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The effect of hand position on handheld microphones' frequency response and directivity

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ABSTRACT

When performing microphone measurements, all obstacles that may disturb the sound field around the microphone are removed. The microphone may even be suspended by thin wires to ensure that the influence of a mic stand is avoided. In real life, some microphones are managed somewhat differently, handheld microphones in particular. Some artists even prefer to cover most of the microphone grid with their hand ("cupping"). This habit affects the performance of the microphone. This paper presents measurements of the influence of five different hand positions on handheld vocal microphones. Both frequency response and directivity are measured.

1 Introduction

Microphones, as such, are nothing but transducers transforming acoustical energy into an electrical signal. However, the many applications for microphones have led to hundreds of brands and thousands of types and models. "*The*" microphone does not exist.

A way to distinguish between the types and models is to study the specifications provided with the microphones. To that end, standards exist [1] that, if followed, result in comparable data. In general, manufacturers do their utmost to get the cleanest results when microphone measurements are carried out in the lab: All obstacles that may disturb the sound field around the microphone are removed. This is the practice for the acquirement of most common microphone data like the directional characteristics and frequency responses. The microphone may even be suspended from thin wires to ensure that any influence of a microphone stand is avoided. Furthermore, the microphones' directional pattern may be determined at a distance different from typical use. For instance, manufacturers may measure handheld microphones at a distance of 1-2 meters because it is important to suppress distant secondary sources as much as possible. Hence, it is important to know what the directional pattern looks like at a distance.

The documentation obtained in the lab is, of course, fine for studio microphones intended for orchestral recordings in concert halls, large studios, and similar spaces. For those applications, the microphones are placed in a – more or less – undisturbed sound field.

Nevertheless, the influence from obstacles close to the microphone has extremely high importance in practical audio engineering. If the tonal balance of the sound is affected, corrections must be made to make it sound right. Engineers know that when using, for instance, body-worn lavalier microphones, the physical placement of a microphone is to a high degree responsible for the tonal balance of the recorded sound [2], [3], [4], [5].

When it comes to handheld microphones, there are different ways to hold them. You can hold around the handle (hence the name "handle"), or you can grab it around the grid – or any position in between. However, the hand is not the only influencing obstacle; also, the singer's head and mouth are very close to the microphone. Both hands and heads affect the sound field. The specific microphone design, in combination with the way the microphone is handled, determines how much the sound of that microphone is influenced. Most engineers in live audio are aware of this phenomenon; however, they may not know how much this influence is.

In [8] and [9], Martin Schneider have done extensive work applying both artificial and real hands on vocal microphones and placing an artificial head (with and without caps and hats) in close proximity to vocal microphones. In addition, the effect of an open/-closed mouth has been investigated. The results show serious changes to the resulting frequency response and the directivity of the microphones.

This paper is partly a repetition of Schneider's work. However, the task here is to get somewhat closer to real-life by involving real head, torso and hands. In addition, the human voice (spoken voice) is applied as the sound source for experiments 1 and 4.

2 Experiment 1

2.1 On-axis frequency deviation

The first experiment was to verify to what extent the frequency response of a person's voice would be affected by the hand's position when holding a vocal microphone.

In other similar earlier works, [3], [4], [5], [6], [7], the authors analyzed LTASS (Long Time Average Speech Spectrum) of speech simultaneously recorded on two tracks, one track for the microphone/voice signal in question and the other track for an unaffected reference. The resolution of the analysis would be 1/3-octave bands. By subtraction, the differences between the two different microphone pick-ups were found.

In the first experiment described in this paper, it was decided to try to improve the frequency resolution of the measurements. Two identical vocal microphones were recorded simultaneously, one on a stand (reference) and one handheld (MUT, Microphone Under Test). The signals were played back and analyzed using transfer function (see figure 1).

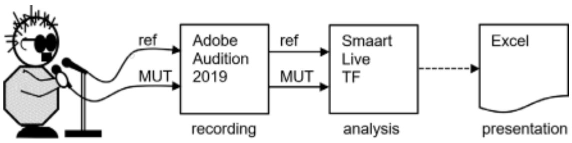


Figure 1. The setup for experiment 1 (and 4).

