ECS614U/ECS749P: Sound Recording and Production

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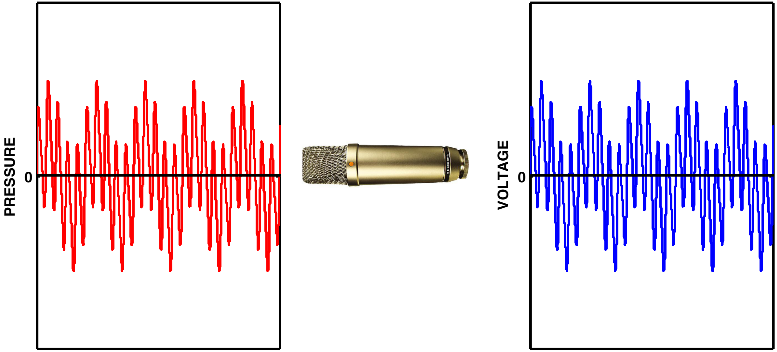
Semester 1, 2013–14

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?

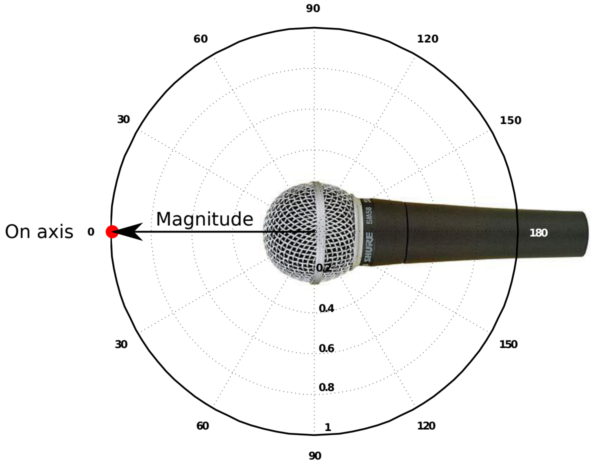
- The microphone capsule contains a diaphragm which will vibrate when exposed to a pressure signal.
- The vibrations are picked up by a sensor which converts them into a voltage signal.
- A good microphone will give a voltage signal that is a good representation of the original pressure signal.

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.

Microphone Polar Response

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



Microphone Polar Response

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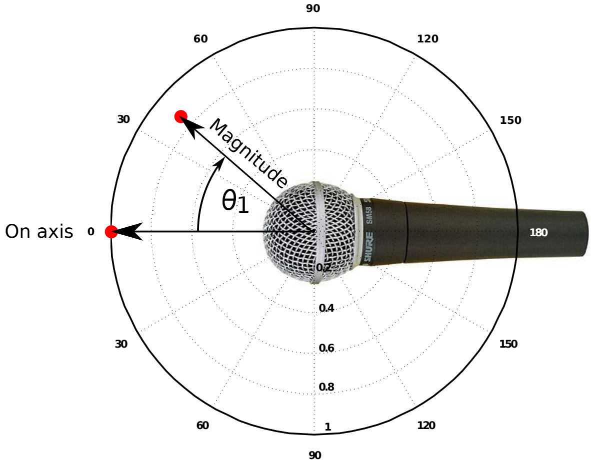

Microphone Polar Response

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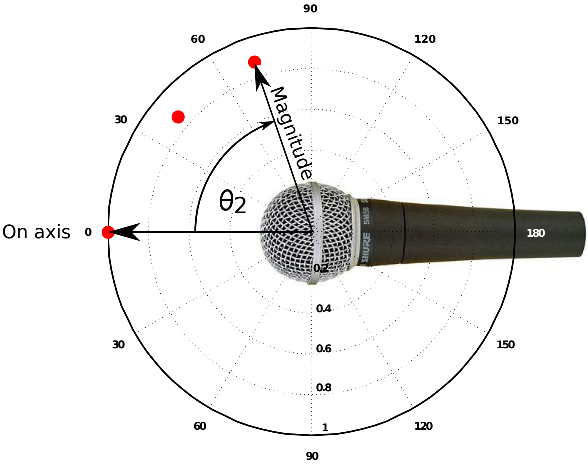

Microphone Polar Response

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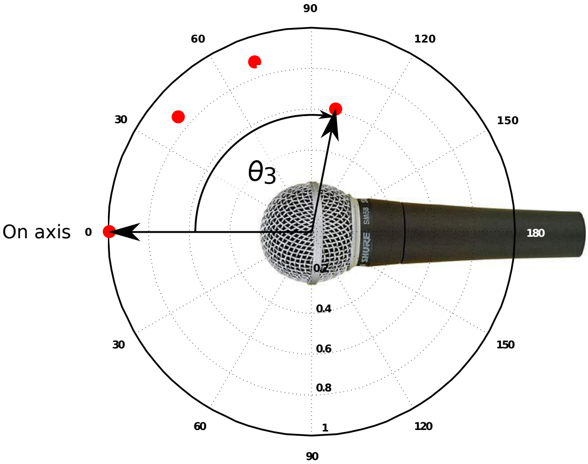

Microphone Polar Response

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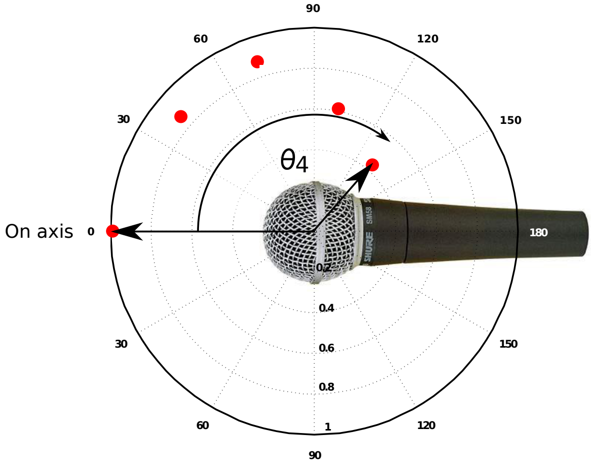

