Microphones

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Early recording

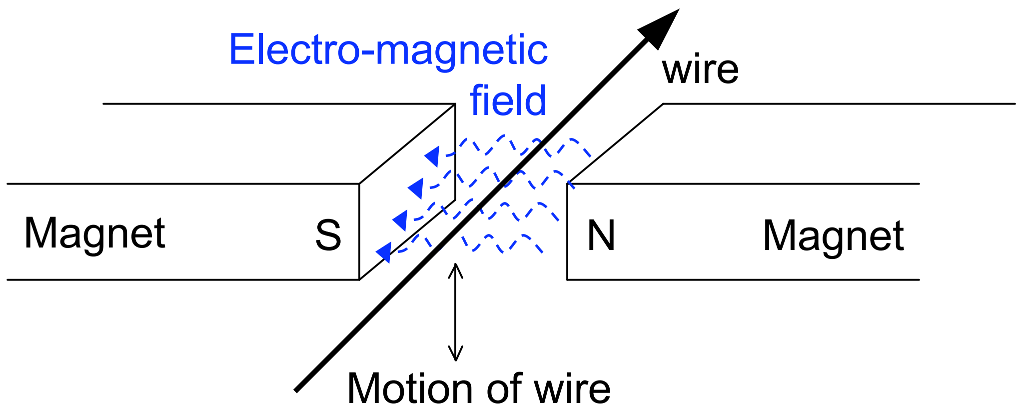
- Early recording and reproduction was entirely acoustic
- Sound was captured by a horn terminated on a diaphragm that vibrated in sympathy with the sound
- The diaphragm was attached to a stylus which cut grooves on foil or wax
- Performers had to clutter around the horn.
- Little control of individual levels

Sound in electrical form

- Sound in electrical form can be amplified, mixed and recorded.
- We can convert the acoustical waveform into an electrical waveform of the same shape
- Amplitude becomes voltage (V), and air particle motion becomes electrical current (I) - electrons playing the role of air particles.
- The current's direction of flow changes with cycles of compression/rarefaction creating an alternating current (AC)
- The flow of electrons in a conductor is impeded by a certain amount of resistance (R)
- The relationship between V, I and R is regulated by Ohm's law: $V = I \times R$. Their relationship with Power (W) is: $W = I^2 \times R = V^2/R$
- In AC systems resistance is replaced by impedance (which also includes reactance). Impedance is frequency dependent

Electro-magnetic induction

- Electromagnetic transducers convert mechanical motion (as produced by, e.g., an acoustic wave) into an electrical signal
- An electrical current is induced (and voltage is produced) if: (i) a static conductor is situated in a changing magnetic field, or (ii) a conductor moves in a static magnetic field
- This phenomenon is characterized by Faraday's law of electromagnetic induction (http://msdaif.googlepages.com/demo_faraday)



- The direction of motion (perpendicular to the lines of flux) controls the direction of current flow in the conductor (e.g. a wire).
- Back and forth movements result in an alternating current (AC) related in frequency and amplitude to the wire's motion

Microphones

- Microphones are transducers that convert acoustical energy into electrical energy.
- The three main types of microphones (according to their principles of operation) are:

