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# Recording and Voice Processing

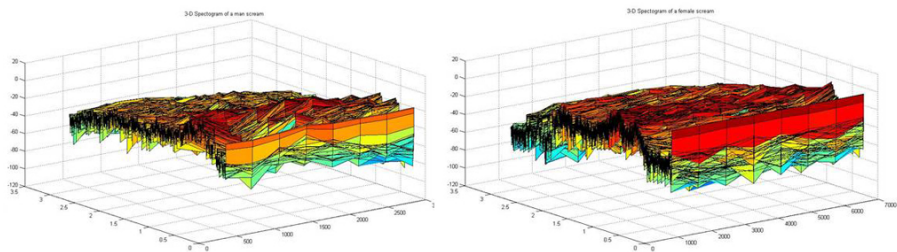
# 1

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*History and Generalities*

Jean-Michel Réveillac

Color Section



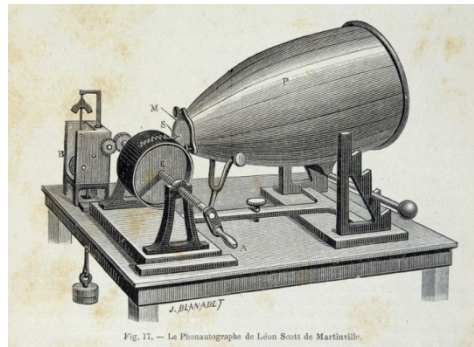
**Figure I.1.** *Vocal differences in the same sentence. 3D spectrogram of a male voice, on the left, and a female voice, on the right (source: [www.projectrhea.org](http://www.projectrhea.org))*



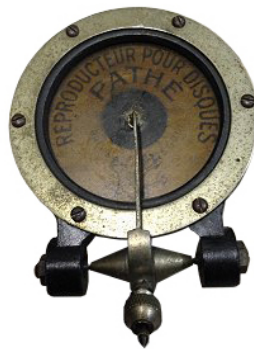
**Figure I.2.** *A wire recorder, the Webster Chicago 180-1 (1949)*



**Figure I.3.** *The famous Neumann U67 tube microphone and its power supply*



**Figure 1.1.** *The phonautograph*



**Figure 1.4.** *A Pathé sapphire pick-up for a vertically engraved disk*



**Figure 1.6.** *The Columbia Graphophone Grand*



*Figure 1.7. The "Edison Concert" phonograph*



*Figure 1.12. A Columbia double-sided 78 with its cover*

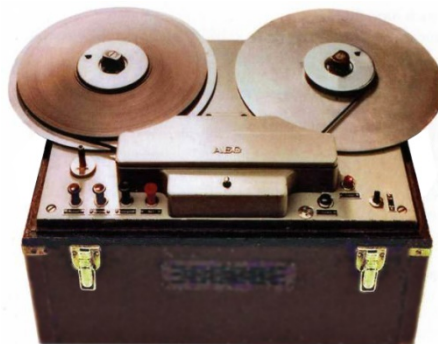




**Figure 1.14.** *Examples of electric pick-up phono cabinets (wireless telegraphy)*



**Figure 1.15.** *A mechanical phonograph case*



**Figure 1.18.** *The AEG K1 tape recorder (the letter K stands for "Koffer", the suitcase)*



**Figure 1.19.** A 4 (rpm) disk and its cover



**Figure 1.20.** An electrophone from the 1950s



**Figure 1.22.** *The Nagra I news reel-to-reel tape recorder with miniature lamps*



**Figure 1.23.** *An 8-track tape and its internal structure*



**Figure 1.25.** *A limited edition 8-track released in 2009 – Cheap Trick – “The Latest”*



**Figure 1.26.** *The Telefunken 76 (Tube) tape recorder, 4 tracks (stereo 2 X 2 tracks), speed: 4.75–9.5 cm/s, reel to 15 cm diameter, dating back to 1960*



**Figure 1.29.** *A type I – C90 (2 X 45 min) mini-cassette from TDK*



**Figure 1.30.** *The Tascam 122 MKII professional cassette deck*



**Figure 1.31.** *The Portastudio 144 stand-alone multitrack from Tascam (1979)*



**Figure 1.32.** *A music cassette – Metallica – “Master of Puppets”*





**Figure 1.33.** *A trimicron disk from MDR*



**Figure 1.34.** *A 24-track 2-inch multitrack (Studer A800 – MKII), a standard of excellence in the studios of the 1970s and 1980s*



**Figure 1.35.** *The first CD released by Sony, Billy Joel – “52nd Street”.  
It came with the purchase of a Sony CD player*



**Figure 1.38.** *Studer D827 Mk II (DASH 48 tracks) with its remote control console*



**Figure 1.39.** Sony PCM 3324 S digital multitrack (DASH 24 Tracks)



**Figure 1.41.** A DAT cassette (73 x 54 10.5 mm), on the left, compared to a mini-cassette (100 x 83 x 12 mm), on the right



**Figure 1.44.** The first-generation ADAT Blackface player from Alesis





**Figure 1.45.** An S-VHS tape for use with an ADAT recorder



**Figure 1.46.** The Tascam DA-88 digital player-recorder



**Figure 1.47.** A 90 minute Hi-8 cassette (95 x 62 x 15 mm)



**Figure 1.48.** *The imposing Akai DR1200 reader-recorder with its bank of vu-meters (DM 1200) and its locator (DL 1200)*



**Figure 1.49.** *The Fostex D80 hard disk recorder – 8 tracks (1996)*



**Figure 1.50.** Tascam MX-2424 – 24-bit, 96 kHz, 24-track hard disk recorder (2004) with its RC2424 remote control



**Figure 1.51.** A minidisc



Figure 1.52. The Tascam MD-801R MKII minidisc player-recorder



Figure 1.54. The Audiomecia II board in Nubus format for Apple Macintosh



Figure 1.55. The 888 interface for Pro Tools III

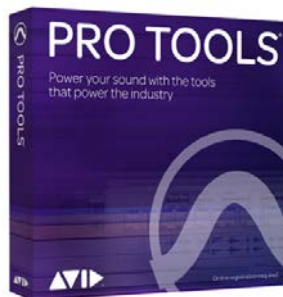
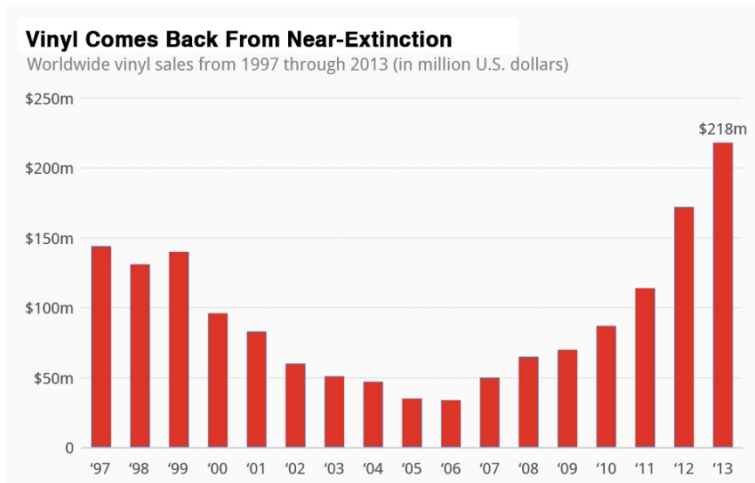
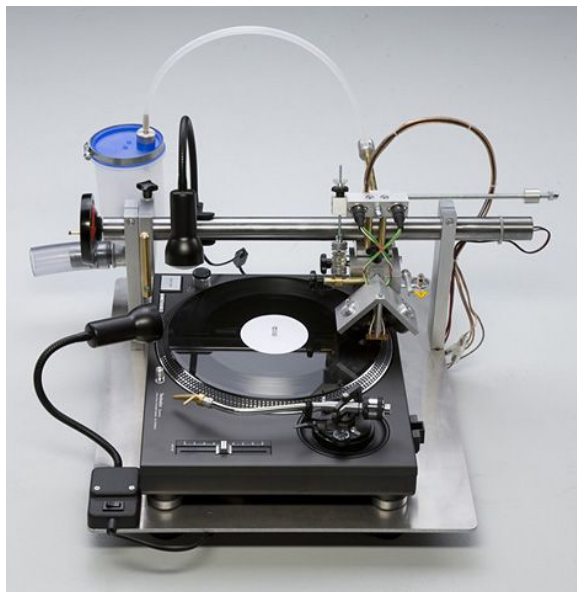


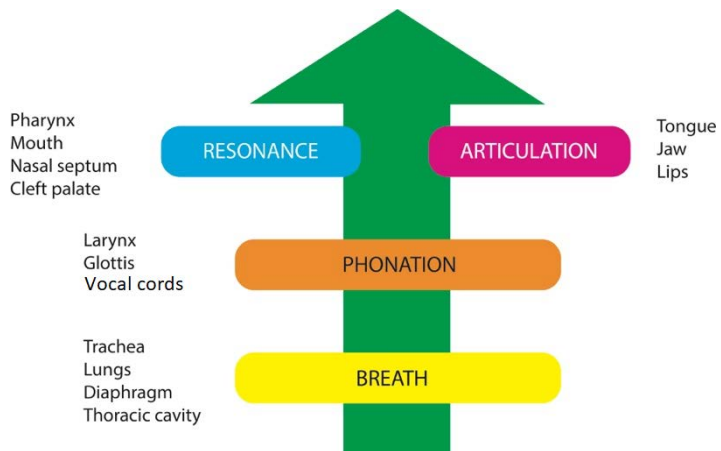
Figure 1.56. Pro Tools 2020 version



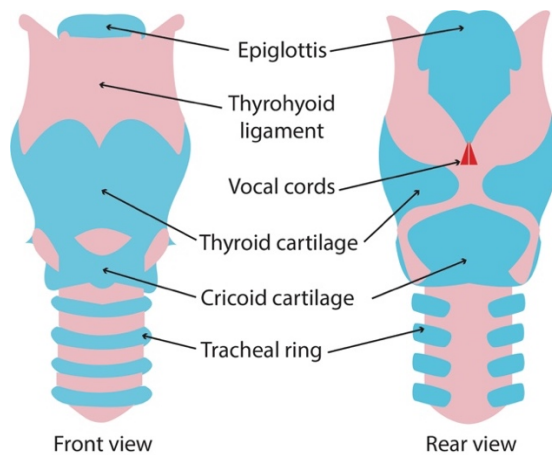
**Figure 1.57.** *Evolution of the vinyl record market worldwide (source: IFPI.com)*



