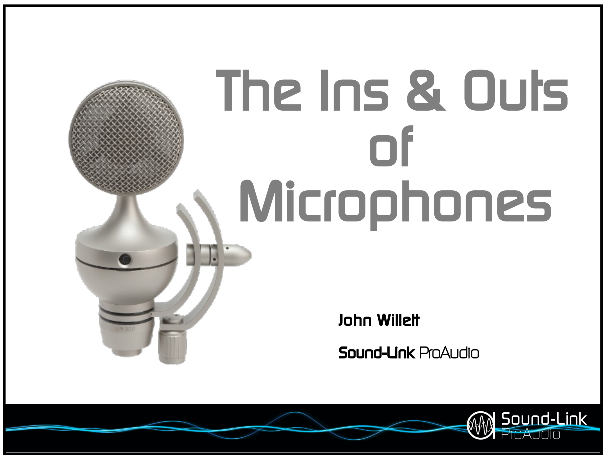
The Ins & Outs of Microphones

John Willett

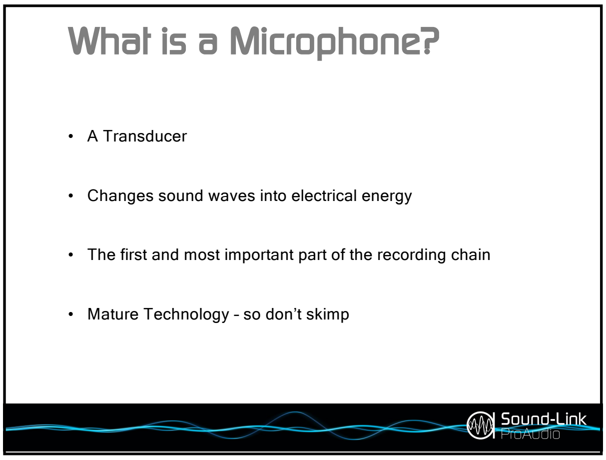


1

The Ins and Outs of Microphones

In this presentation I will take you through various microphone basics:

Different microphone types, polar-patterns, proximity effect, placement distances and a little bit about how the room affects the sound, in the hope that it will help you understand microphones better and will help you to choose the best microphone for the job in hand and place it in the best position.



2

Because a microphone is mature technology, it means that it is an investment for very many years.

A good microphone can last 50 years or more - I am still using microphones that I bought about 40 years ago - they are still in current production and the s/h price is at least double (if not more) what I paid for them.

On the other hand, computer based products have a short life-span and are normally replaced after about 3-years or so and have to pay for themselves very quickly.

So it's always best to invest in the very best microphone you can afford.

3

MICROPHONE TYPES

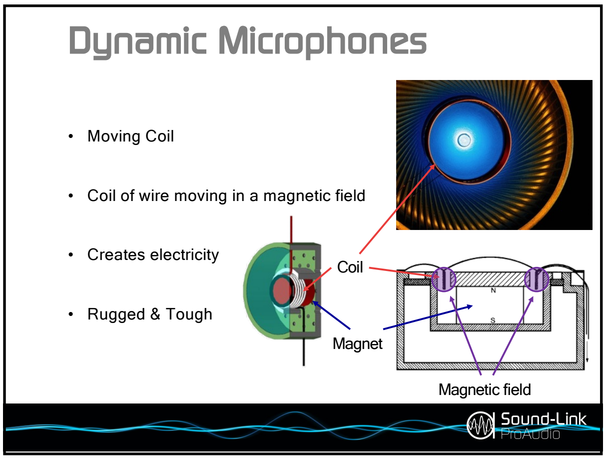
The two main microphone types are Dynamic and Condenser (also called Capacitor) - I have not dealt with rare and obsolete types in this presentation (eg: carbon microphones, piezo microphones and optical microphones) but have stayed with the types that are in everyday use.

4

Dynamic microphones consist of two types: Moving Coil and Ribbon.

Both these types generate their own electricity.

However - please note - that many modern ribbon microphones have a built-in, phantom powered, pre-amplifier that has an output similar to that of a condenser microphone.



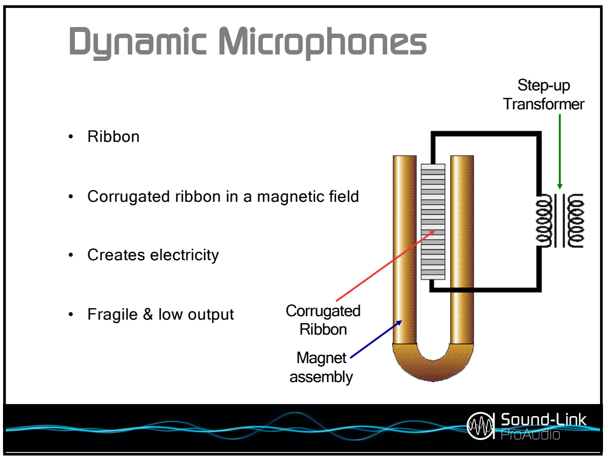
5

Moving Coil Microphones.

A Moving Coil microphone consists of a coil of wire, attached to a diaphragm, that moves in a magnetic field as sound waves move the diaphragm.

This movement creates electricity and the audio output exits via the wires at each end of the coil.

This design is normally tough and rugged.



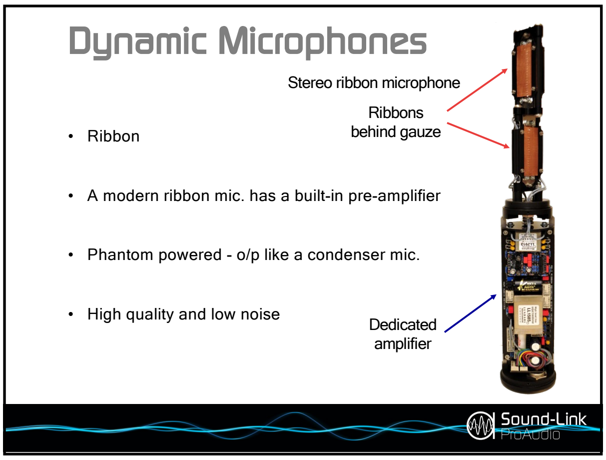
6

Ribbon Microphones.

A Ribbon Microphone consists of a corrugated metal ribbon which moves in the magnetic field of a permanent magnet - this principle is similar to that of a Moving Coil microphone, but the output is low and an integral step-up transformer is needed.

Some manufacturers include an integrated phantom powered amplifier, matched to the microphone, that raises the level equal to that of a condenser microphone.

Ribbon microphones can be quite fragile.



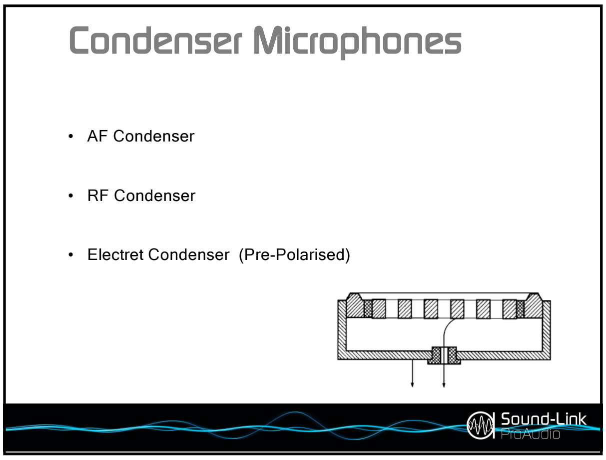
7

This picture shows the internals of a modern stereo ribbon microphone (mono microphones are similar, but I don't have a cut-away picture of a mono ribbon).

The two fig-8 ribbons are at 90º to each other and can be used for XY (AB) or MS recording.

The integrated pre-amplifier is 48V phantom powered and is matched to the ribbons to give an output that is similar in level to a condenser (capacitor) microphone.

As it's well-matched, the sound quality is very high and the microphone has extremely low self-noise without the normal problems that a classic ribbon has.