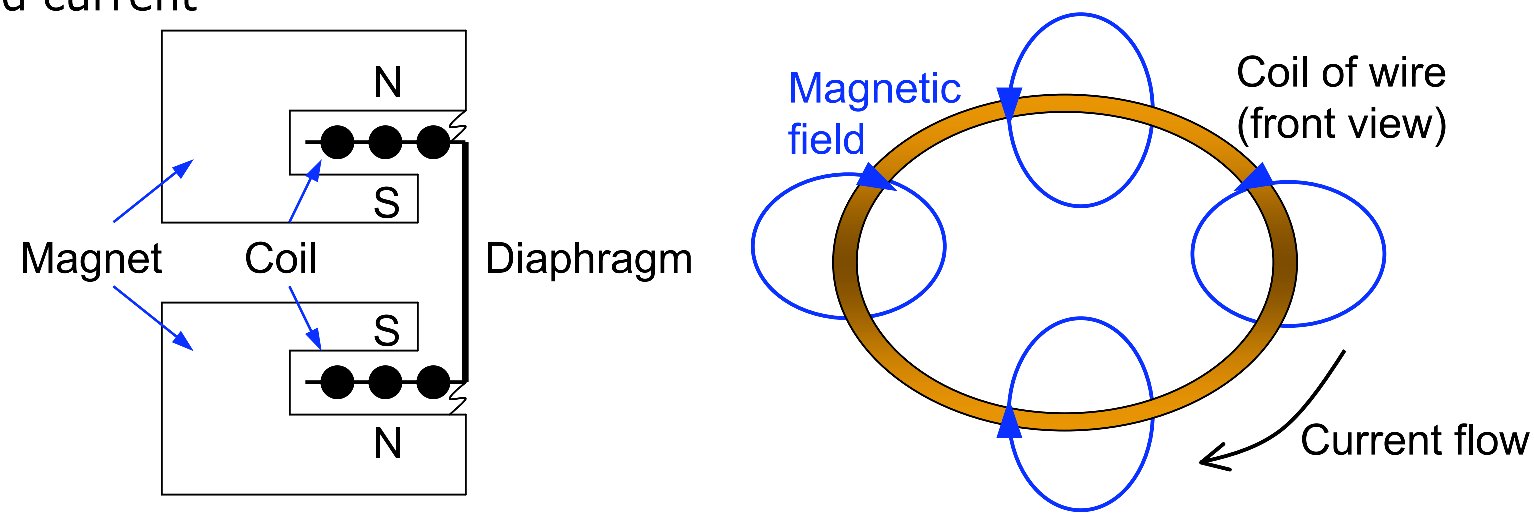
Dynamic (moving-coil)

Ribbon

Condenser

Dynamic microphones

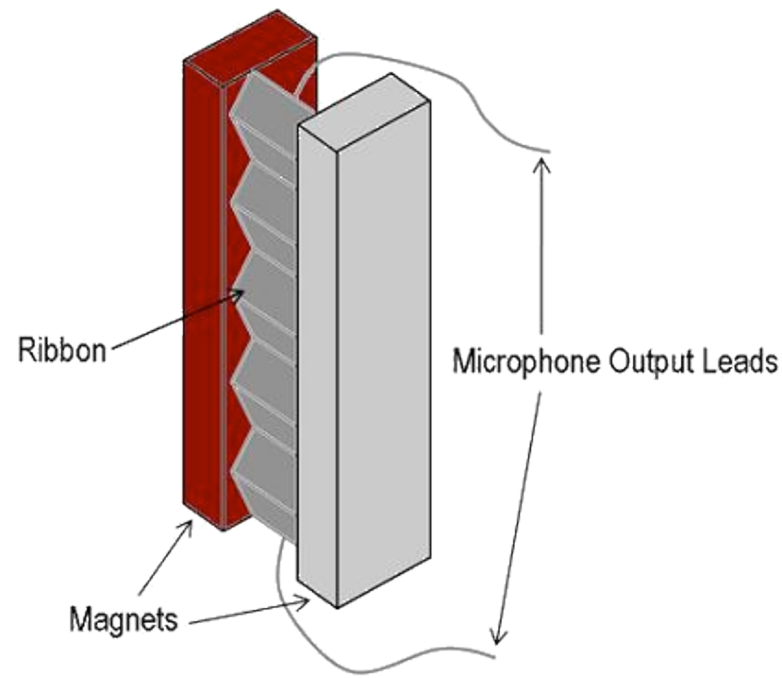
- Dynamic mics consist of a diaphragm suspended in front of a magnet to which a coil of wire is attached.
- The coil sits in the gaps of the magnet. Vibrations of the diaphragm make the coil move in the gap causing an AC to flow
- Coils of wire are used to increase the magnitude of the induced voltage and current



- The mass of the coil-diaphragm structure impedes its rapid movement at high frequencies (where there is usually low response).
- A resonant peak is usually found at around 5kHz, making it a favorite with vocalists.
- Very robust (extensively used for kick-drums)