**Figure 1.58.** *The T560 vinyl engraving bench of the German manufacturer Souri's Automaten*

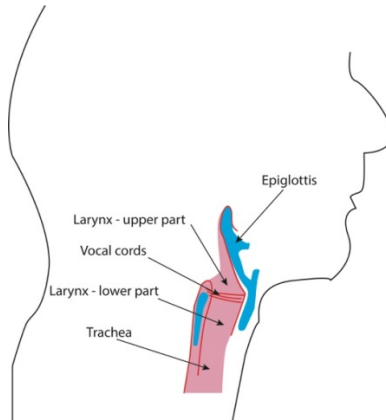


**Figure 2.1.** *The stages of sound creation in a human being*

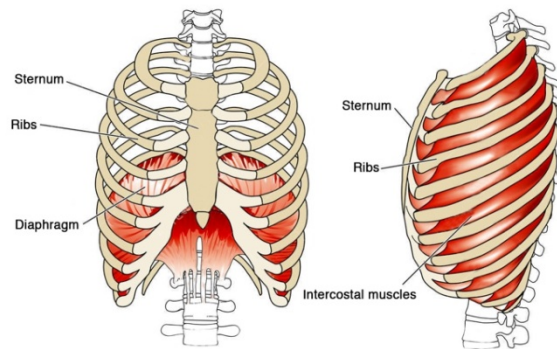


**Figure 2.2.** *The different elements of the phonation chain*

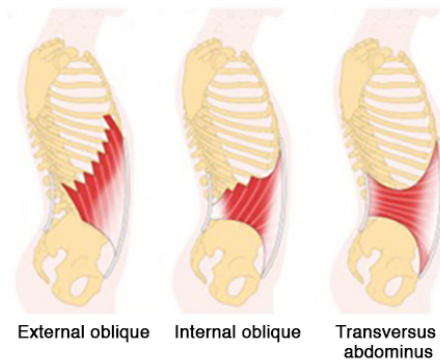




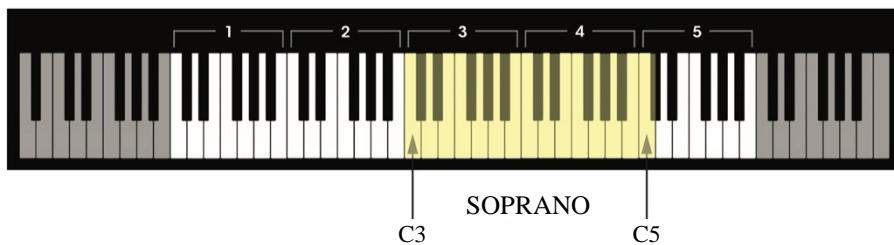
**Figure 2.3.** *Larynx and vocal cords, the key elements of the voice's timbre*



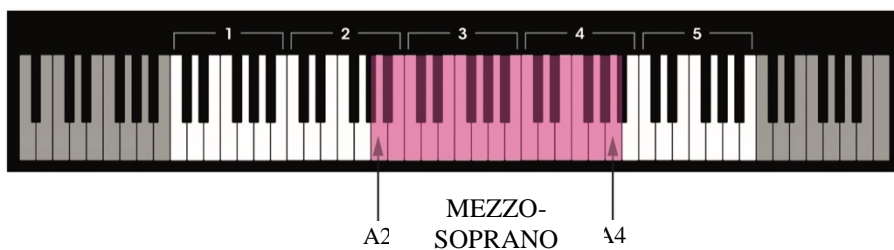
**Figure 2.4.** *Thoracic cage, sternum and intercostal muscle*



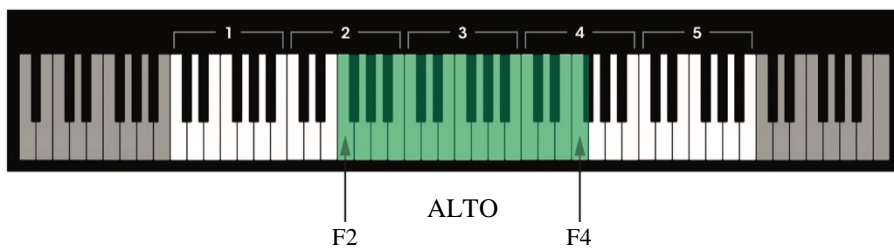
**Figure 2.5.** *The oblique and transverse abdominal muscles*



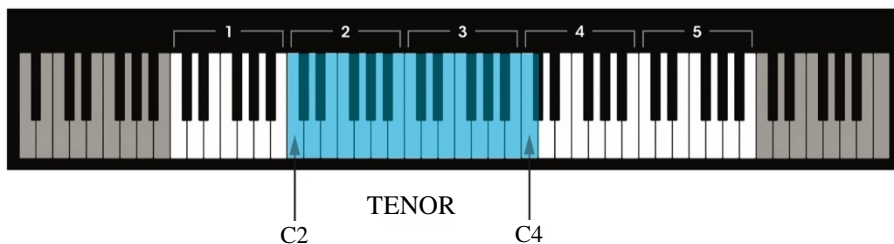
**Figure 2.6.** *The soprano range*



**Figure 2.7.** *The mezzo-soprano range*

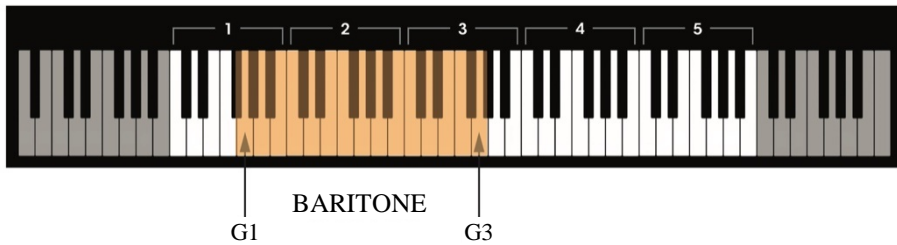


**Figure 2.8.** *The alto range*

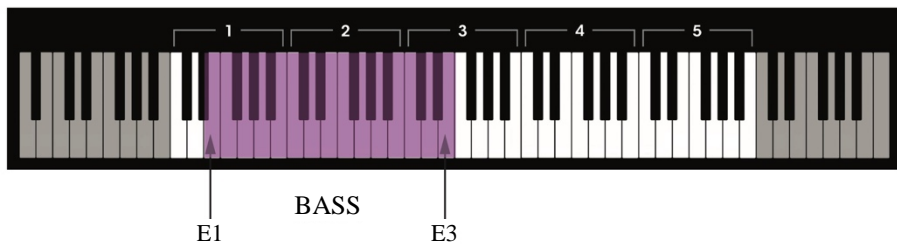


**Figure 2.9.** *The tenor range*

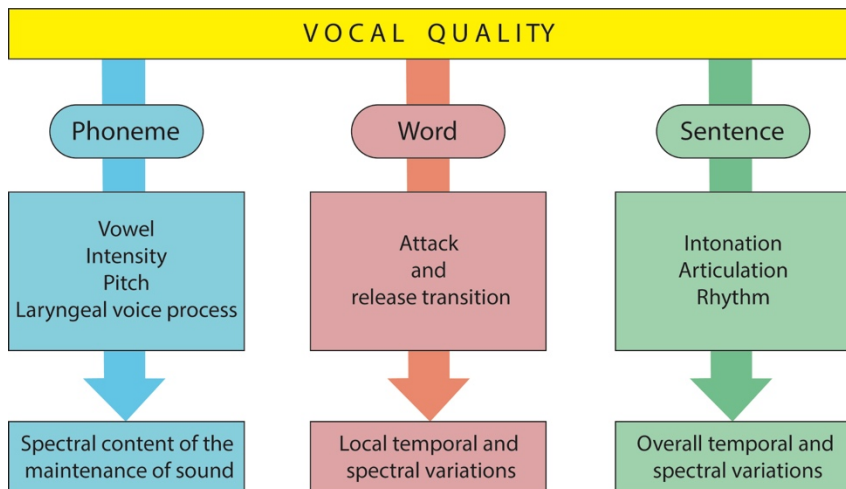




**Figure 2.10.** *The baritone range*



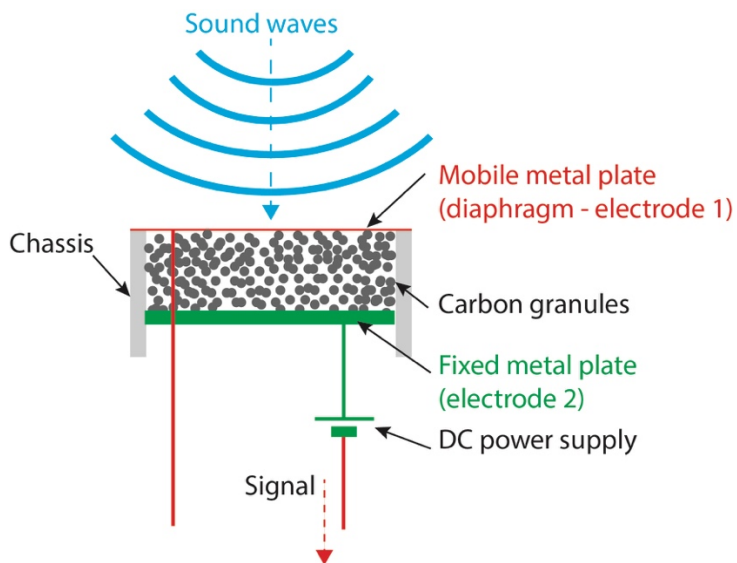
**Figure 2.11.** *The bass range*



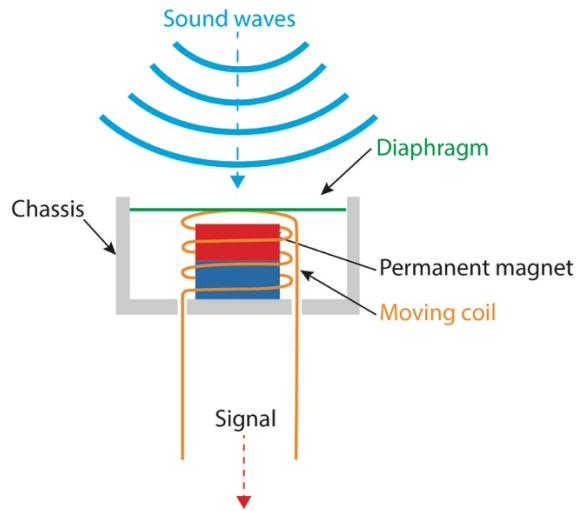
**Figure 2.12.** *Concept of voice quality*