The recordings took place in an acoustically well-controlled studio. Three (male) subjects participated in the experiment. Each would speak for at least one minute for each hand position, keeping a mouth-to-microphone distance of 10-12 cm.

Figure 2. Two identical microphones 10-12 cm from the mouth of the subject. One microphone (mounted in a holder) is the reference, and the other is held in five different ways.

Five different hand positions were applied:

Position 1: Holding the microphone at the end of the handle. (See figure 4a).
Position 2: Holding the microphone at the top of the handle, just beneath the mic head. (See figure 5a).
Position 3: Cupping with the index finger and the thumb flush with the front of the microphone. (See figure 6a).
Position 4: The hand covers half the grid, and the thumb is laid over the top. (See figure 7a).
Position 5: The hand surrounds the microphone head, creating a small cavity in front of the grille. (See figure 8a).

Each subject was recorded twice, one recording for each hand, thus providing six recordings for the analysis of each style of hand position.

2.2 Analysis

The following setup was applied for the analysis:

Microphones: DPA, model "A", super-cardioid.
Preamp: Sound Devices USBPre2 + Laptop.
Recording software: Adobe Audition 2019.
Sampling: 48 kHz/24 bit.
Analysis: Smaart Live v8, Transfer Function
FFT: MTW (Multi-Time Window).
Curve smoothing 1/3 octave.

By applying the technique of transfer-function, the signals were automatically time-aligned (not strongly needed, as the recording distances were identical). However, the coherence function provided a nice indication of the valid frequency range of the sound source (human speech).

2.3 Results

Position 1 and 2
The results are found in Figures 4b-8b. A flat curve tells that the signal is not affected at all. This is the case for hand positions 1 and 2. However, higher frequencies above 8 kHz are slightly reduced (Figures 4b and 5b).

Position 3
Cupping the microphone (hand position 3, figure 6b) results in a frequency-dependent lift in the frequency response in the form of a major resonance.

An indication of the resonances is calculated from the averaged data: f_c = 1528 Hz, bandwidth = 725 Hz, Q = 2.1. Gain (re 200 Hz): 5.8 dB, std: 1.3 dB.

The secondary resonance is found approximately one octave above the first. However, this resonance is not as strong as the primary.

Position 4
This position (fig 7b) also generates a frequency-dependent lift, but with a lower Q. Across six hands the individual peaking frequencies are in the range of 1798-2106 Hz.

Calculated from the averaged data the resonance is indicated to be: f_c = 1893 Hz, bandwidth = 1818 Hz, Q = 1.0. Gain (re 200 Hz): 4.1 dB, std: 1.5 dB.

Position 5
This position (figure 8b) creates two strong resonances and a dip in between.

Resonance 1: f_c = 1424 Hz, bandwidth = 816 Hz, Q = 1.8. Gain (re 200 Hz): 3.8 dB, std: 1.6 dB.

Resonance 2: f_c = 3093 Hz, bandwidth = 1654 Hz, Q = 1.9, gain (re 200 Hz): 2.3 dB, std: 0.5 dB.

The analyses show that holding around the microphone head affects the frequency response of the primary on-axis sound source.

3 Experiment 2

3.1 Directionality/off-axis frequency response

A vocal microphone should not only support the artist in front of it, but it also should suppress distant sound sources on a stage, i.e., musical instruments, the sound from the PA-system, etc. Further, the response should not invite acoustical feedback.

In the next experiment, the off-axis frequency response was measured while holding the microphone in the sound field.

A point source loudspeaker (Genelec 8341A SAM™) was used as the sound source. The signal was pink noise, and the distance between the loud-speaker and the microphone was 1 m. Again, a two-

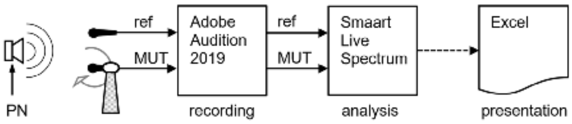


Figure 3. The setup for experiment 2 (and 3).

track recording was made with a reference microphone pointing directly at the source.

The microphone measured was held in a stretched arm perpendicular to the sound field. All five hand positions were applied. However, this time only one subject participated, and only the left hand was used for holding the microphone (see figure 3).

