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

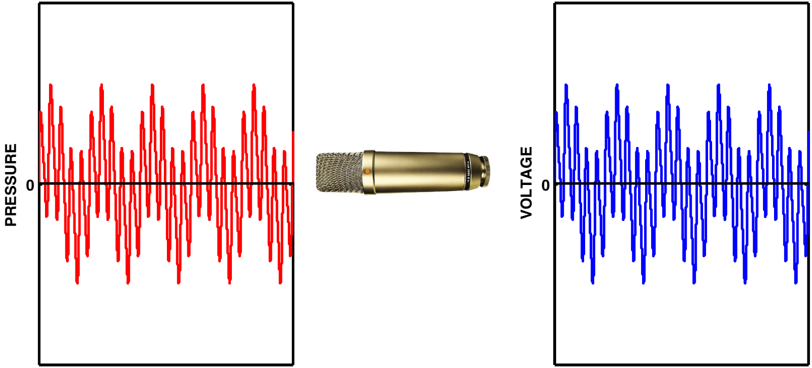
Semester 1, 2013–14

Microphones

What is a microphone?

- In audio production we: capture audio signals, manipulate them, and then output the result as a new audio signal.
- The manipulation part is done by electrical devices which operate on electrical signals.
- The microphone is the device (a transducer) that converts the sound pressure into an electrical signal.

What is a microphone?



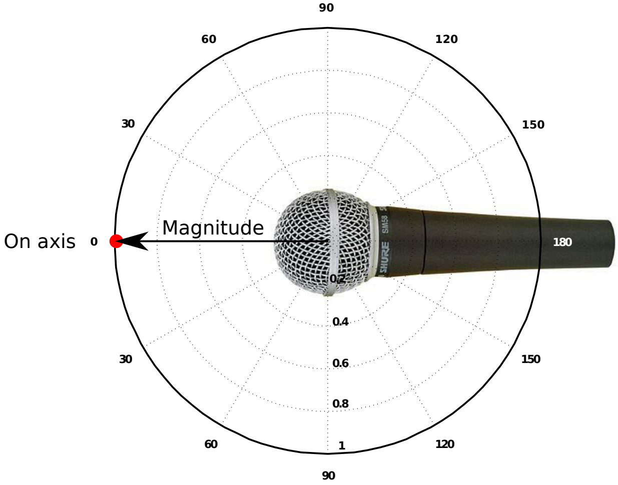
How do microphones work?

- The microphone capsule contains a diaphragm which will vibrate when exposed to a pressure signal.
- The vibrations are picked up by a sensor which converts them into a voltage signal.
- A good microphone will give a voltage signal that is a good representation of the original pressure signal.

Microphone Response

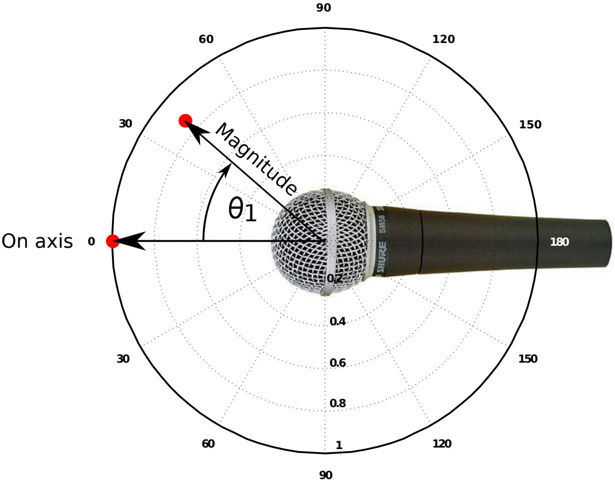
- **Polar Response**: how the conversion of pressure into voltage is affected by sound direction.
- **Frequency Response**: how the conversion of pressure into voltage is affected by sound frequency.

How does the magnitude of my voltage signal vary if the sound comes from different directions?



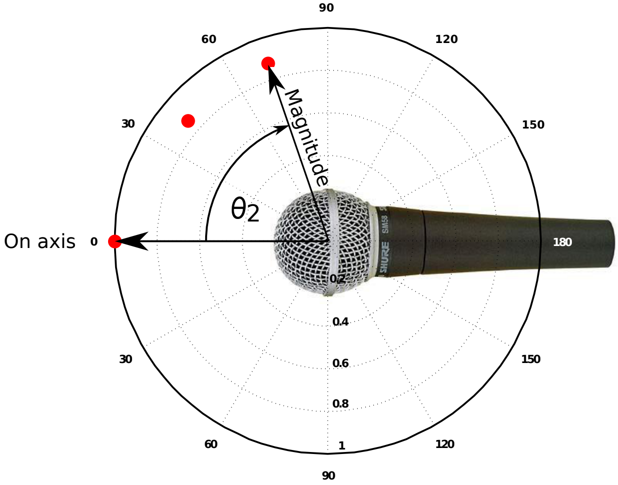
Microphone Polar Response

How does the magnitude of my voltage signal vary if the sound comes from different directions?



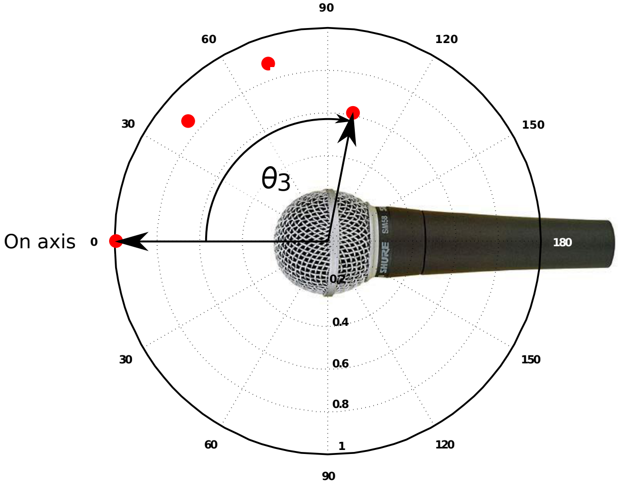
Microphone Polar Response

How does the magnitude of my voltage signal vary if the sound comes from different directions?



