Microphones! #15

I'm Doug Fearn and this is My Take On Music Recording.

Everything recorded needs a microphone. Well, maybe not electronic music, but everything else.

And there are hundreds of microphones, old and new, to choose from.

First, I want to look at the different operating principles of microphone categories. Then we will look at the directional patterns. And, finally some thoughts on how to pick the right microphone for the application.

Microphones fall into two broad categories: condenser and dynamic, and several sub-categories. This is based on how the microphone converts sound waves into electrical signals.

The first microphones used carbon granules with a voltage passing through them. A diaphragm vibrated in response to a sound, putting varying pressure on the carbon granules. That changed their electrical resistance, which was converted to a changing electrical signal.

The carbon mic produces a huge signal – line level, not what we consider mic level. It worked great for the telephone, where it was first used. But it is a pretty lousy mic, with high noise level, extreme distortion, and limited frequency response.

The carbon mic was used for the first electrical recording – to disc, of course. There was no other choice.

Everyone wanted a better microphone.

All microphone types start out with a diaphragm. It's just a piece of lightweight material that is more-or-less free to move in response to sound. Usually a diaphragm in circular, but it doesn't have to be.

Just vibrating in response to sound is not much use. Somehow you have to extract an electrical signal from the diaphragm to have a functioning microphone.

There are a couple of ways to do this.

The condenser mic was experimental in the 19-teens, but it was not ready for prime time. Too noisy and too finicky. It would have to wait. I'll explain that later.

A dynamic microphone works on the principle of a conductor moving through a magnetic field generating a voltage. That's how power generators work. That's how all your electrical power, if it's not solar, is made.

If you connect the diaphragm to a coil of lightweight wire suspended in the vicinity of a magnet, movement of the diaphragm will generate a minute voltage in the wire. The more powerful the magnet, and the more turns of wire, the more output.

But, believe it or not, there were no powerful permanent magnets until around 1930. It took until then for the technology to catch up to the demand for strong and compact magnets that would retain their magnetism indefinitely.

The dynamic mic had to wait.

But when the technology was there, researchers scrambled to make a dynamic mic. We still use them today, in more sophisticated and capable form, although dynamic mics are mostly used in live sound and in recording sounds of very high level, likes close-mic'd drums or electric guitars.

Dynamic mics can sound very good, but for the highest quality, there are better choices.

At the same time as researchers were trying to make a dynamic mic as I just described, another approach showed even better promise, and that was the ribbon mic.

Ribbon mics work exactly the same way as dynamic mics – in fact, a ribbon mic is a dynamic mic!

But with a variation.

The ribbon mic dispensed with the diaphragm and coil of wire and instead made the diaphragm and the wire one in the same.

A very thin -- almost microscopically thin – strip of aluminum foil is both the diaphragm and the conductor, mounted in the magnetic field. Movement of the ribbon generates a voltage.

since we tend to think of them as separate types, I'm going to split these two principles into two categories here: dynamic and ribbon. But remember that technically they are both dynamic mics.

In any microphone, the more accurately the diaphragm can follow the nuances of the sound, the more accurate the reproduction will be. Keeping the moving parts as light as possible, with the least restraint on their movement, results in the best sound. A dynamic mic, with a coil of wire mechanically connected to the diaphragm, provides significant inertia to the sound. It has trouble following sharp sounds, what we call transients, exemplified by the impact on a drum head, or the force of a hammer hitting a piano string.

The ribbon mic has pretty minimal mass to move. Only the ribbon has to move, no coil of wire. The ribbon mic can follow the transient sounds with great accuracy.

This simplicity and elegance give ribbon mics outstanding sound.

Indeed, the first truly high-fidelity microphone, the RCA 44, was a breakthrough when it was introduced in 1930. It remained in production through the 1970s, and RCA would probably be selling them today if the company still existed. Fortunately, Wes Dooley and Audio Engineering Associates continues to make this magnificent microphone today. It's so true to the original that the parts are interchangeable with one from the 1930s!

And you're listening to a modern 44 right now.

