The Technology of RF Condenser Microphones

JOHN WILLETT MIBS Technical Applications Manager for Sennheiser UK, explains why RF Condenser technology, unique to Sennheiser, has such special properties.

A question I am often asked when my fellow IBS members discover who I work for is "Why are 'RF condenser' microphones so good in the wet, being so much less susceptible to humidity problems than the more common 'AF condenser' microphones; and, if this principle is so good, why is it that only Sennheiser make 'RF condenser' microphones?" I don't wish to use this article as an 'under the counter' means of advertising my employer's products, but rather as an opportunity to try to explain the concepts of the RF microphone, and to explain some of the history of its development.

Conventional Condenser Wisdom

To start with I should explain the terms AF and RF in the context of condenser microphones. To put it simply, the normal 'AF' or 'audio frequency' condenser microphone employs a capsule design which is, in effect, a capacitor that stores a static electricity charge.

This charge can be created in one of two ways, but in professional studio mics usually this is generated by a DC polarising voltage applied to the capsule. The amount of charge that can be contained in this capacitor is proportional to various factors, such as the size of the conductive plates (the diaphragm and back plate), and the space between them. These two plates obviously have a fixed size, and the back plate is fixed in position, but the front plate – the diaphragm – is able to vibrate in sympathy with the sound. This vibration back and forth changes the distance between the two plates in direct proportion to the level of the incident sound, and so the value of capacitance varies accordingly. If the capacitance changes, then the size of charge that can be stored changes as well, and a minute current therefore flows in or out of the capsule as that charge ebbs and flows. This current is measured by the head pre-amplifier within the microphone body to generate a more robust audio signal at the microphone's output.

Figure 1. A sectional view of an MKH30 revealing the RF electronics.

This is all well and good, and there are a large number of very high quality AF condenser microphones available from a wide variety of manufacturers. However, this simple system is not without certain inherent problems. One of the most important in the context of this article is that the capacitor capsule has to operate in a high impedance circuit. The charge stored in the capacitor has to be maintained at a constant level until the diaphragm moves in response to incident sound waves, and so the head amplifier must have an extremely high input impedance to avoid drawing current from the capsule. While it is technically possible to achieve this, the stored charge is always looking for others ways to escape, and unfortunately in a humid atmosphere the stored charge often finds it easier to escape on water molecules in the air. The result is a noisy and reduced output, and misery all round.

Innovative RF Magic

The RF system uses the same basic capacitive capsule design, but in an entirely different way. The principle is to use the capsule as the tuning capacitor in an RF (radio frequency) circuit – where it operates in a low impedance mode with a high frequency signal (typically around 8MHz) passing through the capacitor all the time. Changes in the capsule capacitance (caused by sound waves moving the diaphragm) modulates the tuning of an RF oscillator in proportion to the incident sound waves. A simple RF demodulator circuit converts these RF frequency modulations back to a conventional audio signal. This approach is clearly more complex than the simple AF condenser system, (although still very rugged and reliable – see Figure 1), but the low-impedance nature of the circuitry around the capsule helps to make the system far more tolerant of atmospheric humidity. As a result, this technology has become preferred for microphones intended to be used out of doors, or when moving from outside to inside on a cold day!

When condenser microphones were first developed only valve (vacuum tube) technology was available as the active element of the required pre-amplifier / impedance converter. It was simply not a realistic proposition to construct an RF oscillator and demodulator using valve technology if it had to be built into the body of a practical microphone. Thus all of the early condenser microphones were conventional AF condensers. However, by the 1960s transistors had become available...

Sennheiser had only produced dynamic microphones up until that time; but with the advent of the transistor the company began to research ways of producing a condenser microphone using these compact transistors. The problem was that transistors have to operate in relatively low-impedance circuits, but an AF condenser microphone requires a high-impedance environment, which can only be achieved using either a valve or a field-effect transistor (FET). However, as FETs did not exist at the time, Sennheiser's R&D efforts went into finding an alternative way of producing a condenser microphone using transistors and low impedance circuitry. The solution was the development of the RF Condenser principle.

AF Traditions

I should say that at this time other microphone manufacturers were also researching the feasibility of making condenser microphones using RF condenser technology. However, because the field-effect transistor came along very quickly after the bipolar transistor most manufacturers quickly adopted these newer high-impedance devices to produce compact AF condenser microphones. Essentially, they were able to take their existing amplifier circuits, replace the valve with an FET, and immediately produce a condenser microphone with solid-state circuitry. These companies saw no need to spend further time and money developing the technology necessary to manufacture RF condenser microphones when the FET already provided the solution they required. This left only Sennheiser to pursue the RF technology – although it still surprises me that no-one else produces RF condensers today.