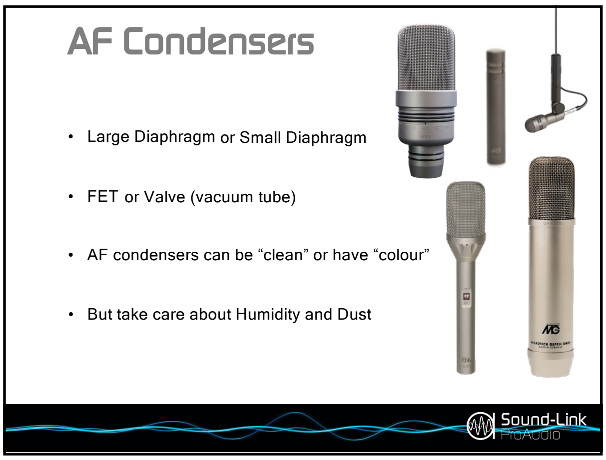
8

Condenser (or Capacitor) Microphones.

There are three main types of Condenser microphone: AF condenser, RF condenser & Electret condenser.

A condenser microphone is a capacitor with a fixed back-plate and a diaphragm, normally made from Mylar, with a sputtering of gold to make it conductive.

However, metal coatings other than gold can also be used. Also, the Georg Neumann M7 capsule uses PVC instead of Mylar, and metal diaphragms made from nickel, aluminium or titanium are also used in some capsule designs.

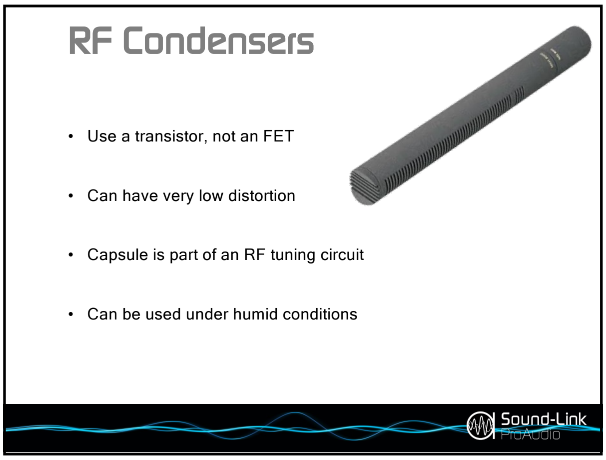


9

AF Condenser Microphones.

An AF condenser microphone has a capsule of very high impedance (Giga Ω) and a high bias voltage (normally about 60-80V, but some can go as high as 200V) and can have a valve ("vacuum tube" in the American language) or FET (an FET is basically a solid-state valve) in the circuit. This is the most popular design for condenser microphones.

But dust, smoke particles and the like are attracted to the diaphragm by electrostatic action, so be careful - especially with microphones used for vocals (EG: used by a smoker). A good Pop Killer can be useful to minimise contamination as well as to prevent plosives.



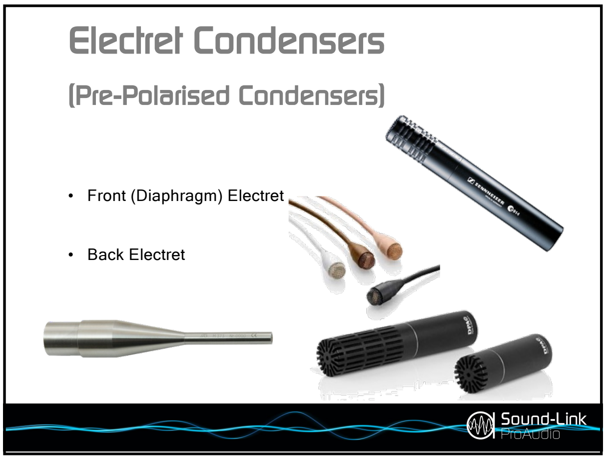
10

Condenser Microphones.

RF condenser microphones have a low impedance capsule and low voltage. A transistor is used in the circuit instead of a valve or FET. The capsule is part of an RF tuning circuit.

This design can be used in humid conditions and is normally the design of choice for outdoor work (especially in damp conditions or fog where an AF condenser can get noisy or "crackly").

Sennheiser MKH microphones use this design.

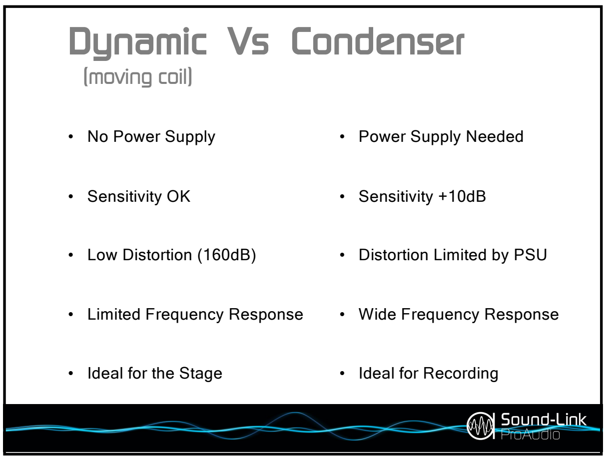


11

Electret (pre-polarised) Condenser Microphones.

Electret condenser microphones use the same principle as AF condensers, but the bias voltage is integral with the electret material. Early electrets used the electret material as the diaphragm - this tends to be cheap and low quality. Modern electrets (or "pre-polarised condensers") use the electret material in the back-plate and have a diaphragm like a normal AF condenser.

This design is capable of high quality similar to that of a normal AF condenser, as can be seen in the DPA range and high quality miniature tie microphones from several manufacturers. Also, back-electrets are also used as measurement microphones as well as normal AF ones.



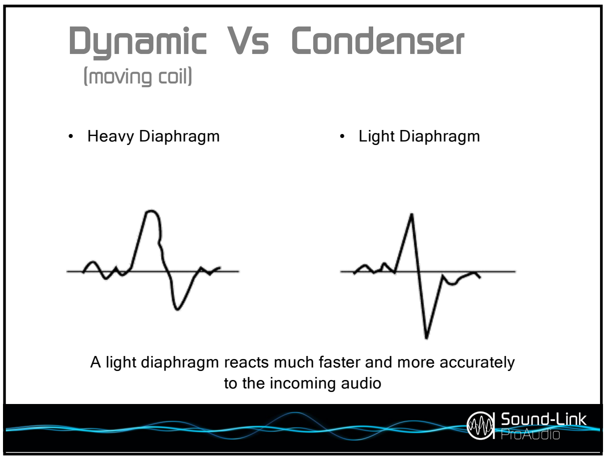
12

Dynamic vs Condenser - the pros and cons.

This slide is mostly self-evident. A dynamic microphone does not need any external power supply, whereas a condenser microphone requires external power (normally 48V phantom power, but 24V and 12V are also in the standard - most microphones either require 48V or will work on any voltage between 12V and 48V); there is also a 12V T-Power (AB-Power) standard that used to be used for microphones for outside broadcast use.

Electret (pre-polarised) microphones can work off lower voltages as they do not require a bias voltage and many will work with an unbalanced "plug-in-power" voltage (EG: from a radiomicrophone transmitter or small portable consumer recorder), but professional studio electrets often work on 48V phantom only.

Ribbons are fragile, of course, so the above mainly refers to moving coil dynamic microphones.



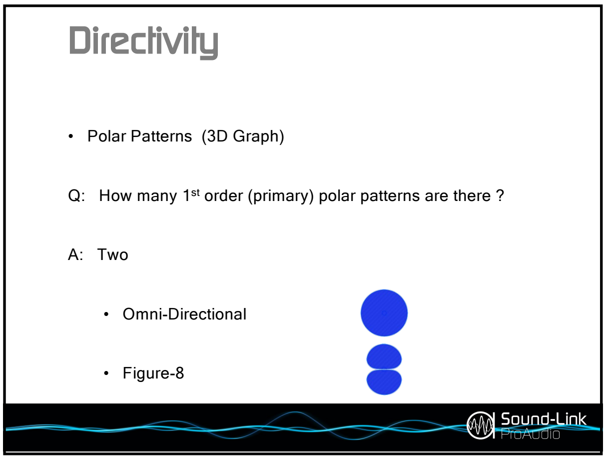
13

This slide illustrates the difference between a heavy and light diaphragm.

A Dynamic moving coil microphone has a heavy diaphragm; the diaphragm itself is far heavier than that of a condenser mic. and it has a coil of wire attached to it. In contrast, a condenser microphone that has a thin diaphragm (a bit like cling-film, to help you visualise it).