Ribbon mics have their drawbacks, however. They are more fragile than dynamic mics and the ribbon can be deformed by even a slight movement of air. They are therefore difficult to use outdoors. And even swinging a ribbon mic through the air on a boom stand might be enough to damage the ribbon.

Ribbon mics can be made to be more durable, but like everything in life, it's a tradeoff. More protection for the ribbon means more material in between the ribbon and the sound. That changes the sound and some of the wonderful transient response is lost.

Another potential problem with ribbon mics is their intrinsic bi-directional pattern. More on that later.

And the output level of a ribbon mic is very low – much lower than a condenser mic. It is comparable to many dynamic microphones in this regard. This is not really a problem, but it does put more emphasis on the quality of the microphone preamplifier.

Condenser mics should really be called capacitor mics. "Condenser" is an obsolete term for a capacitor, a fundamental electronic component found in every device in the studio. But the condenser name has persisted.

The condenser mic utilizes a diaphragm, but there is nothing connected to it. Well, there is an electrical connection, but that is a minor impediment on its ability to move freely in response to sound.

This diaphragm is made of a thin plastic, typically mylar, stretched tightly and coated with a very thin layer of a metal, often gold. This gold layer is very thin indeed. In fact, you can see light through it. It has to be light weight to avoid loading down the diaphragm.

There is a metal plate quite close to the diaphragm, and these two objects create the capacitor.

When sound hits the diaphragm. it moves very slightly in response, and that tiny movement causes a slight change in the capacitance.

That's not much use in itself, but if we can convert that changing capacitance to a changing voltage, we have a useable microphone.

This transformation requires an active device, originally a vacuum tube and later a transistor.

Although tubes and transistors are most often used to amplify a signal, in the condenser microphone they simply convert the changing capacitance to a changing voltage. There is no amplification going on at all.

Tubes are perfectly suited for this job because they have an incredibly high input impedance – just what we need to couple the condenser capsule to the outside world without loading it down. Loading could be mechanical or it could be electrical, and both occur in all microphones. But condenser mics need the lightest possible load to work well.

By the 1960s, transistor technology had come far enough that a type of transistor, the field-effect transistor, could be used in place of the vacuum tube. Normally, transistors are low impedance devices, but the field-effect transistor, or FET, is much more like a vacuum tube. It is well-suited for the job of converting changing capacitance to changing voltage. Maybe not as good as a vacuum tube, some of us would say, but certainly good enough.

Vacuum tubes require at least two different voltages to operate, and one of the voltages needs to be quite high. Tube condenser mics therefore require a rather complex, large, and expensive external power supply to operate, and a fat, multiconductor cable between the mic and the power supply.

FET condenser mics, on the other hand, need only a very low voltage to operate, plus a somewhat higher voltage to make the capsule capacitor work. 48 volts is plenty. A tube condenser mic will need at least 100 volts for its circuitry, along with voltage for the capsule, and voltage to light the filament inside the tube.

A clever system of superimposing two different types of signals on one pair of wires was developed in the mid-1800s for the telegraph system. This method, often called phantom power, was adapted for use with FET condenser microphones.

This really simplified the cables, since a phantom power voltage could be provided by a preamp or console and fed to the mic on the same ordinary cable as the audio signal.

Brilliant idea, and it works very well. But I would suggest that it compromises the performance of the microphone and potentially the performance of the mic preamp. But it is very convenient and is the most common method for powering condenser mics.

By the way, the D.W. Fearn preamps that I designed have phantom power, but when it is not needed, switching it off completely removes all the special circuitry from the mic line. So not only is the 48 volts removed, but also the components that could change the loading on the microphone.

But preamp design is a topic for another time.

A variation of the condenser mic is the electret condenser. This uses the same principle as the conventional condenser, but the capsule has a permanent electrostatic charge and does not require 48 volts or higher. The electret condenser still needs an amplifier, which is invariably a field-effect transistor, but only requires a low operating voltage – 5 to 8 volts. Electret condenser mics are not used much in professional recording, but there are some high-quality mics that use this principle. Most electret mics are found in your mobile phone, or landline phone, for that matter, and other consumer devices that require a mic. Electret condensers mics offer reasonable audio quality in a very cheap and small package.