Ribbon microphones

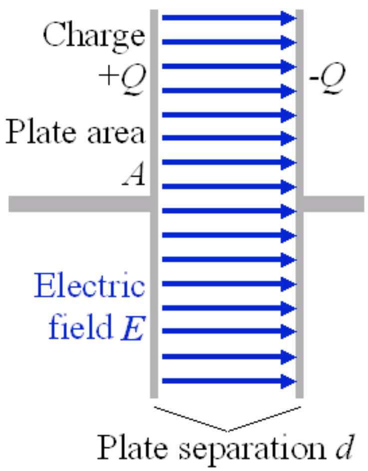
- It consists of a thin strip of conductive corrugated metal (ribbon) between magnetic plates.
- Vibration of the ribbon according to the acoustic wave induces a current
- Its electrical output is very small and needs to be stepped up by a transformer

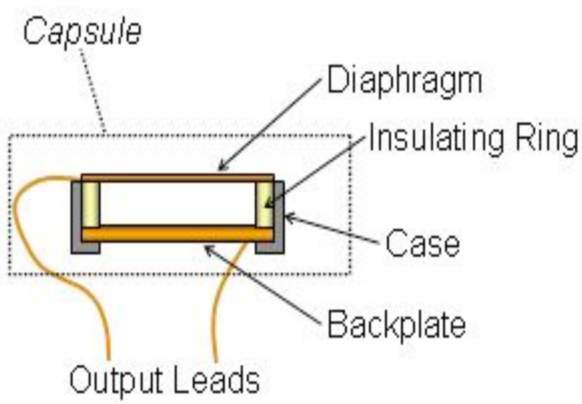


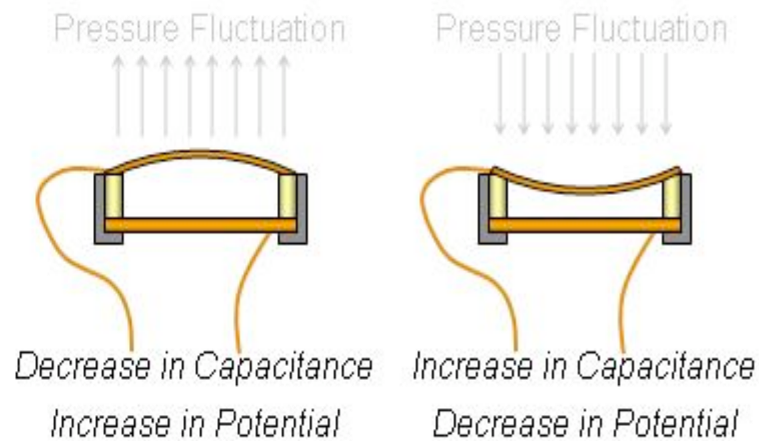
- The lightness of the ribbon guarantees a flat frequency response for mid and high frequencies up to 14kHz. It resonates at very low frequencies (around 40Hz)
- It is very delicate and well suited for the recording of acoustic instruments

Condenser microphones (1)

- A capacitor is an electrical device able to store electrical charge between two closely-spaced conductors (plates)
- Capacitance (C) measures how much charge (Q) is stored for a given voltage (V), such that C = Q/V
- Capacitance is inversely proportional to the distance (d) between plates







