Digital Sound Capstone
DXARTS 460

Lecture 7:
Microphones and recording techniques

Spring 2011

Instructor: Stelios Manousakis

Microphones

Microphones

- Microphones are ***transducers***, i.e devices that change one form of energy into another: From acoustic waves to electrical signals

- Quality of sound pickup depends on *microphone design variables* (such as the microphone's operating type, design characteristics, and quality) and *external variables* (placement, distance, source being recorded, and the acoustic environment)

Microphone properties

- Transducer type
- Polar pattern
- Frequency response
- Impedance
- Maximum SPL
- Sensitivity
- Self-noise
- Signal-to-noise ratio

Transducer types

Mics can be one of 3 types, depending on how the conversion happens:

- Dynamic
- Ribbon
- Condenser

Transducer types

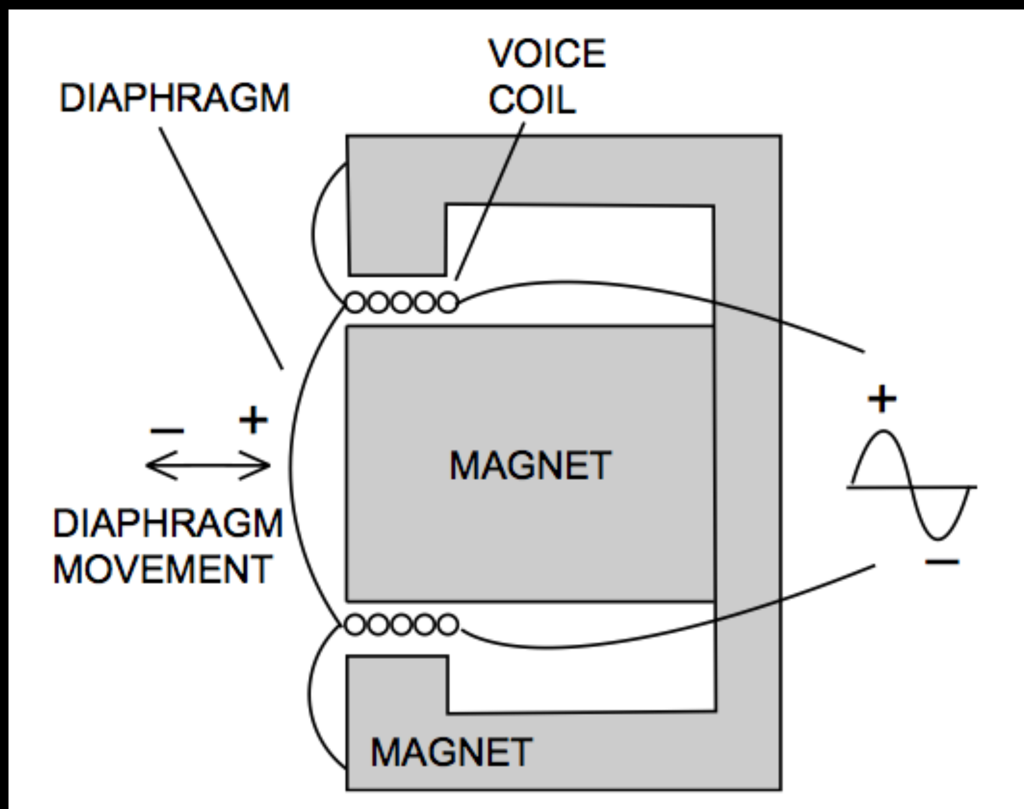
Mics can be one of 3 types, depending on how the conversion happens:

- Dynamic
- Ribbon
- Condenser

Transducer types | Dynamic

- Dynamic

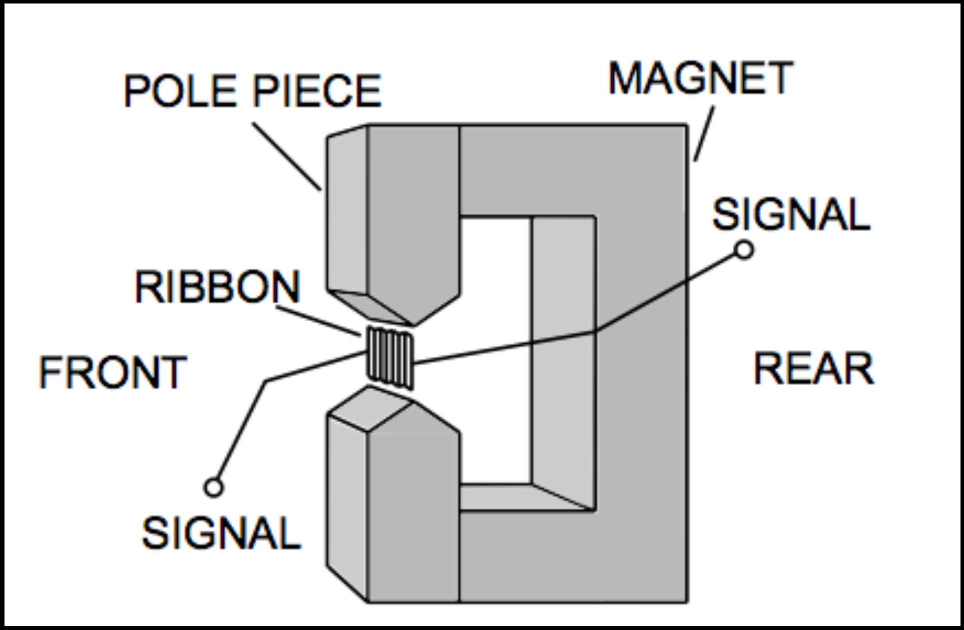
  A coil of wire attached to a diaphragm is suspended in a magnetic field. When sound waves vibrate the diaphragm, the coil vibrates in the magnetic field and generates an electrical signal similar to the incoming sound wave.