As Sennheiser had no history of producing AF condensers they were not bound to existing design traditions, and they could see many fundamental advantages in the RF concept, including the immunity to the effects of humidity, lower self-noise (a valve or FET has higher random noise, especially at low frequencies), and the fact that the RF demodulator circuitry lends itself to generating a balanced audio output by simpler means than having to bolt a large, heavy and expensive transformer onto the back end. It is even simpler than the electronic quasi-balancing circuits used in many modern microphones.

Another useful advantage of the RF condenser design is that it can, theoretically at least, have a frequency response that extends down to zero Hz. This has been demonstrated with the development of special measurement microphones such as the MKH 110, which boasts a frequency response specified down to 1 Hz. There was also the MKH 110-1 variant which went down to 0.1 Hz! These particular microphones were discontinued many years ago, although a large number are still in use, and the modern MKH 20 omni-directional microphone has a frequency response extending down to 12Hz. In fact, with a simple modification it can capture sounds as low as 5Hz – the lower limit is actually determined by the largest physical size of capacitor that can be housed within the microphone body.

Character or Accuracy

There are, I suppose, two main philosophies in microphone design. One says that a microphone is like a musical instrument with its own particular sonic character. The other says that a microphone should be like an acoustic window, neither adding nor subtracting anything, and able to reproduce the original sound wavefront exactly. Both of these philosophies have validity, but it is the latter that Sennheiser has sought to achieve with its MKH range of microphones.

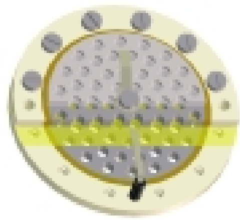


Figure 4. A cutaway drawing of the symmetrical capsule design.

Digital recording is putting more and more demands on the microphone. Often technical deficiencies, which were previously masked by earlier analogue techniques, can now clearly be heard by the listener using even an average hi-fi system. These deficiencies are mostly inherent noise and distortion caused by non-linearities in the microphone.

If your philosophy says that a microphone should have its own character you may be able to live with some of these deficiencies, and even use them to advantage if their effect is pleasing to your ears. However, if you are striving for the perfect acoustic window, anything that alters the sound waveshape has to be eliminated if at all possible.

Capsule Symmetry

As the diaphragm of a condenser microphone moves in relation to the back-plate the acoustic impedance is changing continually. The mechanical impedance increases as the diaphragm moves towards the back-plate, and decreases as it moves away – and this lack of symmetry results in quite a large amount of distortion – see figure 2. This is mainly realised as intermodulation distortion, which may become audible as annoying disharmonic effects.

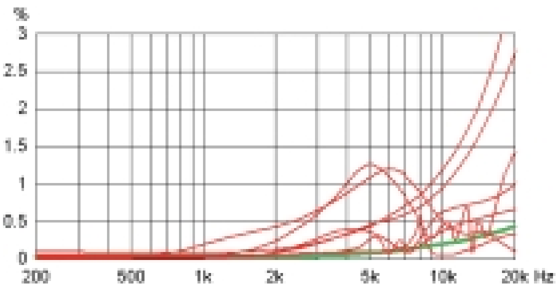


Figure 2. A graph showing the distortion generated by various professional microphones using conventional transducer designs (red curves), and by the MKH 40 with its symmetrical transducer (green curve)

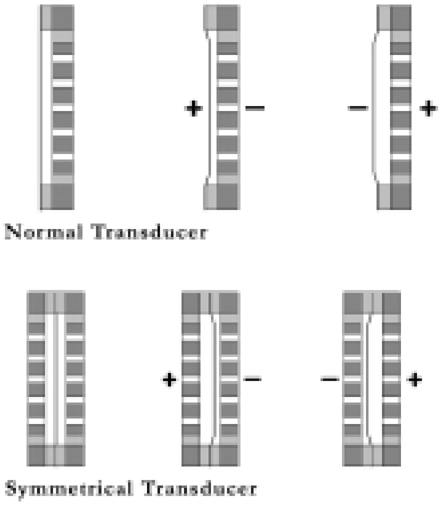
One solution – which, in practice, can only be achieved with RF condenser microphones – is to put a second plate in front of the diaphragm – see figures 3 and 4. This is acoustically transparent, but otherwise electrically identical to the back-plate. This arrangement means that whatever the diaphragm's physical relationship to one plate, it is counteracted by its relationship to the other plate – and the acoustic impedance is thus constant and unchanging. The immediate result is vastly reduced distortion, particularly when relatively large diaphragm movements are incurred, such as when close-miking a sound source.

While the older MKH 416 and 816 gun microphones (and the new MKH 418-S MS-stereo gun mike which was derived from the 416) use very similar RF techniques, they do not share the symmetrical capsule design. However, as these microphones tend to be used at relatively large distances from the sound source and therefore with lower typical sound pressure levels, the transducer distortions tend to be low anyway.