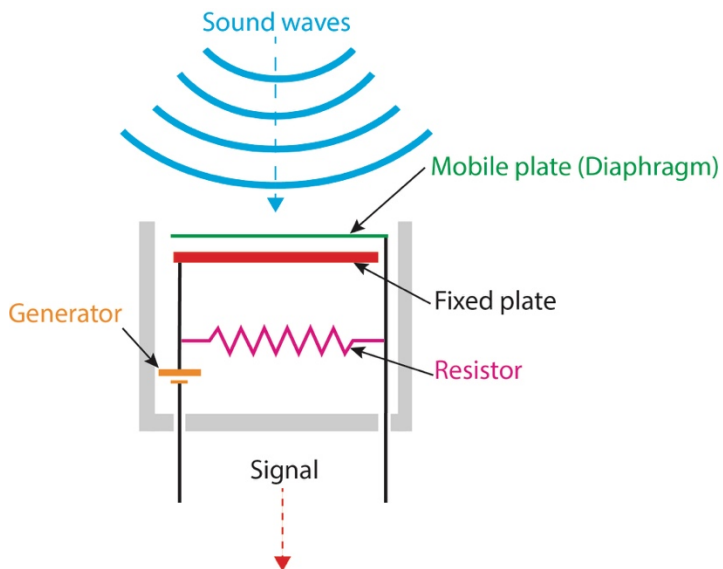
**Figure 3.3.** *Reis's telephone with its transmitter (microphone), left, and receiver, right (source: Deutsches museum)*



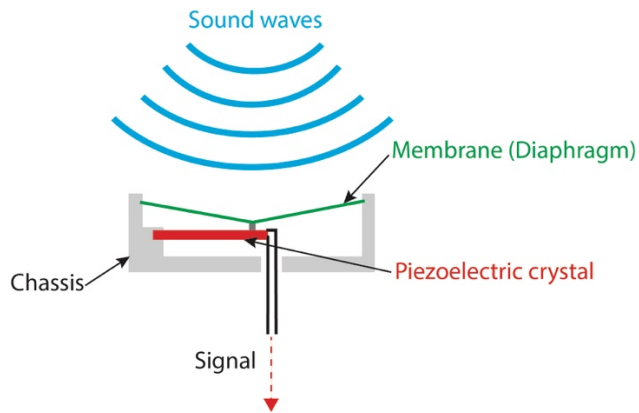
**Figure 3.6.** *Principle of the carbon microphone*



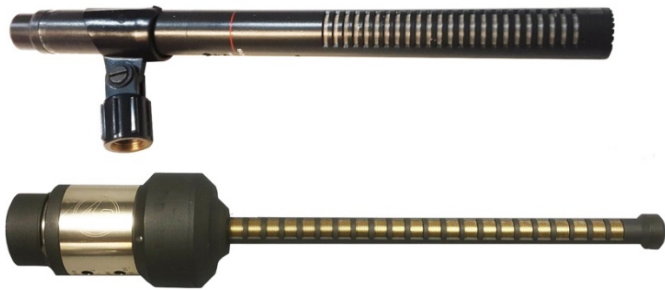
**Figure 3.7.** *Schematic diagram of a dynamic moving coil microphone*



**Figure 3.10.** *Schematic diagram of a condenser microphone*



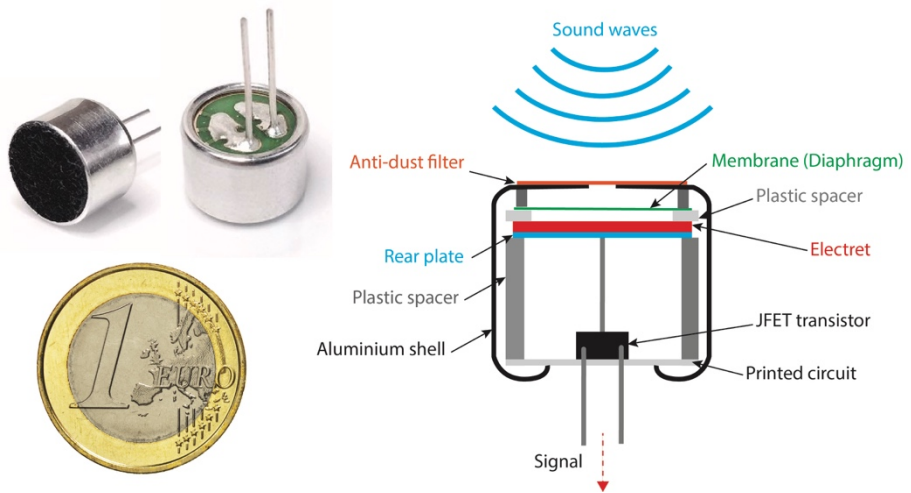
**Figure 3.12.** *Principle of the piezoelectric microphone*



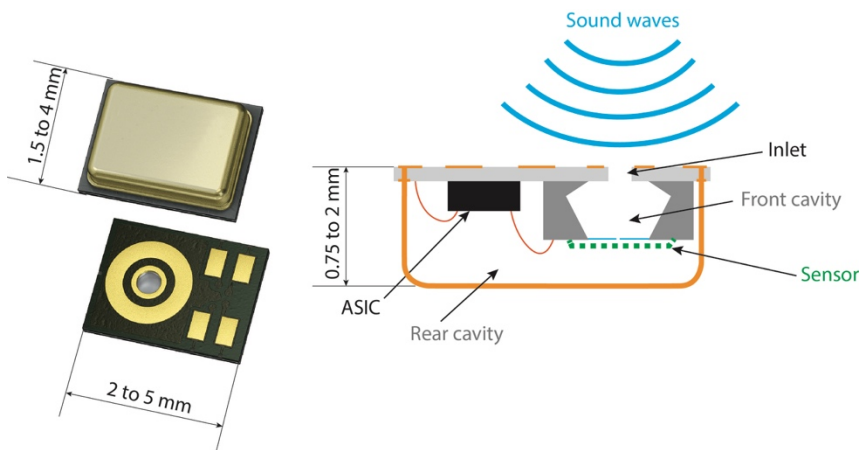
**Figure 3.13.** *Two vintage shotgun microphones: top: Sony ECM672 (1985), bottom: Electro Voice EV642 (1962)*



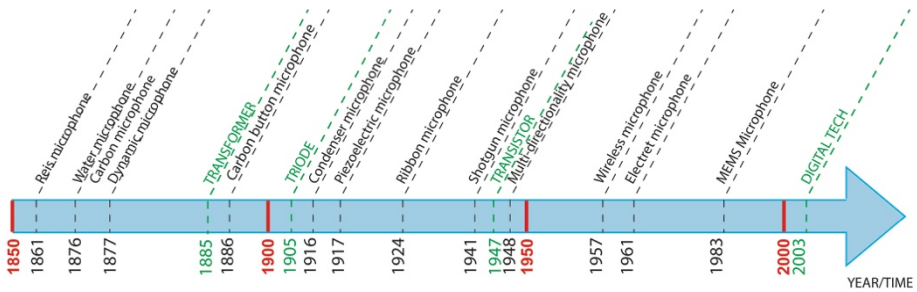
**Figure 3.15.** *The double membrane capsule, named M7, built by G. Neumann*



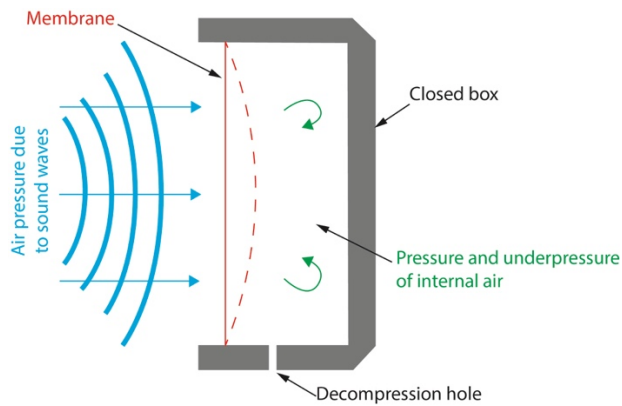
**Figure 3.16.** *The electret microphone and its principle*



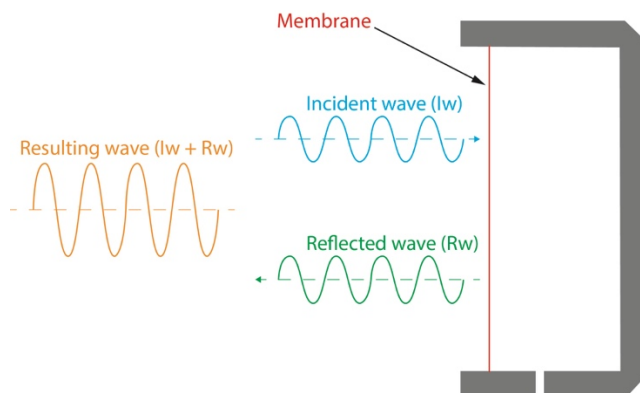
**Figure 3.17.** *The MEMS microphone and its principle*