Microphone Polar Response

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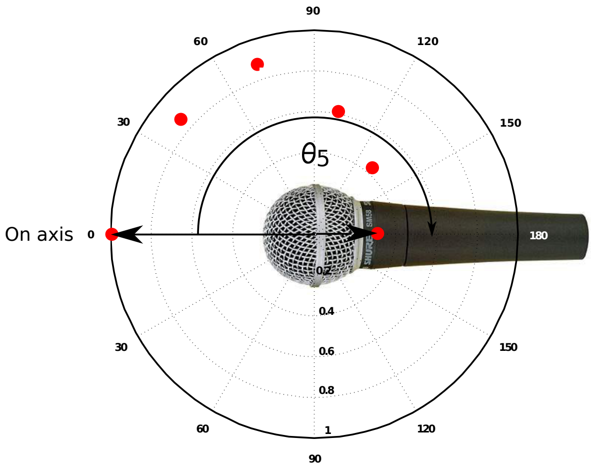

Microphone Polar Response

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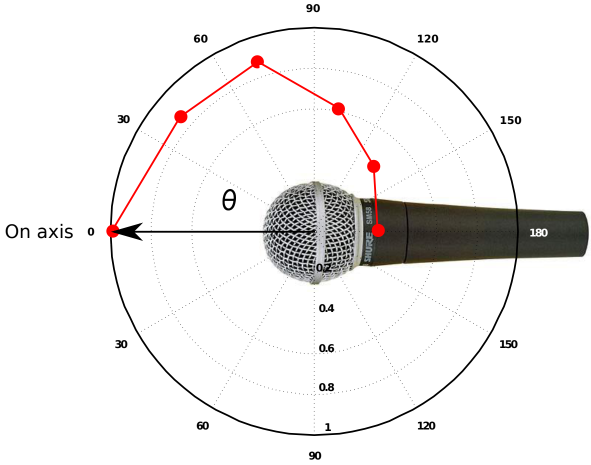

Microphone Polar Response

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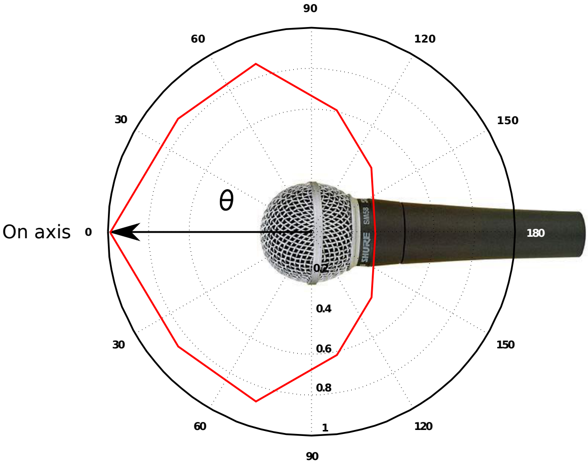
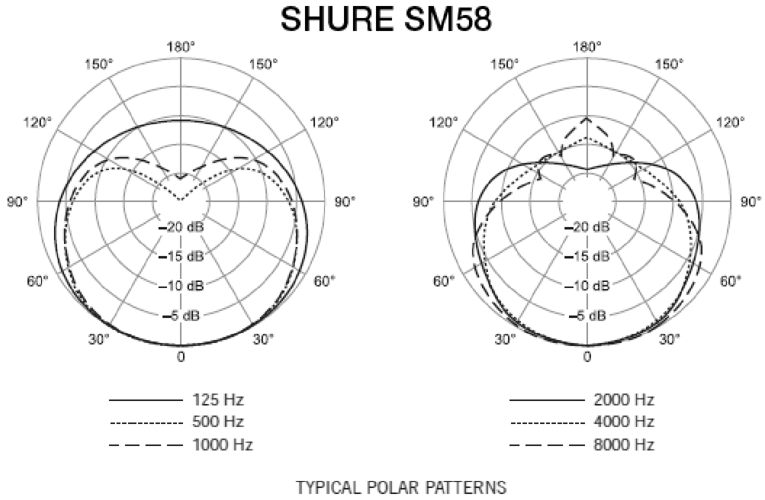
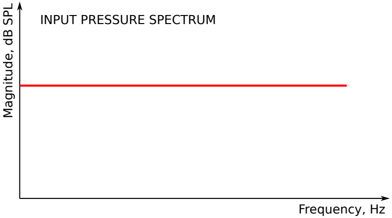


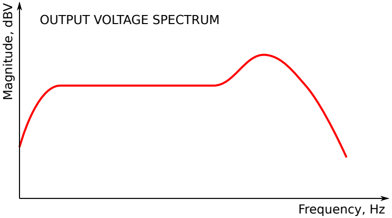
Microphone Polar Response



Microphone Frequency Response

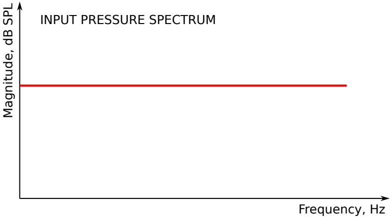
If I record a sound with equal pressure at all frequencies, how does the magnitude of my voltage signal vary with frequency?