Transducer types | Ribbon

- Ribbon

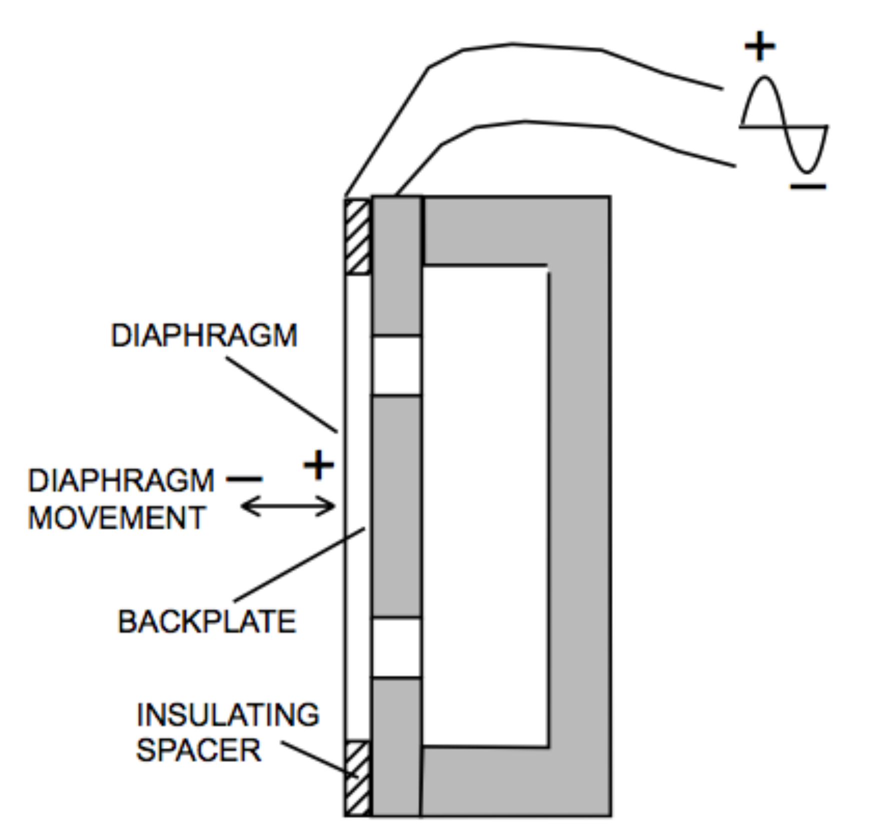
  A thin metal foil or ribbon is suspended in a magnetic field. Sound waves vibrate the ribbon in the field and generate an electrical signal.



Transducer types | Condenser

- Condenser (or capacitor)

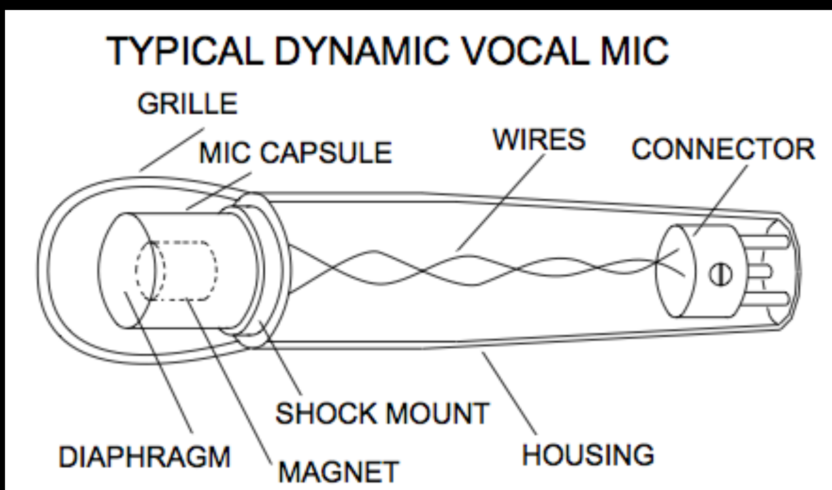
A conductive diaphragm and a metal backplate are placed very close together. They are charged with static electricity to form two plates of a capacitor. When sound waves strike the diaphragm, it vibrates. This varies the spacing between the plates. In turn, this varies the capacitance and generates a signal similar to the incoming sound wave.

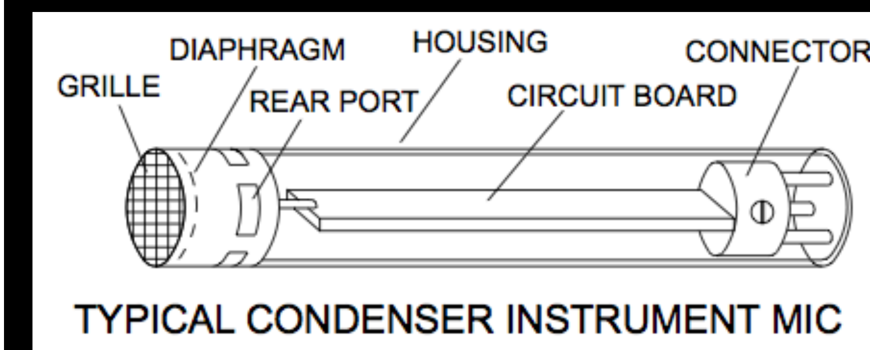


Transducer types | Condenser

- Two condenser types
  - true condenser: charged from a circuit built with the mic
  - electret: use pre-charged material, will discharge with time

- Condenser mics need external power to operate (*Phantom power*), usually between 12-48V, although electret mics use less





