THE EFFECT OF BACKGROUND NOISE ON SOUND POWER IN BOTH A REVERBERANT AND ANECHOIC ENVIRONMENT

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1. INTRODUCTION

Determination of sound power of a source is a useful quantity since sound power theoretically provides a measurement of the amount of sound energy that is radiated from the source independent of its surroundings. While sound pressure level (SPL) measurements are a good indicator of human hearing response, they are highly dependant on the acoustic environment in which they are made, whereas sound power is a characteristic of the source only.

Sound power is not measured directly, but is calculated by sound intensity measurements which is a measure of the radiating power through a surface area. One of the significant advantages of sound power determination, using intensity measurements, is that stationary background sources have negligible influence on the results. This study investigates the validity of such a statement by measuring the effect that an increasing background noise has on a steady broadband noise source through the application of noise intensity measurements in both a reverberant and anechoic environment.

2. THEORY

Sound intensity is calculated from the time-averaged product of the measured pressure and particle velocity. This is derived from:

$$I=\frac{W}{A}=\frac{F\times v}{A}=\frac{F}{A}\times v=P\times v$$

where I is intensity, W is power, A is area, F is force, P is pressure and v is velocity.

Pressure is easily measured by a single microphone but velocity is not. However, with two closely spaced microphones, the particle velocity can be related to the instantaneous pressure change, or pressure gradient, across the distance between the microphones. Knowing the pressure gradient and density of the fluid medium, the particle acceleration can be calculated with Euler's equation shown as:

$$u=-\int\frac{1}{\rho}\frac{\partial p}{\partial r}dt$$

$$I=\overline{p\times u}=-\frac{p_A+p_B}{2\rho\Delta r}\int(p_B-p_A)dt$$

The particle velocity is then derived by integrating the acceleration. Intensity is then given as:

Here $(P_A+P_B)/2$ represents the average pressure which is simply the arithmetic average of the pressure measured by each of the two microphones. Similarly, the term inside the integral is the integration of the finite difference approximation applied to Euler's equation.

As already stated, one fundamental advantage of using intensity measurements for the determination of sound power of a source is that steady background noise has no effect on the intensity measurements. To illustrate this idea, imagine a source within an enclosed surface area for which intensity measurements are conducted. The intensity would then be multiplied by the area to find the total sound power radiated. If the source were now moved outside the surface enclosure, the radiating energy would enter one face of the enclosure then exit from the diametrically opposite face. Given that intensity is a vector quantity, the total net energy contribution from the enclosure due to the external source would then be zero. Effectively, background noise within a measurement environment can be regarded as the external source described above, and therefore, has no effect on the determined sound power. One condition of this is that the background noise must be steady in nature. If it is not, the intensity due to noise entering one side of the enclosure may not equal in magnitude to the intensity exiting the other side, and thus, resulting in a net level other then zero.

3. PROCEDURE

To test the validity of the above statement, intensity measurements were made of a speaker source producing white noise signals. A 6 by 6 grid with a surface area of 1 square foot on the top and a 3 by 6 grid with a surface area of ½ square foot on the four sides was placed around the speaker. Figure 1 shows the speaker with the grid enclosure.

The source speaker was played at a constant sound pressure level (SPL) of 90 dB, measured at a distance of one metre from the speaker. The background noise, also a white

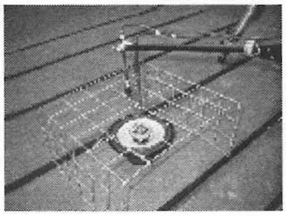

Figure 1: Source Speaker with Grid Enclosure

noise source, was generated by two large loudspeakers placed in opposite corners of the room. The first test involved playing the background noise at an SPL of 80 dB, as measured at the same location as the source speaker, in a semi-anechoic room. Intensity measurements, using the discrete point averaging method, were made of the source speaker using a Hewlett Packard 3569A analyzer which also calculated the overall sound power of the source. The test was then repeated five more times with the background noise increased by 5 dB each time until the background noise was 105 dB, or 15 dB greater than the source speaker. The entire procedure was again repeated, only this time in a highly reflective room. This room was used to investigate the presence of any difference in the results in a reverberant environment.

4. DISCUSSION OF RESULTS

Figure 2 is a graph of the overall sound power level of the source speaker with the various background noise levels in the semi-anechoic room. It can be seen that very little difference exists in the overall sound power of source for the increasing background noise levels. The maximum sound power level was 81.94 dB and the minimum was 81.53 dB giving a negligible difference of about 0.4 dB. In fact, it is usually accepted that "sound power can be measured to an accuracy of 1 dB from sources as much as 10 dB lower than the background noise." [1] Here it is within 0.4 dB with a source 15 dB lower than the ambient. Examination of Figure 2 also illustrates that there was no straight line trend from the low to high background sound level with the maximum level occurring in the middle of the graph suggesting that any differences are most likely random and not influenced by the background noise.

Figure 3 shows the overall sound power level of the source speaker with the six different background noise levels in the reverberant environment. The maximum sound power level was 78.66 dB and the minimum was 77.46 dB with a difference of about 1.2 dB. These differences show a downward trend in source sound power with increasing ambient noise. This is opposite that what would be expected if the background noise influenced the source sound power. Instead, the sound power level should increase. This serves only to suggest that the 1.2 dB difference was due to some other effect other than the background noise. It is suspected that inaccuracies in the source power control influenced these results.

Also noted was that even though the speaker was played at the same SPL measured one metre from the source in both rooms, the power level measured in the semi-anechoic room was greater than the reverberant room. Recall that SPL is influenced by environment. Here the reverberant environment reflected the source energy adding to the SPL while the anechoic room absorbed energy thus requiring more energy output of the source to attain the 90 dB SPL. This reinforces the fact that both environment type and background noise have no appreciable effect on the sound power results.

5. CONCLUSIONS

Sound power determination of a source through intensity measurements have the distinct advantage that they can be determined without influence of background noise and environment. This exercise has clearly demonstrated this fact by showing that a stationary background noise up to 15 dB greater than the source under consideration has no effect on the sound power results in both a reverberant and anechoic environment.

6. REFERENCES

1. *Sound Intensity Primer*, Brüel & Kjaer application notes, September 1993.

2. *Sound Power Measurements Application Note 1230*, Hewlett Packard, 1992.

Figure 2: Semi-Anechoic Environment

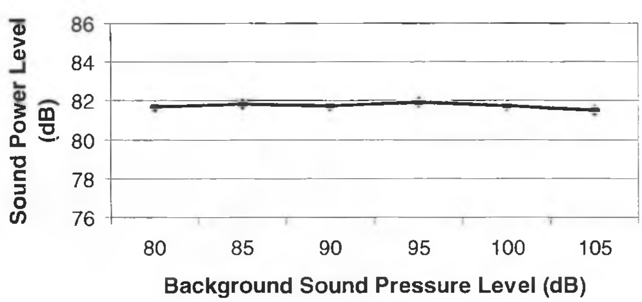

Figure 3: Reverberant Environment