So, we have three different microphone types, using two different methods to convert sound waves into electrical signals for recording.

You know these three types of microphones sound very different, but why is that?

Some of the reasons are due to the different mechanisms used, as you can deduce from the previous discussion. But, of course, it is more complicated than that. Going into the details is beyond the scope of this brief explanation, but some of the differences are related to how the different mics respond to sound.

Let’s look at the ribbon mic first. It is generally my first choice for many types of recording, but I use all three types in my studio.

The ribbon is suspended under light tension within the poles of a powerful magnet. The ribbon is open to that air on both sides. The mic is bi-directional. If you plot its polar pattern, it looks like a figure-8.

You can place two sound sources on opposite sides of a ribbon mic and it will reproduce each side with identical fidelity. But how often do you need that type of pick-up?

In most recording situations, you want to hear the instrument or voice in front of the microphone and little if any of the sound from any other direction. It would seem that a ribbon mic would be a lousy choice for use in a room full of instruments, especially if you want good isolation of each instrument for later processing.

But there is one extraordinary characteristic of the bi-directional pattern, and that is that sound arriving from the "sides" of the mic is totally rejected. And I mean totally. The rejection is so deep that it is difficult to measure.

And this rejection is not just to the sides of the mic, but all around that plane – top and bottom, too.

But, you say, I use cardioid, or super-cardioid mics. Don't they reject everything except what is right in front of the mic?

Yes, they do, so some extent. But the rejection is at best perhaps 20dB, compared to a bi-directional mic that could be 90dB.

And the rejection off-axis of a cardioid mic is not the same at all frequencies. In fact, at very low and very high frequencies, those mics are likely to be omni-directional. That is, they pick up sound equally from all directions.

Does that help explain why you have trouble isolating the high-hat and snare, for example, in a close-mic'd drum kit?

Bi-directional mics retain their rejection of sound off the sides at all frequencies. So, the off-axis sound that does not get completely rejected still sounds the same.

That is one of the main reasons why ribbon mics have their distinctive sound.

And a multipattern condenser mic in the bi-directional setting has many of the same characteristics as a bi-directional ribbon microphone.

The "cardioid" descriptor refers to the heart-shaped polar response pattern of directional microphones. But if you look at the polar pattern of a typical cardioid mic, at the mid-frequencies, the highest rejection is probably not off the back of the mic, but probably somewhere around 135 and 225 degrees, if the mic axis is 0 degrees. You can use this characteristic to aim your cardioid mics for maximum rejection of an unwanted sound.

Normally I think it is better to use your ears than it is to study engineering specifications for a piece of equipment, but in the case of microphones I make a minor exception. By looking at the pattern, you can get a sense of how the mic is likely to respond to sounds off-axis.

And looking at the polar pattern at various frequencies is even more revealing. Unfortunately, some mic manufacturers only publish patterns at one mid-range frequency, where the pattern will look best.

You won't go wrong presuming that your cardioid mic will be closer to omnidirectional below 100Hz and above about 10kHz.

Your bi-directional mic will have the same pattern at all frequencies.

But what about directional ribbon mics?

Making a ribbon mic directional is challenging and full of compromises. But it can be done, and it can work very well. But usually the directional ribbon mic loses some of its intrinsic ribbon sound. Life is full of compromises. Some designs are much better at this than others, which is another way of saying, listen to the mic and trust your ears. Often the compromise in the change in sound is worth it.

There is one other microphone polar pattern we need to discuss, and that's the omni-directional pattern.

Its name would suggest that this mic picks up sound equally from all directions, and that is generally true. But most omni mics have comparatively little pickup towards the connector end of the mic, so the pattern is not really the idealized sphere of equal pickup. But as an approximation, the omni mic picks up sounds from all directions equally.

Why would you want that? Well, there are some obvious applications, such as a bunch of background singers circling an omni mic.

But there are other times when an omni mic is a good choice, even when you need to reject other sounds.

One of the characteristics of all directional mics is proximity effect. That is, an increase in bass response the closer you get to the mic. This can be extreme, such as the 44 ribbon mic, which does not develop its flattest frequency response until you are 9 feet away from the sound!