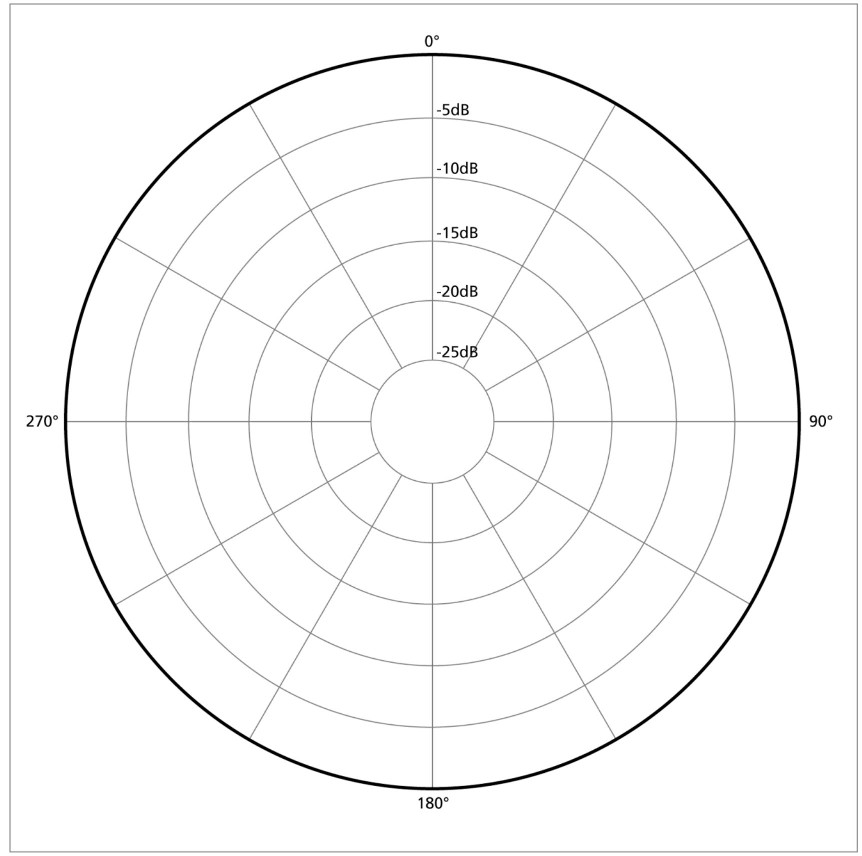
- In condenser mics, the front plate is the diaphragm which vibrates with the sound. The charge (Q) is fixed, thus changes in the distance d between plates result on changes of voltage (V)

Condenser microphones (2)

- Condenser mics can be extremely high quality
- The diaphragm can be very light, rendering a flat frequency response (with a small resonance peak at above 12kHz)
- Output of condenser mics is much higher than for dynamic mics
- High output makes it more robust to noise
- To charge the capacitor a source of power is needed (usually phantom power - to be discussed later in the course)
- An alternative to using a power source is to introduce a permanent electrostatic charge during manufacture, resulting on the “electret” mic.
- Electret microphones can be very small, high quality (back electrets) and cheap, e.g. Tie-clip TV microphones

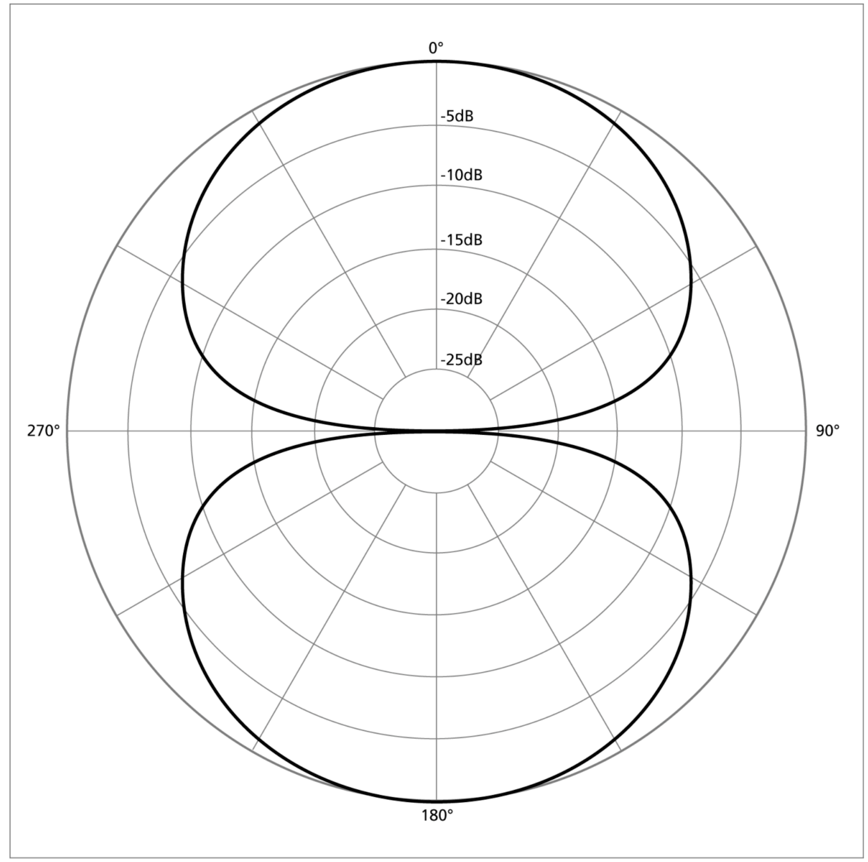
Directional Response (1)