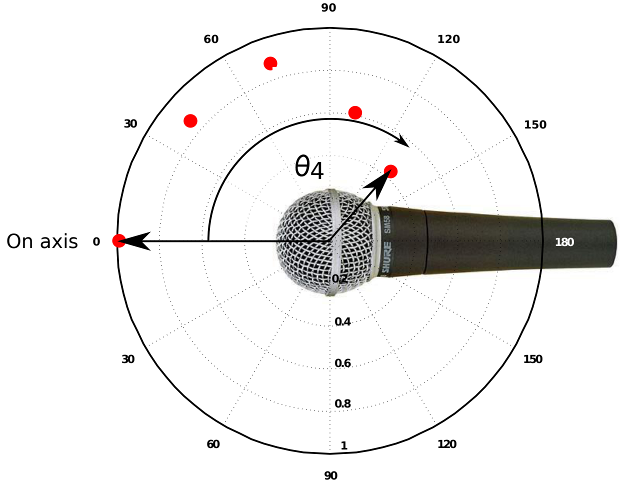
Microphone Polar Response

How does the magnitude of my voltage signal vary if the sound comes from different directions?



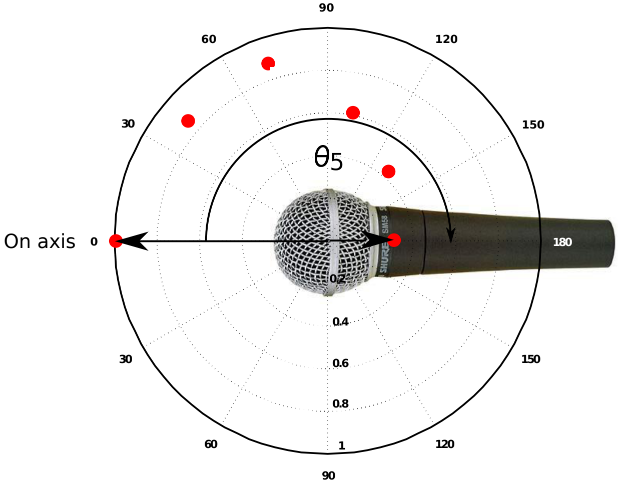
Microphone Polar Response

How does the magnitude of my voltage signal vary if the sound comes from different directions?



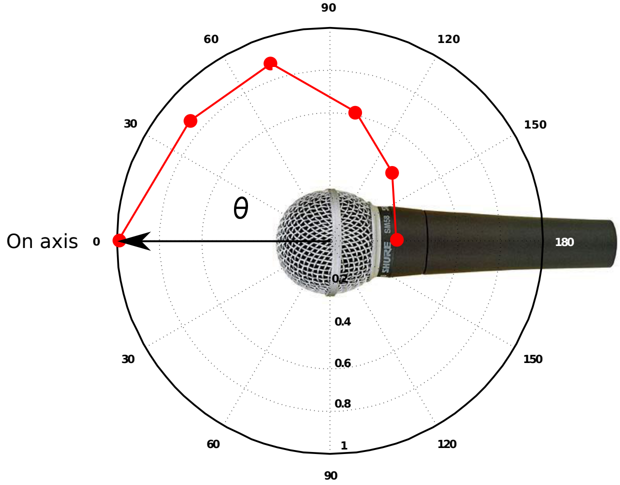
Microphone Polar Response

How does the magnitude of my voltage signal vary if the sound comes from different directions?

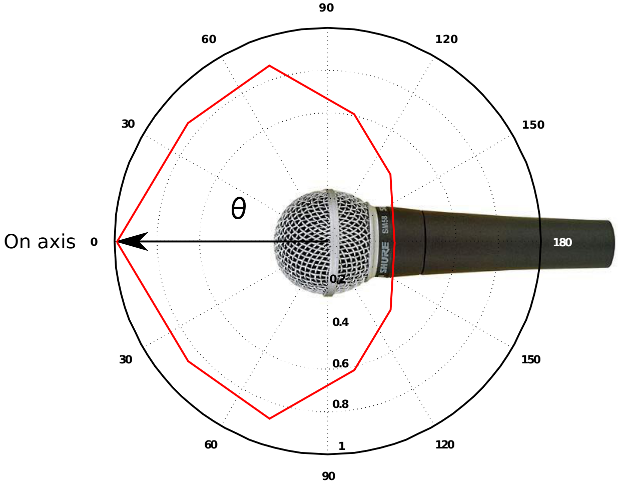


Microphone Polar Response

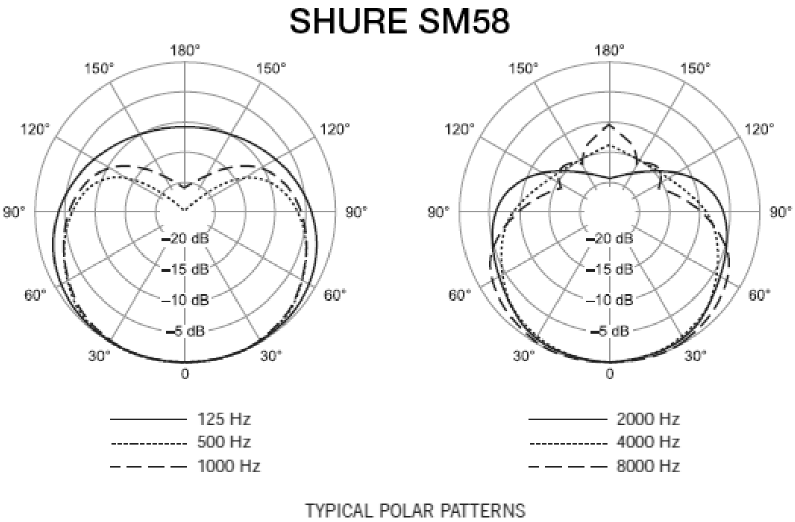
How does the magnitude of my voltage signal vary if the sound comes from different directions?



How does the magnitude of my voltage signal vary if the sound comes from different directions?

