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Vibration-generated output in pro-audio microphones

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ABSTRACT

A microphone is a transducer designed to convert sound into an electrical signal (analog or digital). However, microphones are sensitive not only to acoustic sound but also to mechanical vibrations. This includes microphones for use in professional audio. This paper presents the measurement and analysis of vibration-generated output for four groups of pro-audio microphones. The equivalent SPL per m/s² may reach more than 120 dB SPL. It is suggested that microphones' sensitivity to vibrations should be included in the spec sheets.

1 Introduction

When checking whether a microphone is active, it is common to tap with a finger on the grid. Usually, a sound is clearly heard in the PA system if the microphone is on. However, this is seldom the sound of the finger hitting the grid. This sound is generated due to the vibration of the housing.

A microphone's diaphragm is designed to move only when the air around it vibrates, which is usually the case when keeping the microphone in a fixed position (see Figure 1A).

However, without a sound field, the diaphragm is relatively reluctant to move due to mass, air resistance, and mechanical compliance; if the housing moves more than the diaphragm, this also generates an output (see Figure 1B).

This phenomenon would not be a problem if microphone housings were never vibrated. But microphones are often mounted directly on drum kits, mic stands placed on vibrating risers or floors excited by subwoofers, musical instruments, FOH rigs, etc.

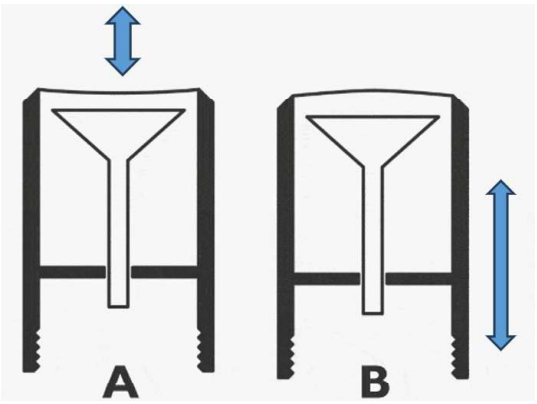


Figure 1. A: Output signal is produced if the diaphragm is moved by a sound wave – and B: output signal is produced if the microphone housing is displaced by vibrations.

The mix of acoustical sounds and mechanical vibrations can create undesirable effects, such as low-frequency feedback, partial timbre shifts of musical instruments, and metallic sounds.

Based on the author's measurements, a drumkit's vibration levels (acceleration, transients) may easily exceed 100 m/s^2, with the worst case being a rimshot on a snare drum. Even stepping on the leg of a mike stand reaches >10 m/s^2 if no shock mount is applied.

This paper presents the results of measurements that quantify microphones' sensitivity to vibration. The intention is to provide a survey that can demonstrate the behavior of a selection of available pro audio microphone types. The literature related to vibration-induced audio in pro audio microphones is very limited. Most published research is related to measurement microphones [1-2], microphones for hearing aids, and/or MEMS microphones [3-6]. Some research papers and application notes related to accessories reducing microphone vibrations (shock mounts) [7-11].

It is the intention that this survey can provide input/ ideas for developing a mathematical model that can take the many coupled parameters into consideration, related to diaphragm/capsule housing, capsule/micro-phone body (internal suspension), microphone/clip, clip/stand and perhaps more.

Despite the limited literature, microphones' sensitivity to vibration is a topic for standardization: IEC 60268-4 Microphones, paragraph 19.2: "Equivalent sound pressure due to mechanical vibration." [12] This standard applies to microphone specifications. Nevertheless, this particular information is almost never found in any pro audio microphone spec sheet.

2 IEC 60268-4 Microphones

In this standard, the following is stated regarding the definition of the characteristic to be specified:

"*For a mechanical vibration, specified by the RMS value of the acceleration, frequency, and direction, the equivalent sound pressure due to the vibration, in the absence of a sound field. The equivalent sound pressure shall be stated for the direction of the vibration for which maximum occurs. The directions for both maximum and minimum influence shall be stated.*

The equivalent sound pressure may be stated for vibrations at specified frequencies or within a specified frequency band having the reference frequency as the geometric mean frequency.

If linear relations exist, the equivalent sound pressure may be specified as a transmission factor relating the equivalent sound pressure and the acceleration."

This standard does not apply frequency weighting except for the band-limiting results (such as third-octave band measurement or the like). In practice, knowing the frequency and direction of excitation at which the maximum equivalent SPL occurs is good information, as it is almost always around a resonance frequency. A single-number weighted level (A or CCIR) might be informative but less relevant compared to resonance "mapping."

