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Hidden Features of Microphones for Drums

by Richard Barnert

No other instrument requires more complex miking techniques than the drum kit does. Low-frequency kick drum beats mix with the wideband spectrum of a splash cymbal or extremely transient rimshots on a punchy sounding snare drum. Obviously, it takes an assortment of different microphones to capture all this variety of drum sounds. So what criteria are really relevant for choosing suitable microphones? Why have some specific microphones become worldwide standards for drums? Do these microphones have "hidden" features that makes them ideal for drums and is there a way to reveal these features?

The Author

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The Objective

Microphones are usually described in such technical terms and “specs” as frequency response, sensitivity, and polar diagram. These characteristics are measured by standard procedures for standard distances between the microphone and sound source, and experienced sound engineers can use this data to get an idea of what a microphone might sound like and how it should work in a specific application. However, there are no standard criteria for assessing real-life recording situations.

Therefore, producers and engineers usually talk about the sonic results in more or less descriptive terms such as “sweet”, “open”, “airy”, “warm”, “silky”, “aggressive”, etc. Although these adjectives may be more meaningful to end users than any technical term, they are nothing but subjective descriptions of the perceived sound. Of course, these descriptions depend to a large extent on other parameters, too, including the peculiarities of the sound source (kick drum, cymbal, snare drum, etc.), the recording environment (studio, concert hall, church, etc.), and last but not least the microphone position.

The Engineering Department of AKG Acoustics conducted a study comparing the sounds and performances of various different microphones in typical recording situations and document the results by measurement data and facts rather than subjective assessments. Using a drum kit is a very good way to reveal the dynamic response of a microphone, i.e., its response to the way the sound spectrum changes over time. These differences in the attack and decay performance go a long way toward shaping the eventual perceived sound but are hardly ever stated in a spec sheet. Therefore, it is all the more interesting to measure microphones under real-life conditions and provide some visual representation of the analyses.
These tests make it obvious that the specifications most manufacturers publish do not adequately describe the performance of a microphone. There must be more, “hidden” features that are important and necessary for describing the sound of a microphone.

So how can these invisible features be revealed?

The Recording Situation

The various instruments of a drum kit (snare drum, toms, cymbals, hi-hat, kick drum) were miked up separately, one after the other. To eliminate any influences of room acoustics, the recordings were made in an anechoic chamber. This allowed us to use a 1/2-inch omnidirectional measurement microphone as a reference for all recordings. The microphones under test were placed as close to one another as possible and the levels equalized. The inevitable distance between the individual transducers may result in small differences in sound. As an important part of our study, we also placed microphones of the same type at different positions to document any position related differences in sound.

Fig. 1: Hi-hat with AKG C 451 B and reference microphone.

Professional drummer Richard Filz (sideman of Bob Berg, Rick Margitza, Bob Mintzer, etc.) played consistent beats that were recorded on a digital eight-track hard-disk recorder. Using a multitrack recorder, we made sure that every microphone would pick up the same source signal, an important prerequisite for meaningful comparative analysis.

Fig. 2: Professional drummer Richard Filz and snare drum in the recording room.

The beats were extracted from the multitrack recording and broken down into separate WAV files for further processing on the computer. A data base was set up to provide access to each individual edited file by the criteria "instrument", "microphone", "position (front/rear, side/center)", "playing technique (hit, roll, rimshot)", and "hit position (center/rim)".

Finally more than 400 edited audio files were available for analysis. The files were analyzed and graphically displayed using an automated computer program. A detailed description of the measurement background was presented at the Tonmeistertagung 2002 [R. Barnert and F. Reining, "The Visible Sound Difference of Microphones", VDT International Audio Convention, Congress Centrum, Hanover, Germany, November 22 through 25, 2002].

The Analysis

The focus of the study was the change in the spectrum as a function of time, which can be calculated from the Fourier transform of the recorded time signal. This kind of plot is generally known as a "waterfall diagram". The waterfall diagram shows very clearly whether the amplitude responses of individual frequency bands present any peculiarities, or whether the attack and decay of some frequency bands are longer or shorter than those of others.