Level Responses

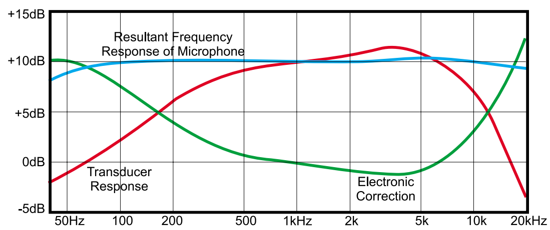
There is also another important design feature of the symmetrical capsule design. The usual method of maintaining a flat frequency response in a condenser microphone is to use resonators and a highly damped diaphragm. The idea is, in effect, to flatten the response by reducing the output level of the microphone to the level of the lowest common denominator.

Figure 3. Conventional and symmetrical transducers



In contrast, the method used in the symmetrical capsule design is to only damp the diaphragm lightly. Simple frequency response correction is then integrated into the microphone electronics to give a remarkably flat frequency response, but with a 6 to 10 dB improvement in the overall signal to noise ratio (see figure 5 and 6).

Figure 5. The natural response of the lightly damped transducer (red), the correction EQ (green), and the resultant (blue).



Inherently, small diaphragm microphones have a higher self-noise figure than large diaphragm microphones, but this construction method enables the relatively small diaphragm symmetrical capsule design to achieve a better noise figure than most current large diaphragm microphones.

Furthermore, as the capsule is untouched by resonators and excessive damping, the designer is also able to achieve a much more accurate polar pattern, and one that is far more consistent over a wide frequency range. The measured polar responses of Sennheiser's symmetrical capsule series of microphones are the closest I have seen to theoretical perfection – of any microphone and by any manufacturer. For example, the figure-of-eight MKH 30 microphone is virtually perfect (see figure 7); and the modest high frequency off-axis attenuation of the omni-directional MKH 20 is due only to the physical size of the microphone body, creating a pressure build-up effect. Even the more difficult pattern of the cardioid MKH 40 is maintained precisely up to 2kHz – the slight off-axis anomalies at high frequencies, again, being due to the microphone body size.

Put it all together – the RF condenser technology with the symmetrical capsule design – and it becomes possible to produce a microphone which has an extremely high immunity to atmospheric moisture, a relatively high output level with very low self-noise, a consistent polar pattern close to the theoretical limits, and a very flat frequency response. In other words the technologies employed in the MKH microphones produce an electrical signal which is as close to the waveshape of the original sound as is currently possible – or, to quote Peter Walker's old 'Quad' slogan: 'the closest approach to the original sound.'

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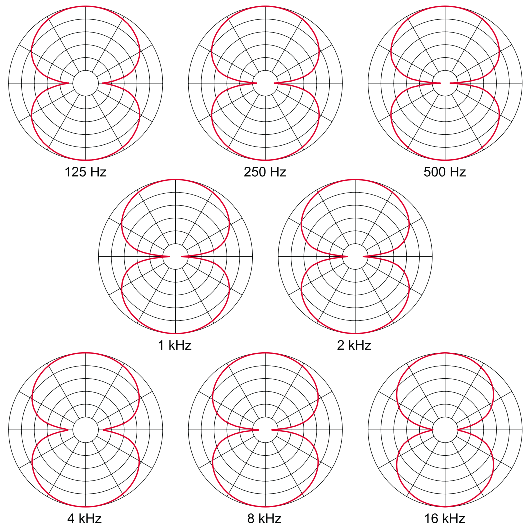

Figure 7.
A set of polar patterns for the MKH30 at different frequencies.

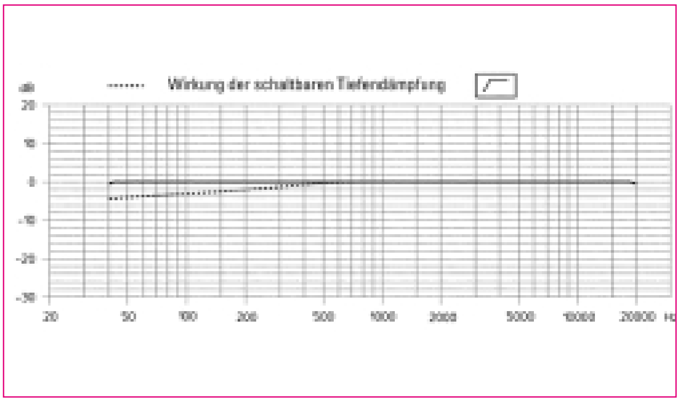

Figure 6.
The ruler-flat frequency response of the MKH 40.