This means that a condenser microphone will follow the waveform far more accurately, as opposed to a moving coil that will require more energy to start it moving and it will take longer to stop.

A ribbon microphone also has a light diaphragm, though it is heavier than the extremely light diaphragm of a condenser microphone.



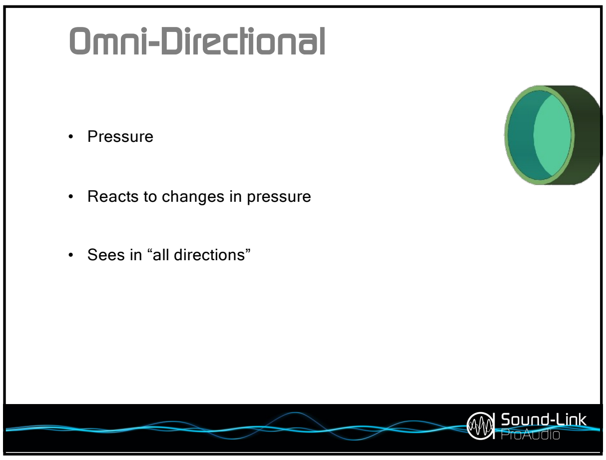
14

DIRECTIVITY

We move on now, from the different types of microphones to discuss their directivity.

Understanding this really helps when you come to use a microphone and will explain why many directional microphones have that annoying out-of-phase rear lobe.

So - to answer the question on the slide - there are just two 1st order (primary) polar patterns...



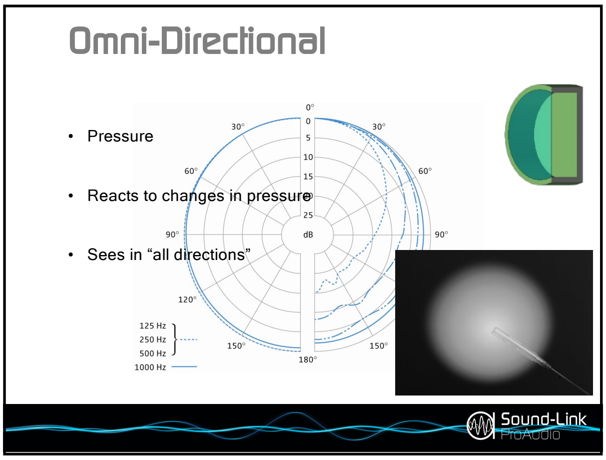
15

Omni-directional - the "pressure" microphone.

The first primary type is a "pressure" microphone. This consists of a diaphragm in a sealed housing. It reacts to changes in pressure and results in an omni-directional polar-pattern.

I have used little green diagrams to illustrate this (thanks to Chris Woolf who let me use his drawings).

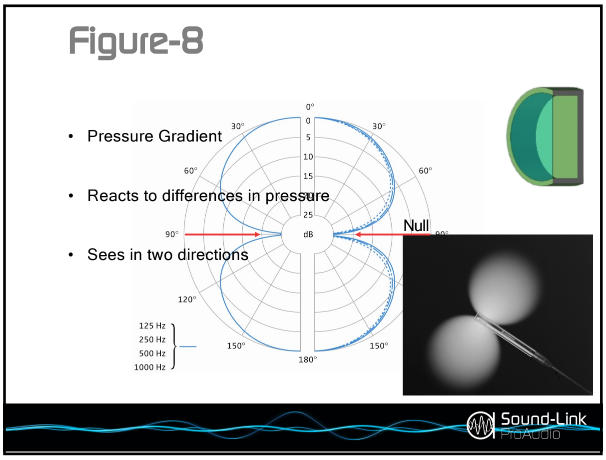
All pressure microphones will have a tiny "pin prick" hole to equalise atmospheric pressure, otherwise the diaphragm would "balloon out" or get "sucked in" as atmospheric pressure changes. This "pin prick hole" is far too small to affect the frequency response as it is far far smaller that the wavelength of the highest audible frequency.



16

Slicing the side of the little green pot lets us see more clearly the sealed design of the omni-directional pressure microphone.

The polar-pattern shown is of a high quality condenser microphone with a 16mm diameter diaphragm. The directivity shown at higher frequencies is caused by the size of the microphone housing. A tiny tie microphone would be fully omni-directional at even the highest frequencies, whereas a large dynamic omni-directional microphone would be even more directional at high frequencies.



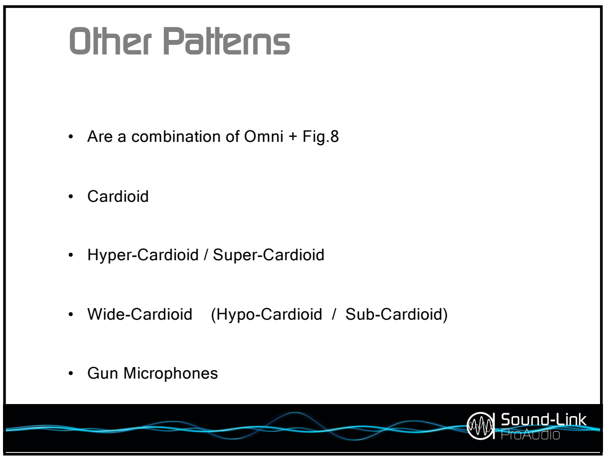
17

Figure-8 - the "pressure gradient" microphone.

The second primary type is the "pressure gradient" microphone. This consists of a diaphragm in a housing with a completely open back - so, to illustrate this, we have cut the back off our little green diagram.

A pressure gradient microphone reacts to differences in pressure (rather than changes) - EG: if you speak from the side, the pressure is the same both sides of the diaphragm, so it doesn't move and we have the null point.

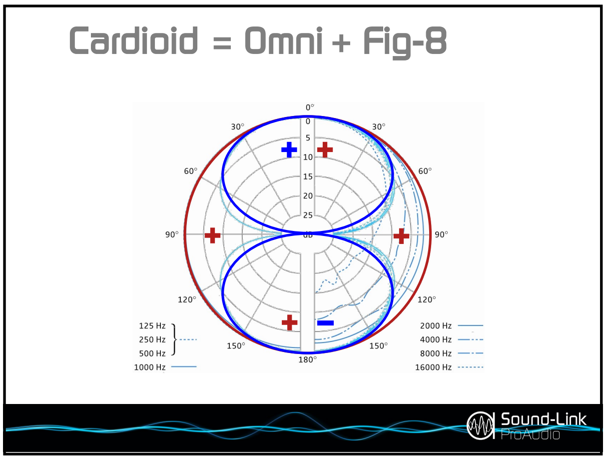
So the resulting pattern of the pressure gradient microphone is a figure-8. Most ribbon microphones are figure-8.



18

Other Patterns.

All other patterns are basically a combination of pressure and pressure gradient, as we shall see …



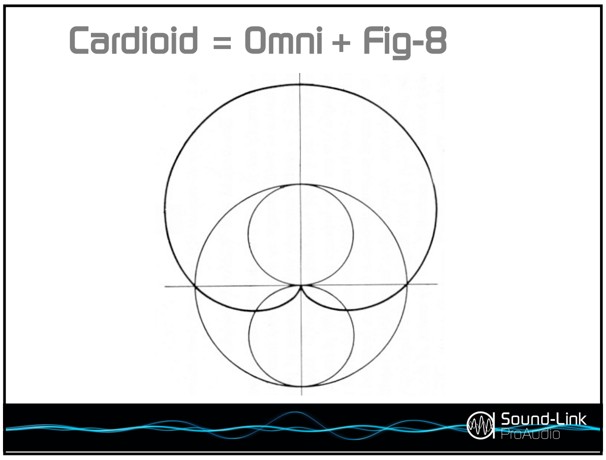
19

Cardioid.

We start with the cardioid pattern, which is half-way between omni and figure-8 and is made up of equal amounts of each.

An omni has positive pressure everywhere, while a fig-8 has positive on the front lobe and negative on the rear lobe.

