Technical Note

147AX Microphone Vibration Sensitivity

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The 147AX microphones is a new design optimized for mounting on surfaces and structures to measure the sound pressure in the surrounding air.

A relevant question to consider is: What happens when the microphone is mounted on a vibrating surface?

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Two aspects of this question need to be considered. One is that by mounting the microphones on a vibrating structure, the structure is loaded by the mass of the microphone and thereby the vibration level and frequency may be changed. This influence can be estimated by comparing the relative mass of the microphone to the mass of the structure. The microphone weight is around 27 grams, and if it is mounted on the solid part of a 500 kg diesel engine the changes to the vibration level end pattern will be insignificant. If, however, the microphone is mounted on a 1 mm aluminium plate structure with a mass of around 30 g per 10x10 cm, the weight of the microphone may change the vibration pattern. This will however not necessarily change the result of the sound pressure measurement made with the microphone if the plate structure itself is not the dominating sound source.

The other aspect that needs to be considered is the influence of the vibrations on the microphone itself. If the microphone is mounted on a vibrating structure, the microphone will vibrate with the structure. The microphone is however not sensitive to vibrations due to its very low diaphragm mass. To measure vibrations one would often use a piezoelectric accelerometer mounted on the structure. To obtain a good sensitivity of the accelerometer, this would be made with a large seismic mass, often in the range of 0.02 to 0.2 kg. The effective mass of the microphone diaphragm is however only around 0.000001 kg (1 mg) and thereby 20.000 to 200.000 times smaller than the accelerometer mass and therefore has very little vibration sensitivity.

Figure 1
147AX – mounting on atomobile engine.

The vibration sensitivity may be more accurately estimated by modeling the microphone as a simple single degree of freedom mechanical system, with a mass, a spring, and a viscous damper. The mass (M) is the mass of the diaphragm and the spring (S) is the tension in the suspended diaphragm. The viscous damper (D) comes from the dampening effect of the air molecules moving in the gap between the diaphragm and the microphone backplate.

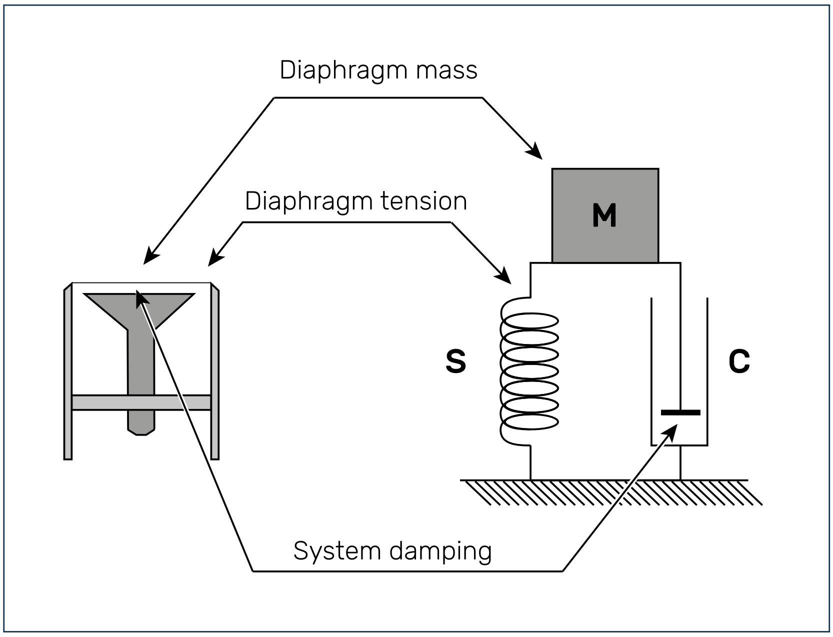

Figure 2
147AX vibration sensitivity modelled as a single degree of freedom mechanical system.

The vibration sensitivity will be determined by how much the microphone diaphragm moves relative to the internal microphone backplate. Below the microphone resonance frequency, this is determined by the diaphragm stiffness, where the impedance of the diaphragm mass is small in comparison to the spring impedance. Above the resonance frequency, the mass of the diaphragm will be dominating and the microphone will be sensitive to vibrations. However, for the 147AX microphone, the resonance frequency is at around 18 kHz and therefore the vibration sensitivity is very low below this frequency. Furthermore, around the microphone resonance frequency, the impedance of the diaphragm system is determined by the damping in the system and there will not be a pronounced resonance peak as often found for accelerometers.