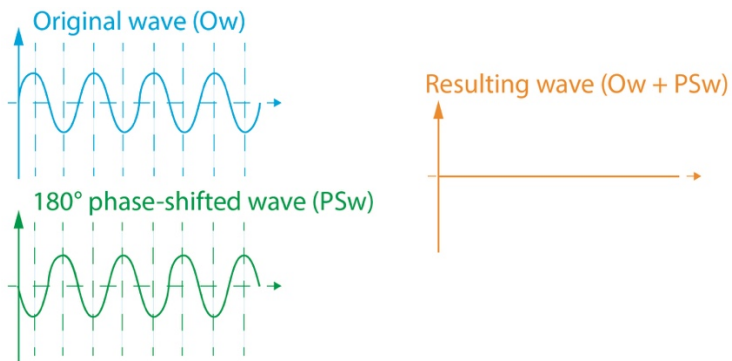
**Figure 3.18.** *Evolution of the microphone over time*



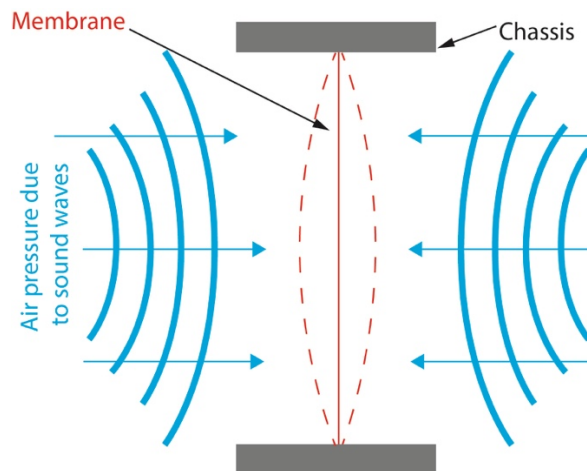
**Figure 3.19.** *Pressure transducer*



**Figure 3.20.** *Sum of incident and reflected waves*



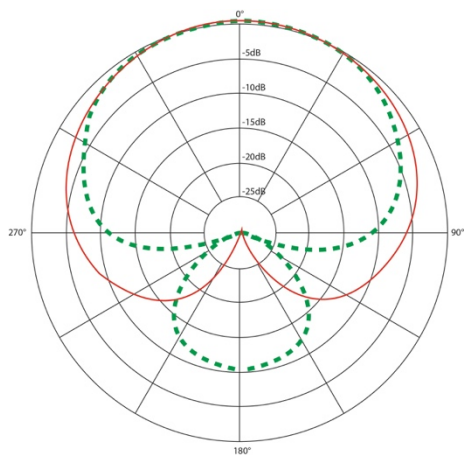
**Figure 3.21.** A phase shift of 180° cancels the signal



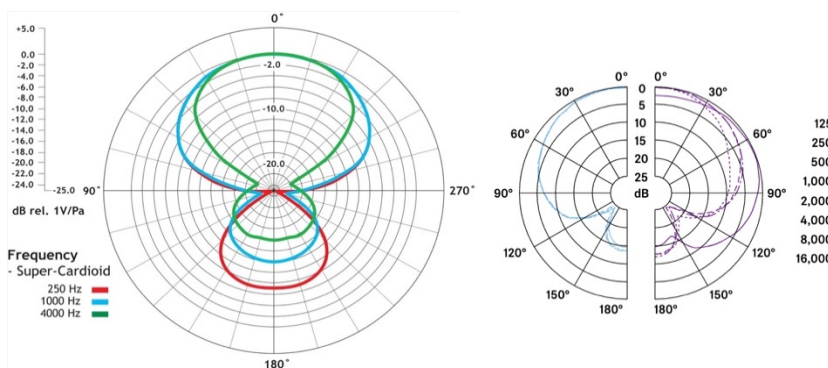
**Figure 3.22.** Acoustic operation of a pressure gradient microphone



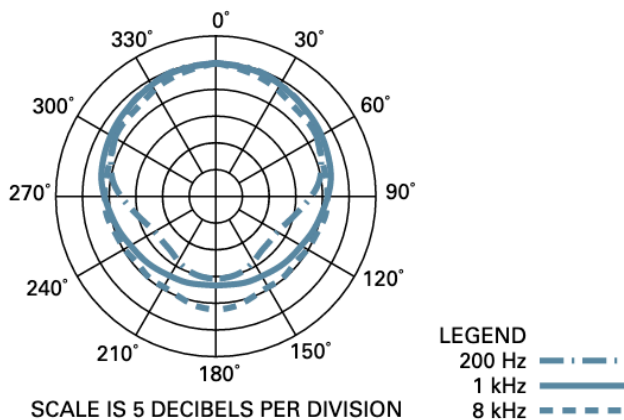




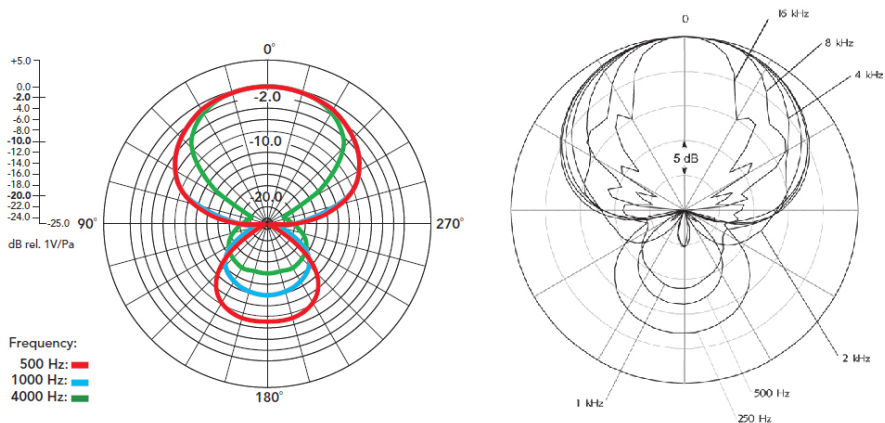
**Figure 3.34.** Comparison of supercardioid directivity, green and dotted, and cardioid, red and solid



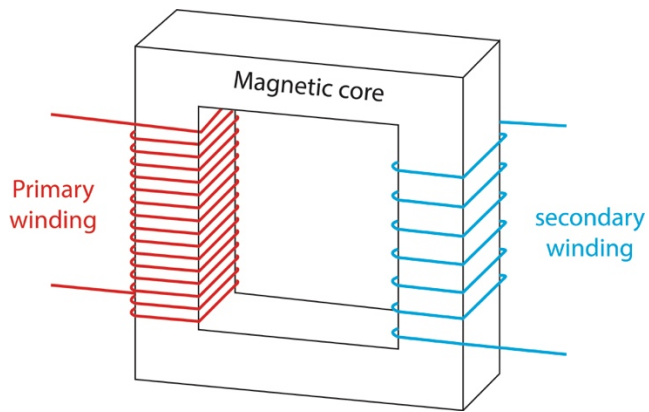
**Figure 3.35.** The directivity diagram for the Rode NTG-2 supercardioid microphone, left, and the Sennheiser E614, right (source: [www.ode.com](http://www.ode.com), [www.sennheiser.com](http://www.sennheiser.com))



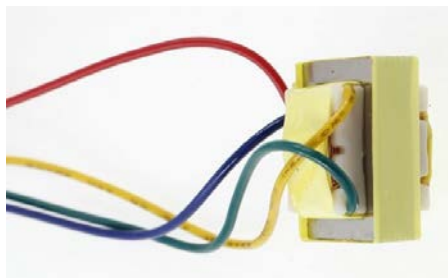
**Figure 3.39.** The directivity diagram for the Audio Technica AT808G subcardioid microphone (source: [www.audiotechnica.com](http://www.audiotechnica.com))



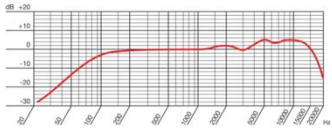
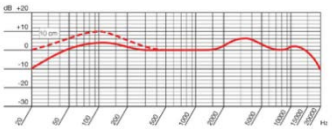
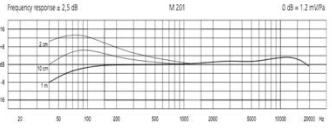
**Figure 3.41.** Directivity diagram for the Rode NTG-1 shotgun microphones, left, and DPA 4017B (source: [www.rodete.com](http://www.rodete.com), [www.dpamicrophones.com](http://www.dpamicrophones.com))

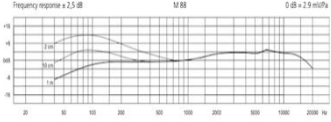
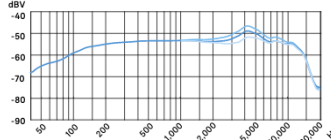
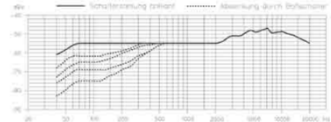
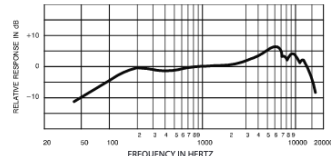
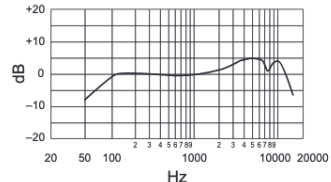


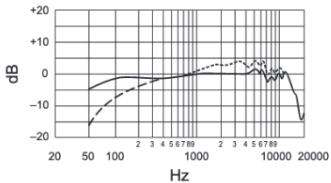
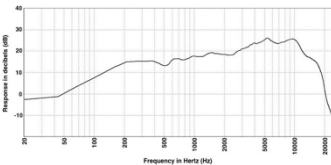
**Figure 3.43.** *A transformer with its core and two windings*



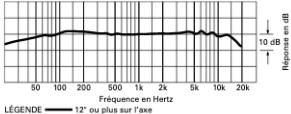
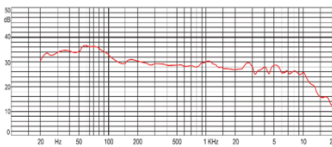
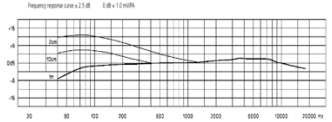
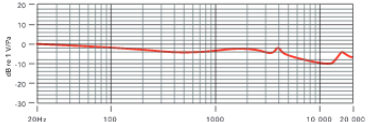
**Figure 3.44.** *A typical microphone transformer (14 x 10 x 12 mm)*

