21M.380 · Music and Technology
Recording Techniques & Audio Production

Microphones

Session 3 · Wednesday, September 14, 2016

1 Student presentation (pa1)

- [redacted]

2 Microphone specifications

- Frequency range (Klepko 2004, p. 122)
- Frequency response (Shure 2012a)
- Self noise (Shure 2012b) or *equivalent noise level* (Williams 2010)
- (Output) sensitivity (Dpa 2008–2013; Shure 2012b; Williams 2010)
- Maximum sound pressure level (Dpa 2008–2013; Shure 2012b)
- Dynamic range (Shure 2012b)
- Polar pattern (directivity; discussed in detail later today)

3 Electric quantities

Quantity	Symbol	Unit	Nature
Voltage	V	V	Field quantity
Electric power	P	W	Energy quantity

Table 1. Electric quantities

3.1 Voltage V and voltage level L_V

Common references V_0:

- $1\,\mathrm{V} \equiv 0\,\mathrm{dB_V}$ (electronics)
- $0.7746\,\mathrm{V} \equiv 0\,\mathrm{dB_u}$ (audio equipment)

$$L_V = 20 \cdot \log_{10}\left(\frac{V}{V_0}\right)$$

Equation 1. Voltage level L_V

3.2 Electric power P and electric power level L_W

Common references P_0:

- $1\,\mathrm{W} \equiv 0\,\mathrm{dB}$ (loudspeakers)
- $1\,\mathrm{mW} \equiv 0\,\mathrm{dB_m}$ (telephone equipment)

$$L_W = 10 \cdot \log_{10}\left(\frac{P}{P_0}\right)$$

Equation 2. Electric power level L_W

3.3 Doubling field quantities

- Doubling a field quantity (e.g., p, V) results in 6 dB increase
- See slides for derivation

3.4 Doubling energy quantities

- Doubling an energy quantity (e.g., I, P) results in 3 dB increase
- See slides for derivation

4 Electroacoustic transducer principles[1]

[1] Cf., Shure 2012c.

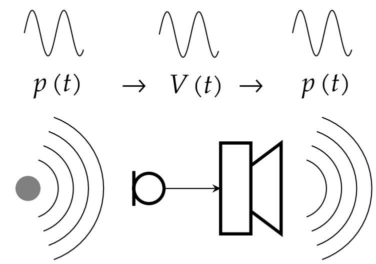


Figure 1. Electroacoustic transduction process

Microphone type	Power needed?	Sound quality	Robustness
Dynamic microphones (electromagnetic induction)			
Moving coil	no	medium/good	robust
Ribbon	no	(very) good	fragile
Condenser microphones (capacitance)			
Regular condenser	yes	excellent	fragile
Electret condenser	yes	(very) good	less fragile
Piezo microphones (piezoelectric effect)			
Contact (pickup) mic	no	low	robust

Table 2. Comparison of different microphones by transducer principle

- Job of a microphone: convert mechanical pressure waves to electrical signals (and vice versa for loudspeaker)
- But how to do this? By exploiting one of several physical phenomena:
  - Electromagnetic induction
  - Capacitance
  - Piezoelectric effect

5 Dynamic microphones

5.1 Electromagnetic induction

- General: Current is induced in a (closed-loop) conductor that moves relative to a magnetic field.
- Dynamic mics: diaphragm as/on conductor oscillates in magnetic field

5.2 Moving coil microphones

- Diaphragm mounted on top of coil (conductor)
- Available in moss: Shure Beta 58a, Shure sm57, Sennheiser md 421-ii, Sennheiser e 604, Audix d6, Blue Microphones encore 200, Audio-Technica atm250de (one of two capsules)

5.3 Ribbon microphones

- Diaphragm *is* the conductor
- Better high-frequency response can be achieved than with moving coil (less mass)
- Ribbon microphones are very fragile (sensitive to wind!)
- Available in MOSS: Royer R-101

6 Condenser microphones

6.1 Capacitance

- General: An electric charge can be stored by a dual-plate capacitor
- Condenser microphones:
  - Diaphragm forms one of two plates of a dual-plate capacitor
  - Movement of diaphragm changes distance between plates (and thus output voltage)