Transducer types | General traits

General traits, with exceptions

- Condenser
  - Wide, smooth frequency response
  - Detailed sound, extended highs
  - Omni type has excellent low-frequency response
  - Transient attacks sound sharp and clear
  - Preferred for acoustic instruments, cymbals, studio vocals
  - Can be miniaturized
- Dynamic
  - Tends to have rougher response, but still quite usable
  - Rugged and reliable
  - Handles heat, cold, and high humidity
  - Handles high volume without distortion
  - Preferred for guitar amps and drums
  - If flat response, can take the "edge" off woodwinds and brass
- Ribbon
  - Prized for its warm, smooth tone quality
  - Delicate
  - Complements digital recording

Polar patterns

- Microphones differ in how they respond to sounds coming form different directions

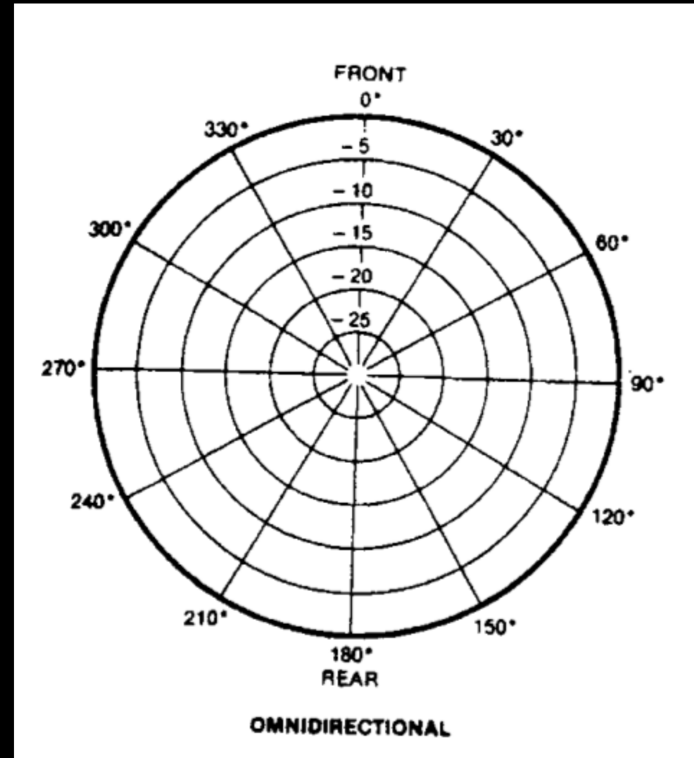
- Omnidirectional vs unidirectional vs bidirectional

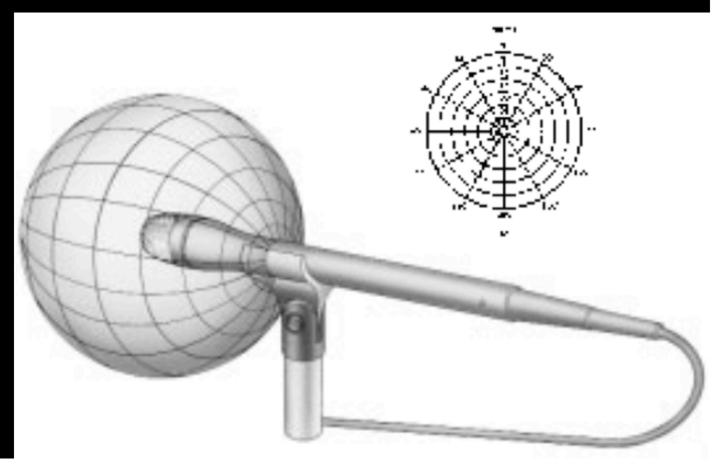
- In a good mic, the polar pattern should be about the same from 200Hz to 10kHz.

- *Condenser* or *dynamic* types can have almost any kind of polar pattern (there are no bidirectional dynamic).
- Some condenser mics come with switchable patterns.
- *Ribbon* mics are either bidirectional or hypercardioid.

Polar patterns | Omnidirectional

- **Omnidirectional**:
  - All-around pickup: equally sensitive to sounds arriving from all directions
  - Most pickup of room reverberation
  - Not much isolation unless you mike close
  - Low sensitivity to pops (explosive breath sounds)
  - Low handling noise
  - No up-close bass boost (proximity effect)
  - Extended low-frequency response in condenser mics
  - Lower cost in general