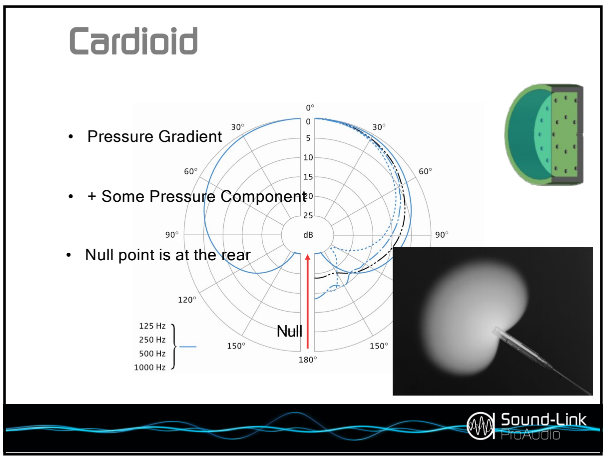
Do the maths:-
Front is: 1 + 1 = 2
Side is: 1 + 0 = 1
Rear is: 1 + -1 = 0



20

Plotting the above out we get this result.

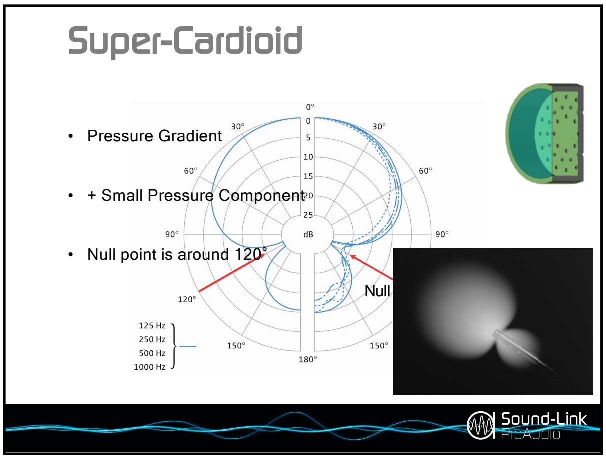
As you can see, the result is the cardioid polar-pattern which picks up well at the front, less well at the sides and with the null point at the rear.



21

In practice you don't actually make a cardioid microphone with two capsules (though there is a Josephson microphone that can do this), instead you damp the rear (often using silk or the like), allowing some sound to enter but in such a way that it cancels at the rear.

Going back to out little green diagram you see that the rear is not open anymore, but neither is it fully closed.



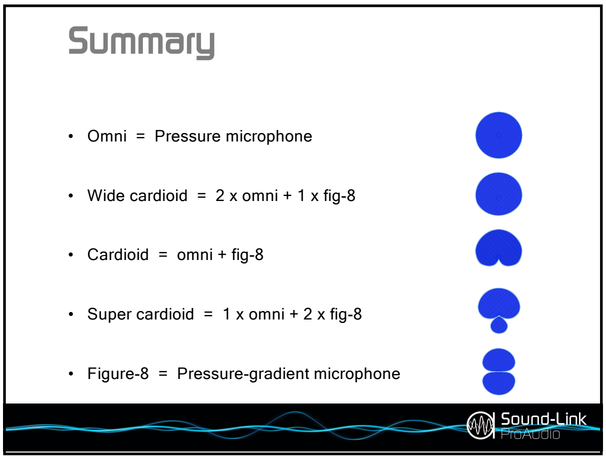
22

Super-Cardioid / Hyper-Cardioid.

The super-cardioid is the half-way pattern between the cardioid and figure-8 patterns…

It is like adding two figure-8 patterns to the omni - so:
Front is: 1 + 1 + 1 = 3
Side is: 1 + 0 + 0 = 1
Rear is: 1 + -1 + -1 = -1

This is why this pattern has an out-of-phase rear lobe. This is the remnant of the second fig-8. The null point is around the 120˚ point. You can see from our little green diagram that more sound is allowed to enter the rear as it is not so heavily damped as the cardioid.

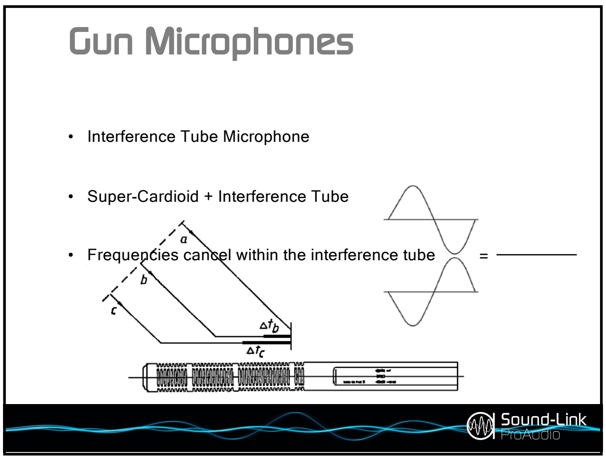


23

This slide is to help you visualise how we get the various polar-patterns from just an omni and figure-8.

To elaborate a little on the difference between the Super-cardioid and Hyper-cardioid patterns. The difference between them is that there is more of the fig-8 in the hyper, making it more directional at the expense of having a larger rear out-of-phase lobe.

However, many modern super-cardioid microphones are half way between the two (as per the polar diagram on the previous slide). These have the same attenuation at the sides and rear, about -10dB which results in the null angle being about 120º round from the front.

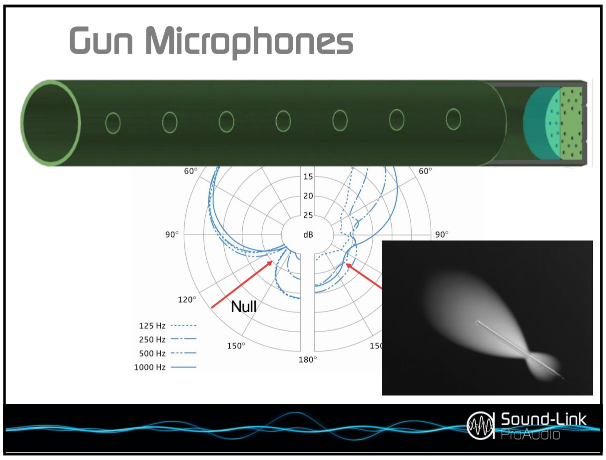


24

Gun (interference tube) Microphones.

A gun microphone, or “interference tube” microphone takes (normally) a super-cardioid capsule and adds an interference tube on the front. Sound coming to the microphone off-axis gets bent down the tube and frequencies cancel within the tube.

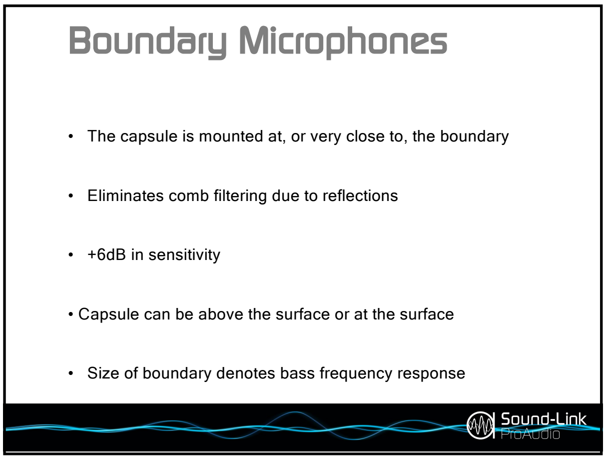
However, tube length defines the frequency at which this starts, the longer the tube, the lower the frequency that increased directivity starts - this is why a super- cardioid capsule is used, as this gives some directivity at low frequencies where the tube is ineffective. Very short gun microphones can therefore only have increased directivity at the very highest frequencies.



25

So we now add the interference tube to the front of the super-cardioid capsule on our little green diagram.

You can see on the polar-pattern that the low frequencies are just the super-cardioid pattern and increased directivity only starts at higher frequencies.



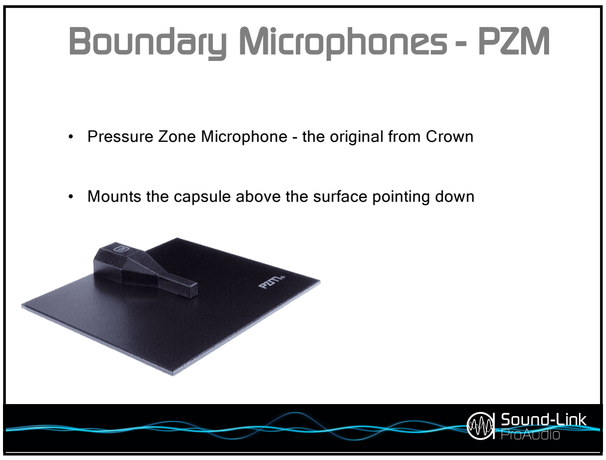
26

Boundary microphones.