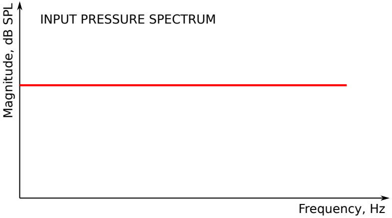


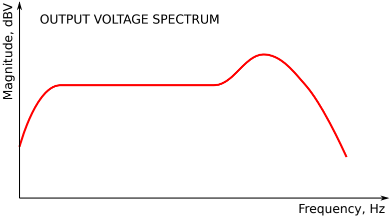
Microphone Polar Response



Microphone Frequency Response

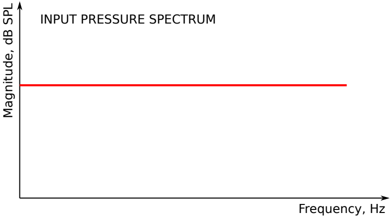
If I record a sound with equal pressure at all frequencies, how does the magnitude of my voltage signal vary with frequency?

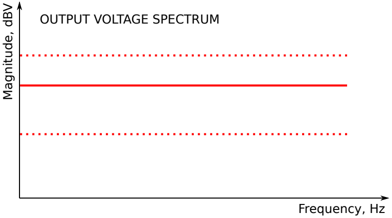




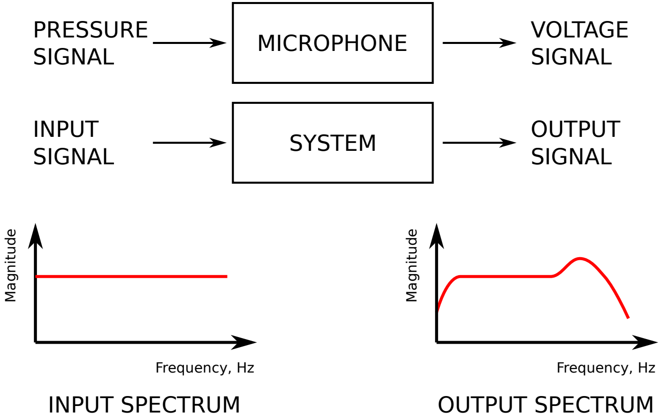
Microphone Frequency Response

If the response is **flat**, it means that the voltage signal has the same frequency spectrum as the pressure signal.





System Frequency Response

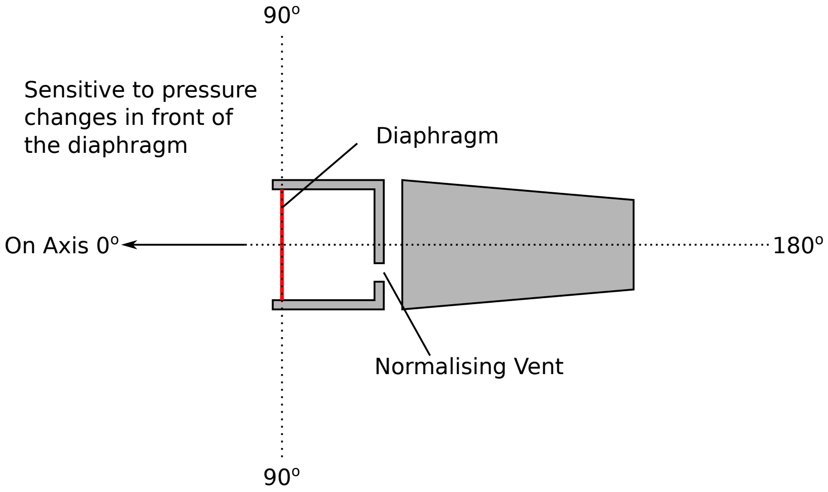


How do microphones work?

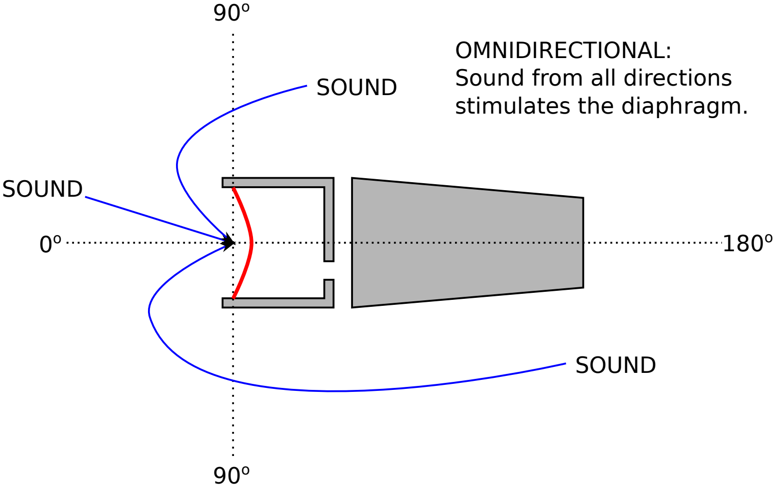
- **Capsule Type** - controls how the pressure waves interact with the diaphragm.
  - Pressure operated.
  - Pressure gradient.
  - Cardioid.
- **Transducer Mechanism** - the mechanism that converts the pressure on the diaphragm into a voltage signal.
  - Moving coil (dynamic).
  - Capacitor (condenser).
  - Ribbon.