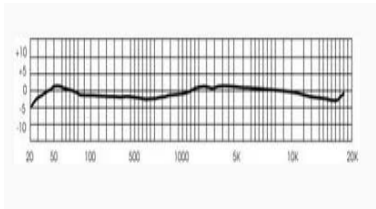
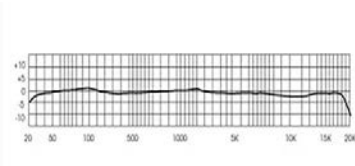
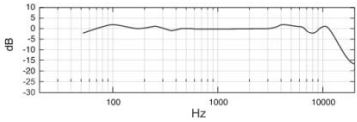
Brand	Model	Frequency response	Sensitivity	Directivity	Output impedance
AKG	D5	70 Hz to 20 kHz	2.6 mV/Pa	Supercardioid	600 $\Omega$
Designed for voice and choir, although it can be versatile. It delivers a significant sound level and its polarity ensures no feedback. It remains clear, precise and very linear in the midrange. Due to its design, its robustness is unparalleled.					
AKG	D112	20 Hz to 17 kHz	1.8 mV/Pa	Cardioid	210 $\Omega$
Specialized in recording sound instruments working in low frequencies such as bass drum, tuba, double bass, timpani, etc., or the dubbing of bass amps. Lots of roundness and warmth with a robust design.					
Beyerdynamic	M201TG	40 Hz to 18 kHz	1.2 mV/Pa	Hypercardioid	200 $\Omega$
A very natural, uncolored sound with great sensitivity. It is an all-purpose microphone, interesting for its small size. It is used for guitar amp pickup, snare drum or hi-hat pedal, brass instruments and even vocals.					

Brand	Model	Frequency response	Sensitivity	Directivity	Output impedance
Beyerdynamic	M88TG	30 Hz to 20 kHz	2.9 mV/Pa	Hypercardioid	200 $\Omega$
A robust product that has been around since the 1960s. It is versatile with a warm yet natural sound. Frequently used on the bass drum, bass amps, some brass instruments for its ability to capture the low end of the spectrum.					
Sennheiser	E906	40 Hz to 18 kHz	2.2 mV/Pa	Supercardioid	350 $\Omega$
Mainly dedicated to amp patching, but can also be used on percussion or brass instruments. It supports high acoustic pressures.					
Sennheiser	MD441	30 Hz to 20 kHz	1.8 mV/Pa	Supercardioid	200 $\Omega$
Its excellent sensitivity and high linearity in the bass and midrange make it a high-end microphone with a very neutral sound. It includes a 5-position equalizer for making adjustments.					
Shure	SM57	40 Hz to 15 kHz	1.6 mV/Pa	Cardioid	310 $\Omega$
Indispensable. A reference in the field of dynamic microphones. Very robust. Suitable for vocals, brass, drums, amps. Supports high acoustic pressure.					
Shure	SM58	50 Hz to 15 kHz	1.85 mV/Pa	Cardioid	300 $\Omega$
Like the SM57, this microphone is a star performer, the most widely used microphone in the world for both spoken and sung voices. It is completely suitable for live use and its grille minimizes wind and breath noise. Its directional pattern easily isolates unwanted background noise and it is extremely robust.					

Brand	Model	Frequency response	Sensitivity	Directivity	Output impedance
Shure	SM7B	50 Hz to 20 kHz	1.12 mV/Pa	Cardioid	150 $\Omega$
A rugged mic with excellent performance on vocals and guitar amp pickups. It has a built-in filter to control bass and midrange. Its rejection of sounds coming from the rear makes it an easily positionable mic.					
Telefunken	M80	50 Hz to 18 kHz	1.54 mV/Pa	Supercardioid	325 $\Omega$
A very good microphone for voices, which it leaves very natural and detailed. The presence of a peak between 5 and 10 kHz makes it a very sharp-sounding microphone in the style of today's recordings. Some use it to pick up a hi-hat pedal or a snare drum.					

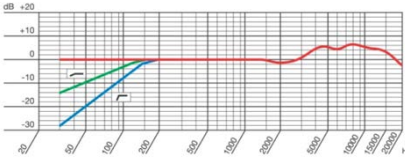
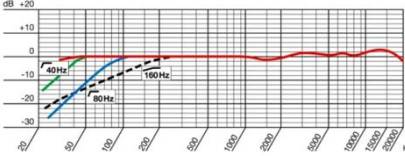
**Table 3.1.** *Some models of dynamic moving coil microphones with their main characteristics*

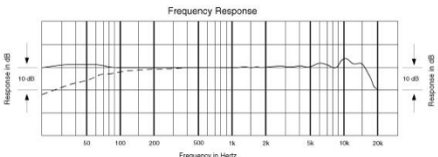
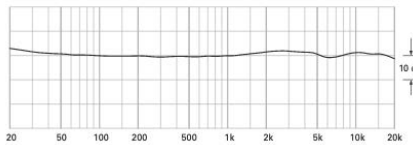
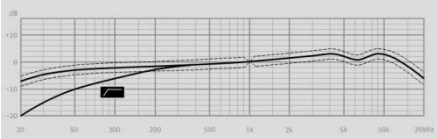
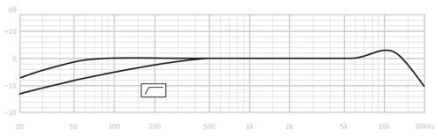
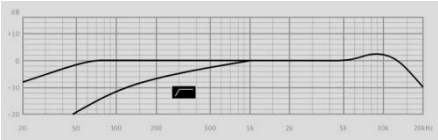
Brand	Model	Frequency response	Sensitivity	Directivity	Output impedance
Audio Technica	AT4081	30 Hz to 18 kHz	−42 dBV	Bidirectional	100 Ω
A microphone with a warm and natural sound. Consists of a double ribbon structure. It withstands high sound pressure levels.		<p>Réponse en fréquence : 30 à 18 000 Hz</p>  <p>10 dB</p> <p>Fréquence en Hertz</p> <p>LÉGENDE — 12° ou plus sur l'axe</p>			
Avantone	CR14	30 Hz to 15 kHz	−52 dBV	Bidirectional	600 Ω
A very natural and detailed sound, very well suited for duets and vocal groups. Interesting for capturing the sound of a piano, guitar amp pickup, acoustic guitar, mandolin and banjo. Effective on a drum overhead.					
Beyerdynamic	M160	40 Hz to 18 kHz	1 mV/Pa	Hypercardioid	200 Ω
Very good for guitar amp patching. Its directionality is very appreciable because it is not very sensitive to rear sounds. Its extra gain in the 5 kHz range gives it an excellent presence.		<p>Frequency response curve ±1 dB 0 dB = 1 mV/Pa</p> 			
Rode	NTR	20 Hz to 20 kHz	30.5 dBV	Bidirectional	200 Ω
A very sensitive microphone with high accuracy in the upper spectrum. Very suitable for voice recording. A robust design with shock absorber.					
Royer	R121	30 Hz to 15 kHz	−47 dBV	Bidirectional	300 Ω

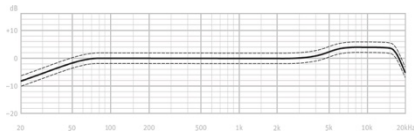
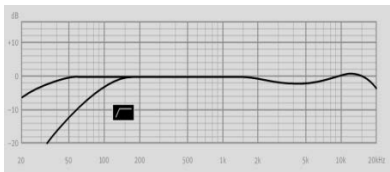
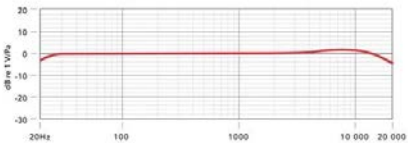
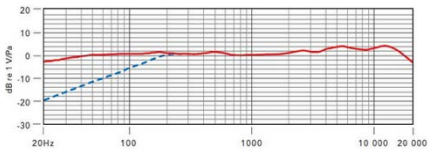
Brand	Model	Frequency response	Sensitivity	Directivity	Output impedance
A ribbon microphone that is a reference. It is very much used for guitar amp pickup where it provides a very detailed midrange and treble.					
Royer	R101	30 Hz to 15 kHz	-48 dBV	Bidirectional	300 $\Omega$
A natural and very soft sound with very present highs. Like its big brother, the R12, it is very popular for recording electric guitars.					
Shure	KSM353	30 Hz to 15 kHz	53.5 dBV	Bidirectional	330 $\Omega$
Very robust ribbon microphone withstanding high acoustic pressure. Ideal for recording fast transients like voice, as well as for acoustic instruments and concert hall recording.					

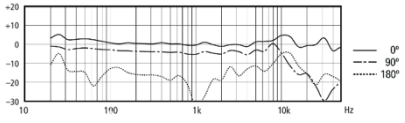
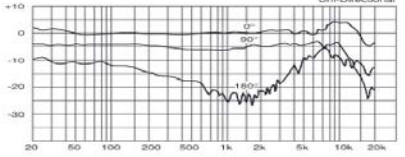
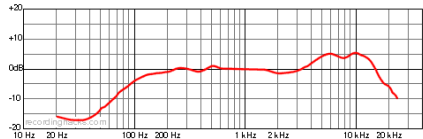
**Table 3.2.** *Some ribbon microphone models with their main characteristics*



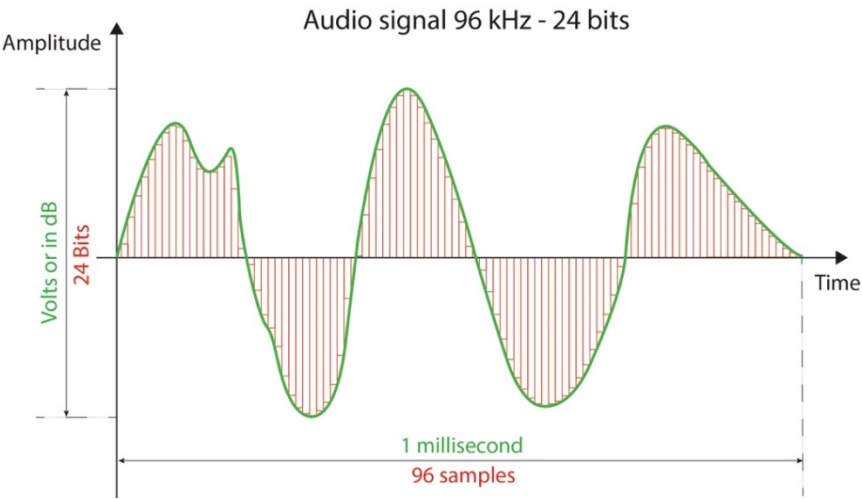
Brand	Model	Frequency response	Sensitivity	Directivity	Output impedance
AKG	C12	30 Hz to 20 kHz	10 mV/Pa	Omnidirectional Cardioid Bidirectional	200 $\Omega$
Tube technology. Very suitable for vocals, brass, woodwinds, struck strings, as well as guitar or bass amp pickups. Very smooth, detailed with great presence and sensitivity.					
AKG	C414	20 Hz to 20 kHz	23 mV/Pa	9 directions	200 $\Omega$
Supports high sound levels with great sensitivity. A classic condenser microphone with a particular grain, especially in the midrange. Very suitable for recording acoustic instruments like strings, especially acoustic guitar.					