The influence of axial Vibration

For 147AX the typical Influence of axial vibration @1 m/s^2 is 63 dB. When you mount the microphone on an object that vibrates with this level, the microphone will see:

The acoustical signal (noise) + the vibration signal converted into an acoustical signal, in other words the sum of the two sources.

Normally, the acoustical signal is much higher than the vibration signal converted in to an acoustical signal, and you therefore don´t have to take the vibration signal into consideration. This is what we see in the measurements shown in Figure 5 and 6.

In general, if the difference in the acoustical signal and the vibration signal is more than 10 dB, the influence of the vibration signal will be less than 0,5 dB and you don´t have to take the vibration signal into consideration. The graph below shows the influence of the vibration signal on the measurement.

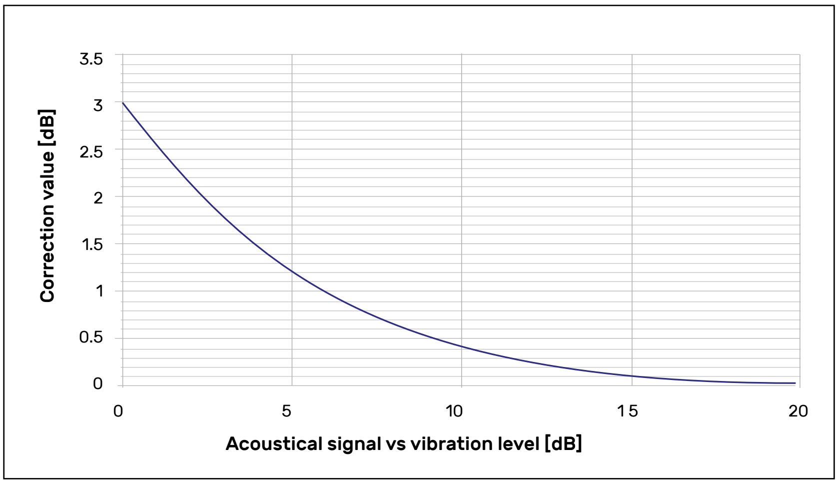

Figure 3
When the difference between the acoustical signal and the vibration signal is very low (<20 dB), the correction curve shown here can be used.

If you are in doubt whether the vibration signal will have too much influence in your measurement, you can mount two 147AX microphones in a way similar to the one shown in Figure 4.

If the measured response from these two microphones is very different it is probably due to the axial vibration signal influencing too much.

147AX Vibration Sensitivity In Practice

Automotive acoustic measurements are often performed on cars while they are driven on roads or test tracks. In these situations, there are both acoustical pressure signals and vibrations. The vibrating parts interact with the surrounding air to generate acoustical energy and the sound waves on the other hand cause vibrations of mechanical parts. A microphone placed in this environment will measure the sound pressure as it is on the diaphragm of the microphone.

Figure 4 shows an example of a measurement position in the engine bay of a passenger car with two microphones mounted in essentially the same position. One microphone is a 146AE free field microphone mounted with duct tape on a foam support acting as a vibration isolator. The other microphone is a 147AX pressure microphone mounted directly onto the mechanical structure with a magnetic base disc.

Figure 4
The two microphones mounted in the engine bay of passenger car

The sound pressure was measured while the car was driving at 100 km/h on a normal road surface and as can be seen in Figure 4, the free field microphone underestimates the sound pressure due to the drop in sensitivity at high frequencies relative to the pressure microphone.