These microphones have the capsule mounted at. or very close to, the surface. This eliminates comb filtering due to reflections from the surface (eg: table) and has the advantage of a 6dB increase in sensitivity.

There are two main ways of positioning the capsule: the first is to have the capsule slightly above the boundary pointing down and the second is to have the capsule at the boundary itself.

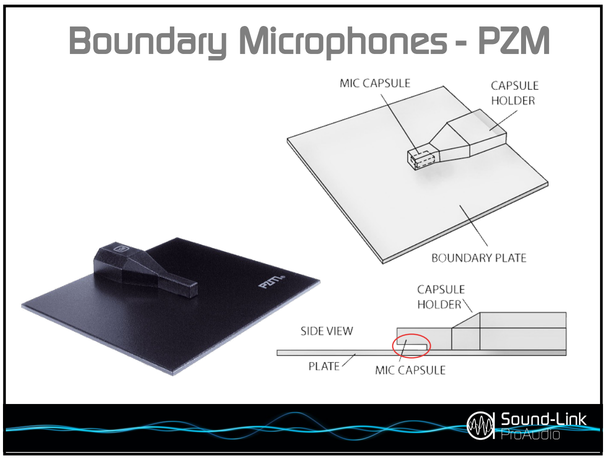
The size of the boundary has an effect of the bass response of the microphone, so the mic. itself will have a limited bass response that will improve when it is placed on the table or floor. I have seen some used on their own, mounted to a large perspex sheet to get the bass response required.



27

The Pressure Zone Microphone (PZM) was the original boundary microphone patented by Crown. They also licensed the design to Realistic (Radio Shack / Tandy) who produced an inexpensive version.

This design mounts the capsule a tiny amount above the surface, pointing down, looking at the surface from above - this tiny gap is the “pressure zone”.

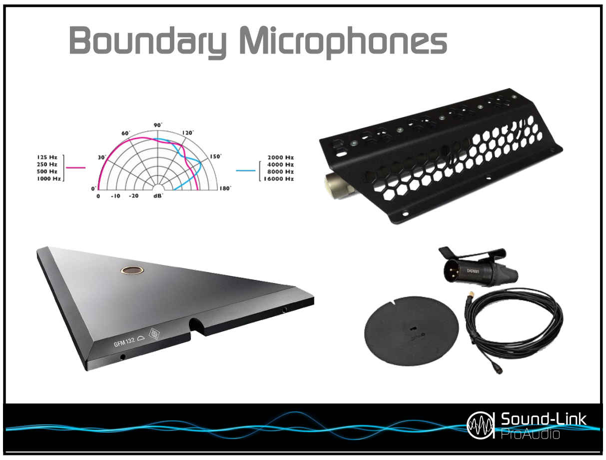


28

The diagram shows the Crown PZM.

The red ring shows the “pressure zone” - the omni-directional microphone capsule is in the housing above the surface, facing down.

The resulting polar-pattern is a half-omni, being a hemispherical response above the surface.



29

But not all boundary microphones are PZMs.

The triangular Neumann boundary microphone has the capsule level with the surface, rather than pointing down and there are very many like this, as they do not have to pay a licence fee to Crown - but they are still genuine boundary microphones.

But the best boundary mics are expensive - the patented “Turtle” enables almost any small diaphragm condenser to be used as a boundary mic., protected by Rycote Lyre suspensions and protected by a metal “shell” that enables the microphone to be used normally at other times.

Tie mics can be stuck to a surface to make a boundary mic. (or, for example, pushed through a tiny hole in a ceiling tile) and DPA even have a special plate to turn their tie mic. into a boundary mic.

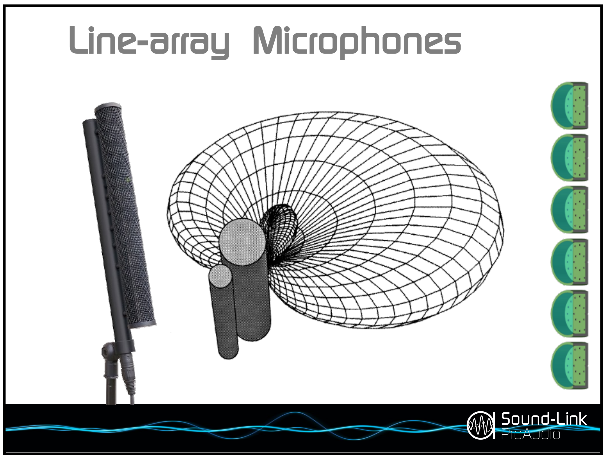
The polar diagram shows the “half-cardioid” pattern if a cardioid mic. is used as boundary microphone.

30

Line-array Microphones.

The line-array microphone is a useful microphone that uses the properties of several microphone capsules close together.

In most cases cardioid capsules are used.

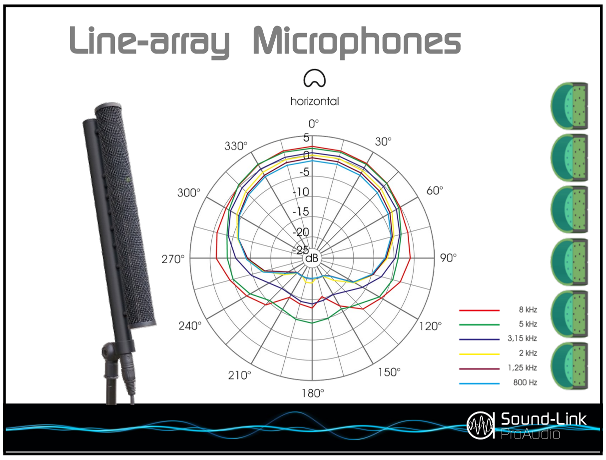


31

Several cardioid capsules are used in a vertical array.

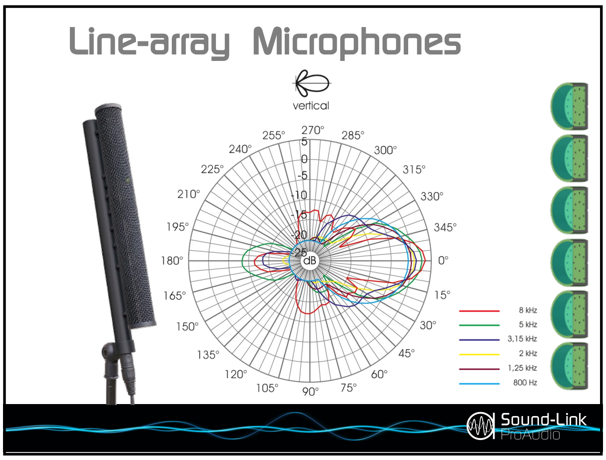
The resulting pattern is cardioid in the horizontal plane with a very narrow vertical pick-up angle.

The microphone pictured is the Microtech Gefell KEM 975 which uses eight cardioid capsules.



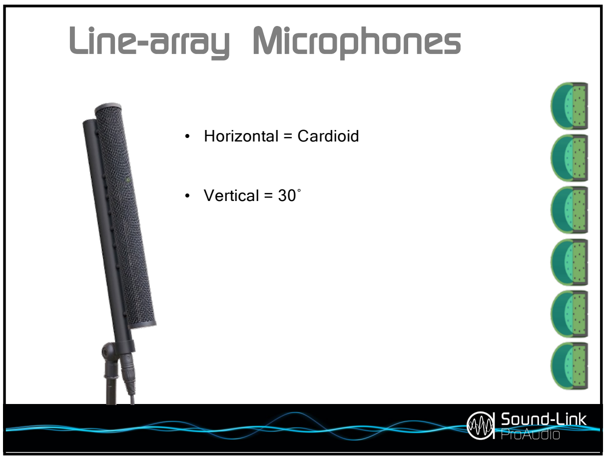
32

This polar-diagram shows the cardioid horizontal polar-pattern of the line-array microphone.



33

This shows the very narrow vertical polar-pattern of the line-array microphone.