6.2 Large vs. small diaphragm condensers

- Small-diaphragm condensers often cigar-shaped
- Large-diaphragm condensers typically addressed from the side
- But can't always tell difference from outside (e.g., Neumann M50 vs. M49)
- Small diaphragm condensers feature more neutral frequency response and polar pattern
- Colored HF response of large-diaphragm mics can be desirable (vocals)
- Available in MOSS:
  - Large-diaphragm condensers: AKG C 414 XL II, Mojave Audio MA-200
  - Small-diaphragm condensers: Audio-Technica AT4041, Earthworks TC20, Audio-Technica ATM250DE (one of two capsules)

6.3 Tube condensers

- Typically come with their own power supply
- Operate best if warmed up before use
- Often mounted upside down (to dissipate heat away from diaphragm)
- Available in MOSS: Mojave Audio MA-200

6.4 Electret condensers

- Pre-charged capacitor
- Popular where small capsules are required (e.g., lavalier or in-ear mics)
- Available in moss: Audio-Technica atm250de (one of two capsules)

6.5 Phantom (and other kinds of) power

- *Phantom power* provided by external preamp through mic cable
- Ideally +48 V, but most mics accept anything from 12 V to 52 V
- Two reasons for phantom power:
  1. Charge capacitor of a condenser microphone
  2. Power internal preamp to amplify low-level output signal
- Rule of 👍: *Condensers need phantom, dynamic mics don't.*
- Reality is more complex:
  – Tube condensers such as Mojave ma200 in moss come with own power supply (and hence do not need phantom from preamp)
  – Blue encore 200 in moss is an *active* dynamic mic (requires phantom)
  – Ribbon mics are dynamic, so generally do not require phantom (e.g., Royer r-101 in moss), but *active* ribbon mics do (e.g., Royer r-122)
  – Electret condenser come with pre-charged capacitor, but to amplify signal might still require 48 V (e.g., Audio-Technica atm250de in moss), or 3 V *plug-in power* from audio input or battery

7 Piezo microphones

7.1 Piezoelectric effect

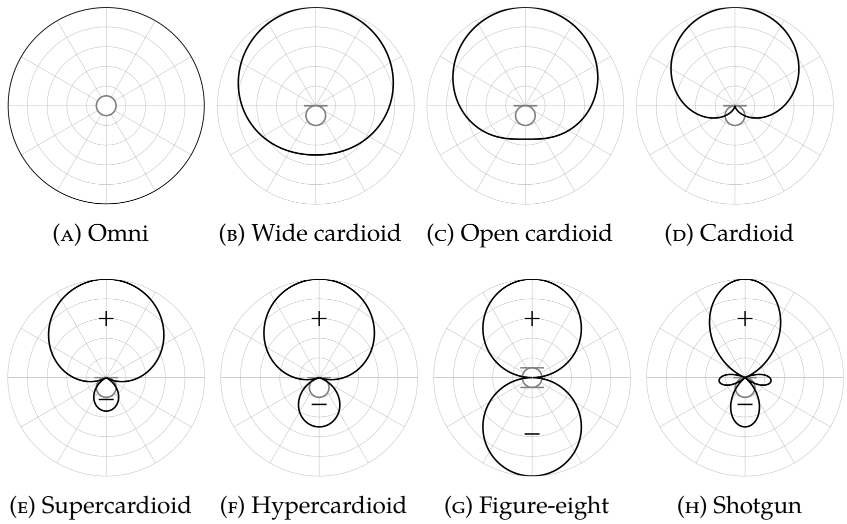
- General: Certain materials (e.g., crytals) generate an electric charge when mechanical stress is applied to them.
- Piezo mics: Mechanical stress conveyed through sound pressure wave

7.2 Contact microphones

- Attached directly to a solid vibrating body
- None available in moss

7.3 Hydrophones

- For underwater recordings
- None available in moss



(A) Omni (B) Wide cardioid (C) Open cardioid (D) Cardioid

(E) Supercardioid (F) Hypercardioid (G) Figure-eight (H) Shotgun

Figure 2. Microphone directivity patterns

8 Directivity[2]

8.1 How to read polar diagrams

- Bird's eye view
- Extend (symmetrically) into 3D

8.2 Stage plan notation

- Distinguish omni-, uni-, and bi-directional microphones
- Or use for *any* mic where directivity is irrelevant

