S&V Questions and Answers

Microphone Selection

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Question: **What is the difference between a free field, random incidence (diffuse), and pressure microphone, and in what applications can each be used?**

First, if you are using a 1/2 in. diameter microphone, the really simple "rule of thumb" answer is that all three types are the same and can be used interchangeably at frequencies below 5 kHz. The free field, random incidence (diffuse), and pressure microphones will all give the same output within 2 dB below 5 kHz. When the frequencies of interest are above 5 kHz, (or 2.5 kHz for a 1 in. microphone) or if accuracy of greater than 2 dB is important to you, then you should read on.

The three different types of microphones are designed to measure sound pressure in the following types of sound fields: A free field, which is characterized by sound waves that are propagating freely in a continuous medium, such as air, without any disturbing objects. A diffuse field is one where the sound waves arrive more or less simultaneously from all directions with equal probability and level. And a pressure field is where the sound pressure has the same magnitude and phase at any position within the field.

Every measurement grade microphone, regardless if it is classified as a free field, random incidence (diffuse), or pressure microphone, is fundamentally a pressure response microphone. A pressure response microphone is designed to sense pressure and not pressure gradients or particle velocity. These microphones are generally supplied with a pressure calibration curve that shows the frequency response of that microphone to sound pressure applied in a pressure cavity environment that simulates a pressure field.

The differences in the microphone's frequency response occur at higher frequencies, where the dimension of the microphone is significant relative to the wavelength of sound. When sound waves arrive at the microphone head-on (0° incidence), the average sound pressure across the microphone diaphragm is amplified because the microphone changes the sound field as it diffracts and reflects the sound waves. The amount of amplification varies according to the physical dimensions of each individual microphone and the angle of incidence of the sound waves to the microphone. These response curves are referred to as "free field" correction curves. Figure 1 illustrates a typical set of "free field" correction curves for a microphone. For a 1/2 in. microphone, 10 dB amplification at 20 kHz is typical, reaching a maximum of 13 dB at 40 kHz. This amplification can result in significant error. For example if a 1/2 in. "pressure" response microphone with a flat pressure response up to 20 kHz is pointed directly at a 20 kHz noise source, the pressure across its diaphragm will be 10 dB higher than the actual pressure that would have existed if the microphone was not present. The output of the microphone would then read 10 dB higher than the actual pressure.

This leads us to the "free field" response microphone type. The "free field" response microphone is simply a pressure response microphone whose high frequency response is carefully rolled off to cancel out the pressure amplification that occurs with a 0° incidence sound wave. Thus you can point this type of microphone directly at a high frequency sound source and get an accurate measurement of the pressure that would have been at that location without the microphone being present. This is why "free field" microphones are said to correct for their presence in the sound field.

A "free field" response measurement microphone is supplied with a calibration chart that has two curves on it, see Figure 2. The curve that attenuates at a fairly low frequency is the actual measured pressure response of the microphone and the curve that is flatter to a higher frequency is the calculated response of that microphone to 0° incidence sound in a "free field."

Only a quick mention is needed regarding the "random incidence" response microphones. For all practical purposes the pressure response of a microphone is the same as it's response to sound waves coming at it equally from all directions, thus "pressure" response and "random incidence" response 1/2 in. microphones are basically the same thing. A couple of manufactures do make microphones optimized for "random incidence."

In summary, whether a microphone is classified pressure, random, or free field refers to which of its response curves is the flattest. However any of the types of 1/2 in. microphones can be used in many but not all measurement situations, for example:

Situation 1: Sound originates from a point source below 5 kHz. You can use any of the three types of microphones and orient the microphone anywhere from 0 to 90° relative to the source. The output of the microphone will vary by less than 2 dB from the actual pressure.

Situation 2: Sound originates from a point source above 5 kHz. You can use a free field response microphone pointed at the source (0° incidence), or use a pressure or random incident microphone and let the sound graze over the diaphragm (70 to 90°).

Situation 3: A diffuse sound field is present with a lot of high frequency content up to 20 kHz. You should use only a pressure or random incidence response microphone in this situation if you are doing a simple broadband measurement. The pressure response of a "free field" microphone will attenuate the higher frequencies (see Figure 2), so you do not want to use a "free field" microphone. If you are doing a spectrum analysis, then it is theoretically possible to correct the higher frequency bands with the "free field" correction curve values, but this is risky because you don't really know the incidence of the sound at each frequency.

Next months Q & A column answers the question: **How is the "% of Critical" for a mode of vibration related to the actual damping in a structure?**

Send your questions or comments to:

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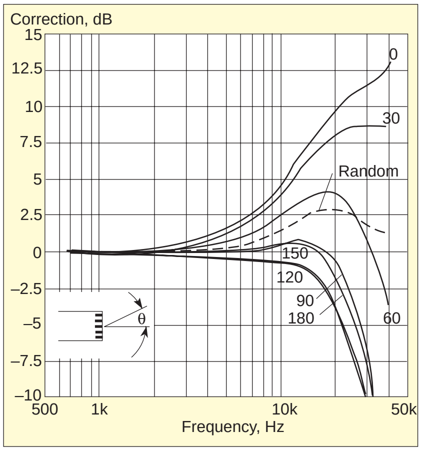

Figure 1. Free-field correction curves for a microphone with protective grid.

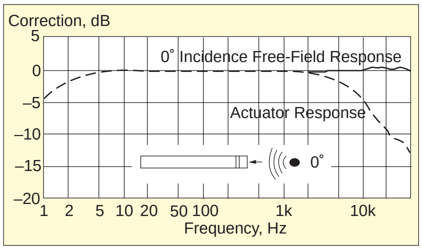

Figure 2. Free-field microphone frequency response chart.