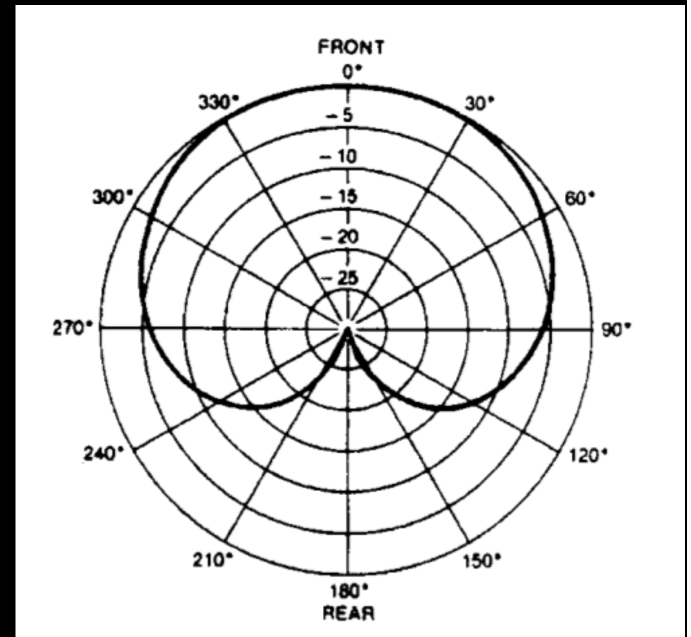


Polar patterns | Unidirectional

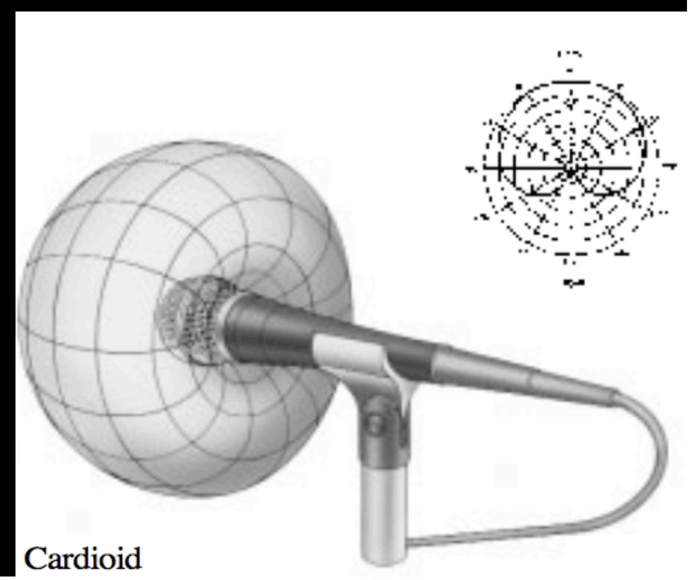
- **Unidirectional** (cardioid, supercardioid, hypercardioid):
  - Selective pickup
  - Rejection of room acoustics, background noise, and leakage
  - Good isolation of sources
  - Up-close bass boost (except in mics that have holes in the handle)
  - Better gain-before-feedback in a sound-reinforcement system
  - Coincident or near-coincident stereo miking

Polar patterns | Unidirectional: Cardioid

- **Cardioid** :
  - Sensitive to sounds arriving from a broad angle in front of the mic
  - It is about 6dB less sensitive at the sides, and about 15 to 25 dB less sensitive in the rear.
  - Broad-angle pickup of sources in front of the mic
  - Maximum rejection of sound approaching the rear of the mic