Table 3. Notation of microphones with different directivity in a stage plan

Directivity pattern	Symbol
Omnidirectional	
Unidirectional	
Bidirectional	

8.3 Comparison

Table 4. Characteristics of omnidirectional vs. directional microphones (Nymand 2005, p. 7)

Property	Omnidirectional	Directional
Gain to feedback ratio	Lower	Higher
Feedback build-up	Slow	Fast
Off-axis coloration	Smooth and even	Less smooth
Proximity effect	No	Yes
Wind, handling, pop noises	Less sensitive	More sensitive
Distortion	Lower	Higher
Channel separation	Only in direct field	Good

8.4 Figure-eights

- Pick up sound from front & rear, but much less from sides
- Classic application: interviews
- Available in MOSS: Royer R-101, AKG C 414 XL II (switchable)

[2] Cf., Shure 2012d.

8.5 Omnis

- In theory pick up sound equally well from all directions
- In practice become directional towards front for $f \gg$ (why?)
- Preferred by some engineers for superior tone quality
- Available in moss: Earthworks tc20, akg c 414 xl ii (switchable)

8.6 Cardioids

- Single preferred direction (less pronounced for $f \ll$)
- Popular for live applications, to avoid feedback loop with monitor loudspeaker
- Available in moss: Audio-Technica at4041, akg c 414 xl ii (switchable), Shure sm57, Sennheiser md 421-ii, Sennheiser e 604, Audix d6,Blue Microphones encore 200, Audio-Technica atm250de (condenser capsule)

8.7 Wide & open cardioids

- Cardioids that are somehwere between cardioid and omni
- *Wide cardioid* closer to omni than *open cardioid*
- But terminology varies, e.g., both might be referred to as *subcardioids*
- Available in moss: akg c 414 xl ii (switchable)

8.8 Supercardioids & hypercardioids

- Cardioids that are somewhere between cardioid and figure-eight
- Hypercardioid closer to figure-eight than supercardioid
- Available in moss: akg c 414 xl ii (switchable), Shure Beta 58a (super), Audio-Technica atm250de (dynamic capsule: hyper)

8.9 Pressure vs. pressure gradient

- Simplest (idealized) microphone: a freely suspended diaphragm
  - What would its polar pattern be? Figure-eight!
  - Why? Diaphragm moves due to pressure *difference* front vs. rear
  - Such a difference across space is called a *gradient* (denoted with ∇)
  - But pressure gradient $\nabla p = 0$ for sounds from the sides!
  - *A pure pressure gradient transducer is bidirectional.*
- Question arises: How to even build an omni, then?
  - Answer: By putting the diaphragm into a closed capsule

  - Sound can now only reach diaphragm from *one* side, not both
  - Hence diaphragm moves according to sound pressure p in front of it
  - *A pure pressure transducer is omnidirectional.*

- And how to build a cardioid?
  - Add slits on *sides* of capsule (*any* capsule is open to front, of course)
  - Acoustical labyrinths control phase of wavefront at rear of diaphragm
  - Resulting interference results in cardioid pickup pattern
  - *A mixed pressure & pressure gradient transducer is unidirectional.*

8.10 Mathematical description

- Equation describes mic directivity as weighted combination of
  - Pressure component $0 \leq A_p \leq 1$
  - Pressure gradient component $0 \leq A_{\nabla p} \leq 1$
- Values for A_p & $A_{\nabla p}$ depend on polar pattern (cf., table 5)
- Above equation gives a polar function for angle ϕ
- Assume $\phi = 0$ for front direction (i.e., top of polar diagram)

$$A(\phi) = A_p + A_{\nabla p} \cdot \cos\phi$$

EQUATION 3. Mathematical description of microphone directivity

TABLE 5. Pressure and pressure gradient components for different microphone directivity patterns

Polar pattern		A_p	$A_{\nabla p}$
Omni		1	0
Wide cardioid	↕	3/4	1/4
Open cardioid		2/3	1/3
Cardioid		1/2	1/2
Supercardioid	↕	1/3	2/3
Hypercardioid		1/4	3/4
Figure-eight		0	1

8.11 Proximity effect

- Directional mics (i.e., those with a pressure gradient component) exhibit a boost in bass frequencies for close, on-axis sound sources.
- Effect becomes weaker as source moves away from mic or off-axis
- Effect does *not* occur at all for pure pressure microphones (omnis)!
- Deliberately exploited by singers, salesmen, etc.

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