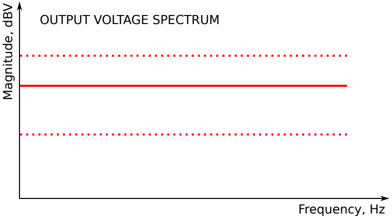




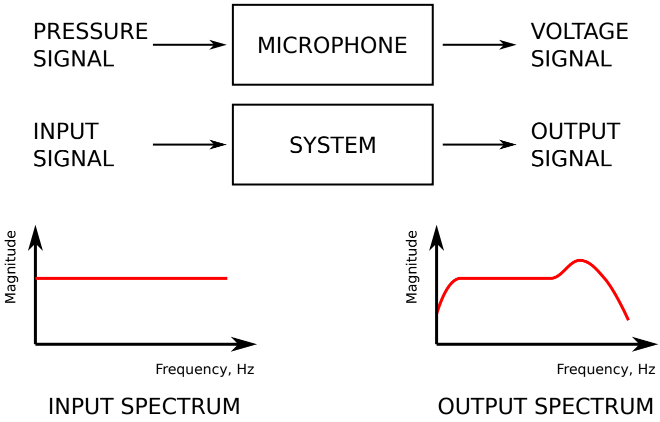
Microphone Frequency Response

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





System Frequency Response



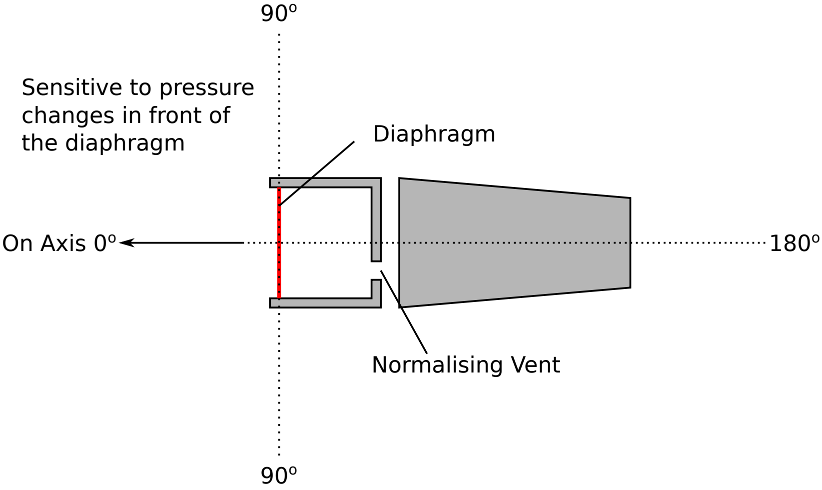
How do microphones work?

- **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.

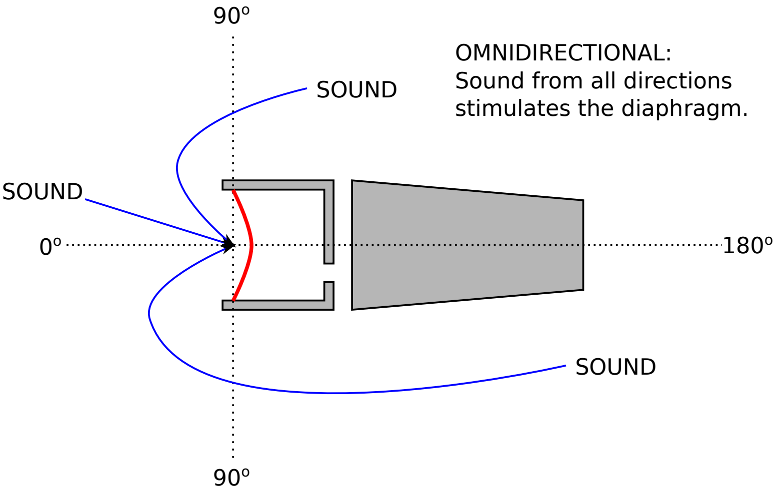
Capsule Type

Pressure operated capsule

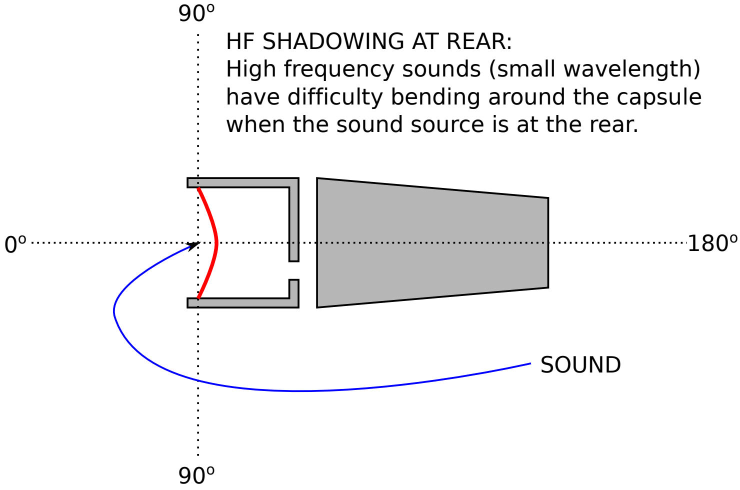
Sensitive to pressure changes in front of the diaphragm