The standard does not mention the practical problems of excluding resonances in the measurement setup or precautions regarding cabling/connectors, which influence factors such as mass and damping.

3 Setup for reported measurements

The exciter setup must be able to vibrate the microphone without making any acoustic sound that affects the measurement. The setup for the reported test was a shaker B&K 4808 with an amplifier B&K 2712.

Each microphone was kept in its position by the microphone's specified type of holder/clip.

The holder was mounted on a short stand extension and a rigid aluminum rod to make it possible to position the microphones at different angles in their respective native holders/clips and attach a cable.

An accelerometer NTI Audio A4580 was mounted on the base of the rod to measure the actual exciting force.

A cable relief was used to minimize the influence of the attached cable. However, though, a standard XLR cable was attached, as this is the case during normal use.

The signal source for the amplifier was an NTI-Audio Minirator MR-Pro. The signal would either be pink noise for the general TF measurement or a sine wave for resonance quantification.

The microphone output, as well as the accelerometer output, were connected to a SoundDevices USBPre 2 Soundcard. The microphone channel was calibrated using the tone generator.

The accelerometer channel was calibrated using a Lantek VMC 606 accelerometer calibrator: 159.2 Hz, 14.14 m/s^2 peak.

The tested microphones' sensitivity to sound was measured in advance.

The transfer function was analyzed (Smaart Live 8/9), and the signals were recorded.



Figure 2. Setup for testing vibration-generated output from microphones. Each microphone is mounted in the clip/holder that follows the product. The measurement results are expressed by the transfer function.

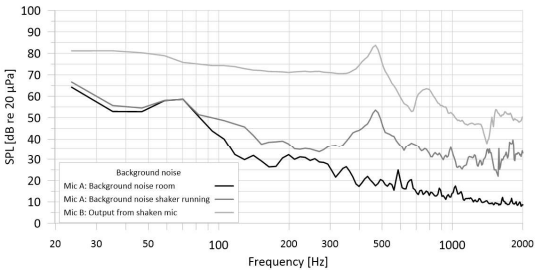


Figure 3. The background noise of the setup. Two identical (omnidirectional measurement) microphones are used. One microphone, A, is placed right next to the microphone under test, B, (distance of 1 cm), which is mounted on the shaker.

The lowest curve shows the FFT spectrum of the room's background noise (mic A) while the shaker is off. The midcurve shows the background noise when the shaker is turned on (mic A). The upper curve shows the output of the microphone under test (mic B) while shaken.



Figure 4. Three directions of excitation: 0° (on-axis), 45°, and 90°.

The recordings were made via Adobe Audition. The absolute sensitivity at the major resonance was determined from recorded (steady-state RMS) output signals at that given frequency.

By nature, most microphones are sensitive to vibrations in a direction perpendicular to the diaphragm, which, in the case of the tested microphones (except one), is the on-axis direction (i.e. the direction providing the highest acoustic sensitivity).

In this this test, on-axis excitation was performed, supplemented by excitation angles of 45° and 90° (by turning the clip; see Figure 4).

4 Groups of microphones

The microphones were selected among pro audio types that are often exposed to vibrations from handling or placement in vibrating surroundings. Hence, the tested microphones were chosen from the following groups: Vocal microphones (for live handheld use), instrument microphones, kickdrum microphones, and shotgun microphones.

A larger number of microphones (5-7 in each group) have been measured. However, only two exemplars from each group are reported here, largely defining the scale of apparent maximum equivalent SPL in each group. Other measured microphones fell in the gap between the reported microphones.

4.1 Vocal microphones

Vocal microphones for handheld use typically have a conical shape of the housing. Further, a rigid grid protects the capsule and provides the space for wind damping and protection against pops. Often, these microphones may have built-in protection against vibration or at least some reduction of hand-generated noise. The transducer types are dynamic (moving coil) or condensers (externally charged or electret types). Another feature is typically a roll-off at lower frequencies, both for noise reduction and reduction of

low-frequency background sounds below the voice spectrum (also with the aid of the proximity effect).

Further, most vocal microphones are pressure-gradient types (unidirectional: cardioid or super-cardioid), which are generally more sensitive to vibrations than pressure types (omnidirectional) due to a more "sloppy" diaphragm and a semi-open cavity behind it.

One of the two vocal microphones reported here is an electret condenser type with a built-in low-cut filter, and the other is a dynamic type.