Normally, a microphone with the form factor of a vocal microphone has a symmetrical behavior.

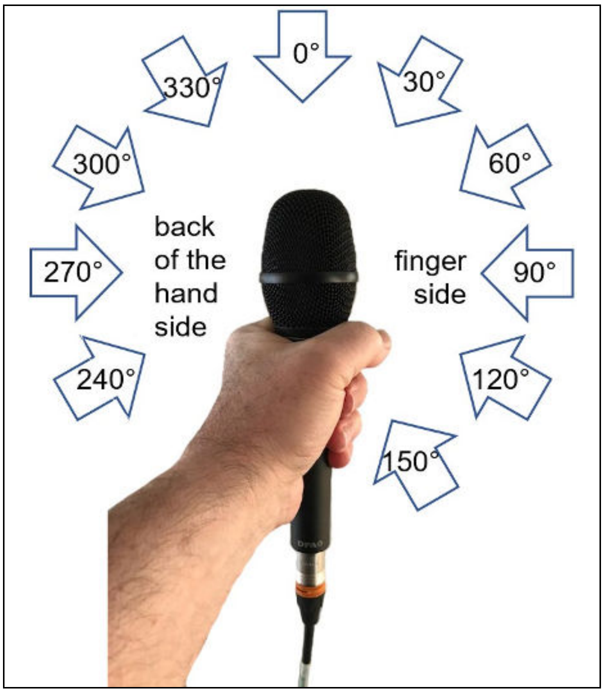


Figure 3. Directions measured. Normally symmetrical results are obtained. However, the hand is not "symmetrical." Here, one side is called the "finger side," and the other is called "back of the hand side".

However, in this situation, adding one hand on the microphone, one cannot be certain whether the symmetry persists. Hence, the measurements were carried out in a full circle.

The responses were measured every 30 degrees. Figure 2 explains the angle of sound incidence. One side is denominated the "finger side" and the other side is the "back of the hand side".

To keep the microphone in the right angle, some aiming lines were arranged at a sufficient distance, not disrupting the sound field.

3.2 Analysis

The analysis was carried out in the same way as described in 2.2.

However, this time the 0-degree response was applied for normalizing all other responses.

3.3 Results

The results are found in figures 3cd - 7cd.

Position 1
The response is nicely symmetric, and the angle-based attenuation is rather constant with frequency.

Position 2
Now the attenuation is not completely symmetric. However, the deviation is at a minimum.

Position 3
The directionality has changed. It shows that the resonance around 1500 Hz seems to be stronger at 30, 60, and 90 degrees than it is on-axis, but only on the "finger side."

Position 4
Asymmetrical behavior. At lower frequencies, the effect of the hand is mostly seen on the "back of hand" side.

Position 5
Now the resonance is affecting both sides of the microphone making it more or less omnidirectional in this frequency range.

a
Hand-position 1.

b
On-axis frequency deviation.

c
Frequency response 0-180 deg. Finger side.

d
Frequency response 180-360 deg. Back of the hand side.

e
Polar plot 1 octave.