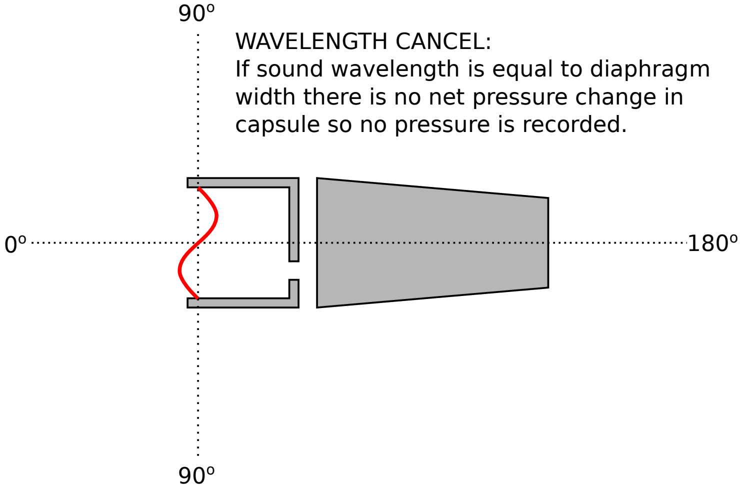
Pressure operated capsule



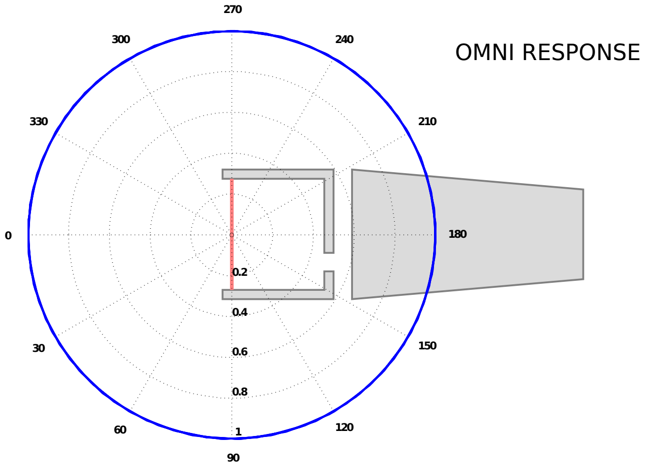
Pressure operated capsule



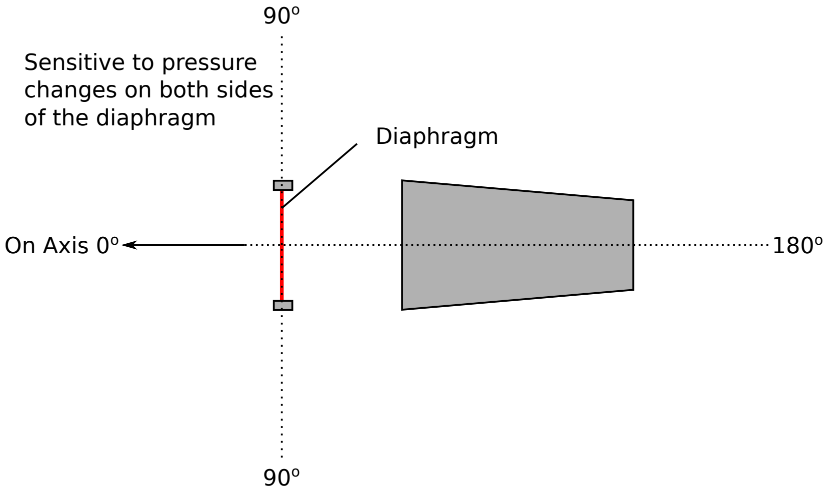
Pressure operated capsule



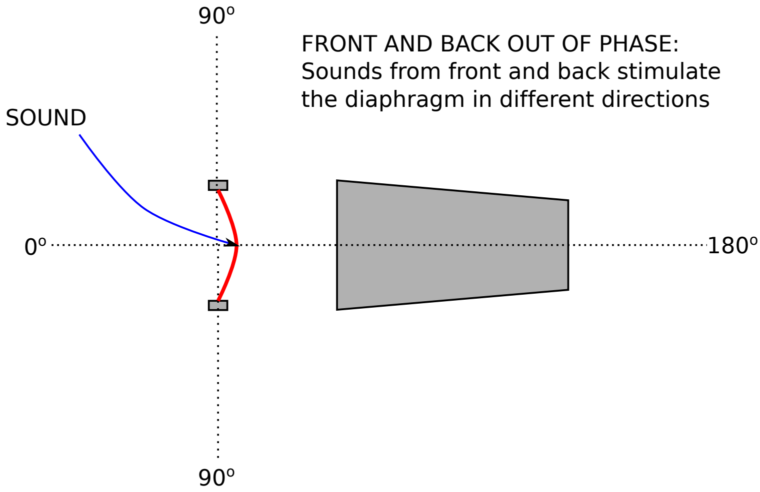
Pressure operated capsule



Pressure gradient capsule

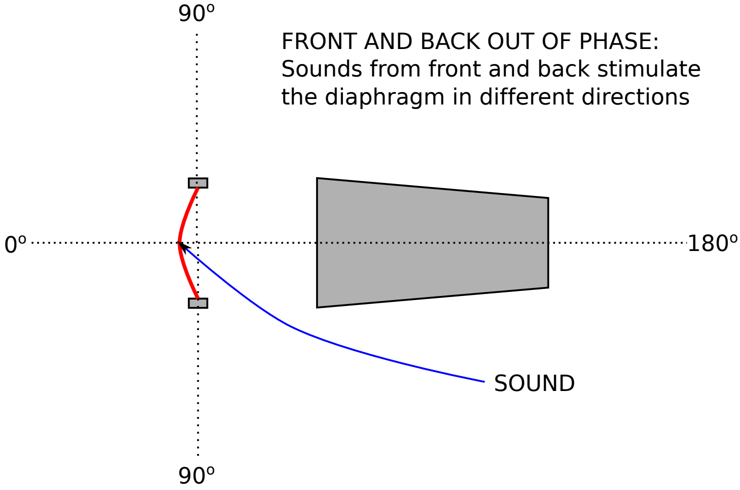


Pressure gradient capsule

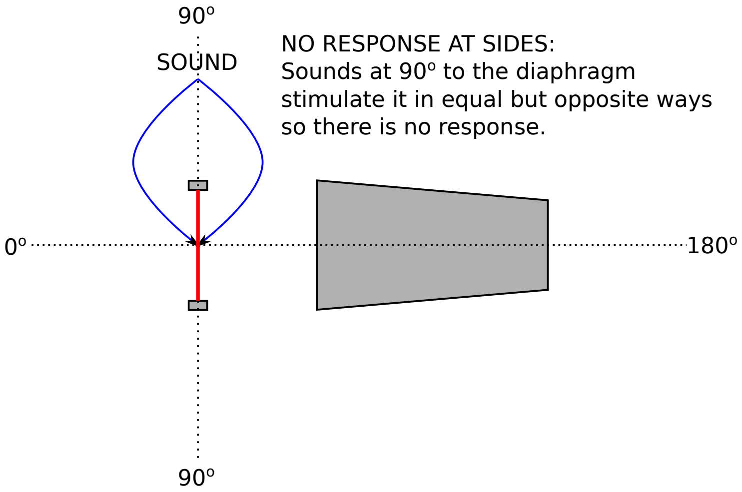


Pressure gradient capsule

FRONT AND BACK OUT OF PHASE:
Sounds from front and back stimulate the diaphragm in different directions

