Engine Bay Measurements: Pressure vs Free-field Microphone

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Free-field microphones have been used as the primary sensor to cover many types of automotive NVH tests. In some cases, such as in engine bay measurements, the use of a pressure microphone is better suited compared to a free-field microphone. Free-field microphones are optimized to have a flat frequency response in a free-field environment when pointed at 0 degree angle of incidence from a sound source.

An engine bay is far from being a free-field environment and this is why the use of a free-field microphone for these tests will result in an underestimation of the measured sound in frequencies above 1 kHz. This application note uses a practical case to show the differences in results between using a free-field and a pressure microphone for engine bay testing, and expands on why a pressure microphone is better suited for the application.

Comparison

The 147AX is a new design in measurement microphones optimized for automotive application measurements in the engine bay, in wheel cases, and inside the car cabin. The microphone is easily mounted with magnetic base plates and can be taken off and re-mounted in the same position for improved measurement repeatability.

The 147AX is a pressure microphone and therefore accurately measures the sound pressure level on the microphone diaphragm in all situations. This may give slightly different results at higher frequencies than if the same measurements were performed with a free-field type microphone which can underestimate the sound pressure on the microphone diaphragm at higher frequencies. The effect can be illustrated with a typical measurement in the engine bay of a car where a pressure microphone and free-field microphone are mounted in essentially the same position as shown in Figure 1.

Figure 1
A pressure and a free-field microphone mounted in the same position in the engine bay.

Figure 2 shows the spectra from the two microphones recorded when driving 60 km/h on a normal road. It can be seen that the response of the free-field microphone is lower than the pressure microphone at frequencies above 1 kHz. This is due to the reduced sensitivity of the free-field microphone to compensate for free-field condition diffractions around the microphone. If the response of the free-field microphone is corrected for the reduced sensitivity at high frequencies (as in Figure 3), it can be seen that the results are almost identical except for small differences in the 8-20 kHz range. These differences are probably related to the fact that the microphones were not in the exact same measurement position.

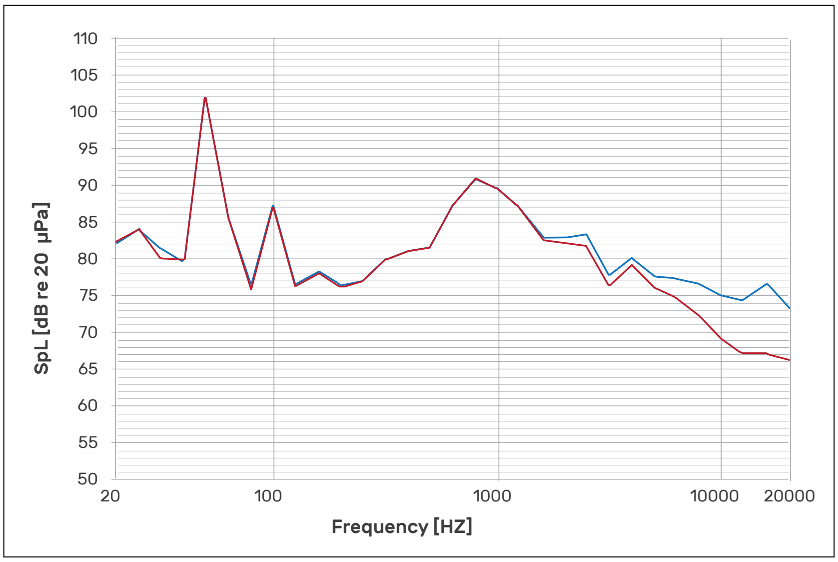

Figure 2
Comparison of free-field and pressure microphone response.
Free-field response (146AE)
Pressure response (147AX)