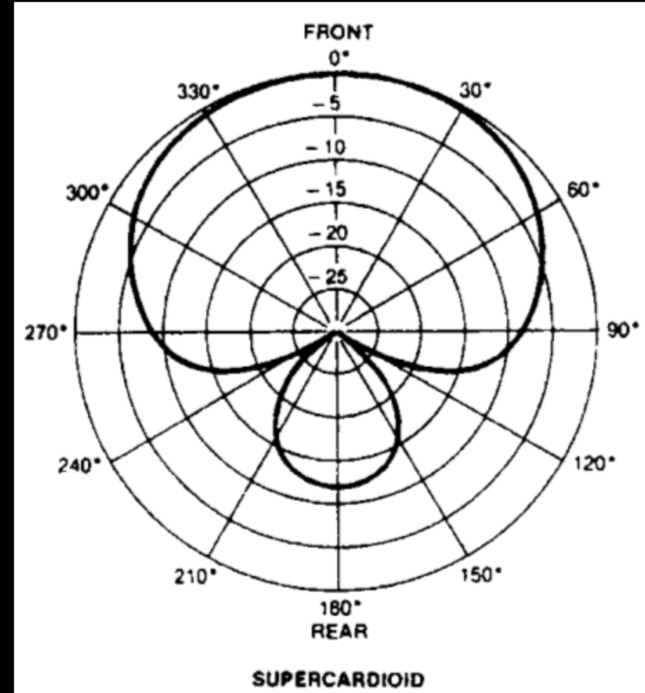


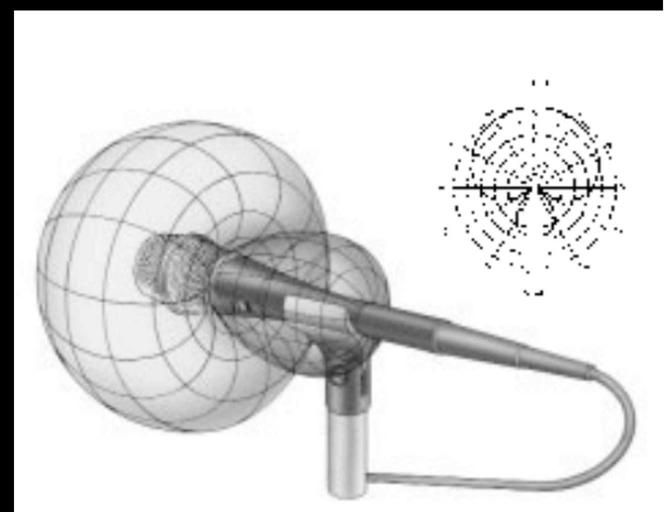
CARDIOID


Cardioid

Polar patterns | Unidirectional: Supercardioid

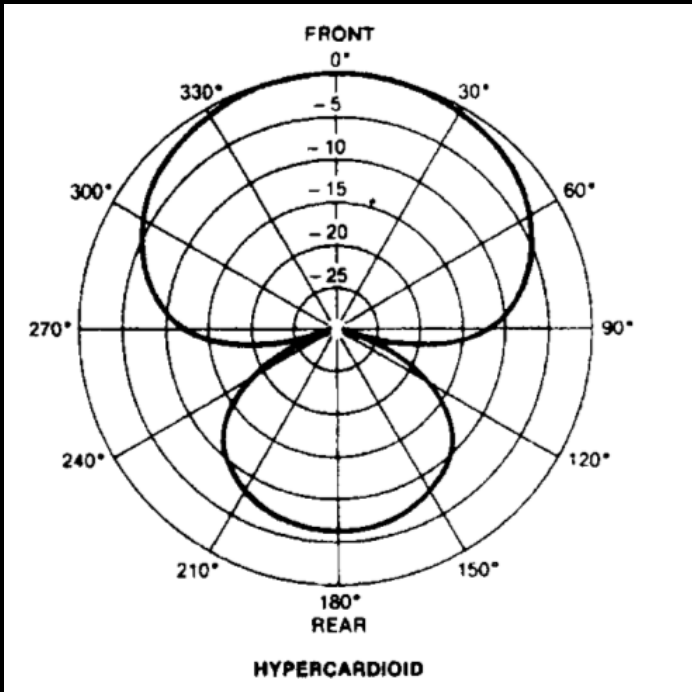
- **Supercardioid** :
  - Rejects sound from the sides more than the cardioid. More directional, but picks up more sound from the rear than the cardioid.
  - 8.7 dB less sensitive at the sides and has two areas of least pickup at 125 degrees away from the front.
  - Maximum difference between front hemisphere and rear hemisphere pickup (good for stage-floor miking)
  - More isolation than a cardioid
  - Less reverb pickup than a cardioid





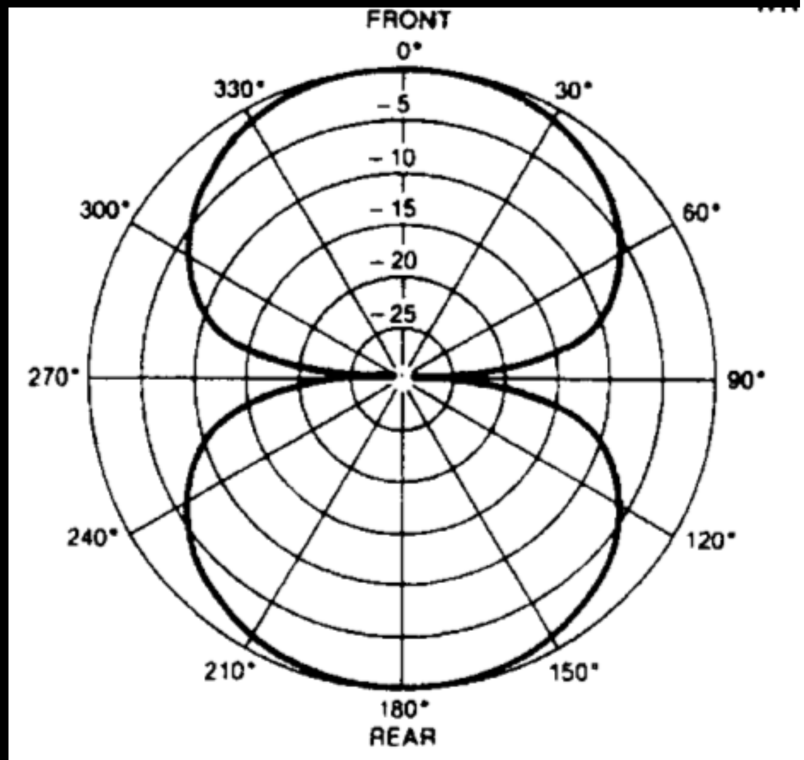
Polar patterns | Unidirectional: Hypercardioid

- **Hypercardioid** :
  - Rejects sound from the sides more than the cardioid. More directional, but picks up more sound from the rear than the cardioid.
  - 12dB less sensitive at the sides and has two areas of least pickup at 110 degrees away from the front.
  - Maximum side rejection in a unidirectional mic
  - Maximum isolation, i.e. maximum rejection of reverberation, leakage, feedback, and background noise



Polar patterns | Bidirectional

- **Bidirectional** (or 'figure of eight'):
  - Front and rear pickup, with side sounds rejected (for across-table interviews or two-part vocal groups, for example)
  - Maximum isolation of an orchestral section when miked overhead
  - Useful for Blumlein stereo miking (two bidirectional mics crossed at 90 degrees)



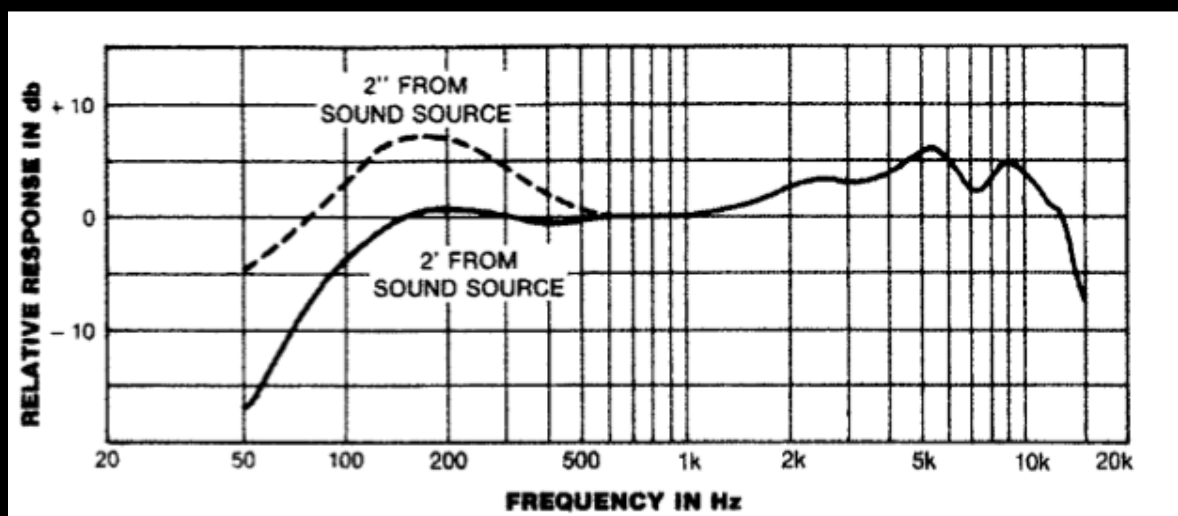
BIDIRECTIONAL

Frequency response

- A microphone's frequency response is the range of frequencies that it will reproduce at an equal level (within a tolerance, such as ±3dB).