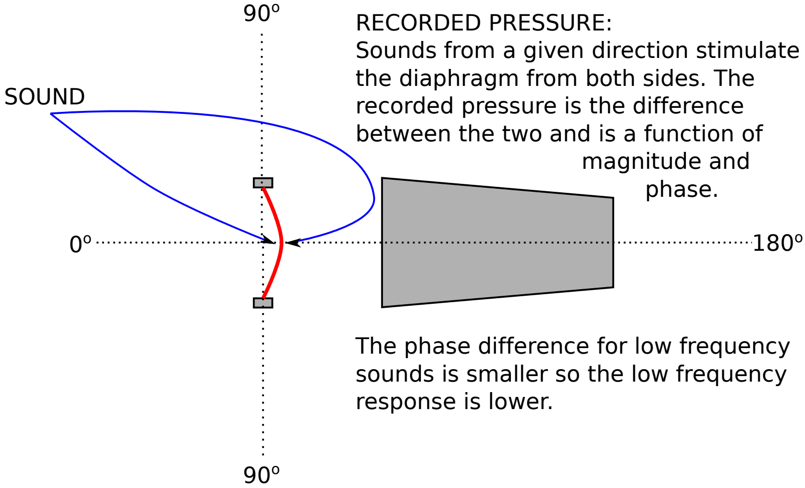


Pressure gradient capsule



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

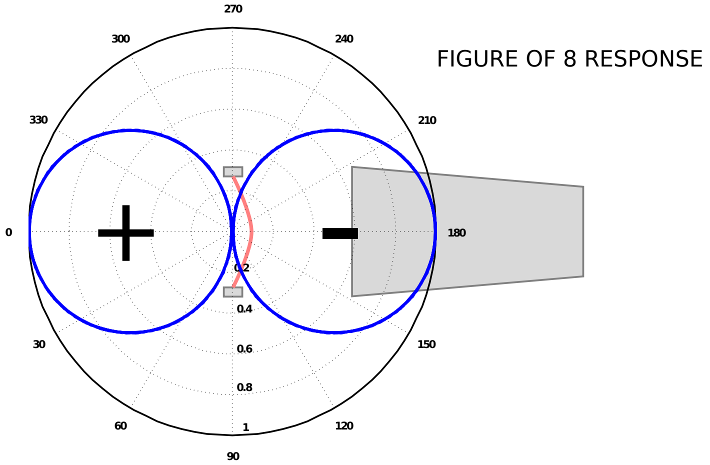
Pressure gradient capsule



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.

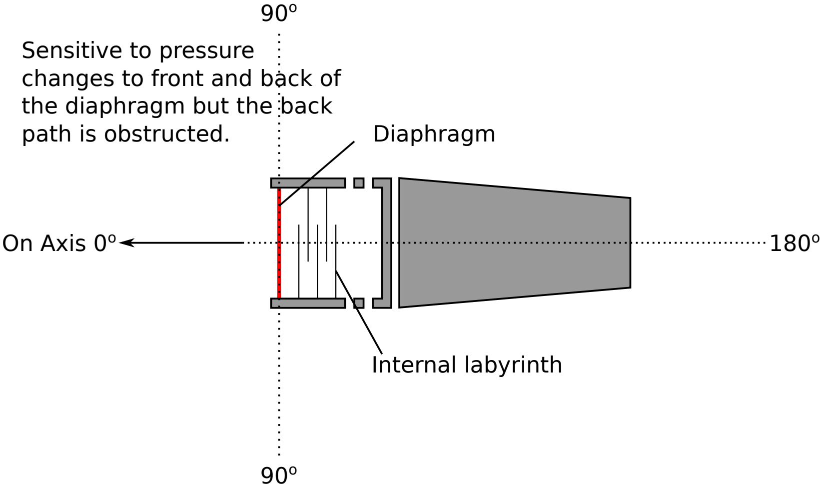
The phase difference for low frequency sounds is smaller so the low frequency response is lower.