Audio Technica	AT4050	20 Hz to 18 kHz	15.8 mV/Pa	Omnidirectional Cardioid Bidirectional	100 $\Omega$
Withstands high sound pressure levels. Perfect for vocals, piano, strings, guitar amps and overheads. Suitable for stage and studio use. Equipped with an 80 Hz low-cut filter. Transformer-less technology minimizes distortion.					
Audio Technica	AT5047	20 Hz to 20 kHz	35.5 mV/Pa	Cardioid	150 $\Omega$
Designed around four diaphragms to handle extreme sound pressures with high dynamics and very low noise.					
Neumann	U47	40 Hz to 16 kHz	8 mV/Pa	Cardioid	150 $\Omega$
A reference in condenser microphones. FET technology. A very warm sound, which is excellent for voices and singing. It supports very high acoustic pressures. Very effective for picking up guitar or bass amps and the bass drum.					
Neumann	U67	20 Hz to 20 kHz	5 mV/Pa	Cardioid Bidirectional Omnidirectional	200 $\Omega$
Like the U47, this microphone has proven itself. Tube technology. Its main quality is its universality, making it suitable for all types of recording. It is very warm and soft in the high range, with unrivaled definition. If there is one microphone that should be chosen, this is it.					
Neumann	U87	20 Hz to 20 kHz	22 mV/Pa	Cardioid Bidirectional Omnidirectional	200 $\Omega$
Like the U47 and U67, this is a must-have. A very neutral and versatile microphone. Very good on vocals, backing vocals, acoustic guitar, mandolin, banjo, violin and percussion. Great presence and very airy.					
Neumann	TLM103	20 Hz to 20 kHz	23 mV/Pa	Cardioid	50 $\Omega$

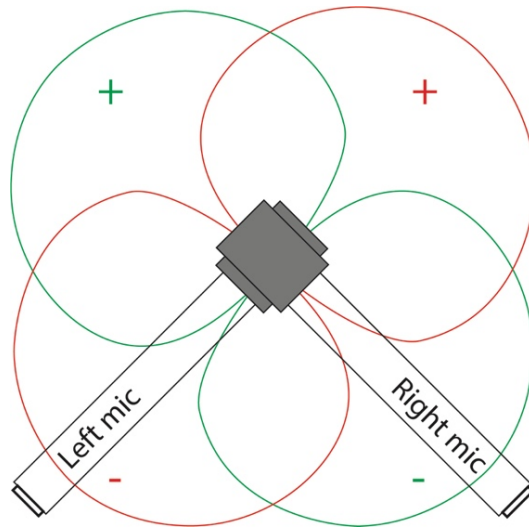
<p>The little brother of the U87. Low noise and high power handling. Does not contain a transformer. Great neutrality but may be sensitive to positioning. Excellent for voice and brass.</p>					
Neumann	TLM170R	20 Hz to 20 kHz	8 mV/Pa	Cardioid Hypercardioid Bidirectional Omnidirectional	50 Ω
<p>A microphone with a detailed sound but perhaps a little limited on transients. Excellent low frequency response with a dense sound that is not very colorful. The various polar patterns make this microphone suitable for all situations. Very good for guitar miking, drum room and piano.</p>					
Rode	NT1	20 Hz to 20 kHz	35 mV/Pa	Cardioid	100 Ω
<p>A great tonal smoothness for this microphone. Very versatile and well suited for voice. Very low noise floor. A great linearity and never aggressive, even in the high end of the spectrum. An argument not to be neglected is its cost, which remains very affordable.</p>					
Rode	NT2-A	20 Hz to 20 kHz	16 mV/Pa	Omnidirectional Cardioid Bidirectional	200 Ω
<p>Like the NT1, a very versatile microphone and well suited for voice with a choice of directionality. It is equipped with an adjustable low pass filter (40, 80 Hz). A good linearity gives it a clear and powerful sound.</p>					
Sony	C100	20 Hz to 50 kHz	-31 dBV	Omnidirectional Cardioid Bidirectional	90 Ω

A very accurate microphone, well suited for piano and string instruments, such as violin, cello and acoustic guitar. Very interesting and effective in its cardioid configuration. An airy side with a lot of space that is very appreciable.					
Sony	C800G	20 Hz to 18 kHz	-32 dBV	Omnidirectional Cardioid	100 $\Omega$
Tube technology. Very popular and excellent for voice, it accepts very pronounced transients. Has a cooling system to limit distortion and background noise.					
Telefunken	ELA M251	20 Hz to 20 kHz	17 mV/Pa	Omnidirectional Cardioid Bidirectional	200 $\Omega$
Tube technology. Perfect in overhead, especially on a battery. Very transparent and detailed. Well suited for percussion and acoustic guitar. Has an interesting and natural coloration with a low end.					

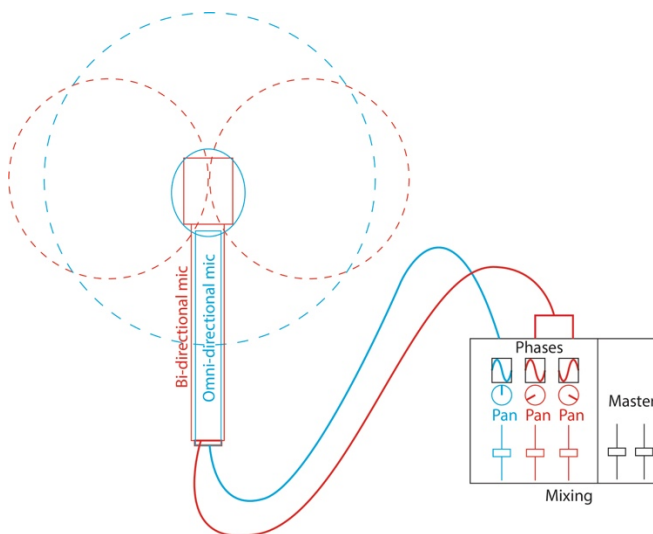
**Table 3.3.** Some condenser microphone models with their main characteristics (note: for the Neumann, Rode NT2-A, Sony, and Telefunken ELA M251 models, the frequency response curves shown are associated with the cardioid polar pattern)



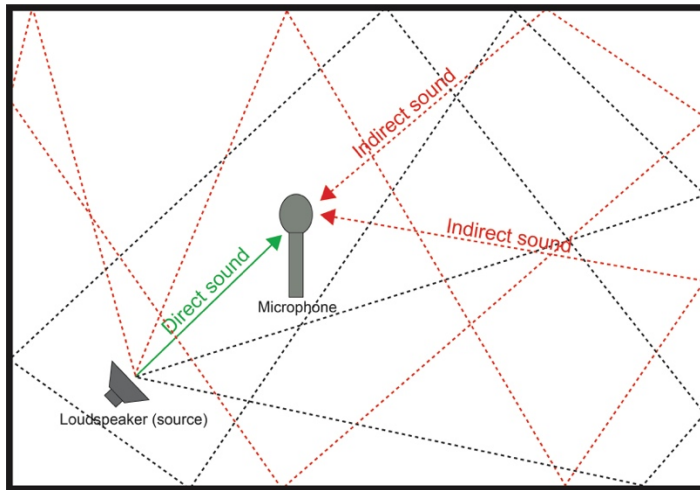
**Figure 3.45.** A 1 ms audio signal sampled at 96 kHz



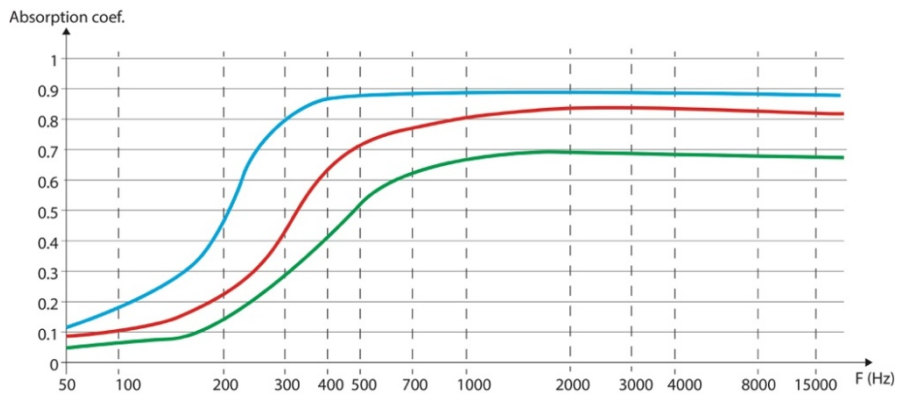
**Figure 3.46.** Microphone configuration according to the Blumlein system



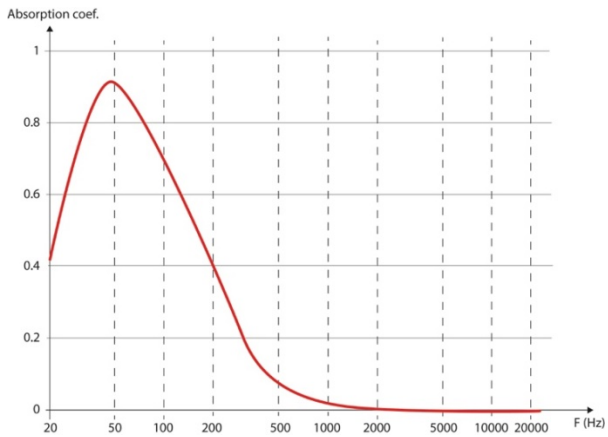
**Figure 3.47.** Microphone configuration according to the MS system