- The appropriate frequency response depends on the sounds you are recording. A wider response would generally be best/more versatile, but not in all cases, e.g. if you want to record a bass drum. For field recordings you need the widest response you can get.

- A frequency-response curve is a graph of the mic's output level in dB at various frequencies. We use 1Khz as the reference point.



Frequency response

- The ideal response depends on the material you are recording
- Many dynamic mics have a ‘proximity effect’
- In general, mic placement can greatly affect recording quality

Impedance

- Impedance is the mic's effective output resistance at 1 kHz. A mic impedance between 150 and 600 ohms is low; 1000 to 4000 ohms is medium; and above 25 kilohms is high.

- Use low-impedance mics when available. If you do, you can run long mic cables without picking up hum or losing high frequencies

Maximum SPL

- SPL = Sound Pressure Level
- The maximum amount of sound pressure that the microphone capsule can physically take before overloading
- If the maximum SPL spec is 125dBSPL, the mic starts to distort when the instrument being miked is putting out 125dBSPL at the mic. A maximum SPL spec of 120 dB is good, 135 dB is very good, and 150 dB is excellent.

Sensitivity

- How much output voltage a mic produces when driven by a certain SPL.

- A high-sensitivity mic puts out a stronger signal (higher voltage) than a low-sensitivity mic when both are exposed to an equally loud sound. A low-sensitivity mic needs more mixer gain than a high-sensitivity mic. More gain usually results in more noise.

Self-noise

- Aka ‘equivalent noise rating’
- The electrical noise or hiss a mic produces (all electrical circuits make noise).
- It’s defined as the dBSPL of a sound source that would produce the same output voltage that the noise does.
- Since a dynamic mic has no active electronics to generate noise, it has very low self-noise (hiss) compared to a condenser mic.

Signal-to-Noise ratio

- The difference in decibels between the mic's sensitivity and its self-noise. The higher the SPL of the sound source at the mic, the higher the S/N.
- Given an SPL of 94dB, an S/N spec of 74dB is excellent; 64dB is good. The higher the S/N ratio, the cleaner (more noise-free) the signal, and the greater the "reach" of the microphone.
- "Reach" is the clear pickup of quiet, distant sounds due to high S/N.

Recording techniques

Some things to consider

- Which mic to use?
- How many mics to use?
- Where to put the mic? How close?

Microphone pickup styles

- **Distant** miking
  Record at a distance of 3 feet (1 meter) or more from the source:
  - preserves overall tonal balance by picking a large portion of a musical instrument or ensemble
  - also picks up the acoustic environment
  - add a live, open feeling to a recorded sound
  - not surgically clean sound
  - not good in spaces with bad acoustics

- **Close** miking
  Mic positioned about 1 inch to 3 feet from a sound source
  - Creates a tight, present sound quality
  - Excludes the acoustic environment
  - The mic may colorize the sound too much
  - Only a portion of the sound source may be captured

- **Accent** miking
  A compromise between close and distant miking

- **Ambient** miking
  The mic is placed at such a distance that the reverberant or room sound is more prominent than the direct signal of the sound source

Spatial hearing

Our brains use perceptual cues to localize sound:

Locational cues

- **Interaural Time Difference** (ITD): Difference in *time* of the signal arriving to our ears.
- **Interaural Intensity Difference** (IID): Difference in *intensity* of the signal arriving to our ears.
- **Head Related Transfer Functions** (HRTF): Phase cancelations caused by one's own head

Distance cues:

- **Intensity of the acoustic source**
- **Ratio between reverberated and direct signal**
- **Absorption of high frequencies**

Other cues:

- **Doppler effect**
- **Haas Effect or Precedence Effect**: the first signal to arrive to our ears is considered to be the direct one
- **Directional characteristics of the sound source**

Stereo miking techniques

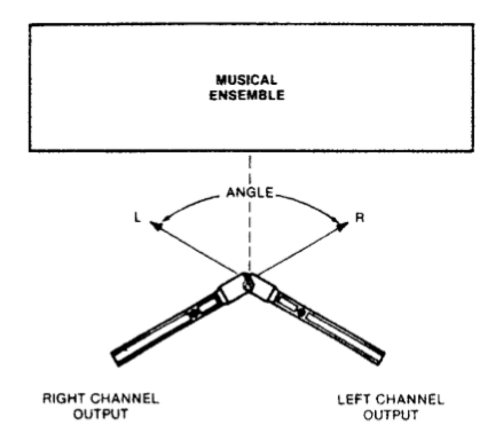
- Using two microphones to obtain a coherent stereo image

- Four fundamental techniques:
  - Coincident pair (X/Y or M/S (mid/side))
  - Spaced pair (AB)
  - Near-coincident pair (ORTF, etc)
  - Baffled pair (sphere, OSS, etc)

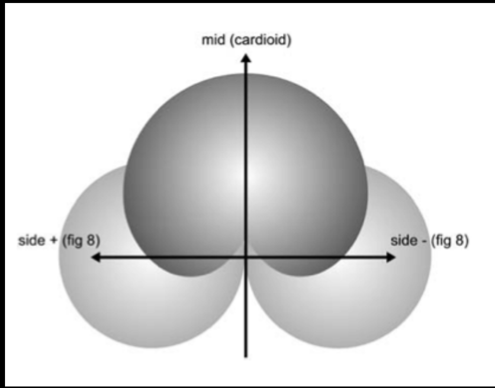
Stereo miking techniques | Coincident pair