These differences may result from a variety of causes including the playing technique, instrument, microphone position, or, finally, the response of the microphone. For the rest of the study, the waterfall diagram was the preferred method of representing the measured data. Although a "normal" spec sheet would never reveal the effects shown here, they do exist and make an essential contribution to the sound of a recording.

Basically, these phenomena are easy to explain. They are caused by mechanical/acoustic resonances originating from cavities sealed by acoustic resistors inside the microphone capsule. These cavities are inherent parts of every microphone and act as resonators. They do not only affect the amplitudes of specific frequency bands, they also have the side effect of potentially causing marked attack and decay processes. This is governed by the law that the smaller the bandwidth is in the frequency domain, the greater will be the influence in the time domain and vice versa.

The diaphragm of every dynamic microphone has a marked resonance that is dampened by cavities and added masses so that the frequency response will be nearly flat. This does not mean, however, that the resonance has disappeared. The waterfall diagram mercilessly shows that it is still there. We should not conclude, though, that these features are necessarily "bad" for every application.

Many live-sound engineers appreciate the limited-bandwidth, "fat" sound of a dynamic transducer on a snare drum and the slight distortion at high sound pressure levels caused by the voice coil leaving the linear range of the magnetic field. It is not without reason that they prefer dynamic microphones for miking up percussion instruments on stage. Studio recording presents a different situation. Most engineers strive for "authentic" reproduction and therefore tend to prefer condenser microphones. These have diaphragms with extremely low mass so they cover wider frequency bands and respond much faster to transients. These features necessarily make them more expensive.

Designers of condenser microphones also use acoustic resonators, usually Helmholtz resonators, to shape the frequency response of their microphones. However, the effects of these resonators are much less obvious in condenser microphones than they are in their dynamic counterparts. Of course, the acoustic design of these resonators is an important factor in determining the time-domain performance and thus the sound of a microphone. But as we have seen earlier, the resulting sound will not necessarily be "good" or "bad". It is up to the tonmeister to use the microphone's features in the best possible way and turn what looks like a shortcoming into a benefit for a specific application.

The Theory

Here is a summary of the engineering background. Like any man-made transmission system, a microphone can be described by its transfer function H(f).

$$\underline{H}_{(f)} = \frac{Output}{Input}$$

The complex transfer coefficient g is equivalent to the negative logarithm of the transfer function

$$\underline{g} = -\ln H = a + jb$$

where a is the attenuation and b the phase of the transfer function. Any system can be broken down into the product of a so-called minimum-phase system with an allpass filter. Minimum-phase systems are characterized by a defined relationship between attenuation and phase, whereas an allpass filter will cause no attenuation but only a phase shift (theoretically, of any desired angle). The delay of a signal is characterized by the so-called group delay t_G.

$$t_G = \partial b / \partial \omega$$

where ω is the complex angular frequency $2\pi f$. If the attenuation coefficient is known, it is easy to calculate the group delay for a minimum-phase system. In the case of a minimum-phase microphone, this would mean that the time-domain performance of the microphone would be completely characterized by its frequency response. A minimum-phase microphone would take longer to cease vibrating at any frequency where its frequency response has a peak.

This does not happen, though, because most microphones cannot be minimum-phase systems due to their very design. It is therefore reasonable to assume that an analysis of the waterfall diagrams should reveal some surprising performance features in the time domain that simply cannot be guessed from the frequency response.

The Results

To keep the length of this article within reasonable limits, we decided to present a selective summary of the results of our study in the following sections.

The snare drum
The snare drum is probably the most complex instrument of the entire drum kit. It can be played in many different ways, with the snares on or off, with the damper on or off, in various techniques such as hit, roll, or rimshot, using brushes, sticks, or mallets. Similarly, there are many different ways of miking up a snare drum, delivering different audio results for different playing techniques. The sound can be picked up from above or below, from close-in or far away, at various angles to the skin, with the microphone pointing at the rim or the center of the skin.