Capsule Type

Pressure operated capsule

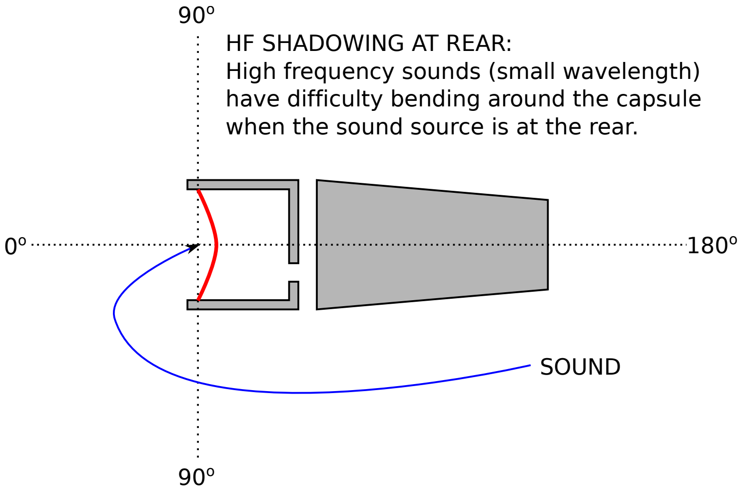


Pressure operated capsule



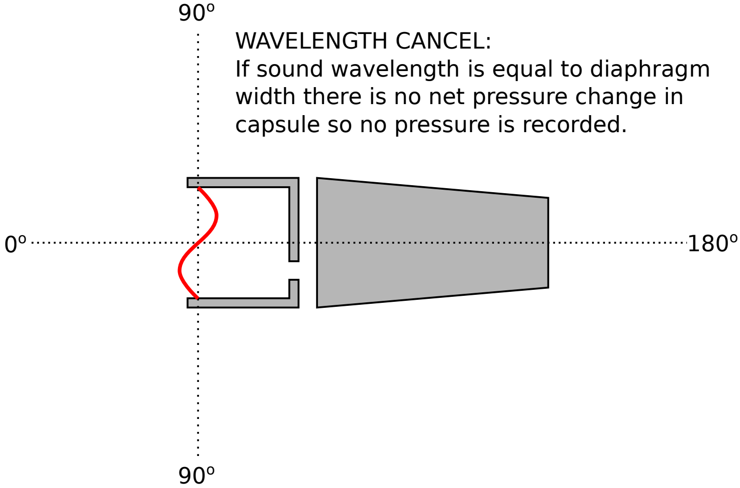
OMNIDIRECTIONAL:
Sound from all directions stimulates the diaphragm.

Pressure operated capsule

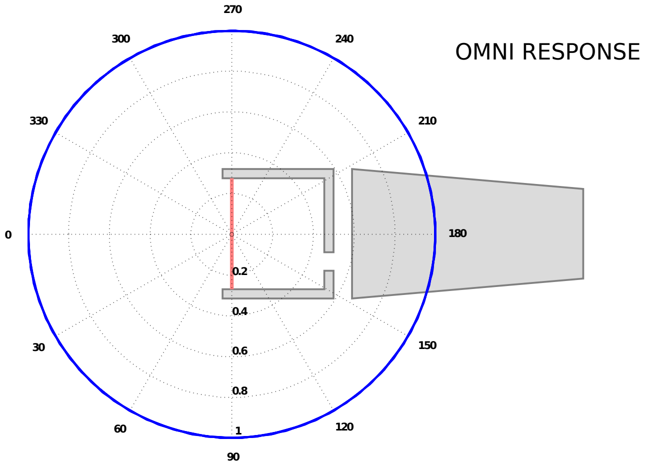


Pressure operated capsule

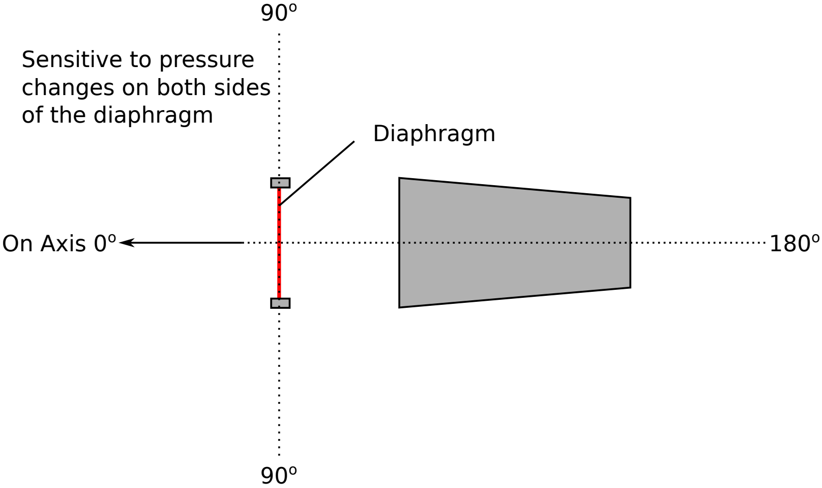
WAVELENGTH CANCEL:
If sound wavelength is equal to diaphragm width there is no net pressure change in capsule so no pressure is recorded.