- Microphones are designed to have a directional response pattern
- This pattern is characterized by a polar diagram showing magnitude of the output (in dB) vs angle of incidence
- An omnidirectional microphone picks up sound equally in all directions
- This is achieved by opening the diaphragm at the front and completely enclosing it at the back
- At high frequencies the wavelength is comparable to the size of the capsule, resulting in a loss of gain off front center
- Smaller capsules result in better high-frequency performance
- TV tie-clip microphones are usually omni electrets



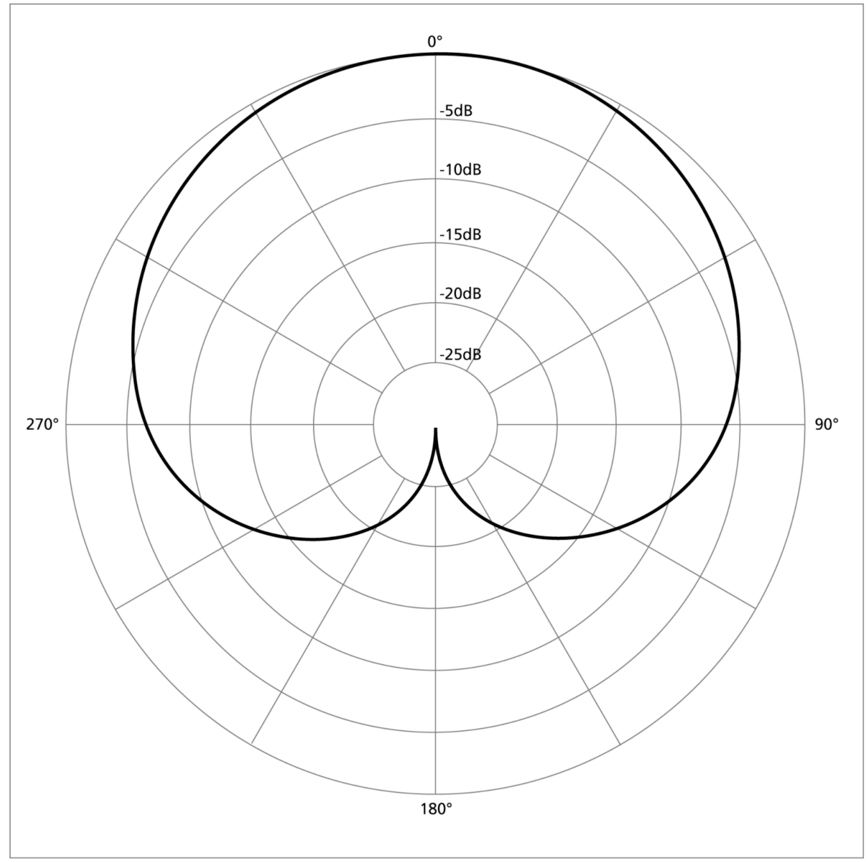
Directional Response (2)

- Figure eight or bidirectional microphones have an output close to cos(θ), where θ = angle of incidence
- This directional pattern is mostly associated with ribbon microphones (open both at the front and rear)
- The response is thus the result of the pressure difference between diaphragm front and rear (which is why response is null at 90/270°)
- The long wavelengths at low frequencies (resulting in small phase differences) cause a reduction of the output
- Because of the ribbon's shape, ribbon mics have a better polar response when upright or upside down, than when positioned horizontally