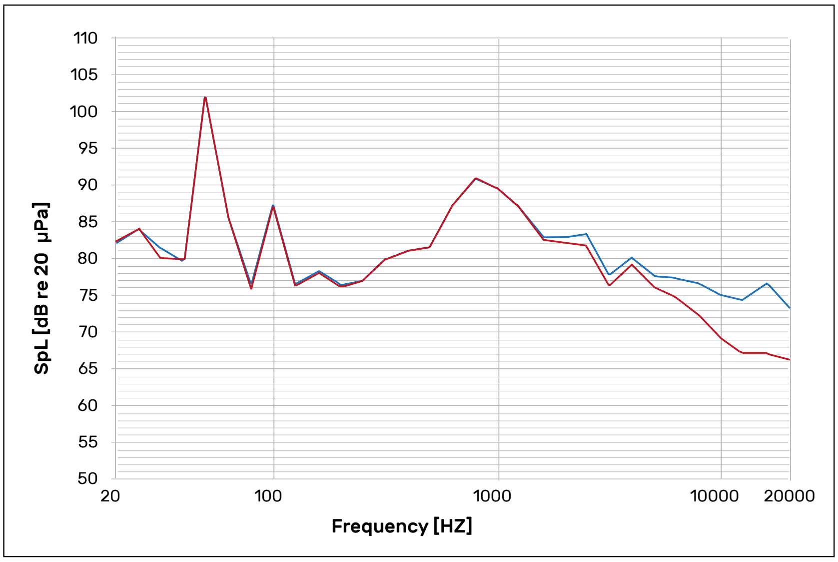

Figure 5
Measurement results for 146AE and 147AX in same position
Free-field response (146AE)
Pressure response (147AX)

If we correct the results from the free-field microphone with the free field correction response for a ½" microphone (see Figure 6) we can see that the microphones give almost the same results. There are still some small differences at higher frequencies, where the wavelength of sound waves are small, and the distances between the microphones can not be ignored.

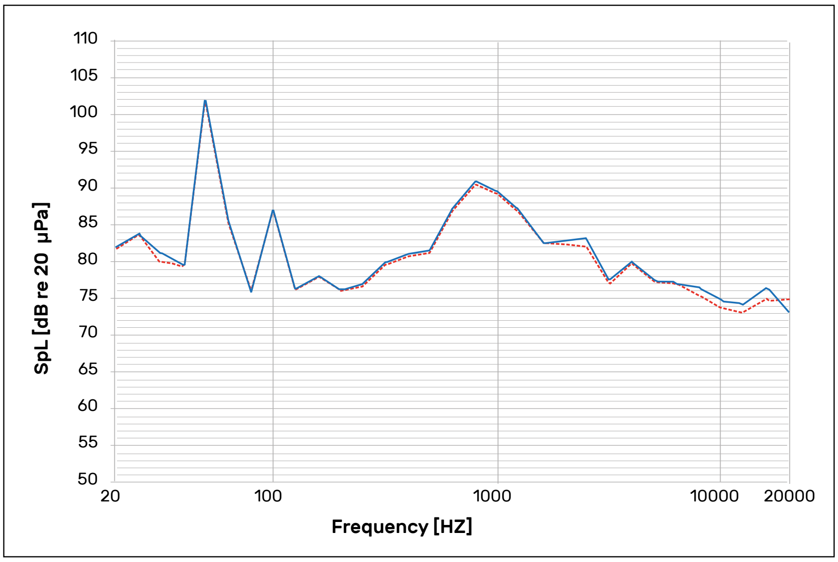

Figure 6
The same measurement as in Figure 5, but now with correction for the decreasing sensitivity of the free-field microphone at high frequencies.
Corrected free-field response
Pressure response

The data in Figure 6 have been analyzed in 1/3-octave and the filter bandwidth may hide smaller differences in the response of the two microphones so the signals were also analyzed with narrowband FFT analysis.

Figure 7 shows the low frequency part of the spectra and it can be seen that there are no local resonance frequencies indicating differences caused by vibrations.