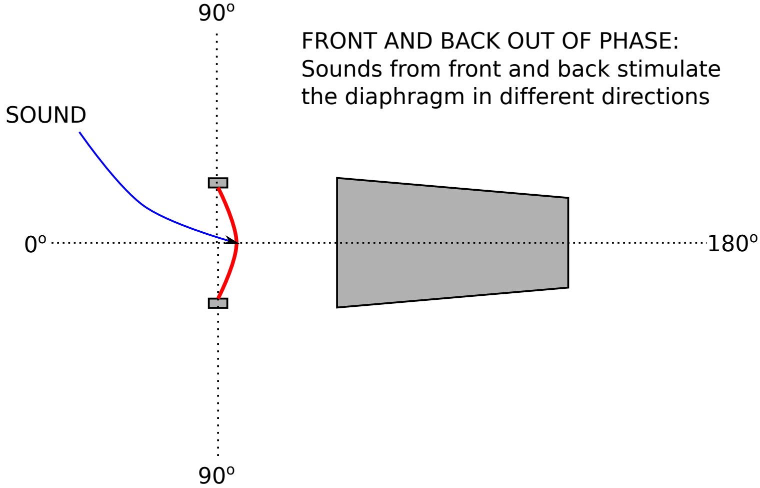
Pressure operated capsule



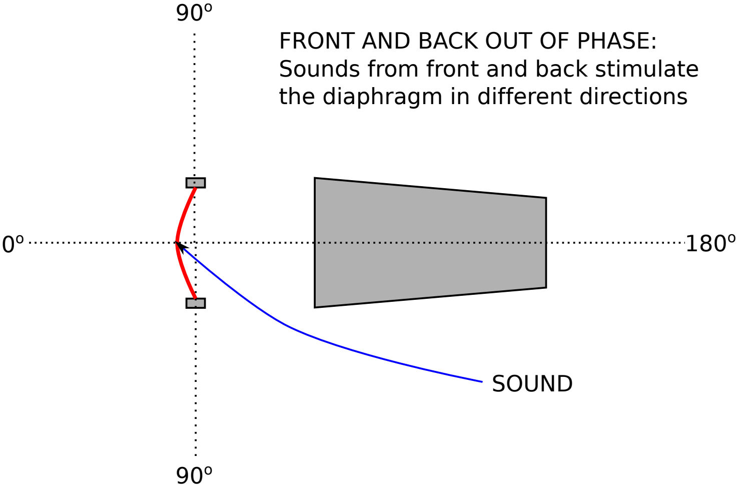
Pressure gradient capsule



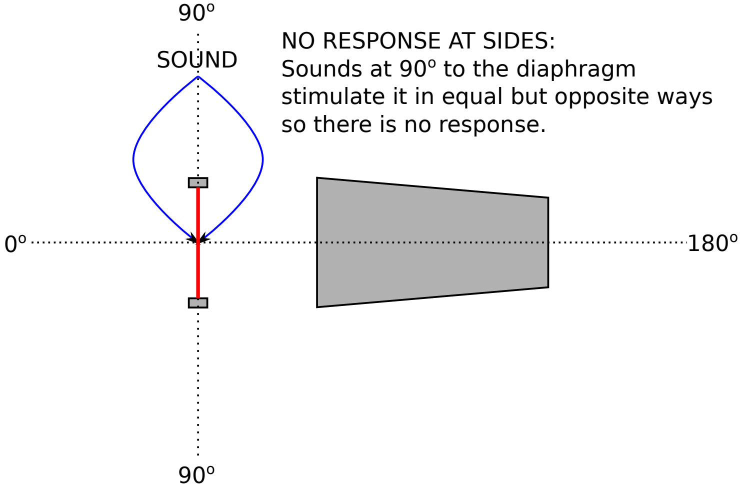
Pressure gradient capsule



Pressure gradient capsule

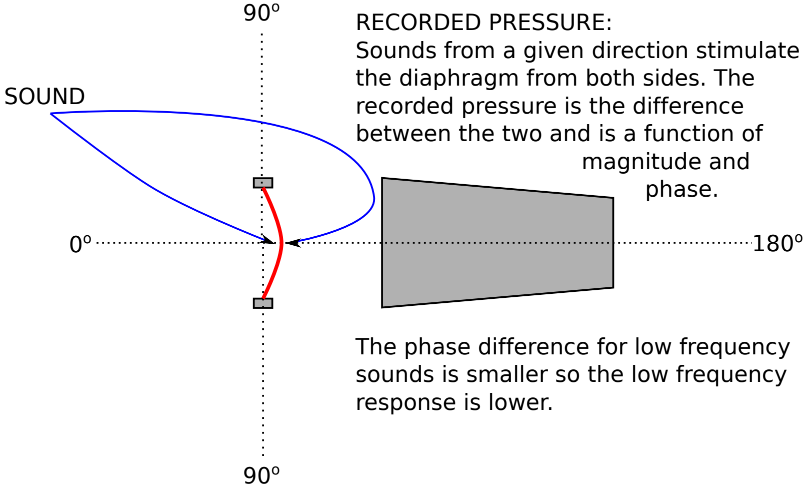


Pressure gradient capsule



NO RESPONSE AT SIDES:
Sounds at 90° to the diaphragm stimulate it in equal but opposite ways so there is no response.

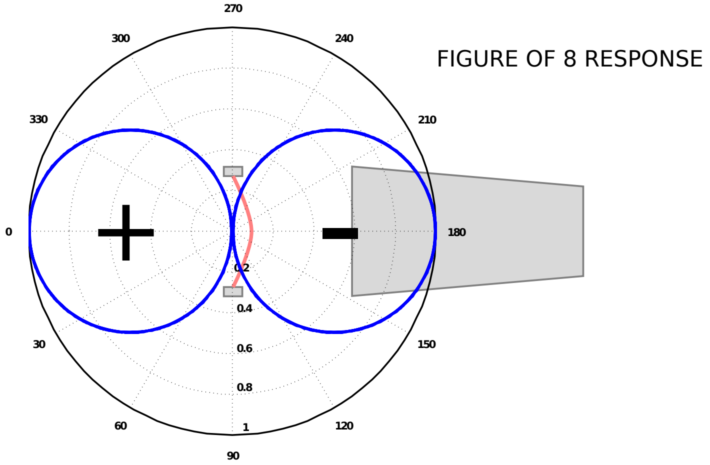
Pressure gradient capsule



RECORDED PRESSURE:
Sounds from a given direction stimulate the diaphragm from both sides. The recorded pressure is the difference between the two and is a function of magnitude and phase.

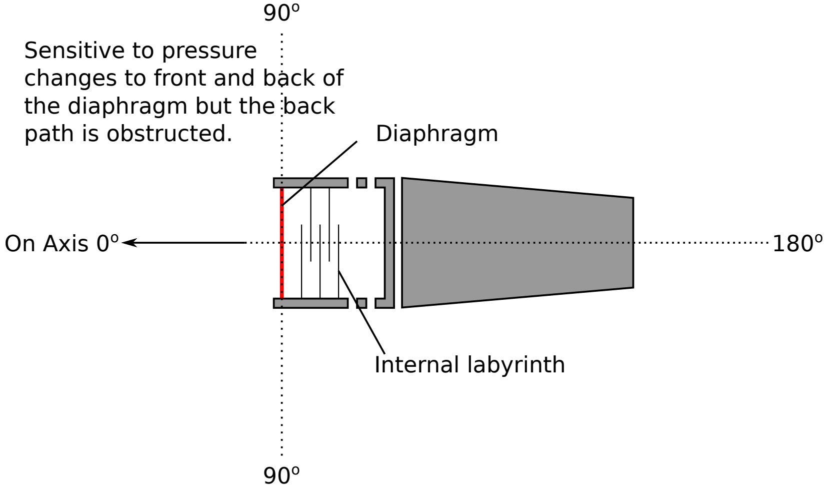
The phase difference for low frequency sounds is smaller so the low frequency response is lower.