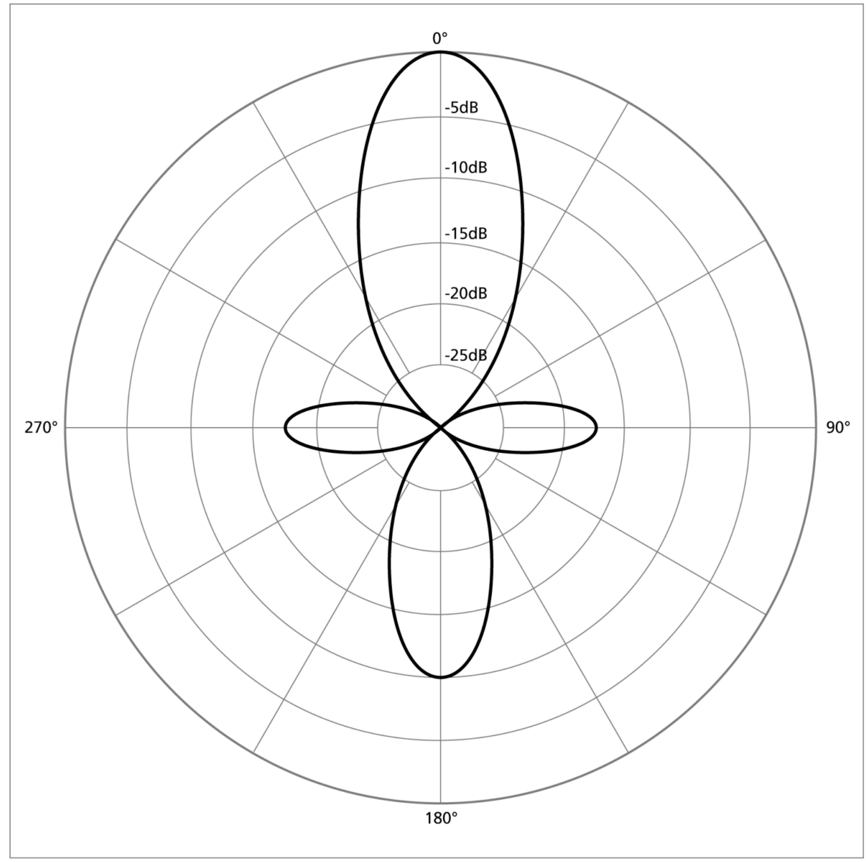
Directional Response (3)

- Cardiod microphones result from the combination of omnidirectional and bidirectional patterns
- Their output is close to 1 + cos(θ)
- They are unidirectional
- The response is obtained by leaving the diaphragm open at the front while using acoustic labyrinths in the rear to cause differences of phase and amplitude in the incoming sound
- Mid frequency response is usually very good
- At low-frequencies it tends to omni
- At high frequencies it becomes too directional
- This is common to dynamic cardioids
- Top range condenser cardioids behave much more ideally



Directional Response (4)

- There are a number of specialized microphones such as so-called shotgun microphones or parabolic microphones which are highly directional
- A shotgun mic, for example, is cardiod with a long barrel with openings aimed at causing canceling phase differences



Characteristics of microphones

- Professional microphones have a low-impedance usually around of 200 ohms - this enables the use of long leads
- Another important characteristic is sensitivity, i.e. a measure of the electrical output (in volts) per incoming SPL
- Sensitivity is usually given in terms of a reference SPL, e.g. 94 dB or 1 Pascal (Pa).
- Condenser microphones (5-15 mV/Pa) are more sensitive than moving coils (1.5-3 mV/Pa) and ribbons (1-2 mV/Pa)
- More amplification is needed for moving-coils and ribbons (which are thus more susceptible to interference). Also, low-sensitivity mics need high-quality (low noise) amps and mixers.
- All microphones generate some noise. This is usually expressed in “A-weighted” self-noise (given in dBA).
- High-quality condenser and moving-coil mics achieve self-noise of 17-18dBA. Ribbon mics’ noise can be of the order of 23dBA, which means that for quite signals low-noise amps need to be used. A self-noise in the region of 25dBA results in poor performance.

Useful References

- Francis Rumsey and Tim McCormick (2002). "Sound and Recording: An Introduction", Focal Press.
  - Chapter 3: Microphones

- For a quick reference on coils and electromagnetism see: Marshall Brain. "How Electromagnets works". http://science.howstuffworks.com/electromagnet4.htm

- Microphone photos, ribbon, condenser mic and polar diagrams from:
- http://en.wikibooks.org/wiki/Acoustics/Microphone_Design_and_Operation
- http://en.wikipedia.org/wiki/Microphone