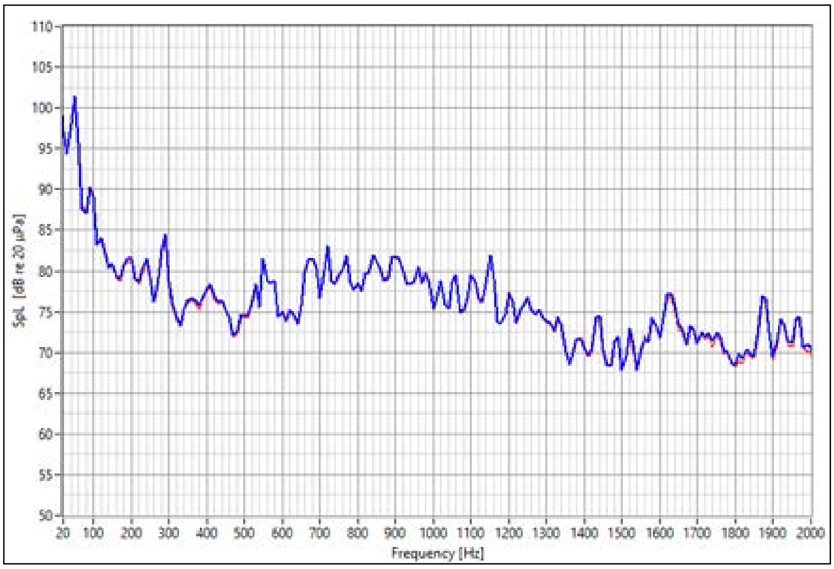

Figure 7
Narrowband spectra from 147AX and 146AE with correction for free-field response

Similarly, for the high frequency part of the spectra, as can be seen in Figure 8, there are no local resonance frequencies indicating differences caused by vibrations.

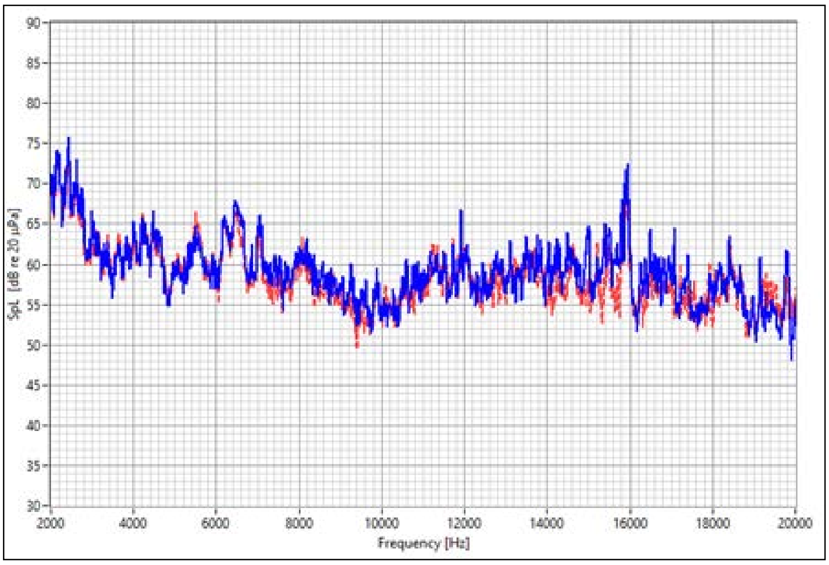

Figure 8
Narrowband spectra from 147AX and 146AE with correction for free-field response

This example shows that the two microphones measure almost identical results in the specific situations. Mounting microphones on vibrating structures should however always be done with special attention to the specific circumstances. Both the vibration isolated mounting of the free-field microphone and the direct magnetic mounting will load the structure onto which they are mounted. If this structure is for example a thin plate structure or thin beam, the mass of the microphone will load the structure and may therefore change the vibration pattern of the structure and this may change the acoustic field around the structure.

Even if the microphones are mounted onto a more solid structure, both the direct mounting and the-vibration isolated mounting may result in unintended resonance in both the structure and the microphone assembly. This may cause rattling and other sound generation from the microphone mounting system.

Conclusion

Below its resonance frequency at 18 kHz, the 147AX's sensitivity to vibrations is very low. Even at the resonance frequency, the damping is sufficient to prevent a peak similar to that found in accelerometers. As shown in figures 5 to 8, there is no indication that a 147AX is any more sensitive to vibrations than a standard tube-shaped free-field microphone set mounted in the same location with foam to isolate from vibrations. The response is the same after correction for free-field response, and there are no signs of local resonances indicating interference caused by vibrations.

Therefore, 147AX can safely be mounted on vibrating structures without significant impact on measurement results except on very light and undamped structures, where the added mass presented by the microphone must be taken into account.