Pressure gradient capsule

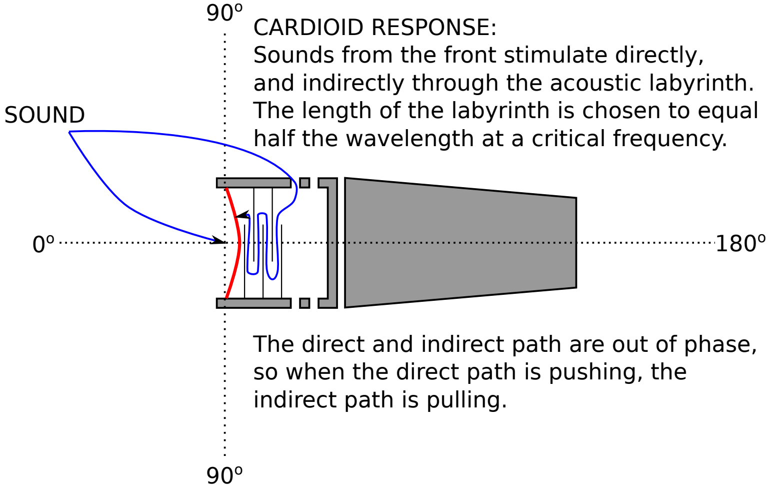


Cardioid capsule

Sensitive to pressure changes to front and back of the diaphragm but the back path is obstructed.



Cardioid capsule

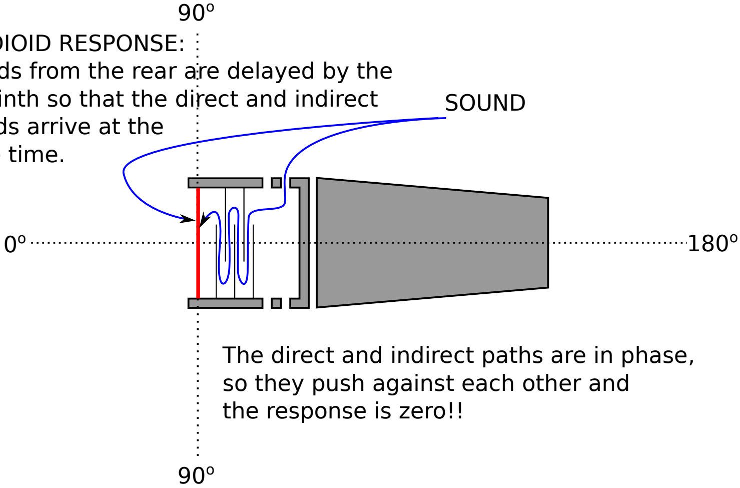


CARDIOID RESPONSE:
Sounds from the front stimulate directly, and indirectly through the acoustic labyrinth. The length of the labyrinth is chosen to equal half the wavelength at a critical frequency.

The direct and indirect path are out of phase, so when the direct path is pushing, the indirect path is pulling.

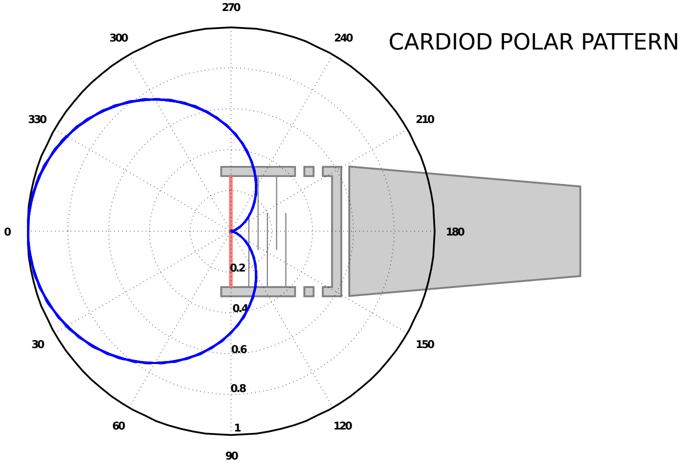
Cardioid capsule

CARDIOID RESPONSE:
Sounds from the rear are delayed by the labyrinth so that the direct and indirect sounds arrive at the same time.



The direct and indirect paths are in phase, so they push against each other and the response is zero!!

Cardioid capsule



Microphone capsule recap

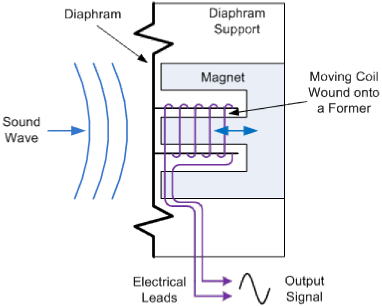
- Three microphone capsule designs have been discussed.
    - Pressure operated - OMNIDIRECTIONAL.
    - Pressure gradient - FIGURE OF EIGHT.
    - Cardioid - CARDIOID.
- More complex polar patterns can be obtained by combining different capsules.

Transducer Mechanisms

Transducer mechanisms

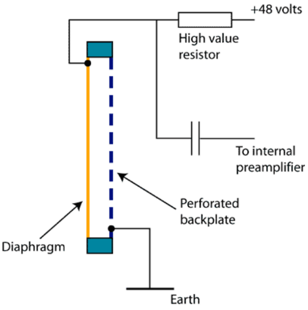
- The transducer mechanism is responsible for converting the pressure acting on the diaphragm into a voltage.
- Three transducer mechanisms are considered.
  - Moving coil.
  - Capacitor.
  - Ribbon.
- In theory it is possible to use any capsule design with any transducer mechanism.

Moving Coil (Dynamic) Microphone



- Coil of fine-gauge wire attached to a rigid diaphragm via cylindrical former. Coil moves in magnetic field so electric current is induced.
- Resonant peak at $\sim$5 kHz, rapid roll-off after 8–10 kHz.
- Very robust - good for hand-held vocals or strongly transient signals e.g. bass drum.

Capacitor (Condenser) Microphone



- Movement of the diaphragm changes the capacitance of the circuit, and the resultant modulation in voltage is measured.
- Requires phantom power.
- Resonant peak at $\sim$12–20 kHz, less prominant than moving coil.
- Electret designs use static charge in diaphragm instead of phantom power.