Pressure gradient capsule

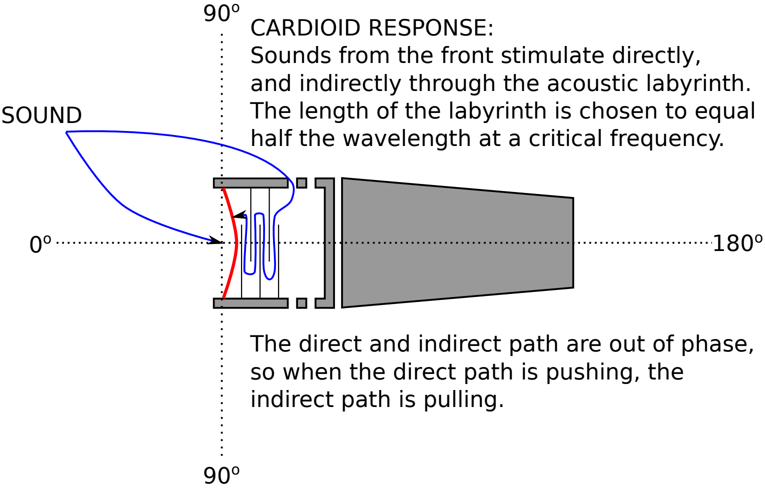


Cardioid capsule

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



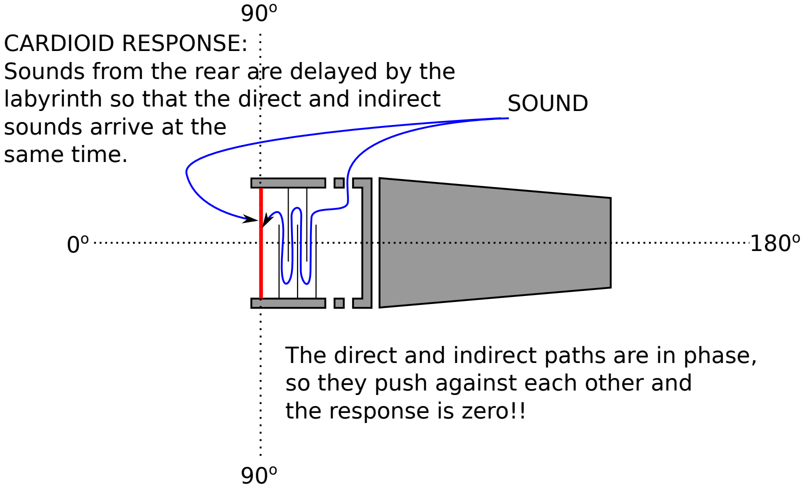
Cardioid capsule



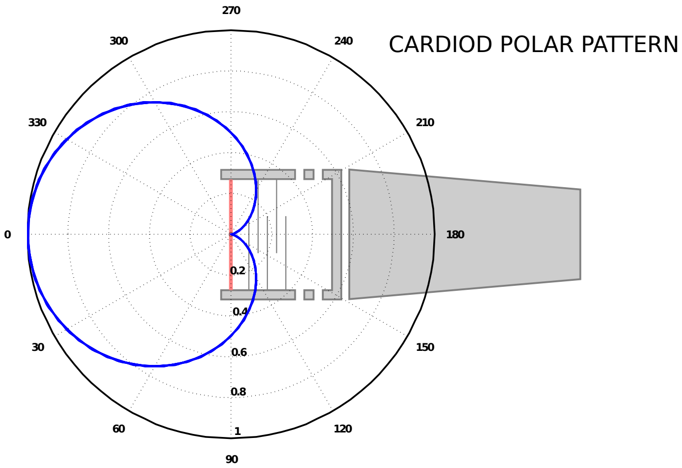
CARDIOID RESPONSE:
Sounds from the front stimulate directly, and indirectly through the acoustic labyrinth. The length of the labyrinth is chosen to equal half the wavelength at a critical frequency.

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

Cardioid capsule



Cardioid capsule



Microphone capsule recap

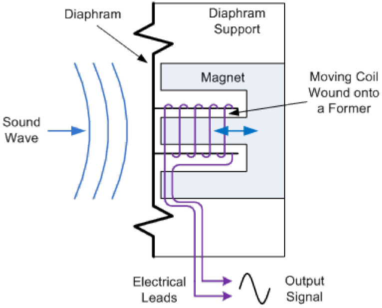
- Three microphone capsule designs have been discussed.
  - Pressure operated - OMNIDIRECTIONAL.
  - Pressure gradient - FIGURE OF EIGHT.
  - Cardioid - CARDIOID.
- More complex polar patterns can be obtained by combining different capsules.

Transducer Mechanisms

Transducer mechanisms

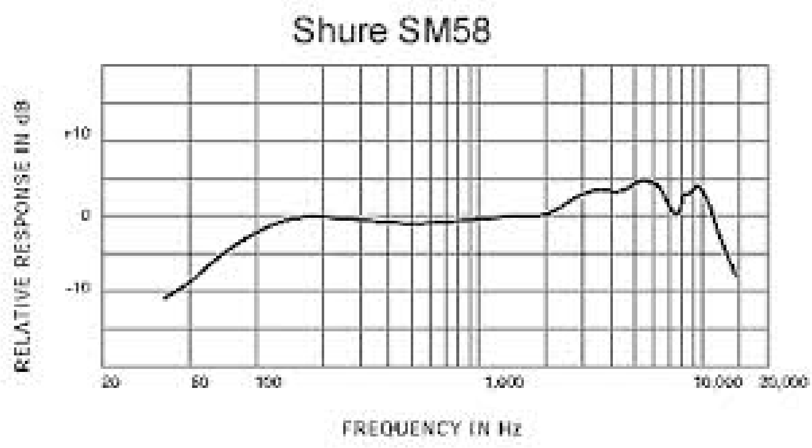
- The transducer mechanism is responsible for converting the pressure acting on the diaphragm into a voltage.
- Three transducer mechanisms are considered.
  - Moving coil.
  - Capacitor.
  - Ribbon.
- In theory it is possible to use any capsule design with any transducer mechanism.

Moving Coil (Dynamic) Microphone

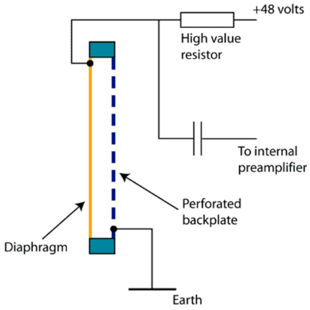


- Coil of fine-gauge wire attached to a rigid diaphragm via cylindrical former. Coil moves in magnetic field so electric current is induced.
- Resonant peak at $\sim$5 kHz, rapid roll-off after 8–10 kHz.
- Very robust - good for hand-held vocals or strongly transient signals e.g. bass drum.