- **Coincident pair**
  - Encodes position into level differences

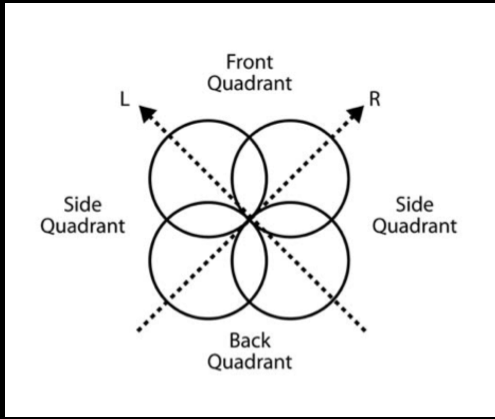
X/Y:
- 2 identical unidirectional mics



M/S::
- A cardioid and a figure 8 mic

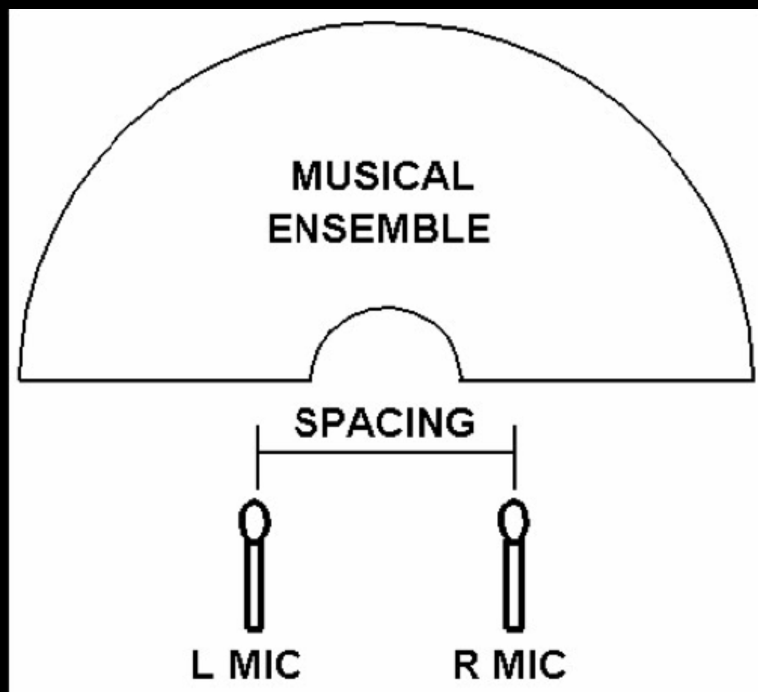


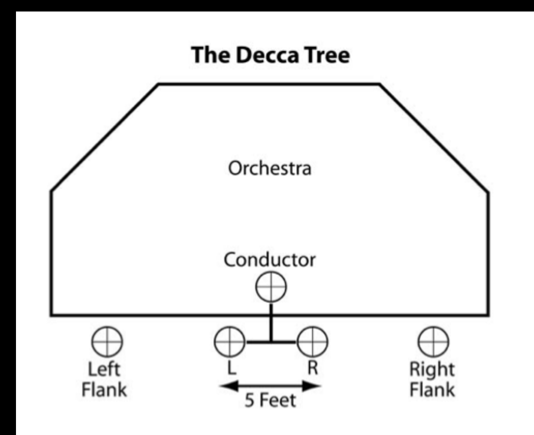
Blumlein array:
- 2 figure 8 mics



Stereo miking techniques | Spaced pair

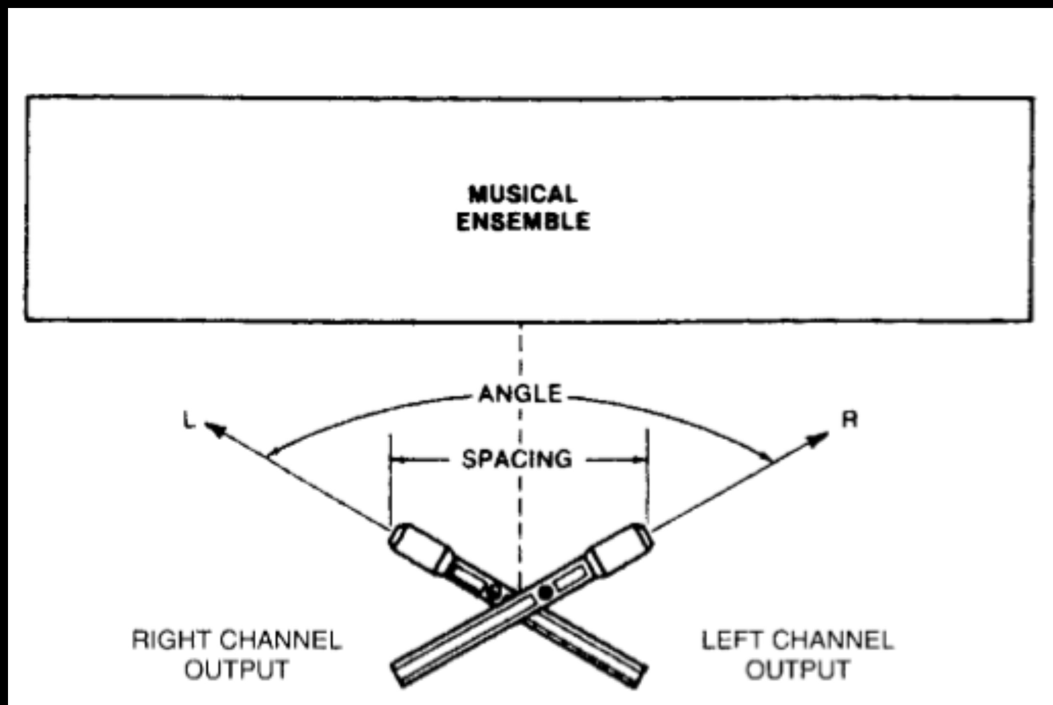
- **Spaced pair**
  - 2 identical mics. Most commonly omnis
  - Encodes instrument positions into time differences between channels.