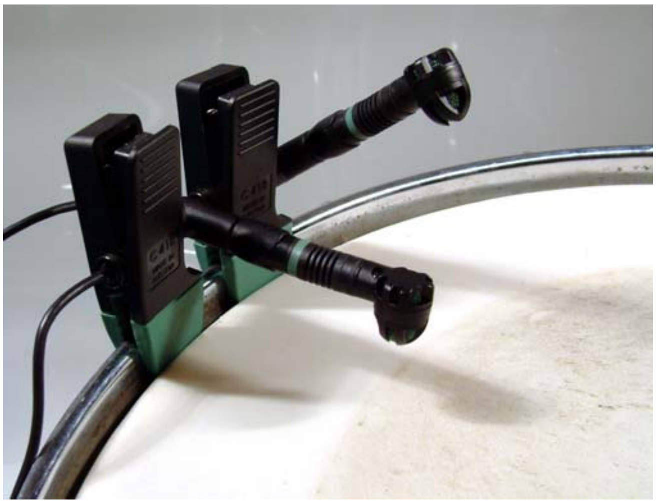

Fig. 3: AKG C 418 in two different alignments.

A comparison between front and rear skin miking was interesting, too. Figs. 4 and 5 show the waterfall diagrams of the AKG D 440 dynamic microphone and the AKG C 451 B condenser microphone for a stick hit. Note the marked front skin resonance around 600 Hz as compared to the much wider spectrum and generally shorter decay of the rear recording.

The diagrams also show that the spectrum of the C 451 B condenser microphone is much wider that that of the dynamic D 440 and, since the C 451 B emphasizes the high frequency range, extends to the highest audible frequencies. The D 440 has a presence peak at approx. 3 kHz and the diagrams clearly show up the longer decay times for several frequency groups. There is also a marked difference in sound between condenser and dynamic microphones when the snare drum is played with brushes. Although we found hardly any differences in time-domain performance, condenser microphones with their smoother frequency responses revealed much more sonic details than their electrodynamic counterparts. Therefore, using a condenser microphone on the snare drum is almost a must for any jazz drummer.

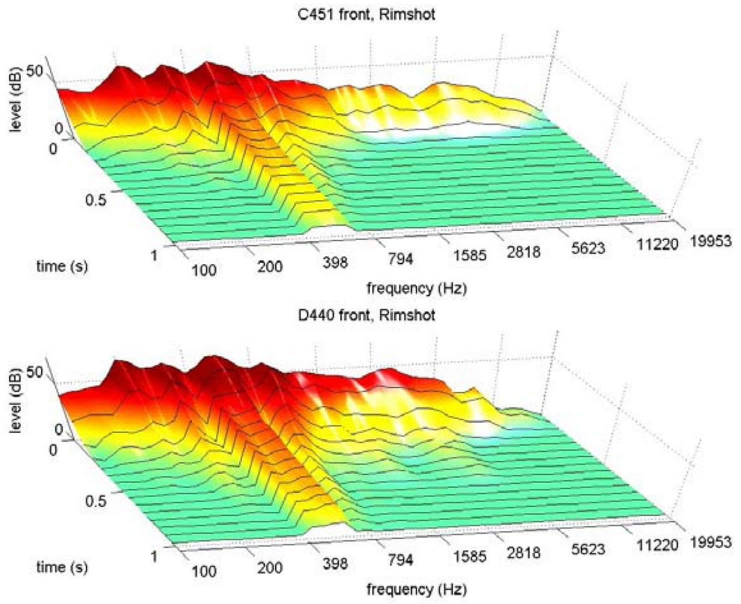

Fig. 4: AKG C 451 and D 440, snare drum rimshot miked up from the front.