16 kHz
8 kHz
4 kHz
2 kHz
1 kHz
500 Hz
250 Hz
125 Hz

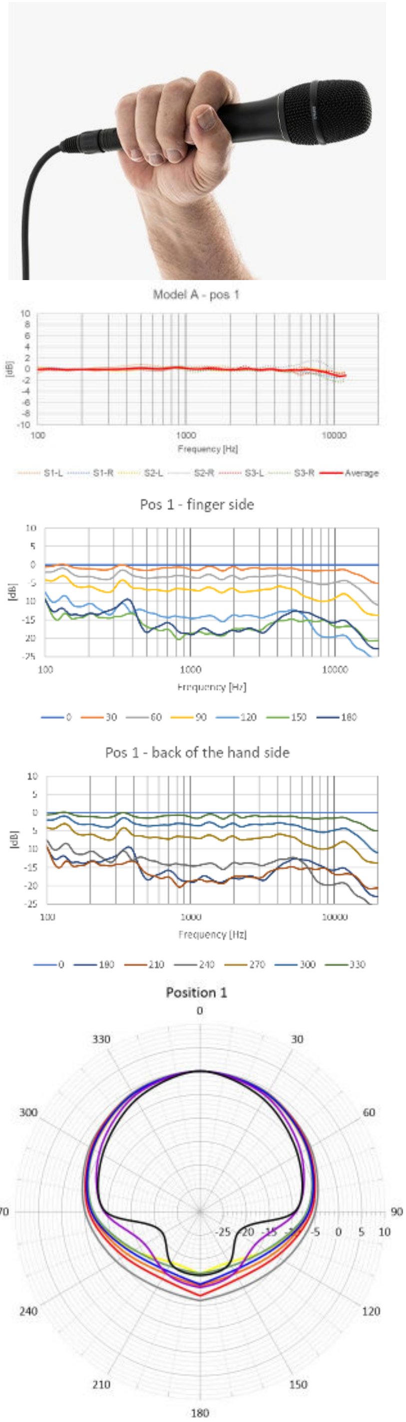


Figure 4. Hand position 1 - Upper curve: Influence on frequency response. Mid curves: Off-axis frequency response. Bottom curve: Polar plot.

a
Hand-position 2.

b
On-axis frequency deviation.

c
Frequency response 0-180 deg. Finger side.

d
Frequency response 180-360 deg. Back of the hand side.

e
Polar plot 1 octave.

16 kHz
8 kHz
4 kHz
2 kHz
1 kHz
500 Hz
250 Hz
125 Hz

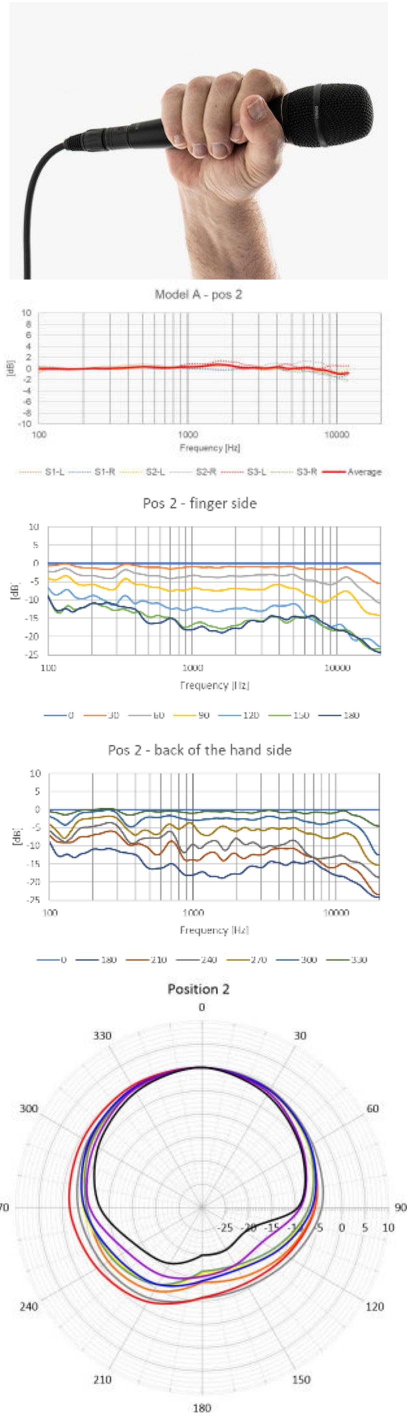
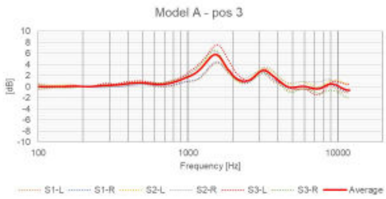


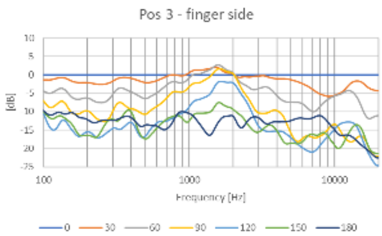
Figure 5. Hand position 2 - Upper curve: Influence on frequency response. Mid curves: Off-axis frequency response. Bottom curve: Polar plot.

a
Hand-position 3.