4.2 Instrument microphones

Instrument microphones are often characterized by their ability to be mounted directly on a musical instrument. Some of these types have a shock mount as an integral part of their design; others do not. In this case, one of each type represents the instrument microphones.

One of the two instrument microphones reported here is an electret condenser type, and the other is a dynamic type.

4.3 Kick drum microphones

Microphones dedicated to use with kickdrums usually have rugged construction due to their placement in a "hostile" environment. However, the physical size of the microphone is limited, as it is often preferred to place it inside the kick drum through a hole in the resonator head.

Kick drum microphones must be capable of handling high SPL, which may exceed 150 dB re 20µPa inside the drum. Thus, their sensitivity is rather low, typically in the range of 1-2 mV/Pa.

Both dynamic types and condenser types are available for the purpose. The frequency response of these microphones varies to some degree; some are almost flat, while others exhibit a reduced frequency range focused around the drum's main sound.

One of the two kick drum microphones reported here is an electret condenser type (almost flat frequency response and an effective frequency range 40 Hz–18 kHz), and the other microphone is a dynamic type super-cardioid, with a frequency response of 20 Hz to 19 kHz).

4.4 Shotgun microphones

Shotgun microphones (aka. interference tube micro-phones) are, in principle, first-order cardioid micro-phones with an attached interference tube in front of the capsule.

They are always used at a distance, so their sensitivity is rather high, typically 20-40 mV/Pa.

Usually, they are mounted on a boom or handheld pole that transmits vibrations from handling to some degree.

Some types are equipped with a low-cut filter, either fixed or switchable.

One of the two shotgun microphones reported here is an electret condenser type with a built-in low-cut filter, and the other is an RF condenser type.

Both exhibit approximately the same directivity.

5 Results

5.1 Equivalent SPL per m/s^2

When measuring the output of a vibrated microphone, it is possible to describe an equivalent SPL that would produce the same signal out of the microphone as the vibration now does. This level is typically in the range of 55-105 dB SPL/m/s^2.

Meaning: Vibrating the microphone at 1 m/s^2 yields a signal of the same magnitude as a sound source with an SPL of 55-105 dB would generate.

The results of the measurements are given in Figures 5a-5h on page 5 and Table 1 on page 6.

5.2 Resonance frequencies

Any vibration-generated microphone output of a certain magnitude is below 2 kHz.

The output spectrum is typically dominated by one resonance frequency. However, other resonances may be close.

The data show that the resonances of the dynamic microphones are generally lower frequencies and at a lower Q than those of the condenser microphones.

It can also be noticed that the resonances may change when the direction of excitation is changed. This phenomenon is especially evident with condenser microphones.

The results utilize the SI system; hence, the unit for acceleration is in m/s^2.

Some may prefer the SPL/G, which can be found by adding 19.83 dB to the results as 1 m/s^2 equals 0.10197162129779283 G-force.

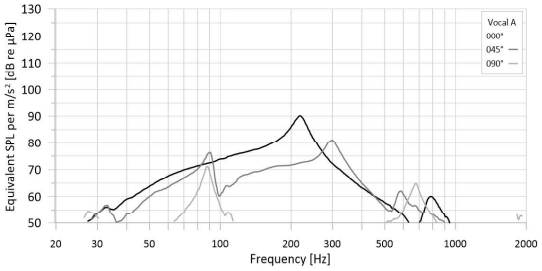


Figure 5a. Vocal microphone A:
Electret condenser, HP filter, supercardioid.

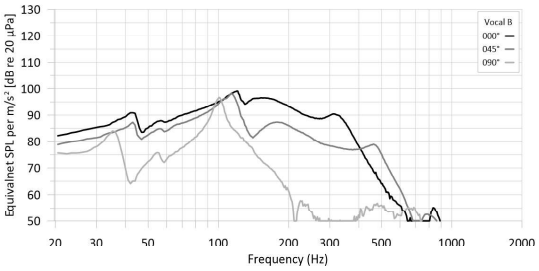


Figure 5b. Vocal microphone B.
Dynamic, cardioid.

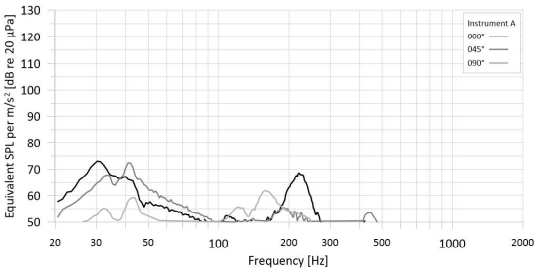


Figure 5c. Instrument microphone A
Electret cond., built-in shock mount, super-cardioid.