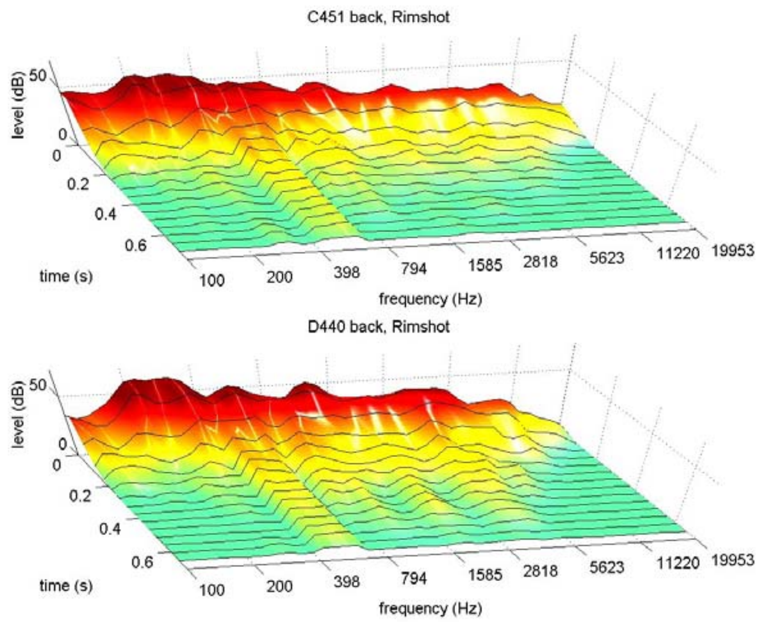

Fig. 5: AKG C 451 and D 440, snare drum rimshot miked up from the rear.

The kick drum

For lack of space, the kick drum microphones were only place to the side of the sound hole, although many engineers place a microphone inside the shell. We used AKG C 414, AKG D 112, and AKG D 550 microphones. In the listening test, the C 414 sounded the most similar to the reference microphone and its waterfall diagram shows no appreciable deviations from the reference recording, either. The D 112 has a slight rise at 2 kHz that adds a characteristic sense of presence to the microphone sound without causing the kind of ringing typical of resonators. The D 550, although it delivers a little less high-frequency content than the reference microphone, has a very short decay phase that gives the microphone a definitely powerful sound. The D 550 certainly does not sound "realistic", but this is exactly why it does such an excellent job on the kick drum.

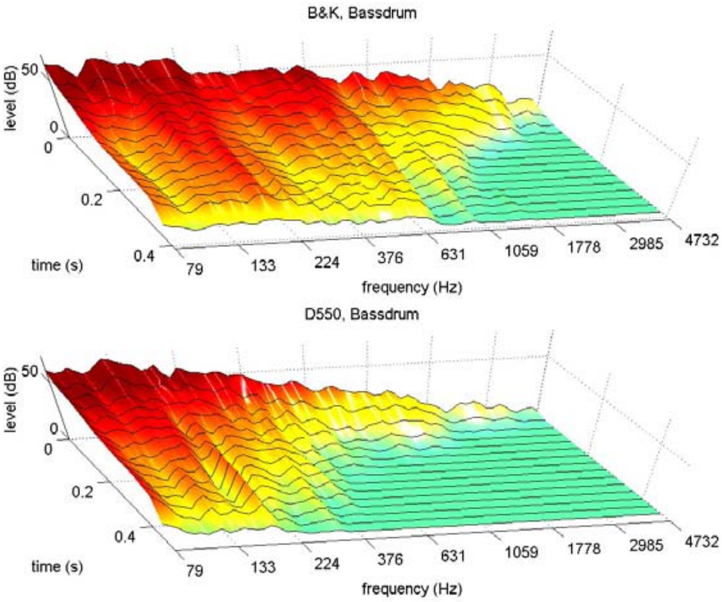

Fig. 6: AKG D 550 on a kick drum.

Hi-hat and cymbals

For the hi-hat and cymbals, we compared AKG C 451 B, AKG C 430, AKG C 414 B-ULS, and AKG C 391 B microphones, placing them in an overhead position. We used no dynamic microphones here. Again, there are various ways of playing and miking the hi-hat and cymbals. As an example of the results obtained, we will present a splash cymbal hit hard on its rim.

This type of cymbal requires a microphone with excellent resolution in the high-frequency range. All candidates gave very similar results, although their responses again differed from that of the reference microphone, mainly in the high-frequency range. All the more remarkably, the waterfall diagrams for the C 451 B and the reference microphone were almost identical. The double-blind listening test, too, revealed no difference. This is interesting mainly because the specifications of the AKG C 451 B differ widely from those of the reference microphone. Nevertheless, these two microphones sounded almost the same (in this application).