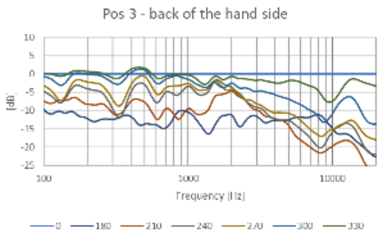
b
On-axis frequency deviation.



c
Frequency response 0-180 deg. Finger side.



d
Frequency response 180-360 deg. Back of the hand side.



e
Polar plot 1 octave.

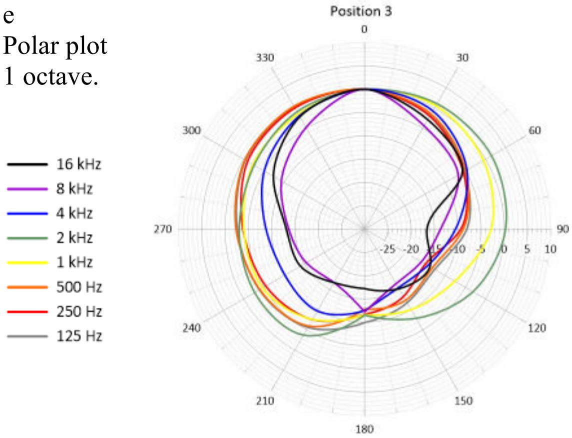
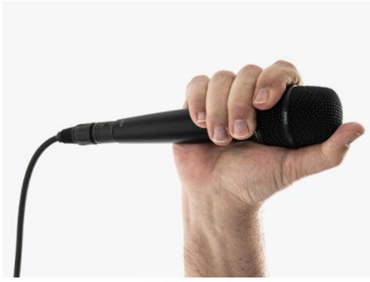
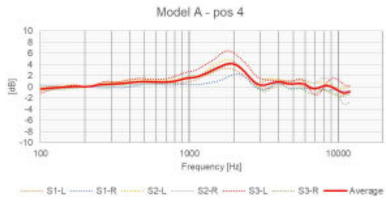


Figure 6. Hand position 3 - Upper curve: Influence on frequency response. Mid curves: Off-axis frequency response. Bottom curve: Polar plot.

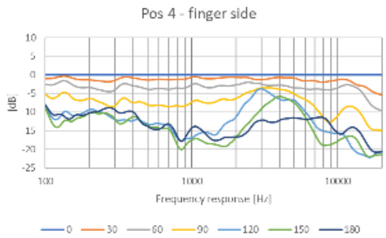
a
Hand-position 4.



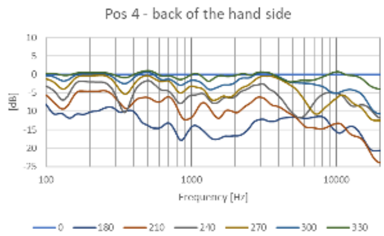
b
On-axis frequency deviation.



c
Frequency response 0-180 deg. Finger side.



d
Frequency response 180-360 deg. Back of the hand side.



e
Polar plot 1 octave.

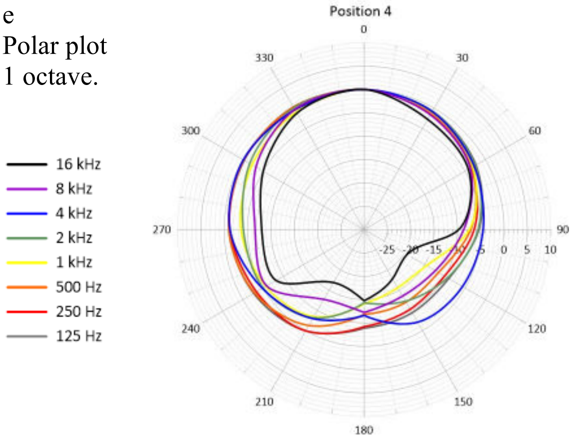
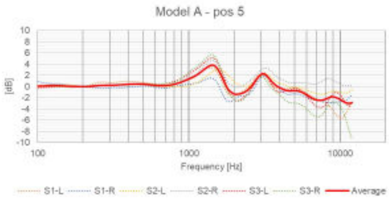


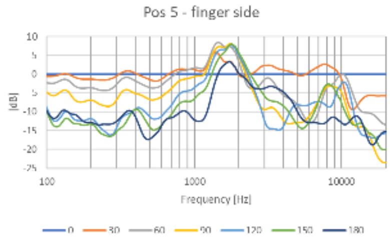
Figure 7. Hand position 4 - Upper curve: Influence on frequency response. Mid curves: Off-axis frequency response. Bottom curve: Polar plot.

a
Hand-position 5.

