Technical Note

147AX Microphone Positioning Guide for Engine Noise Reduction Measurements

By Santiago Rayes

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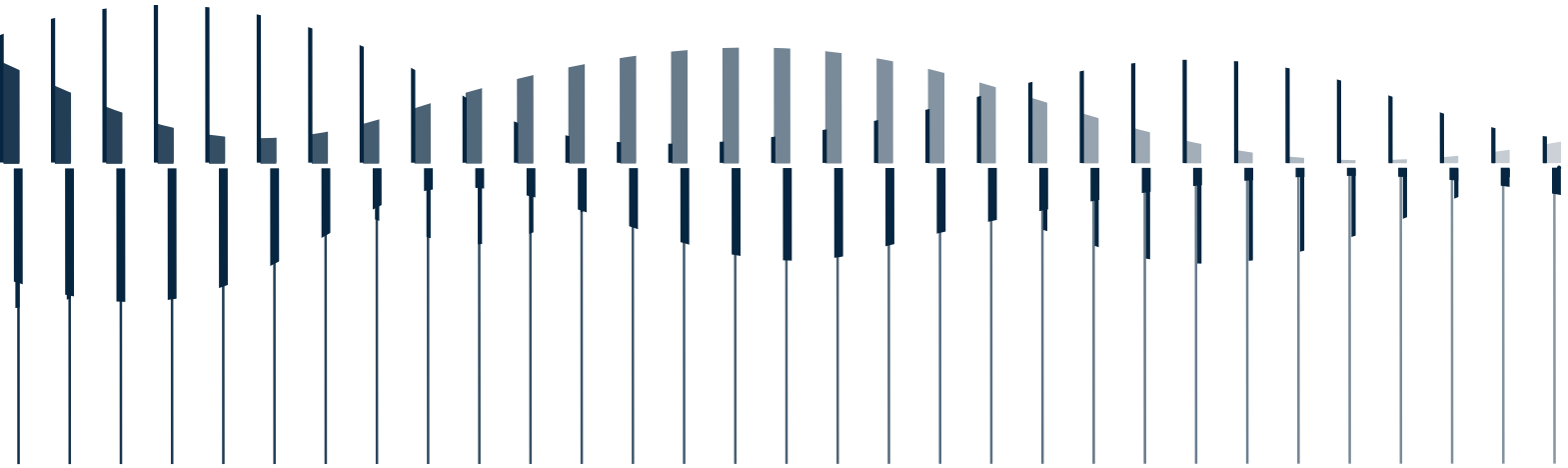

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GRAS Sound & Vibration

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Engine Noise Reduction (ENR) testing is usually performed under laboratory conditions using the reverse Transfer Path Analysis (TPA) technique. Here, multiple microphones are placed inside the engine bay, while one or more volume velocity source (VVS) locations are used inside the car cabin (engine is turned off).

As to microphone placement inside the engine bay, different NVH laboratories will normally take multiple approaches when it comes to their exact positioning. GRAS´s approach is to use the same microphone positions across platforms when possible. This facilitates the gathering of consistent data that can be reliably compared among every project for benchmarking.

GRAS recommends using the 147AX CCP Rugged Pressure Microphone with MagMount™ (Figure 1) system for TPA test. The main advantages are the fast and easy rigging of the car and the improved repeatability of the results. Once the MagMount™ mounting discs are placed in the desired positions inside the engine bay, it will be possible to install the microphone in the exact same position over and over again. This will reduce the influence of operator-errors (due to slight changes in microphone positioning from test to test) to a minimum. More information regarding the advantages of using GRAS 147AX for Engine Noise measurements can be found at grasacoustics.com/147ax.

To get reliable and comparable data, common mounting areas inside the engine bay have to be found among all the platforms. This is why we recommend selecting areas on the car body inside the engine bay, rather than positions on the engine itself. This will also facilitate the microphone positioning process.