Ribbon Microphone

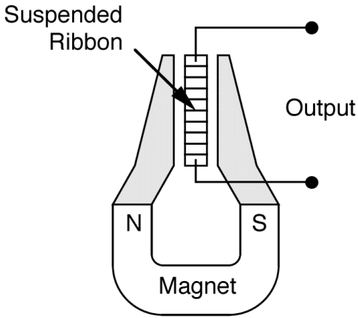


Fig1: Ribbon and Magnet Arrangement

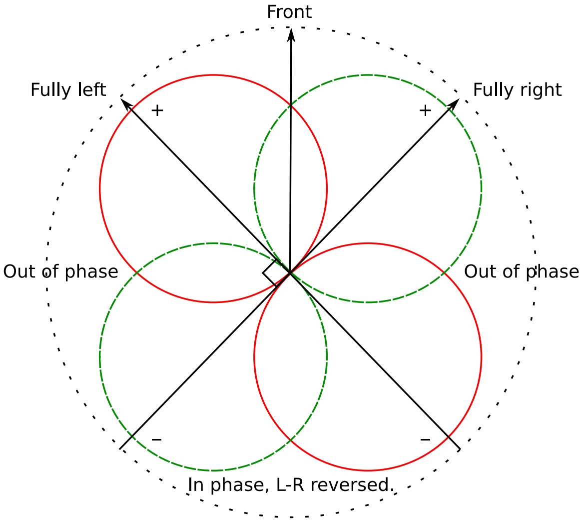
- Corrugated ribbon suspended in a magnetic field. Electric current is induced in the ribbon as it moves.
- Resonant peak at $\sim$40 Hz, response is smooth above peak, rolling off after $\sim$14 kHz.
- Low output voltage, needs step-up transformer.
- VERY delicate, easy to destroy with wind or loud transients.

Spatial Microphone Techniques

Spatial microphone techniques

- When we listen to live music a sense of the space in which we are listening is encoded into what we hear.
- A range of microphone techniques are used to capture a sense of this spaciousness.
- You are attempting to trick the brain into thinking you are in a certain space.
- The simplest encodings are stereo.

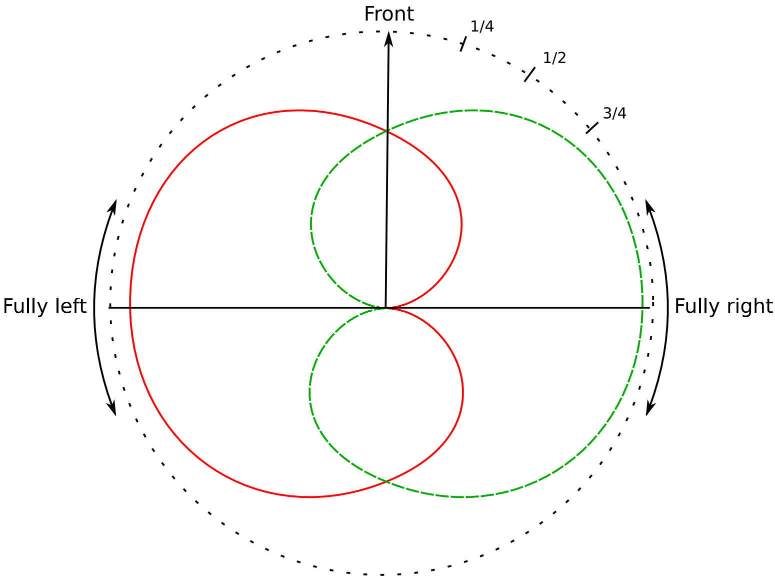
Blumlein Coincident Figure-of-Eights at 90°



Blumlein Coincident Figure-of-Eights at 90°

- Fully left is at dead axis of right mic.
- Only front 90° are usable for direct sound due to out of phase regions.
- Very accurate mapping of physical position to image within front 90°.
- Out of phase and left-right reversed regions no problem for reverberation since it is random and incoherent anyway.
- Can take sum and difference to get Mid and Side signals instead - can control stereo width with 1 fader.

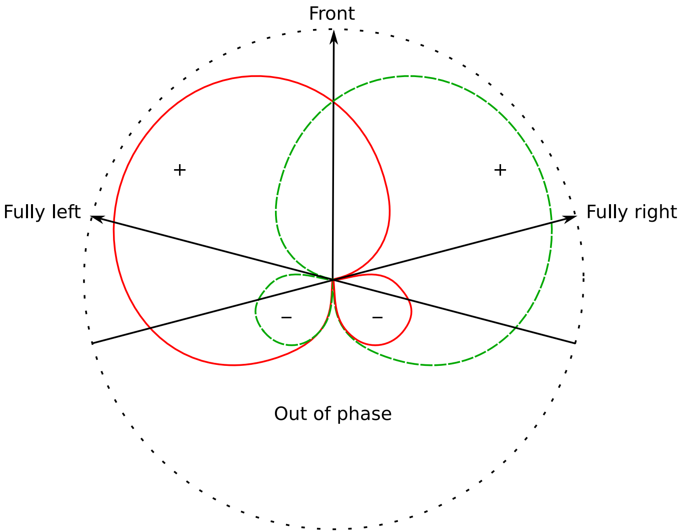
Back-to-Back Cardioids



Back-to-Back Cardioids

- No out of phase regions.
- Frequency response at front is poor especially with large diaphragms.
- Very wide front angle
- Can narrow the angle between capsules down to 90° to give a better response at the front, as well as a narrower stereo image. Optimum angle is about 130°.