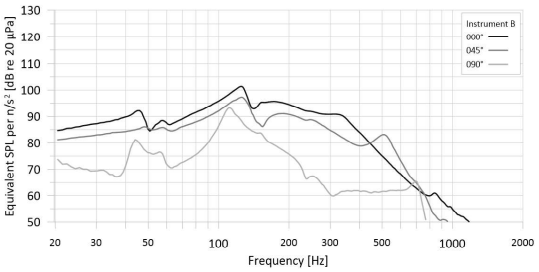


Figure 5d. Instrument microphone B
Dynamic, cardioid.

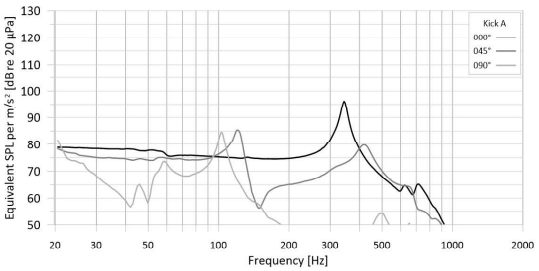


Figure 5e. Kickdrum microphone A.
Electret condenser, open cardioid.

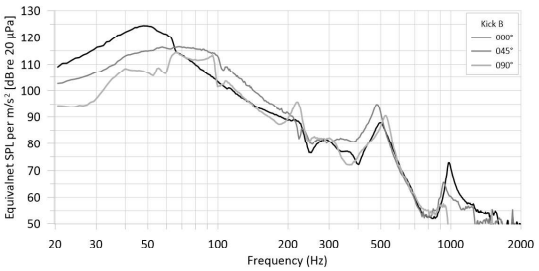


Figure 5f. Kickdrum microphone B.
Dynamic, super-cardioid.

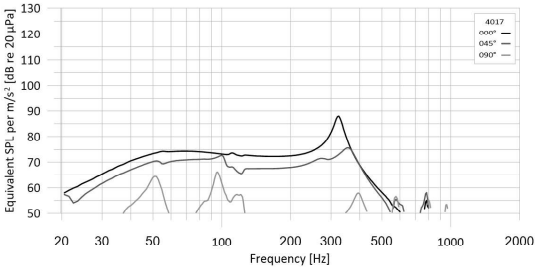


Figure 5g.Shotgun microphone A.
Electret condenser, lobar.

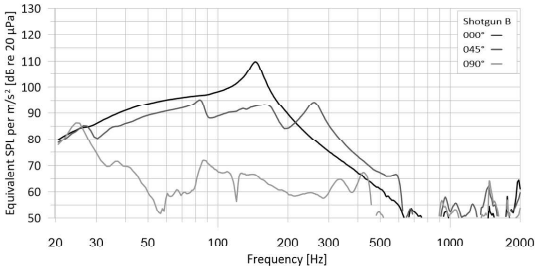


Figure 5h. Shotgun microphone B.
HF-condenser, lobar.

Mic. Type	Transducer	Eq. SPL (RMS) [dB re 20 uPa]	Frequency [Hz]	Direction [Degrees]
Vocal A	Electret condenser	90.1	218	0
Vocal B	Dynamic	99.2	120	0
Instrument A	Electret condenser	73.1	30.3	0
Instrument B	Dynamic	101.4	125	0
Kickdrum A	Electret condenser	96.2	344	0
Kickdrum B	Dynamic	124.5	47.9	0
Shotgun A	Electret condenser	88.0	324	0
Shotgun B	RF condenser	110.0	145	0

Table 1: The results of the measurements, four groups of pro audio microphones.

Conclusions

The measurements show that the microphones' response to vibrations is very much related to resonances. Also, the sensitivity is the highest when vibrated in the on-axis direction (±180º), even though other directions may come close.

The difference in sensitivity within same-group microphones is remarkably high. I.e. the case for kick-drum microphones (>28 dB).

However, the difference in sensitivity between the measured instrument microphones is more obvious, as instrument microphone A has a shock mount as an integral part of the design (>28 dB).

The difference between the shotguns (<22dB) is surprising, as these mics basically have very similar mechanical designs.

The general saying that condenser microphones are more sensitive to vibration than dynamic micro-phones cannot be found in these measurements.

Derived conclusion: Whenever possible, shock mounts should be used, and microphones' sensitivity to vibrations should be a part of any mics' spec sheet.

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