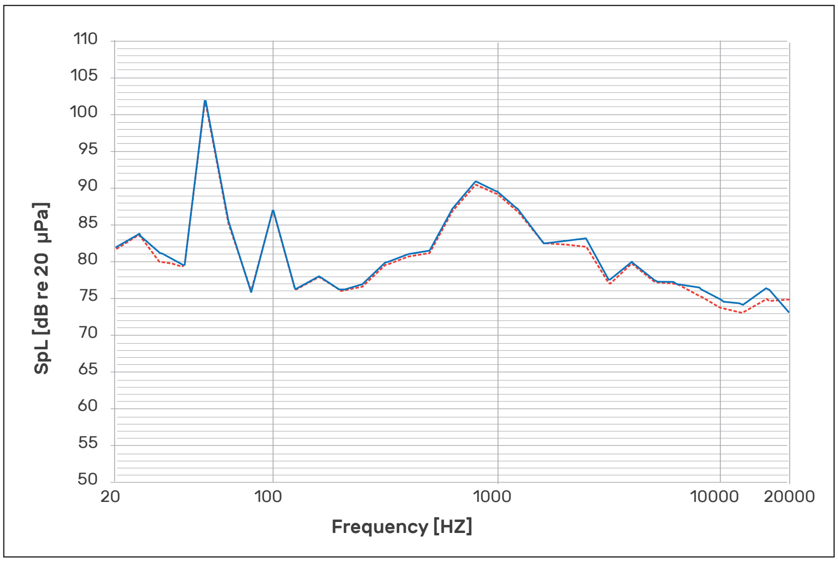

Figure 3
The same measurement as in Figure 2, but now corrected for the decreasing sensitivity of the free-field microphone at high frequencies.
Corrected free-field response
Pressure response

Even though free-field microphones have been used in the past (and sometimes still are) for engine bay testing, a pressure microphone is more relevant for this application. A free-field microphone is specifically designed to measure correctly in free fields but the acoustical environment in an engine bay is very far from a free-field condition. For an acoustical field to be considered a free field it has to be an open environment with no reflections and have a sound source in a well-defined position radiating in one direction relative to the microphone so that the microphone can be pointed towards the sound source. Neither of these conditions is fulfilled inside an engine bay. Firstly, there are many sound sources distributed around the microphone and secondly, the entire structure is reflecting the sound in all directions within the volume. This can also be seen from the fact that the results for the two microphones in Figure 3 are the same although the microphones were mounted pointing in perpendicular directions, as shown in Figure 1. If the sound field was even slightly directional as in a free-field acoustical field, the results in Figure 3 would differ for the two microphones due to the directionality effect of the microphone shape.

This can also be seen from the example in Figure 4, where two microphones are mounted pointing towards each other.

Figure 4
Pressure and free-field microphone mounted facing each other

Figure 5 shows that after correcting the free-field microphone response for the under estimation at high frequencies, the results are almost identical for both microphones.

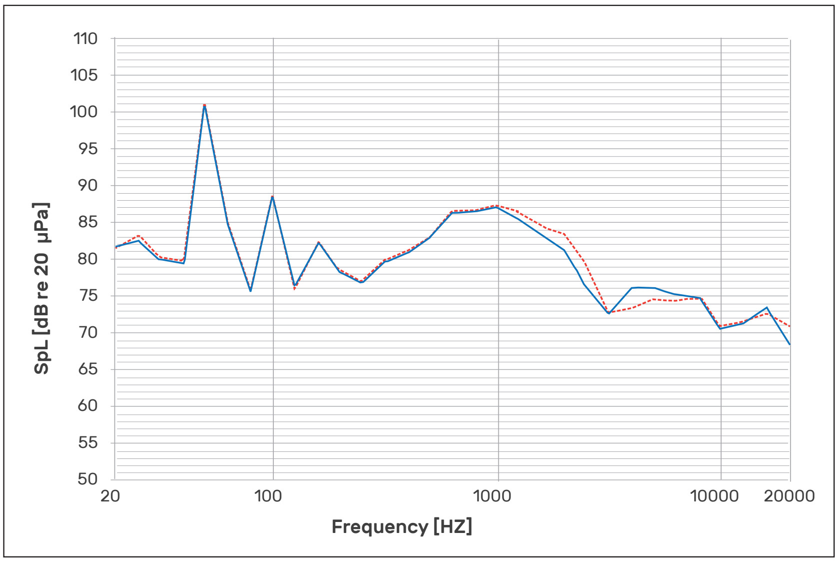

Figure 5
Pressure and free-field after correcting the free-field microphone response for the underestimation at high frequencies, the results are almost identical for both microphones. The differences above 1 kHz are probably due to reflections.

Free-field response
Pressure response

Conclusion

Inside enclosures like in an engine bay, it is recommended to use pressure type microphones as free-field type microphones will underestimate the sound pressure level. If free-field microphones are used, the data should be corrected for the general under-estimation caused by the decreased sensitivity at higher frequencies.