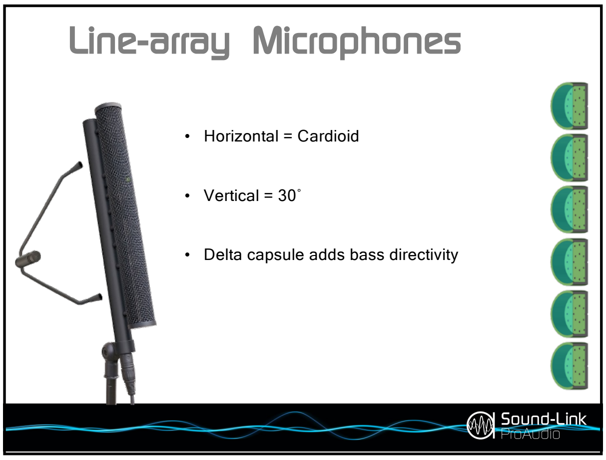


34

The resulting polar-pattern is cardioid horizontally and 30º vertically.

This sort of microphone is very useful in acoustically difficult situations.

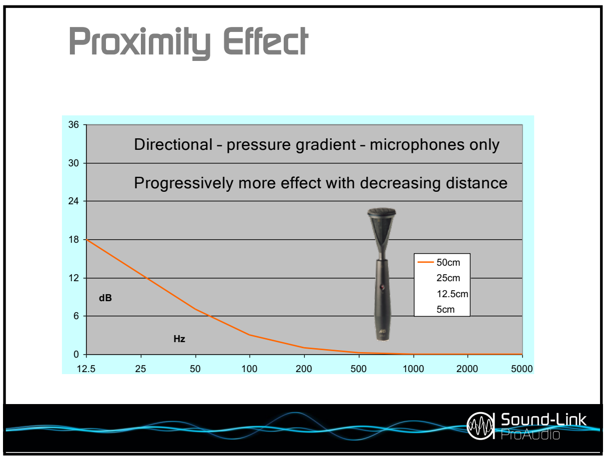
Also - turned on its side - you get a cardioid vertical pattern with a tight horizontal spread. This usage is ideal for lectern use, as it copes with speakers of different heights, sitting or standing, and rejects people from either side.



35

The increased directivity of a line-array microphone is defined by its length (similar to an interference tube microphone); so, at the lower frequencies, the microphone is fully cardioid. So short line-array microphones only have the increased directivity at the highest frequencies.

To help overcome this (especially for music recording) Microtech Gefell introduced an optional “Delta” capsule to the rear of their line-array microphone that makes the array more directional at low frequencies. But I won’t elaborate here as this is a subject for a different presentation (and a paper that I presented to the Institute of Acoustics in the past). But it does enable the microphone to be used to pick-up a choir located behind an orchestra without suffering from spill-over from the timpani at the rear of the orchestra.



36

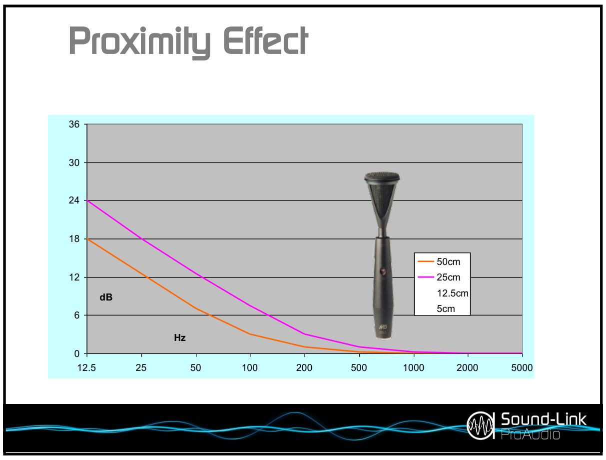
PROXIMITY EFFECT

We move on now to “proximity effect” - this is the increase in bass that occurs when a directional microphone is moved closer to the sound source.

This effect only happens with pressure gradient microphones.

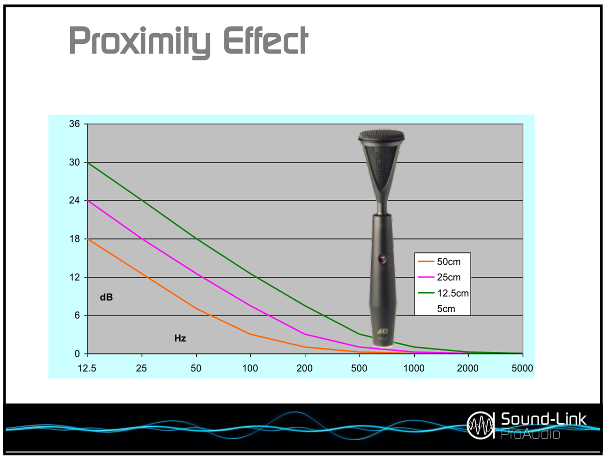
The closer the distance the more the bass is increased.

Also, the more directional the microphone, the more proximity effect there is. So, a Super-cardioid microphone has more proximity effect than a Cardioid microphone.



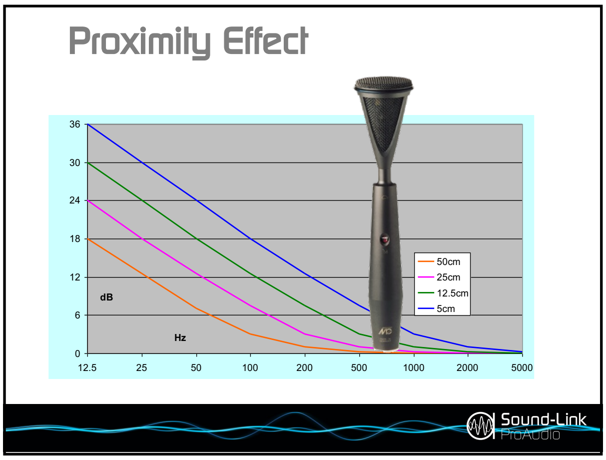
37

As the diagrams show, as you get closer bass increases.



38

We are getting quite close now - and the bass is increasing even more

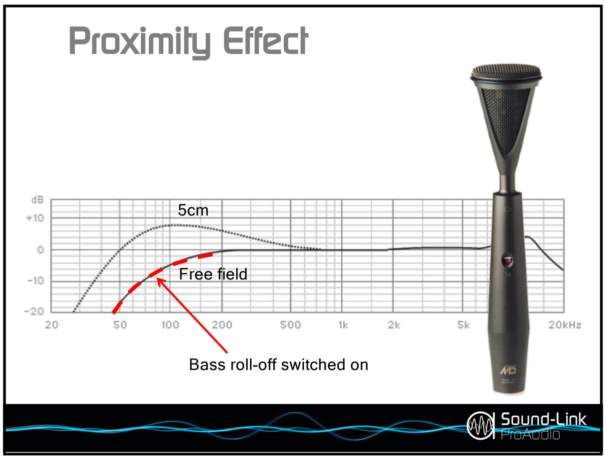


39

As you can see, there is a lot of bass increase with quite small changes in microphone position.

For a singer, it is important that he/she understands the microphone used and finds the best distance from the mouth that most suits his/her voice.

One tip: try having the microphone slightly to the side, but still pointing at the mouth. This method minimises plosives and the audience can see the performer's face more clearly, which gives the performer a better rapport with the audience.

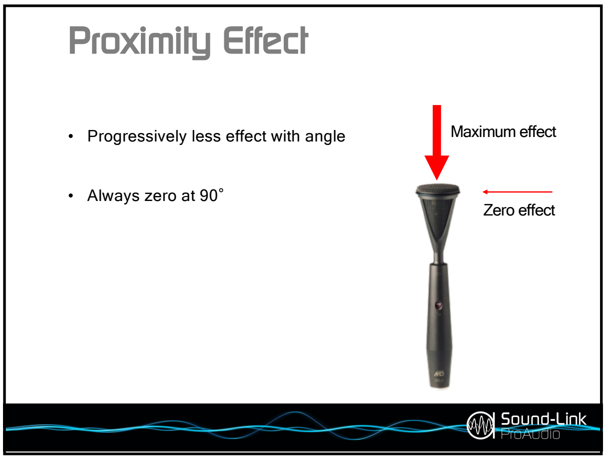


40

Microphones designed for singers will often have a drooping bass response (or will have a bass roll-off switch).