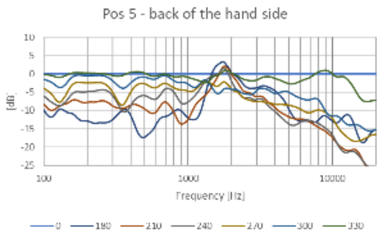
b
On-axis frequency deviation.



c
Frequency response 0-180 deg. Finger side.



d
Frequency response 180-360 deg. Back of the hand side.



e
Polar plot 1 octave.

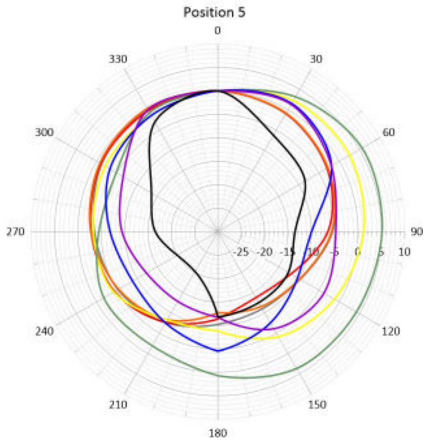


Figure 8. Hand position 5 - Upper curve: Influence on frequency response. Mid curves: Off-axis frequency response. Bottom curve: Polar plot.

4 Experiment 3

4.1 Directionality, polar plots

The shape of the polar plot is most often used to describe the directionality of a microphone. This is the reason for describing microphones by names like cardioid, figure of eight, etc.

4.2 Analysis

As it would be interesting to see the impact of the holding hand on the polar plots, all the pink noise signals recorded by the handheld microphone were analyzed as simple octave band levels vs. angle of incidence. The polar plot is always normalized at 0 degrees. As measurements were taken each 30 degrees, spline smoothing is applied to the plots covering the octave bands from 125 Hz to 16 kHz.

4.3 Results

The results are found in figure 4e-8e. Due to the spline function, some details may get lost; however, the plots provide a good indication of the influence from the hand.

Position 1
The plots are symmetrical. However, it is difficult to see the characteristics of a super-cardioid (some of this presumable due to the 30-degree resolution).

Position 2
On the "back of the hand side" the low-frequency directivity is reduced.

Position 3
Due to the effect of the resonance, the directivity at 1-2 kHz is reduced.

Position 4
As in position 2, the low-frequency directivity is reduced.

Position 5
Reduced directivity on the "finger side" at the 1-2 kHz octave bands. Actually, the sensitivity now is higher here compared to on-axis sensitivity.
Also, from these measurements, it is evident that cupping – or even just approaching the microphone grid – affects the properties of the microphone.

5 Experiment 4

5.1 Comparing microphone models

After analyzing the influence of the hand on the same model vocal microphone, it would be interesting to see whether the phenomenon only exists on this particular microphone or other models also would be affected.

It was decided first to compare with DPA model "B" as it has a slightly smaller protection grid (8.2 cm^3) compared to the model A (10.6 cm^3). However, it also would be interesting to find out whether other brands exhibited behavior like the model A.

Hence, experiment 1 was repeated, now including DPA model B. Further, three non-DPA, professional condenser vocal microphones as well as one professional dynamic vocal microphone were measured.

5.2 Analysis

The analyses were carried out as described for experiment 1. In this experiment (the same), three subjects participated using both left and right hand.

5.3 Results

The results are found in figure 9. All hand positions were measured. However, only the results of hand position 3 are presented here, as each group of measurements exhibits almost identical behavior.

The conclusion is that the frequency responses of all the measured microphones are affected by the hand's position. Surprisingly enough, the resonances are found to be quite similar, although the Q of the dynamic microphone's resonance is slightly lower.