In reality, the proximity effect decreases quite rapidly with distance, so after 2 or 3 feet, it is not that noticeable. And sometimes you want that effect. It can make vocals sound quite impressive, or provide some great low-end to a kick drum. Just don't get your ribbon mic too close to a kick drum. If you can feel the air moving at the mic position, it is likely to damage your ribbon mic.

Proximity effect also applies to directional condenser mics, especially the large-diaphragm type.

Proximity effect will also be apparent with directional dynamic mics, although some are designed to minimize that.

All this leads to the characteristic that omni mics generally have no proximity effect at all. You can place them as close as you want to a sound, and the frequency response will still be reasonably flat.

You can see how this could be useful in some situations. By putting the omni mic extremely close to the sound source, you can sometimes obtain more rejection of unwanted sounds than you could with a directional mic.

Part of understanding this requires knowledge of the inverse square law. Don't worry, this is a pretty simple concept.

It simply states that if you double the difference between the sound and your mic, the level will drop by a factor of four. Double it again, and it drops by another factor of four. And so on.

This is not totally true in real-world situations, but it gives you a feel for the rapid drop-off in level with distance.

A very close mic will have a lot of output, obviously. What isn't so obvious is how little other sounds may get into that very close mic. This obviously won't make it possible to record a soft vocalist in the middle of an extremely loud band, no matter what you do. But you can use this knowledge to improve isolation in many situations.

You might think that directional microphones would be the best choice for everything, and many terrific recordings are made with only directional mics. But they aren't the only tool in your mic toolbox. Exploring some of the other patterns might lead you to some new techniques.

Many condenser mics have multiple patterns that you can select, ranging from hyper-cardioid to omni-directional in some mics. Try some of the other patterns to compare the difference in sound.

I discovered the bi-directional pattern on my condenser mics very early in my career. I immediately preferred that sound and that is what I use 90% of the time.

We all have our own style, so I am not suggesting that this is the answer for everyone, but it might be worth exploring.

If we were to try to explain the differences in the sound of various mics, what words would we use?

For those of us who grew up with condenser mics, we might describe them as life-like, pleasantly bright, intimate when worked close, and easy to use.

That would have been my answer at one point, and I still think those attributes are accurate.

But condenser mics, in general, do not have a flat frequency response. As part of the nature of their design, almost all condensers have a broad "presence peak," which might start as low as 2kHz and peak around 6-8kHz. That makes the sound of the mic cut through, especially for vocals. Often that is necessary, and explains the universal appeal of these mics. It's a good choice for many types of music.

Ribbon mics often have the reputation of dull sound, lacking in highs. But compared to what? A bright condenser? Actually, well-designed ribbon mics have pretty flat frequency response up to at least 10kHz. And as you may recall if you listened to the first episode of this podcast, "Your Hearing Is Amazing," it is unlikely that you or your listeners can hear much above 10kHz anyway. Even if you can hear to 20kHz, after your recording gets to that listener, it might take a 10-year old with a superlative stereo system to hear 20kHz.

My point it, flat mic response to 10kHz is pretty good. And ribbon mics don't just drop off at 10k. Most of them roll off very gradually and are down only a few dB at 20kHz. The best ones still have response up to 30kHz and above.

I reject the notion that ribbon mics are dull-sounding. I think many condenser mics are overly bright.

It may take many hours of listening to ribbon mics to appreciate this, and you may still find you don't like the sound. That's fine. But do some experimenting and you might find a new technique.

And you can always add eq to change the sound of your ribbon mic. I used to do that, to make them more compatible with condenser mics, but eventually I found I was doing less and less eq on the ribbon mics until now I often use them entirely flat, or maybe roll off the low end a bit to compensate for proximity effect.

What you are hearing now has no high-end boost at all, just a couple of dB of shelving roll-off at 40Hz.

My voice is not great, and the mp3 of the podcast is far from perfect, so try it on your own projects to see what you think.

There are a few more factors that affect how a microphone sounds. These can be pretty subtle, so I won't go into much detail. But they may give you some insight into your mics, and give you something to think about.