This is to compensate for the increased bass of the proximity effect when the microphone is used close to the mouth, and results in a frequency response that is not overly bass heavy when the microphone is close to the mouth.

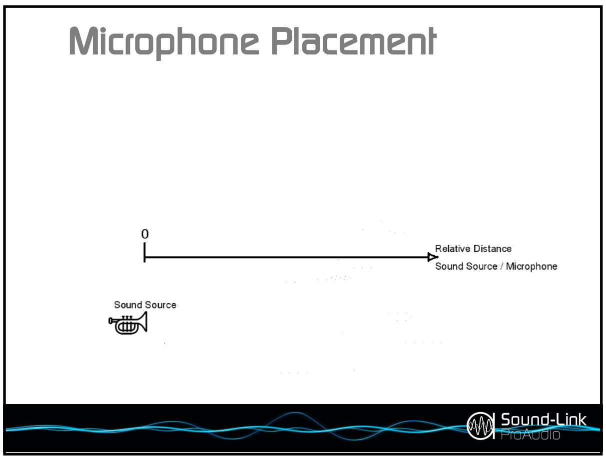
It is very important for a vocalist to know and understand the microphone he/she is using to get the very best from their voice.



41

One thing about proximity effect is that it has its maximum effect directly on-axis and it progressively decreases as you go off-axis.

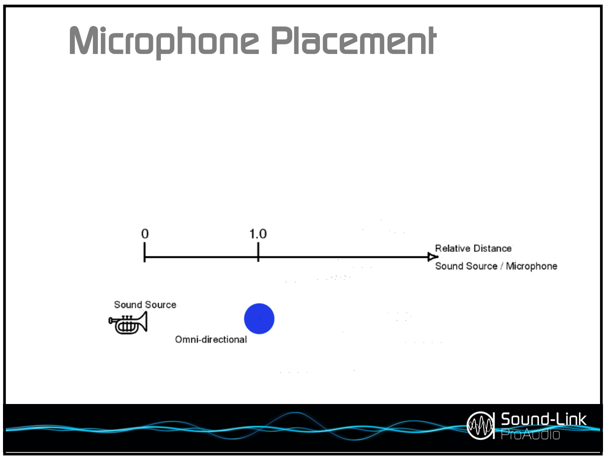
At 90º off axis (from the side) the proximity effect is zero.



42

MICROPHONE PLACEMENT

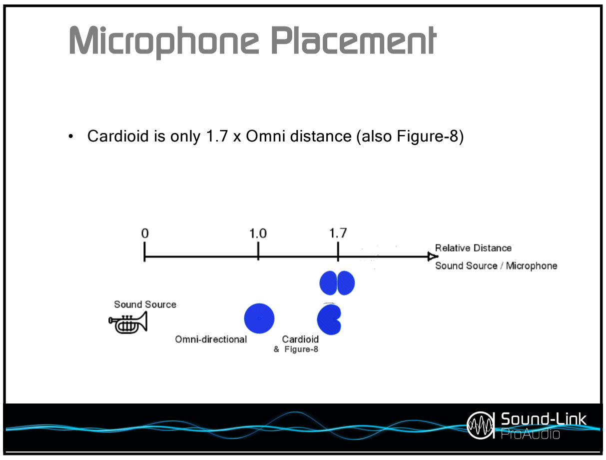
We come now to microphone placement and how far you can place a microphone from the sound source to get the same sound.



43

So, to start, let’s assume we have an omni-directional microphone one metre from the sound source.

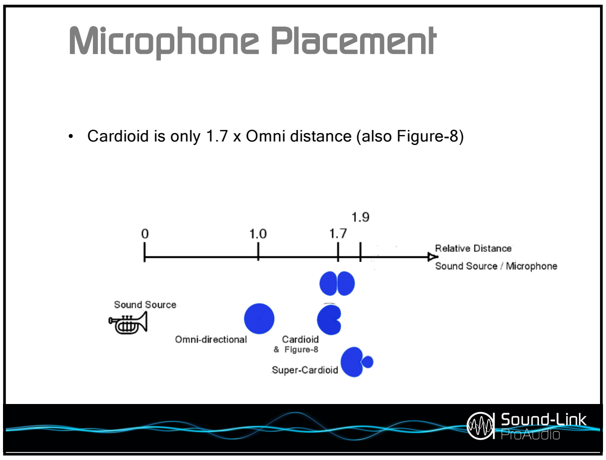
So - where would we place a cardioid microphone to get the same effect?



44

It’s actually closer than many people may think, the cardioid microphone is placed just 1.7 metres from the sound source.

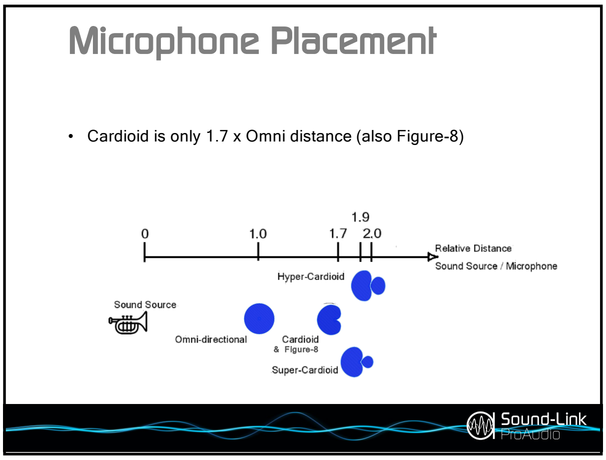
A figure-8 microphone would be placed at the same distance, also at 1.7 metres.



45

Maybe we find that a cardioid microphone is too close for us so, instead, we choose a super-cardioid.

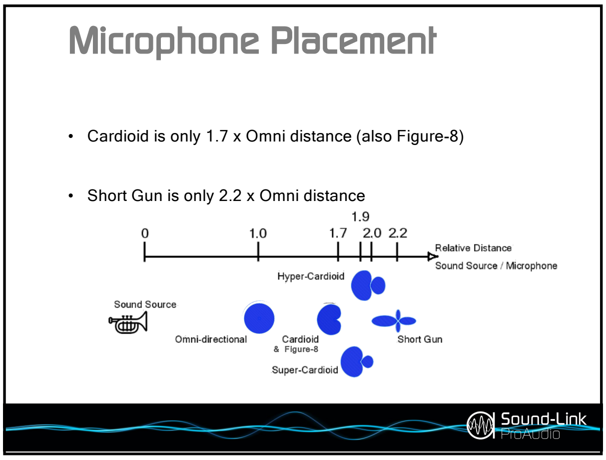
That would have to be placed at a distance of 1.9 metres to get the same sound as an omni at 1 or a cardioid or figure-8 at a 1.7 metre distance.



46

A hyper-cardioid would have to be placed 2 metres away.

A hyper-cardioid has slightly more directivity than a super-cardioid, but pays for it by having a larger rear out-of-phase lobe (see slide 48 for the actual null point angles).

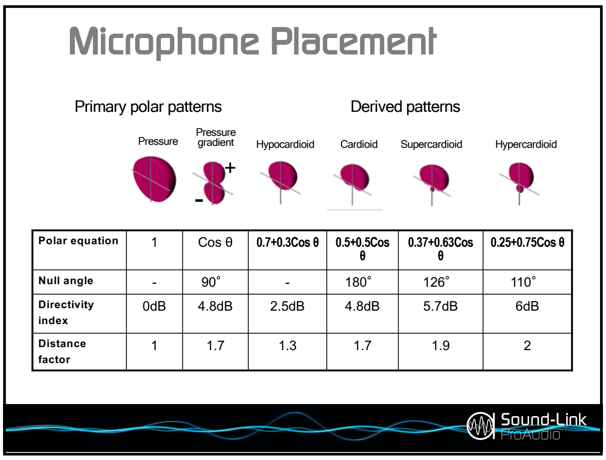


47

A short gun microphone can be placed only 2.2 metres from the sound source (not "way back" as many people think - I actually got this wrong the first time I was asked the question many years ago, I had suggested it would be 5 metres away.☺).

This is why a sound recordist working with film or video will get as close as possible to the sound source, drop the mic. just into shot to learn the limit and then pull back so the mic. is just out of shot.