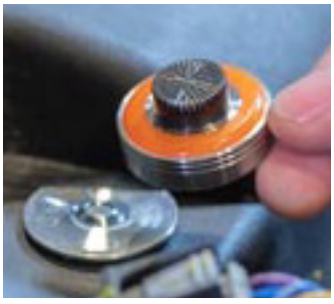

Figure 1
147AX – mounting on atomobile engine.

We recommend dividing the engine bay into different areas around the engine/motor: front, back, right, left, bottom, and get an even distribution of microphones among the different areas to get an overall good representation of the sound field in the engine bay (Figures 2 and 3).

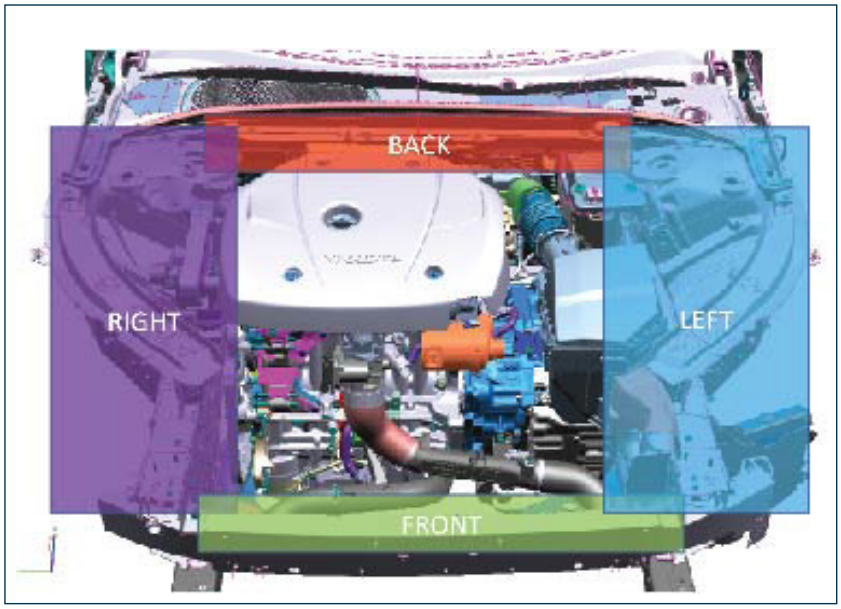

Figure 2
Different areas inside the engine bay.

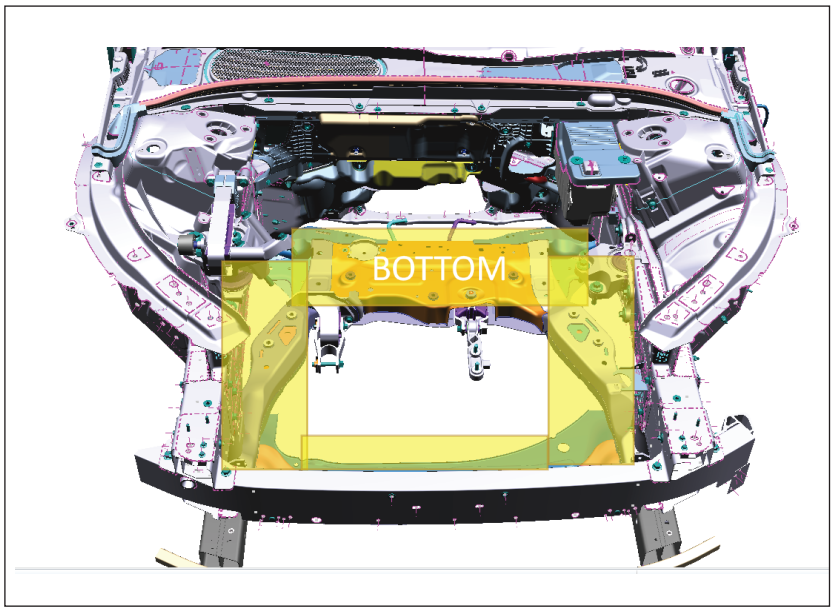

Figure 2
Bottom area inside the engine bay.