In table 1, the characteristics of the lowest resonance are listed. It shows that the model B exhibits a slightly higher resonance frequency compared to the model A. This corresponds partly to the fact that the cavity of model B is slightly smaller. The secondary resonance differs from microphone to microphone, and the same is seen for the third resonance around 8-10 kHz.

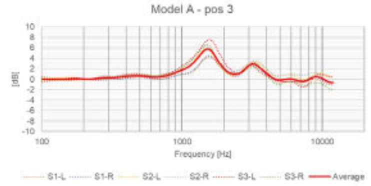
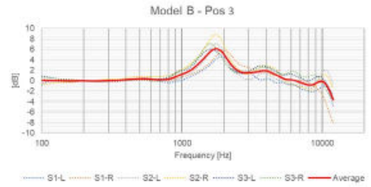
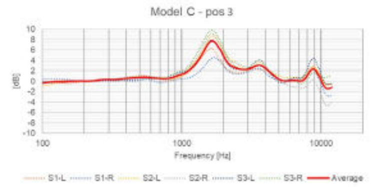
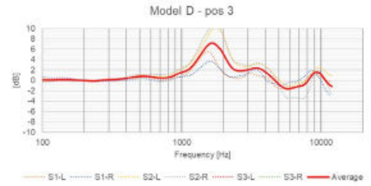
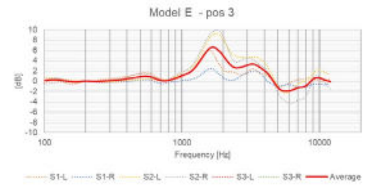
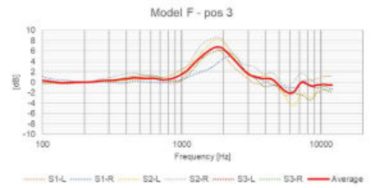
Position 3	
Model A Condenser Super-cardioid	
Model B Condenser Super-cardioid	
Model C Condenser Super-cardioid	
Model D Condenser Cardioid	
Model E Condenser Super-cardioid	
Model F Dynamic Cardioid	

Figure 9. Comparing professional vocal microphones. Hand position 3 - Model A to model E are condenser microphones, and model F is a widely used dynamic microphone.

Mic	f_c [Hz]	bw [Hz]	Q	gain [dB]	std [dB]
Model A	1528	725	2.1	5.8	1.3
Model B	1752	909	1.9	6.1	1.7
Model C	1656	623	2.7	7.7	2.0
Model D	1648	768	2.1	7.2	3.4
Model E	1680	824	2.0	6.6	3.4
Model F	1848	1373	1.3	6.2	2.0

Table 1. Hand position 3, cupping: characteristics of the frequency lift caused by the resonance of six different professional vocal microphones based on averaged measurement across the subjects.

The latter could be related to the cavity of the microphone condenser capsules. The attenuation around 5-7 kHz also has some minor variations.

6 Discussion

Measuring microphones is a very delicate work that needs high precision. The measurements made in connection with this work perhaps lacks some of this precision. However, these measurements represent the way microphones are used in daily life.

There are still topics to investigate, for instance, to which degree the damping of the cavity behind the grille has an influence. The empty volume of the microphone heads has not been measured. At this point, it is not possible to predict the effect of cupping and the like - other than what the measurements have shown.

7 Conclusions

The effect of hand position on handheld microphones' frequency response and directivity has been measured.

The on-axis deviation was measured using humans as the sound source and the subjects' hands on the microphone.

The directivity measurements were carried out using pink noise reproduced by a loudspeaker but a human hand on the microphone.

Only when holding close to the end of the microphone's handle, the hand's effect is negligible.

Any degree of cupping the microphone leads to a frequency lift of in the range of 1.5-1.9 kHz of up to 10 dB. Secondary resonances occur in some situations.

At the major resonance, the directionality of the microphones is reduced leading to the risk of acoustical feedback in connection with PA-systems.

A dynamic vocal microphone exhibited a resonance with a slightly lower Q but approximately the same gain, compared to the condenser microphones.

(As a side-effect, the frequency lift that occurs when cupping the microphone may enhance speech intelligibility in situations where there is no risk of acoustical feed-back).

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