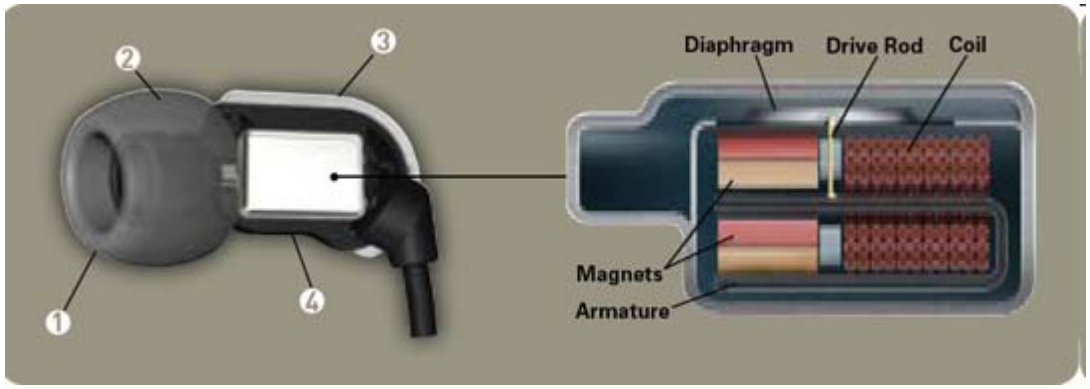
Product examples



Creative

Philips SHE9850

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Noise cancelling

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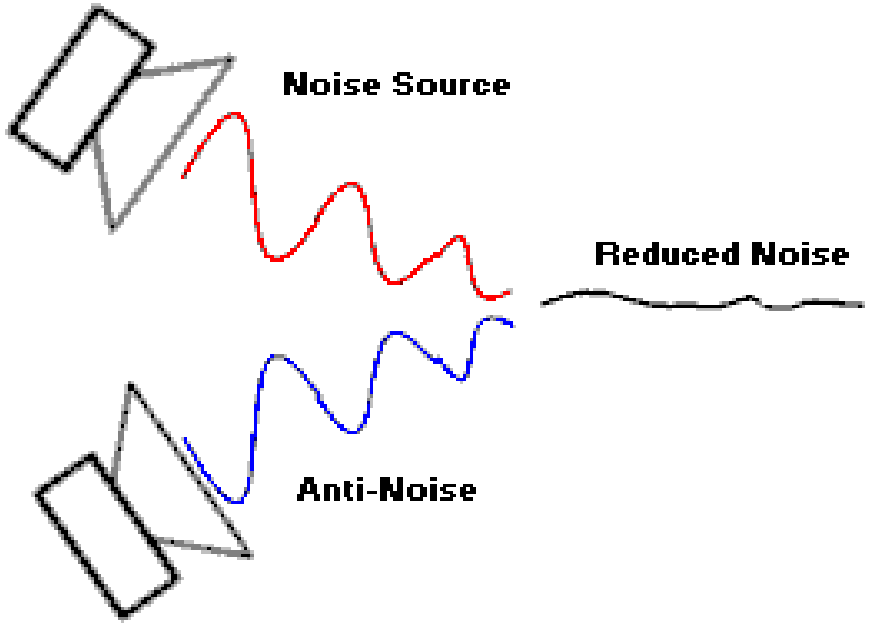
Active noise cancelling headphones
Principles

Two “out of phase” sources to create “silence”



Active Noise Reduction

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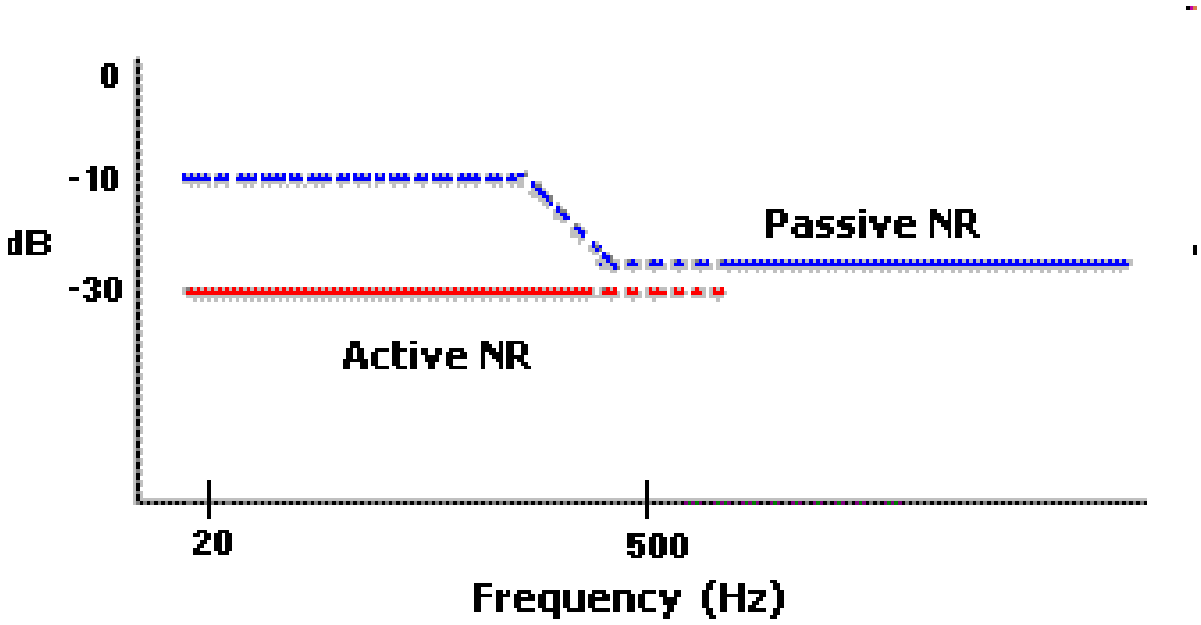
Active noise cancelling headphones

Passive/Active attenuation

The headphone itself blocked external noise with passive attenuation.



Operational Range of Active and Passive Noise Reduction

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Noise cancelling headphones

- Different architectures are available:
  - Microphones inside the ear-shell (feed-back)
  - Microphones outside the ear-shell (feed-forward)

- The listener could activate an externally-mounted microphone to hear speech and other sounds filtered for greater intelligibility in high noise environments.


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HRTF

"The **head-related transfer function *HRTF***, also called the **anatomical transfer function *ATF***, describes how a given sound wave input is filtered by the diffraction and reflection properties of the head pinna and torso before the sound reaches the transduction machinery of the eardrum and inner ear"

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HRTF: Head Related Transfer Function