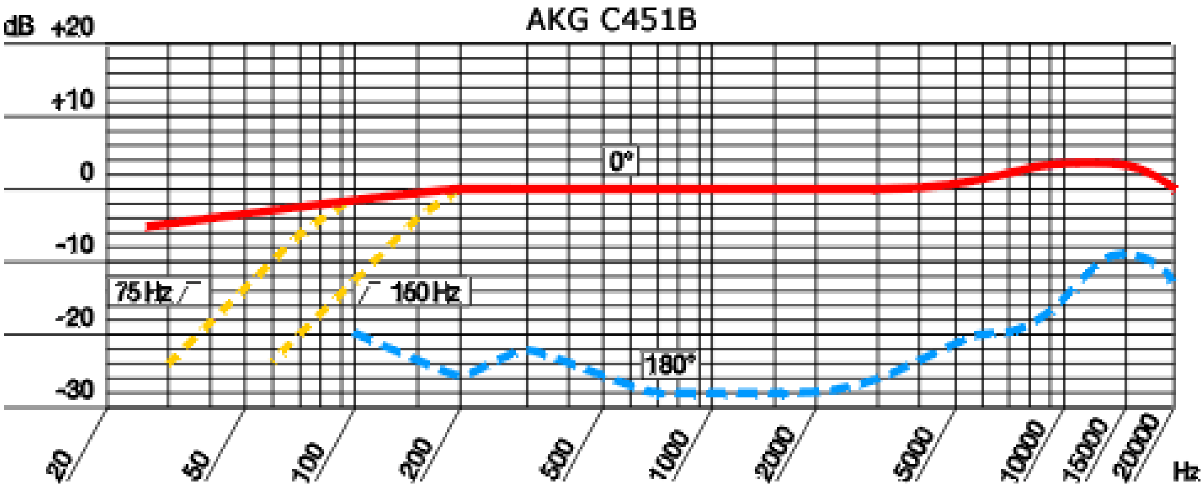

Fig. 7: AKG C 451 B frequency response.

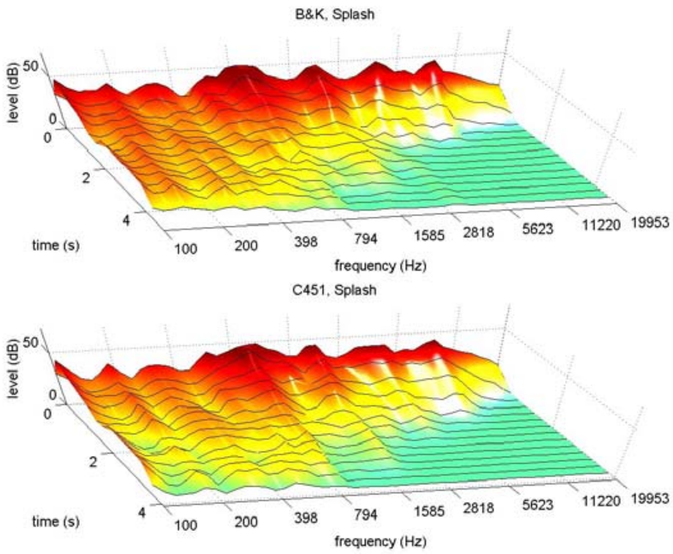

Fig. 8: Splash cymbal.

Conclusion

The published specifications of a microphone do not provide a full picture of its sound and performance. To reveal its actual qualities, we should test the microphone under real-life conditions. It might be a good idea for sound engineers to make this kind of analysis before a recording session because reflections and resonances that affect the sound are not usually revealed by the specified frequency response of a microphone.

Although time-domain performance makes one of the most important contributions to the overall perceived sound, it is not mentioned in the specification sheets of most microphones. Plotting a recorded sound as a waterfall diagram can provide very useful insights. The diagram also reveals the peculiarities of specific instrument miking techniques so that corrections can be made if required. □