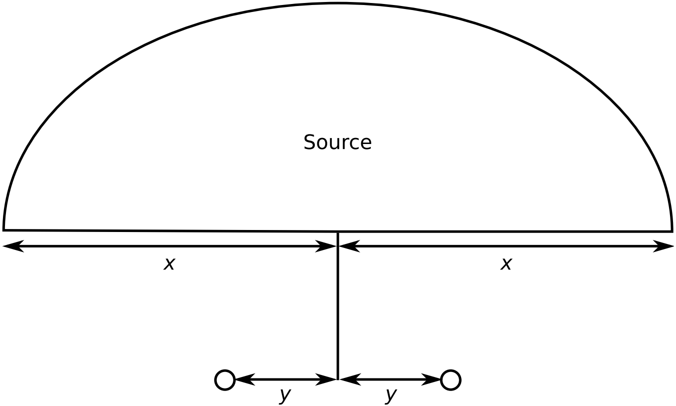
Coincident Hypercardioids



Stereo Image Width

Narrow image	Far from source	Narrow capsule angle	Cardioids
$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
$\downarrow$	$\downarrow$	$\downarrow$	Hypercardioids
$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
Wide image	Close to source	Wide capsule angle	Figure of Eights

Spaced Omnis

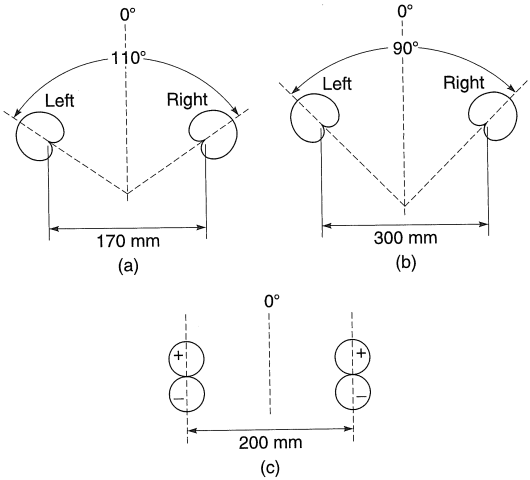


$$\frac{x}{3} \leq y \leq \frac{x}{2}$$

Spaced Omnis

- Good for smaller sources.
- Phase difference changes with frequency $\therefore$ image is not clear. Can be an advantage for e.g. piano, choir, organ.
- Subject to the "hole in the middle" effect. If there is a large time of arrival and large level difference the brain makes the image wider.
- Decca tree attempts to solve this by adding a central mic slightly in front of the pair. (Decca also require a pair of wider mics, giving a total of 5 omnis.)

Near-Coincident Techniques



(a) ORTF, (b) NOS, (c) Faulkner.

Spot Mics

- Usually mono and panned.
- Can have stereo pair for wide sources e.g. woodwind section of an orchestra.
- Must pan to same position as in main pair.
- Image tends to collapse towards spots due to Haas effect, so must use several at different positions.

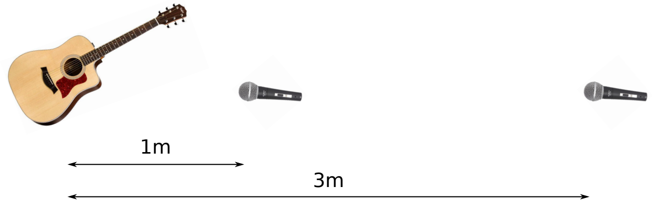
Sound Field Microphones

- Audio is recorded using a soundfield microphone array which contains one omni-directional and three figure of eight mics.
- The signals are encoded into B-Format.
- B-Format is a standarised storage and transmission format.
- B-Format can be decoded and the sound field recreated using a range of spatial audio techniques, i.e. nth order ambisonics, binaural etc.

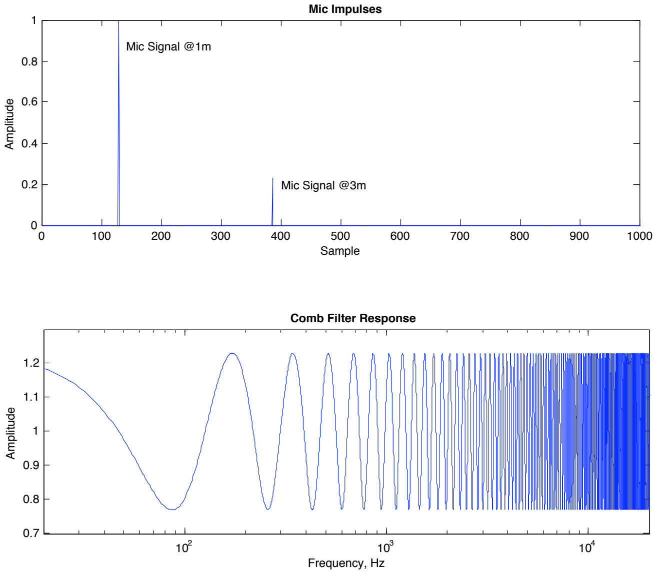
Microphone Comb Filtering

Multiple Microphone Comb Filtering

- Multiple microphones recording a common source will be susceptible to comb filtering.

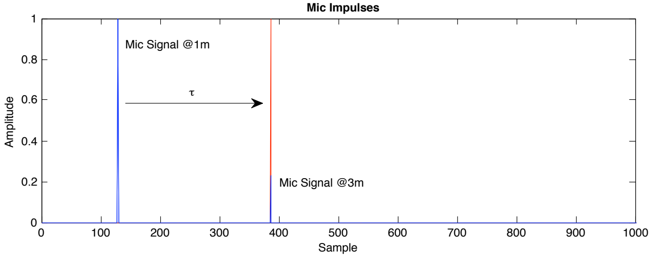


Multiple Microphone Comb Filtering



Time Offset Correction

- A time delay, τ, is added to the close mic to align the signal with the far mic.



Microphone Placement

Points to Consider 1: Content

- How do I record the sound that I want, and minimise the sound I don't want?
  - Source placement.
  - Microphone selection e.g. polar and frequency response.
  - Microphone placement.

Points to Consider 2: Separation

- How do I control spill/bleed from other sources?
  - Source placement.
  - Microphone selection, e.g. polar response.
  - Microphone placement.

Points to Consider 3: Perspective

- How do I convey the sense of space, e.g. apparent distance and stereo image, in my recording?
  - Source placement.
  - Microphone selection, e.g. polar response.
  - Microphone placement.

Points to Consider 4: Balance

- How do I balance sources that have different sound pressure levels?
  - Source placement.
  - Microphone selection, e.g. polar response.
  - Microphone placement.