SM58 Frequency response (moving coil)

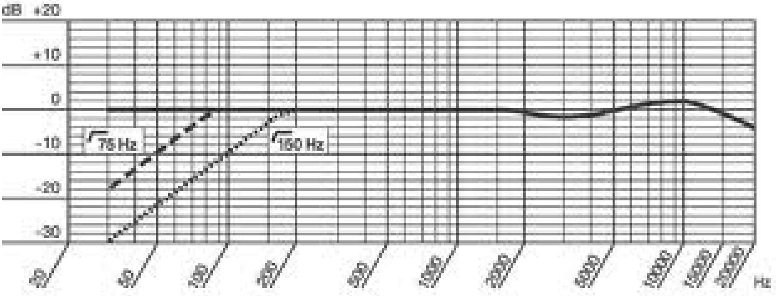


Capacitor (Condenser) Microphone



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

AKG414 Frequency response (capacitor)



Ribbon Microphone

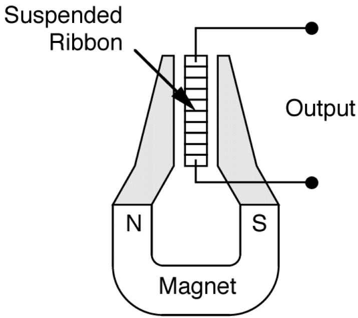
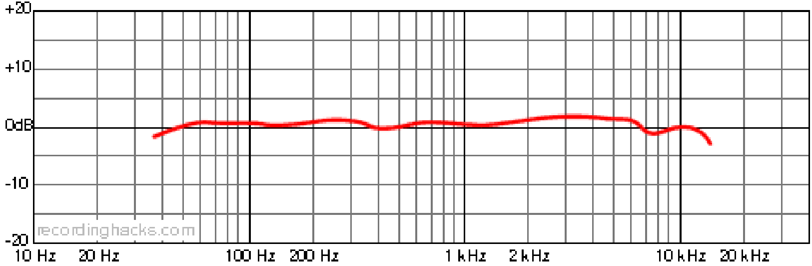


Fig1: Ribbon and Magnet Arrangement

- 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.

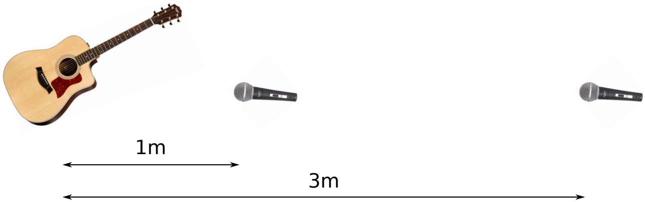
Coles 4038 Frequency response (ribbon)



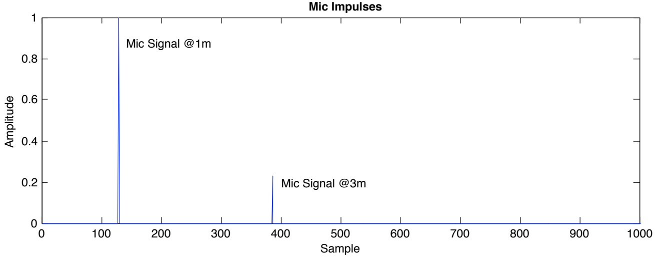
Microphone Comb Filtering

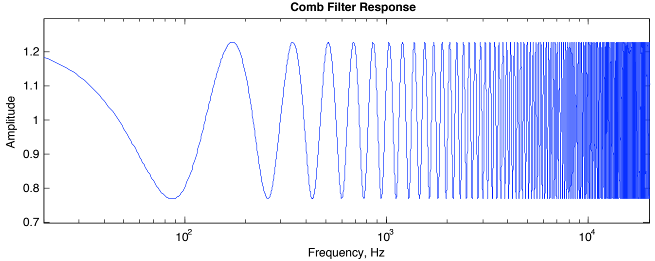
Multiple Microphone Comb Filtering

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



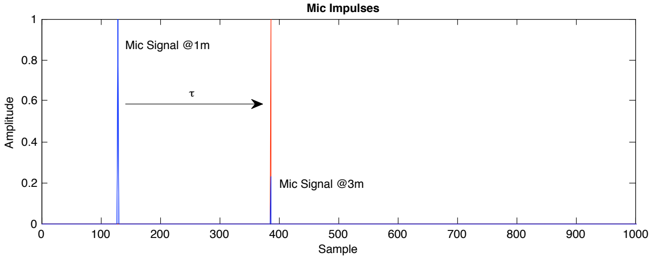
Multiple Microphone Comb Filtering





Time Offset Correction

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



Spatial Microphone Techniques

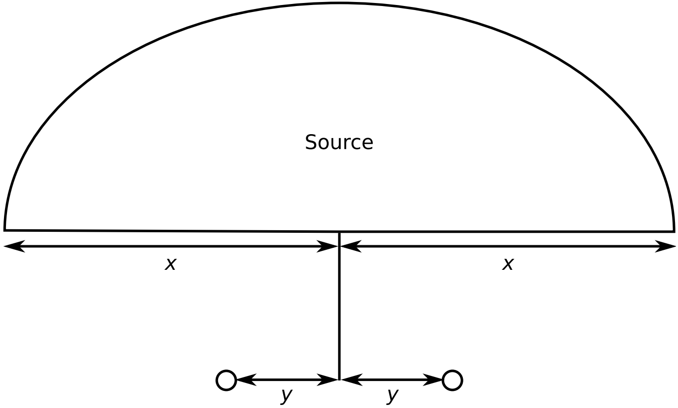
Spatial Microphone Techniques

- When we listen to live music a sense of the space and source position 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.
- The simplest encodings are stereo, i.e. left and right.

Stereo Mic Techniques

- We are able to sense the direction of a sound because we have two ears.
- Stereo mic techniques use two (or more) microphones to pick up sound from different directions or locations.
- The signals are then sent to different loudspeakers to produce a stereo effect.

Spaced Omnis



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

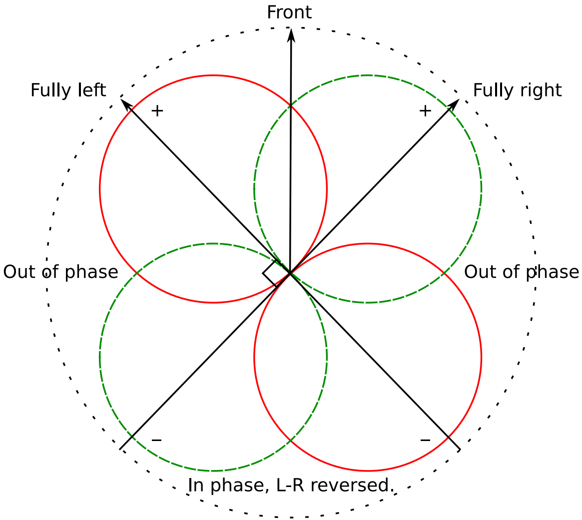
Spaced Omnis

- Phase difference may change with frequency giving an unclear image $\rightarrow$ can be an advantage, e.g. for piano, choir, organ.
- Subject to the "hole in the middle" effect if distance between the mics is large, whereby the time of arrival and level difference makes the image seem 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.)