**Figure 4.1.** *Direct sound and indirect or reflected sound*



**Figure 4.4.** *Porous absorber – absorption curves (without absorber (green), absorber thickness: 20 cm (red), absorber thickness 50 cm (blue))*



**Figure 4.5.** Example of an attenuation curve for a Helmholtz absorber



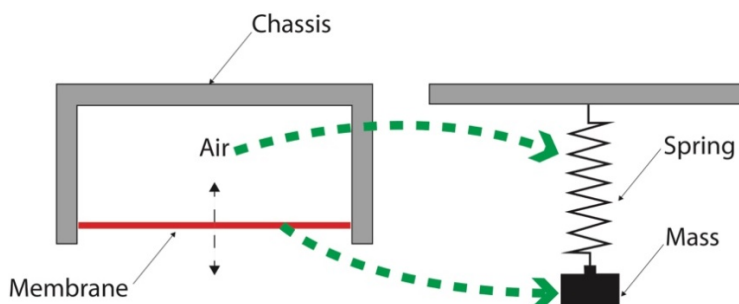
**Figure 4.6.** Perforated Helmholtz panel (*Acoustissimo*, left) and laminar resonator (*Madeinacoustic*, right)



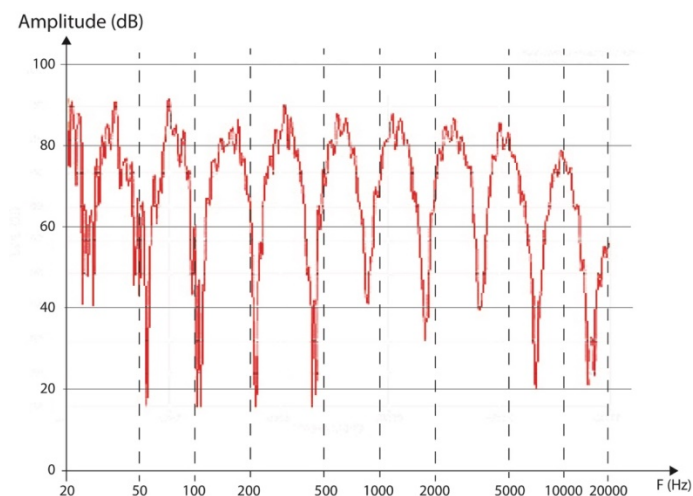
**Figure 4.7.** Cylindrical Helmholtz absorbers (*Vicoustic* and *Hofa*)



**Figure 4.8.** *Diaphragm bass traps (GIK Acoustics)*



**Figure 4.9.** *Mechanical analogy for a diaphragm or flexural bass trap*

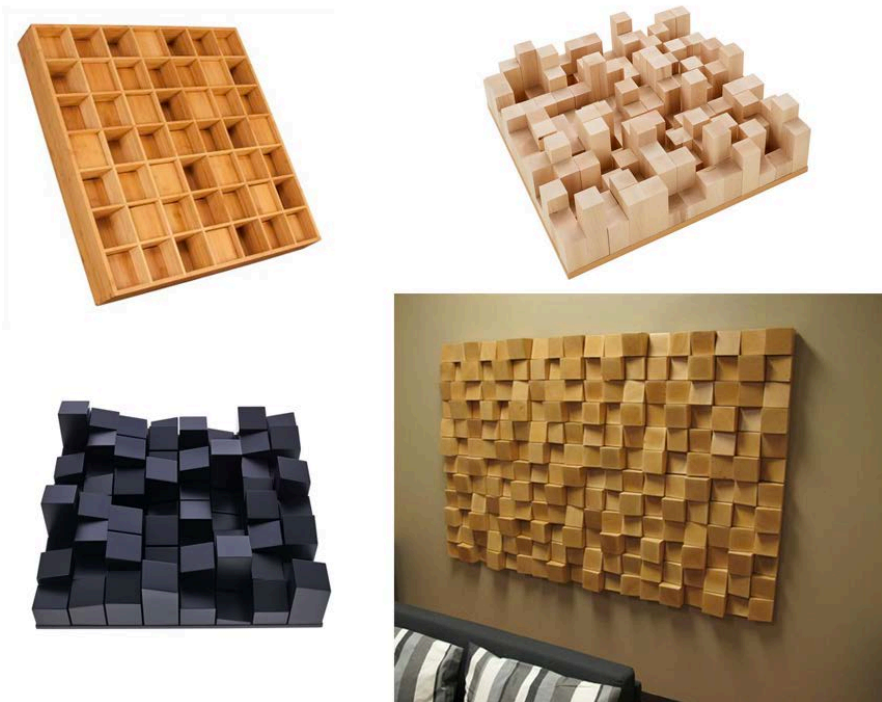


**Figure 4.12.** *Comb filtering between 20 and 20 kHz*

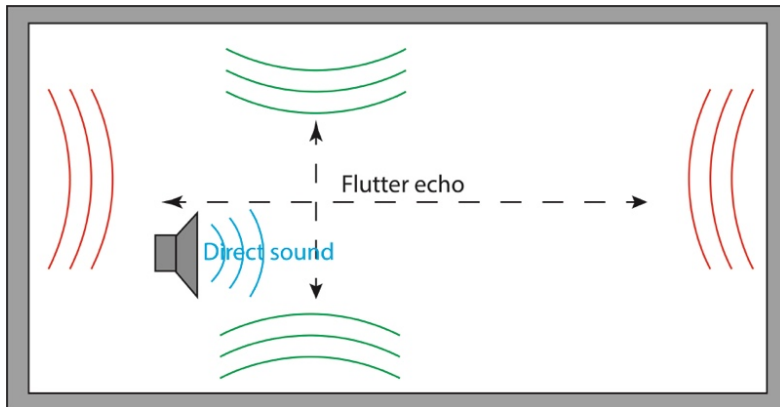




**Figure 4.13.** *Two Schroeder diffusers*



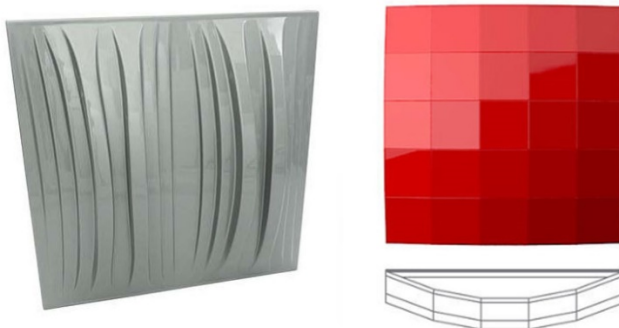
**Figure 4.14.** *Quadratic diffuser, also called QRD diffuser  
(Auralex, t.akustic and Vicoustic)*



**Figure 4.15.** *The flutter echo principle*



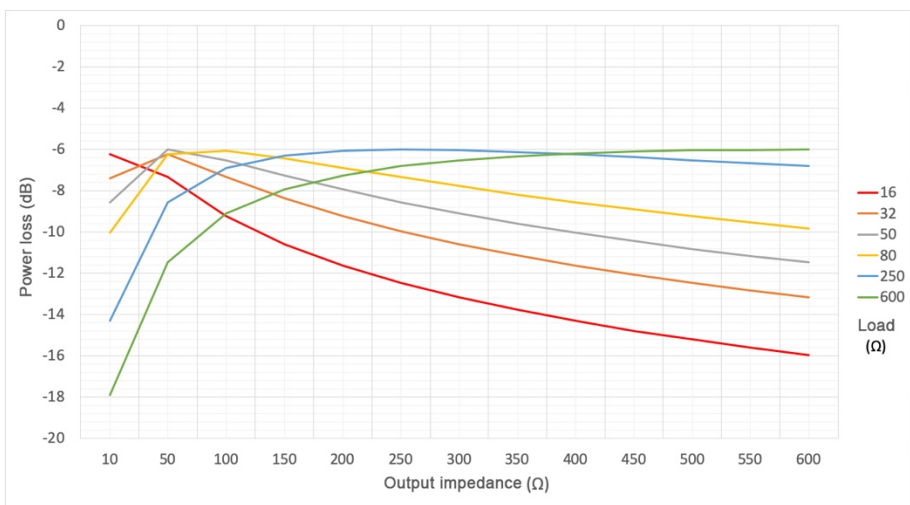
**Figure 4.16.** *A poly-cylindrical diffuser (Acoustic Geometry and GIK Acoustics)*



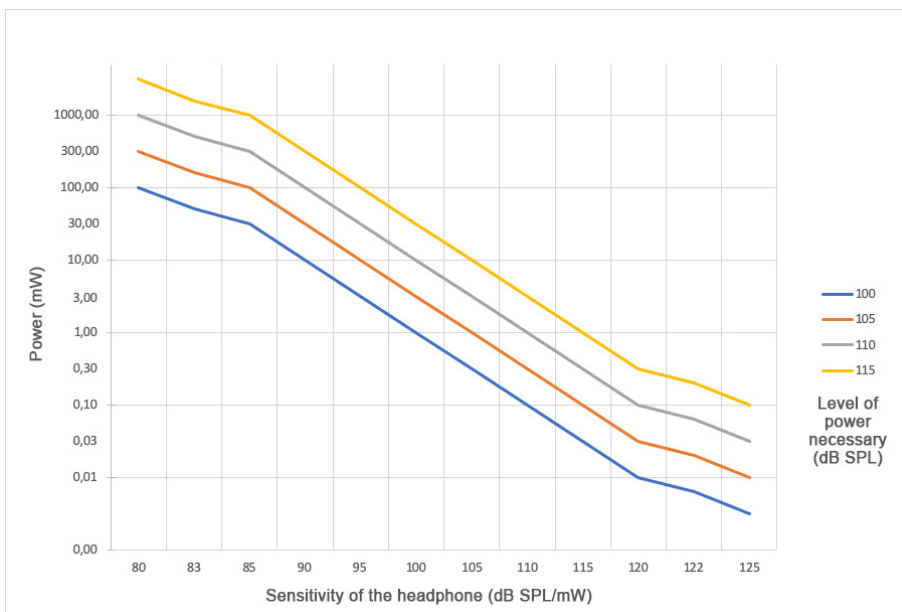
**Figure 4.17.** *Diffusers with original designs (Jocavi and Jaya)*