Please be aware that a camera-mounted microphone will often be too far away and can, in addition, pick-up noises from the camera itself and also of the camera operator.



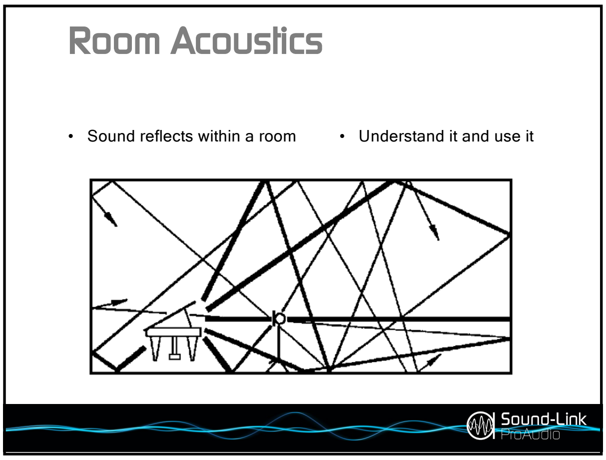
Polar equation	1	Cos θ	0.7+0.3Cos θ	0.5+0.5Cos θ	0.37+0.63Cos θ	0.25+0.75Cos θ
Null angle	-	90˚	-	180˚	126˚	110˚
Directivity index	0dB	4.8dB	2.5dB	4.8dB	5.7dB	6dB
Distance factor	1	1.7	1.3	1.7	1.9	2

48

This slide shows the maths.

With super/hyper-cardioid microphones the super- cardioid has a rejection of -8.7dB at the sides and -11.6dB at the rear. The hyper-cardioid has a rejection of -12dB at the sides, but only -6dB at the rear. The null angle you can see on the left.

Many microphone manufactures now tend to balance out their super-cardioid designs so that the attenuation at both sides (90º) and rear (180º) is about -10dB and the null angle then comes to 120º and this seems to be the best compromise for practical use.



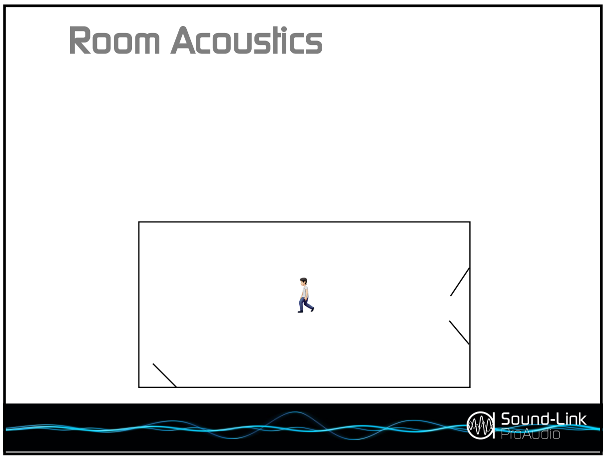
49

ROOM ACOUSTICS

We come now to room acoustics.

It is important to understand that sound reflects within the room and how this affects microphone placement.

I won't go into complicated details, but will show you a little test that you can do yourself to help you understand. I found this test extremely valuable when someone did this with me many years ago and it really helped me to understand and hear what a room does to the sound.



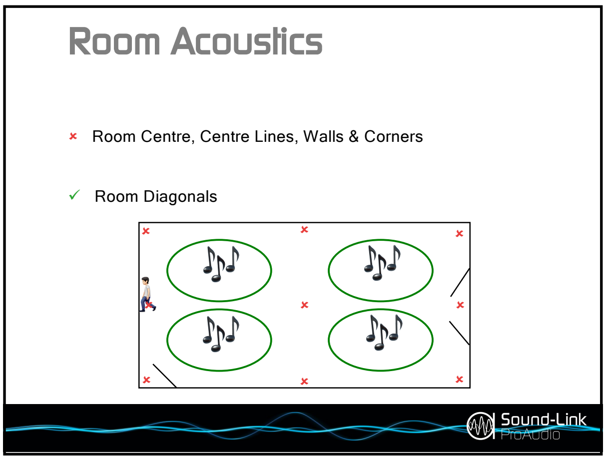
50

First, find a room with reflective walls; a school or university classroom is ideal, or maybe a sports hall or the like.

Now, stand dead centre, speak and listen carefully to your voice. It will sound nasty and honky.

This is caused by standing waves as you are equidistant between the two side walls and also between the two end walls and, in many rooms, your head is also equidistant between floor and ceiling.

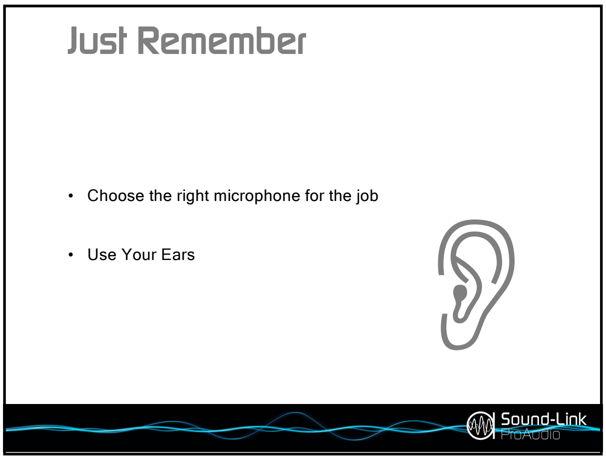
You can hear how nasty this sounds.



51

Now, stay on a centre line and walk along the room. The honky effect will reduce as you walk away from the centre, but you will still hear some effect as you are still on a centre line. Coming close to the end wall you will hear an increase in bass due to the wall effect. Now move along the wall and the bass will increase as you get to the corner, but the honky effect will go away as you are no longer on a centre line.

If you now stand on a room diagonal, away from the corner and room centre you will hear much clearer sound, as you are not now on any centre line and are away from the nasty points. These are the best areas to record.



52

Remember ...

It is good to be able to properly understand microphones, their types and characteristics, so you can choose the right microphone for the job.

And use your ears, as these are the best listening devices available.

After doing the room test I described above for myself, the understanding has stuck with me and I hear room effects more clearly - and also corridor effects and what a curved wall can do to the sound. So this little test is really well worth doing.

53

Listening to how the sound changes as you move a microphone round a musical instrument will help you find the best position. Just listening in different positions before you place the microphone is also very helpful.

The best mic. position will likely vary according to the room and the particular instrument used, so don't rely on what you did before if the room is different.

When I record ~I often go into the room and listen with my ears, I move around, and where it all sounds good to my ears I place the microphone in that position, normally it turns out to be the best place.

54

I hope this has been helpful.

After all - the most important thing is the music and the performance.

Choosing the right microphones and placing them properly will enable you to capture the performance at its best.

The same goes, of course, for the spoken word.

55

ABOUT THE AUTHOR

John Willett is the Managing Director of Sound-Link ProAudio Ltd. who are the official UK distributors for Microtech Gefell microphones, ME-Geithain studio monitors, HUM Audio Devices ribbon microphones and the LAAL (Look Ahead Analogue Limiter), Håkan Pop Killers, True Phantom, and the Maier Sound "Turtle" boundary microphone adaptor. He purchased Sound-Link from the previous owner in 2012.

He is also a freelance consultant, writer and classical music recordist. He established Circle Sound Services (his recording business) in 1978, initially as a "spare time" business. He has recorded a number of CDs including one in Classic FM's "Full Works" series and is well regarded for his solo piano recordings. He recently recorded the inaugural concert for "Sono Vivo", a charity that performs classical music concerts to raise money for cancer charities.

Microphones have always been his passion as is also his desire to "capture the performance". He has been recording digitally since 1983 and (according to "Music Week") was the first to produce an album by digitally overdubbing using a pair of PCM-F1 units. He has been using digital microphones since 2006 and is regarded as an expert on the subject. He has written for several publications including Sound On Sound and Line Up and has presented several papers at AES conferences as well as one to the Institute of Acoustics. He is a past President of the International Federation of Soundhunters and was Chairman of the British Sound Recording Association (formally the Federation of British Tape Recordists) for many years.

He is on the Executive Committee of the Institute of Professional Sound. He is also a member of the APRS and ISCVE, he is a Life Member of the AES. In a past life he was Technical Manager at Sennheiser UK.