Why do otherwise similar mics sometimes sound so different? Well, one reason may be the grille – the covering over the mic to protect its delicate diaphragm. This structure is different on every microphone design, and may reflect the marketing department's idea of a look more than the engineering department might like.

The grille not only protects the diaphragm from physical injury, but it also include devices to reduce the mic's susceptibility to pops when used on voices.

But few grilles are totally transparent to sound, and this is especially true as you move off-axis on the mic. Take one of your mics and walk around it, picturing the path from your voice to the diaphragm. In most mics, you will see that the perforated metal or other structure presents a different path to the diaphragm depending on the angle. In some positions, the diaphragm may be totally blocked from the sound. The sound has to go around the structure to get to the diaphragm, and that is going to change the sound.

That's not necessarily a bad thing. The grille design is part of the intrinsic sound of the mic. But you can see how an otherwise identical mic with a different grille is going to sound different.

An external pop screen may do the same thing. It will change the sound, particularly off-axis.

Another subtle factor is the mechanical resonance of the microphone housing. Some mics are massive and solid, and tapping on a disconnected mic may just produce a dull thud. But other mics have thinner materials that will emit a distinct tone when you tap the case. When those mics are exposed to sound, that resonance may impart a characteristic frequency peak to the sound. It can be very subtle, but that, too, might be part of the intrinsic sound of the mic.

And one last factor I will discuss today is the shock-mounting of the mic. This can vary from no shock mounting at all in some mics, to elaborate suspensions, carefully tuned to reduce any low-frequency vibration from being transmitted through the mic stand and into the mic. We all know that sound when someone hits the mic stand, but what happens when sound from the kick drum goes through the floor, into the mic stand, and then vibrates the mic? This interference might come from outside the studio, as anyone who works in a studio in a city with a subway system knows.

Just some things to think about….

OK, we have three different microphone principles – dynamic, ribbon, and condenser.

Dynamic mics are the most rugged microphones and can handle very high sound levels without a problem. But they tend to smear the attack of percussive sounds. Their output level is low. They are usually the least expensive of all the microphones. You can drop them.

Ribbon mics are the most fragile of the microphones and can be damaged by careless handling. Their pickup pattern is natively bi-directional, although they can be made uni-directional. They cannot be omnidirectional. They have excellent transient response and can sound the most natural of all the microphones. Their output level is low. Good ribbon microphones can be moderately expensive. Expect to spend a lot of money to repair a dropped ribbon mic.

Condenser mics are not as fragile as ribbon mics, but a lot more delicate than a dynamic mic. Most can handle high sound levels. Their transient response is very good, and their output level is very high. Most condenser mics have a peaked response in the highs, which may or may not work well for the application. Condenser mics are the type most commonly used in the studio. They are the most expensive of the microphone types. A condenser mic may survive a fall onto a carpeting floor but don't count on it.

The uni-directional or cardioid pickup pattern is designed to reject sounds that are not directly in front of the mic, although many directional mics lose their directionality at low and high frequencies. Most cardioid mics have proximity effect, which exaggerates the low frequencies when placed closed to the sound source. That can be a problem or a tool. This is most commonly used pattern in the studio. All three microphone types can be made to be directional.

The bi-directional, or figure-8, pattern picks up sounds equally well in front of the mic or in back of it, but rejects sounds to the sides. The side rejection is remarkable. A bi-directional mic tends to have the same frequency response from all directions, so the sound just gets softer off-axis but the sound stays the same. There is a lot of proximity effect.

The omnidirectional pattern picks up sounds equally from all directions. It has no proximity effect, and the sound quality does not change significantly as you move off axis.

Understanding these various characteristics can help you choose the best microphone for the instrument or voice you are recording, and provide the desired rejection of other instruments when that is important.

There are no rules about this, however, and you should experiment with your mics on various sounds and decide what works best for your style. I have often been surprised at how good a mic sounds when I try something I have never done before. This usually happens when I find it necessary to do a quick overdub and I use the closest mic already set up.

But the more insight you have into your microphones, the better you will be able to visualize what might work and what might not.

This is My Take On Music Recording. I'm Doug Fearn. See you next time.