Coincident Stereo Mic Techniques

- Coincident stereo techniques place the two microphones at the same point in space to eliminate comb filter effects.
- The image width is controlled by:
  - The type of microphone capsules.
  - The angle between the microphones.
  - The distance from the microphones to the sources.

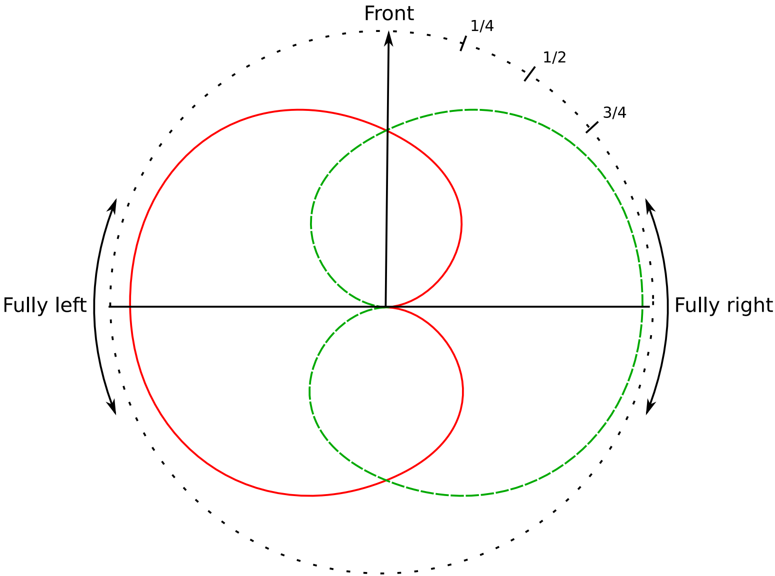
Blumlein Coincident Figure-of-Eights at 90°



Blumlein Coincident Figure-of-Eights at 90°

- Fully left is on the dead axis of the right mic (and vice versa).
- Only the front 90° are usable for direct sound as the other regions are out of phase.
- Very accurate mapping of source position to stereo image within the front 90°.
- The out of phase (rear) and left-right reversed regions aren't a problem for reverberation since it is random and incoherent.

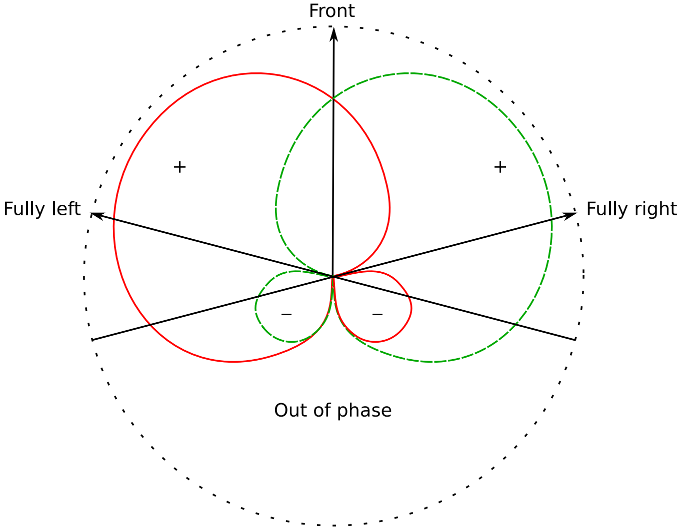
Back-to-Back Cardioids



Back-to-Back Cardioids

- There are no out of phase regions.
- The frequency response at front is poor, because the off-axis response of a cardioid will vary with frequency.
- The very wide front angle enables wide sources to be captured.
- The angle between capsules can be reduced down to 90° to give a better response at the front, as well as a narrower stereo image. The optimum angle is about 130°.

Coincident Hypercardioids



Stereo Image Width

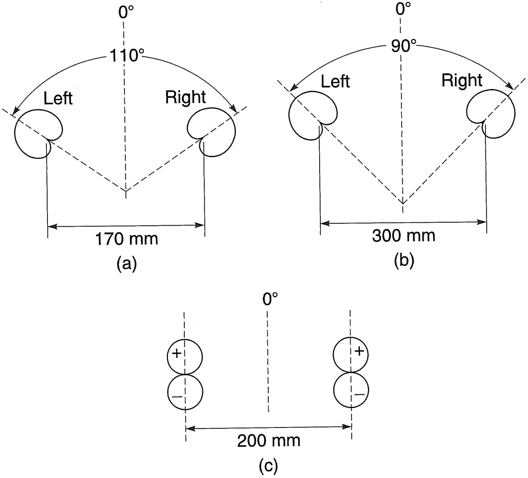
Narrow image
↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓
Wide image

Far from source
↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓
Close to source

Narrow capsule angle
↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓
Wide capsule angle

Figure of Eights
↓ ↓ ↓ ↓
Hypercardioids
↓ ↓ ↓ ↓
Cardioids

Near-Coincident Techniques



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

Spot Mics

- Individual mono mics placed very close to a single source, e.g. snare drum mic on a drum kit.
- Often used in conjunction with stereo recordings, and must be panned to the same position.
- Spot mics may be a stereo pair for a wide source in a large ensemble, e.g. the woodwind section within an orchestra.
- A spot mic recording is unlikely to sound natural due to the close proximity of mic and source.

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 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.