**Figure 4.20.** *Premanufactured acoustic booths (Vicoustic and Keoda)*



**Figure 4.26.** *Power loss (attenuation) curve according to amplifier output impedance and headphone load impedance*



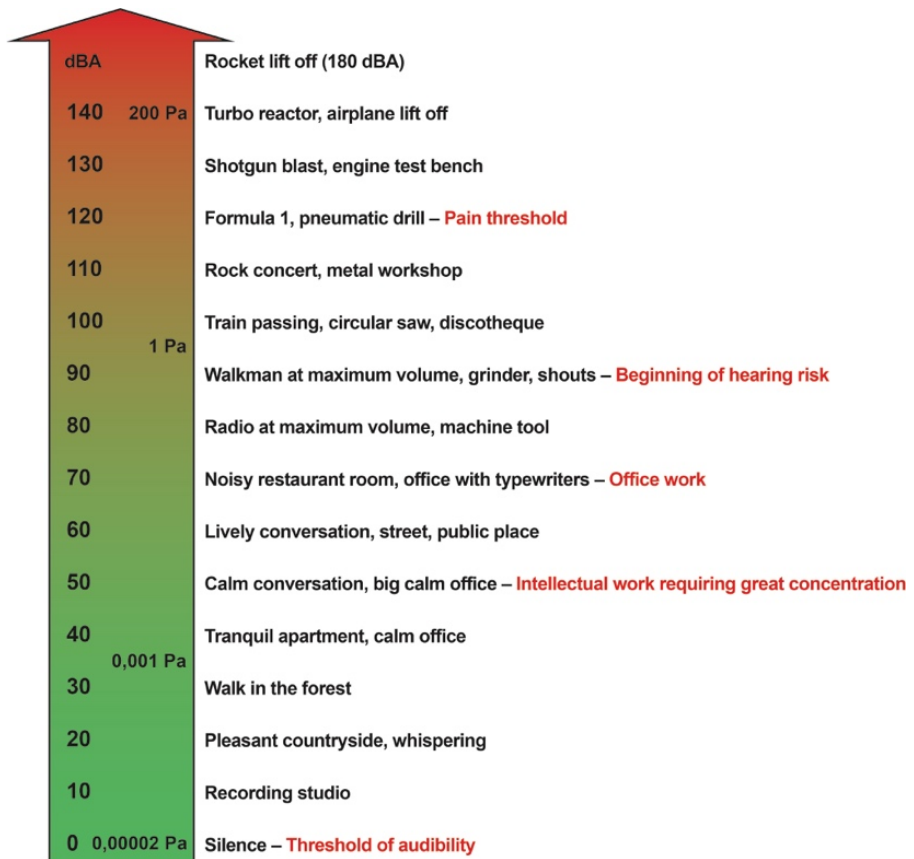
**Figure 4.27.** Graph for determining the power required for a headphone based on its sensitivity



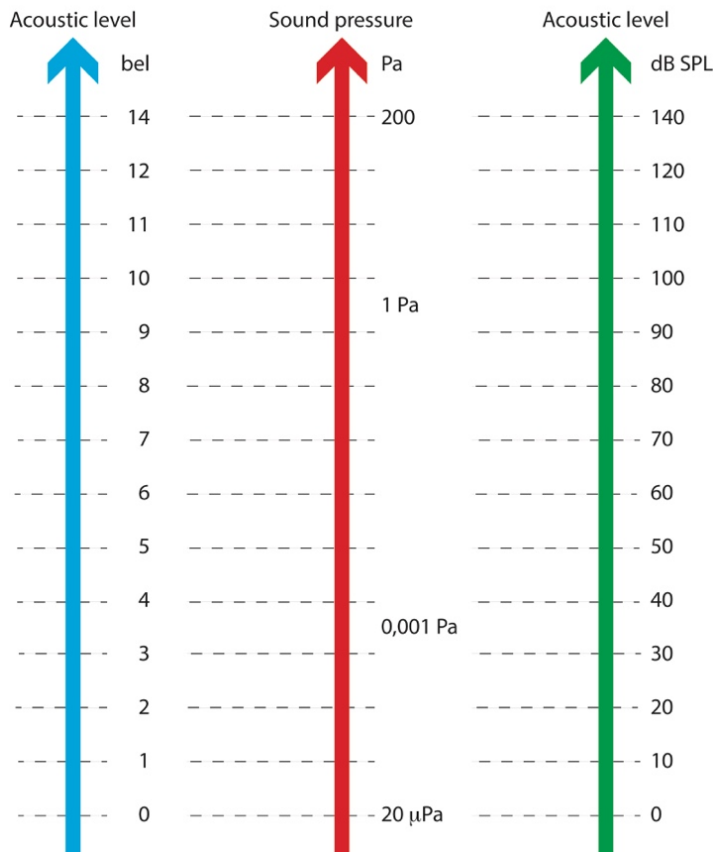
**Figure 4.35.** Different types of foam cups (Shure, Sennheiser and Rode)



**Figure 4.38.** An anechoic chamber (CNRS, LMA Laboratory and Aix-Marseille University)



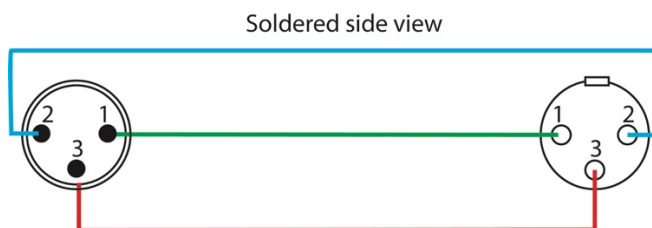
**Figure A1.1.** Sound level scales (source: Wikipedia)



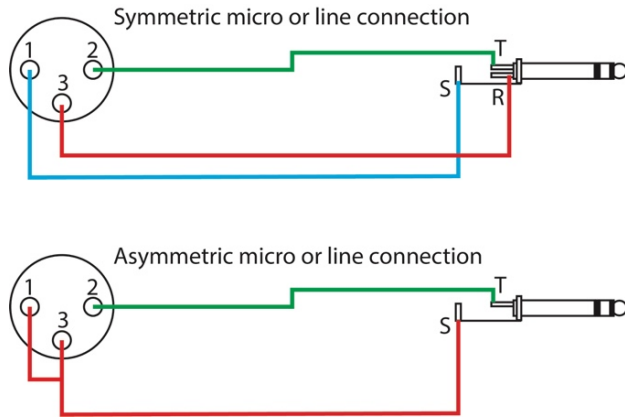
**Figure A1.2.** Comparison of bel, decibel (dB SPL) and pascal (Pa)



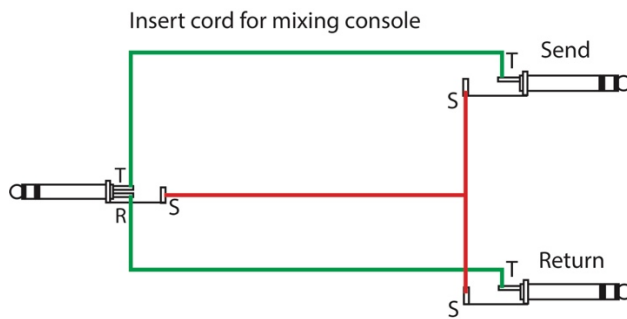
**Figure A2.1.** Some models of coaxial jacks. 1) subminiature 2.5 mm mono male jack, 2) 3.5 mm miniature stereo male jack, 3) 3.5 mm miniature multi-pole male jack, 4) 6.35 mm (1/4") stereo male jack, 5) 6.35 mm mono male jack, 6) 6.35 mm angled mono male jack, 7) 6.35 mm chassis stereo jack, 8) 6.35 mm chassis mono jack, 9) 6.35 mm chassis mono jack



**Figure A2.5.** Wiring diagram of a classic XLR cable



**Figure A2.6.** *Wiring diagram of XLR jack adapters*



**Figure A2.7.** *Wiring diagram for an insert cord*

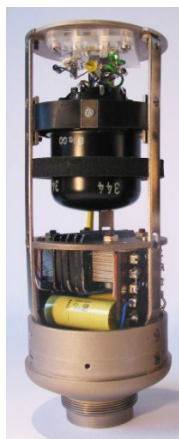


**Figure A2.10.** *Some Sub-D connectors and a female Sub-D/XLR breakout cable*

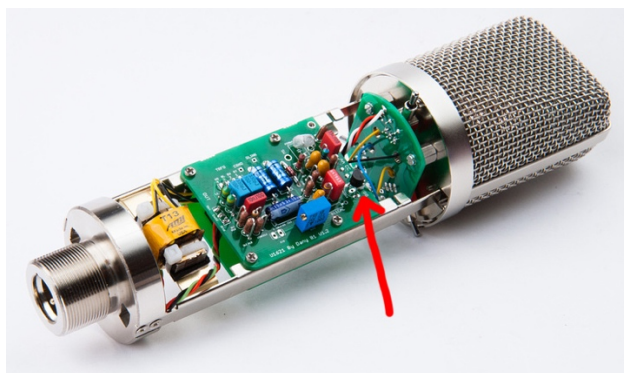




**Figure A2.12.** RCA male and female connectors and chassis



**Figure A4.1.** A tube microphone, Neumann U47. The tube can be seen in the center, above the transformer



**Figure A4.5.** A Neumann U87 clone. The arrow indicates the famous JFET (2N3819) mounted on the electronic board



**Figure A5.11.** *Decca tree installation* (source: [www.musictech.net](http://www.musictech.net))



**Figure A5.13.** *A Blumlein installation* (source: [www.musicradar.com](http://www.musicradar.com))



**Figure A5.16.** *A Jecklin Disk installation* (source: [Wikipedia](https://en.wikipedia.org))