The number of measurement microphones used will depend on the maximum uncertainty that is allowed for the measurement and the frequency range for the test. An ICE will typically cover a range of around 300 Hz to 5 kHz. However, when electric vehicles are taken into consideration, measurements up to 10 kHz or more are performed. When this is the case,

a low number of microphones can increase the uncertainty of the results in the upper frequency range. This happens partially due to the increased directionality of the sound sources used for this type of test when the frequency is increased. A TPA setup for ENR tests will typically have between 18 and 60 microphones evenly distributed among the different areas inside the engine bay. Therefore, using free-field microphones under the above mentioned conditions, will affect the quality and repeatability of the TPA results. Having a large amount of microphone will, sometimes unnecessarily, increase the complexity of the setup, data analysis and post-processing.

However, there are cases where a higher amount of microphones is needed to reduce the measurement errors at frequencies above 3 kHz.
One way of deciding the final amount of microphones that are going to be used is by performing a multiple-step TPA measurement where a large number of microphones are used (e.g.: 60 microphones, 12 on each area). Once the results are obtained, the measurement can be repeated removing some microphones from each area. When removing microphones, the results will start deviating from the first measurement result. When the deviation starts getting considerable for the goals of the test (e.g. deviation <3dB from 300 Hz to 6 kHz compared to the original measurement), the microphone amount limit has been found.

The GRAS 147AX is a pressure microphone. Historically, most of the TPA measurements for ENR have been performed using free-field microphones (in some cases also random incidence microphones). A free-field microphone has a flat frequency response when pointed at 0° incidence at a sound source in a free-field environment. However, the sound field inside the engine bay is far from being an ideal free field or diffuse field, and therefore small changes in positioning and angle of incidence of the microphone will affect the microphone´s frequency response considerably (Figure 4).

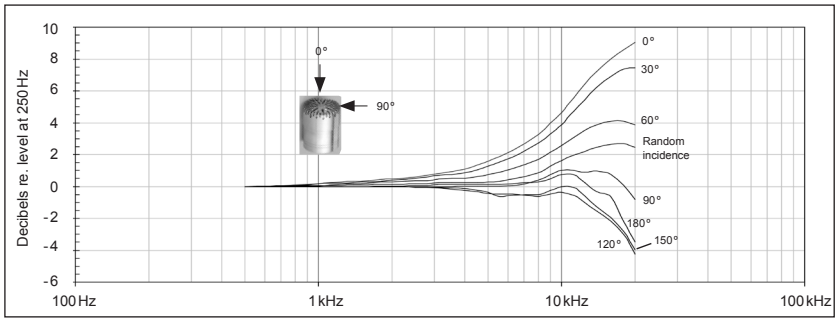

Figure 4
Typical ½" microphone free-field corrections for different angles of incidence.

Therefore, using free-field microphones under the above mentioned conditions will affect the quality and repeatability of the TPA results.

Overall, using a setup with surface mounted pressure microphone sets (like GRAS 147AX), placed in common mounting areas in the car body inside the engine bay, will produce different results than measurements performed with a different approach (e.g.: cylindrical free-field microphones placed in very specific parts of the engine bay). However, experience has taught us that a pressure microphone with a precise mounting method (like MagMount™), used in common mounting areas, produces more reliable and repeatable results in the entire frequency range.

Finally, it is advised to check that the noise floor of the test chamber used for the test is sufficiently low in the entire frequency range to allow a healthy signal to noise ratio. 10dB SNR is a typical value used for this test, but lower values can be used. Most standard sound sources typically used for these tests will struggle to get enough energy up to 10 kHz and above. So when doing high-frequency tests, it is advised to use special sound sources that can produce high SPL in these frequency ranges to improve the SNR and get reliable data in the entire frequency range of the test. Sometimes it will be necessary to divide the frequency range into two sections where tests will be performed with different types of sound source.