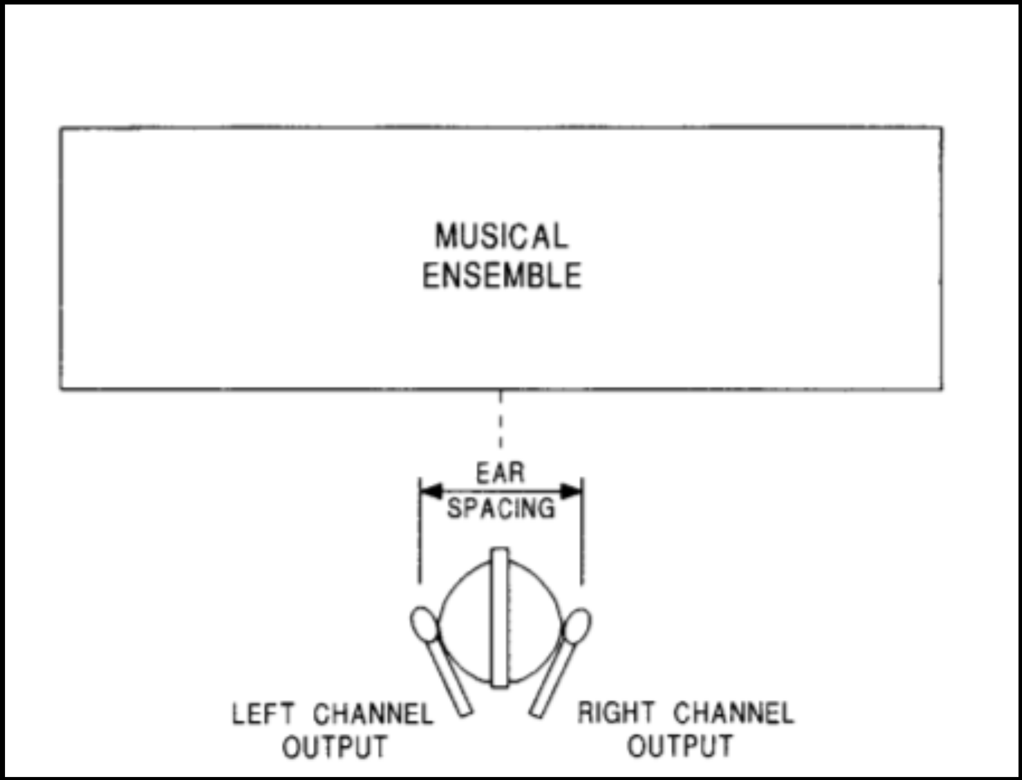
Stereo miking techniques | Near-coincident pair

- **Near-coincident pair**
  - 2 identical unidirectional mics
  - Encodes position into level differences and time differences



Stereo miking techniques | Near-coincident pair

- **Baffled omni pair**
  - 2 identical omni mics
  - Encodes position into level differences at high frequencies and time differences at low frequencies
  - The baffle creates a sonic shadow (spectral changes)



Stereo miking techniques | comparison

- Coincident pair:
  - Uses two directional mics angled apart with grilles touching.
  - Level differences between channels produce the stereo effect.
  - Images are sharp.
  - Stereo spread ranges from narrow to accurate.
  - Signals are mono compatible.

- Spaced pair:
  - Uses two mics spaced several feet apart, aiming straight ahead.
  - Time differences between channels produce the stereo effect.
  - Off-center images are diffuse.
  - Stereo spread tends to be exaggerated unless a third center mic is used, or unless spacing is under 2 to 3 feet.
  - Provides a warm sense of ambience.
  - Tends not to be mono compatible, but there are exceptions.
  - Good low-frequency response if you use omni condensers.

Stereo miking techniques | comparison

- Near-coincident pair:
  - Uses two directional mics angled apart and spaced a few inches apart horizontally.
  - Level and time differences between channels produce the stereo effect.
  - Images are sharp.
  - Stereo spread tends to be accurate. Provides a greater sense of air than coincident methods.
  - Tends not to be mono compatible.

- Baffled omni pair:
  - Uses two omni mics, usually ear-spaced, with a baffle between them.
  - Level, time, and spectral differences produce the stereo effect.
  - Images are sharp.
  - Stereo spread tends to be accurate.
  - Good low-frequency response.
  - Good imaging with headphones.
  - Provides more air than coincident methods.
  - Tends not to be mono compatible, but there are exceptions.

Bibliography

- Bartlett, B., & Bartlett, J. (2009). *Practical recording techniques* (5th ed.) Boston, MA: Focal Press
- Di Liscia, O. P. *Spatial Listening and its Computer Simulation* in *Electronic Music*
- Huber, D. M., & Runstein, R. E. (2005). *Modern recording techniques.* Boston: Focal Press/ Elsevier
- Owsinski, B. (2009). *The recording engineer's handbook*. Boston, MA, Course Technology.

- Di Liscia, O. P. *Spatial Listening and its Computer Simulation* in *Electronic Music*

NOTE: All images were taken from these books/papers, besides the 3D microphone polarity pattern diagrams, which were taken from 'Microphone techniques for live sound reinforcement, Shure'