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

Microphones
Session 3 · Wednesday, September 14, 2016

1 Student presentation (PA1)

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

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Symbol</th>
<th>Unit</th>
<th>Nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>V</td>
<td>V</td>
<td>Field quantity</td>
</tr>
<tr>
<td>Electric power</td>
<td>P</td>
<td>W</td>
<td>Energy quantity</td>
</tr>
</tbody>
</table>

Table 1. Electric quantities

3.1 Voltage $V$ and voltage level $L_V$
Common references $V_0$:
- $1 \text{ V} \equiv 0 \text{ dB}_V$ (electronics)
- $0.7746 \text{ V} \equiv 0 \text{ dB}_u$ (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 $P_0$:
- $1 \text{ W} \equiv 0 \text{ dB}$ (loudspeakers)
- $1 \text{ mW} \equiv 0 \text{ dB}_m$ (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

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

• 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 ATM250D/E (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., crystals) 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
8 Directivity

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

8.3 Comparison

<table>
<thead>
<tr>
<th>Property</th>
<th>Omni-directional</th>
<th>Directional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain to feedback ratio</td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td>Feedback build-up</td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td>Off-axis coloration</td>
<td>Smooth and even</td>
<td>Less smooth</td>
</tr>
<tr>
<td>Proximity effect</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Wind, handling, pop noises</td>
<td>Less sensitive</td>
<td>More sensitive</td>
</tr>
<tr>
<td>Distortion</td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td>Channel separation</td>
<td>Only in direct field</td>
<td>Good</td>
</tr>
</tbody>
</table>

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)
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 somewhere 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 \( \nabla \))
  - 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 $\phi$
• Assume $\phi = 0$ for front direction (i.e., top of polar diagram)

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.

References & further reading


