Experimental Measurement Lab: Near Field Polar Responses and Periodicity Effects

In this post, we evaluate the effects of the speaker and microphones not being in the far field, which is required to completely minimize sample size effects, and describe how the diffusion coefficient is significantly reduced when an array of diffusers is periodically arranged on a surface to cover a larger area.

Near Field vs. Far Field

All free field measurements suffer from the problem that the relative levels within the polar response are dependent on the distances from the source and receivers to the surface, unless the source and receivers are in the far field. Unfortunately, in reverberant room measurements, it is usual for sources and receivers to be in the near rather than the far field, unless the test surface is small. In the spatial domain and in the far field, the effect of a diffuser should be to move energy from the specular zone, described in DR 220505, to other angles. So, unless receivers are placed both outside and within the specular zone, measuring energy levels alone will not detect the effects of diffuse reflections. One criterion to describe the far field is when the differences between path lengths from points on the surface to the receivers are negligible compared to wavelength. Typically, a receiver needs to be hundreds of meters away from the sample to completely reach the far field. Fortunately, a pragmatic approach may be taken. This is paticularly true when a diffusion coefficient is going to be evaluated, as this involved reducing the many scattered pressure values in a polar response to a single figure of merit.

The situation is also less critical when one-third octave bandwidths are used, as is normal practice. Therefore, the true far field does not have to be obtained. It is sufficient to ensure that a majority of receivers are outside the specular zone can be measured. Then a reasonable approximation to the far field polar response can be obtained. ISO 17497-2 recommends that 80% of receivers are outside the specular zone. For the 2D goniometer we have been describing, this means a compromise must be achieved between the sample size and the speaker and microphone radii, as shown in DR 220505. In a room that was 25' x 25' x 12', the Goniopter program satisfied the 80% requirement with a sample size less than 19", with microphone and speaker radii of 57" and 87", respectively.

Periodicity Effects

It is important to test a sample that is representative of the entire structure to be applied in real applications. *For instance, one period of a diffuser should not be tested if the intention is to apply the diffuser periodically to cover a desired surface area because the scattering from a periodic array and a single diffuser will be vastly different.* Since the diffusion coefficient is determined from the autocorrelation of the polar responses, anything that disrupts a uniform angular scattering response will decrease the metric. Periodicity produces what are called grating lobes, or preferred diffraction directions, which result in angular gaps in the polar response, as shown in Figure 1. The diffraction directions, θ, are determined by the angle of incidence, Y, the wavelength, l, and the width of the scattering device.

For the reflection phase grating, the width is now Nw, the produce of the prime number N, and width of a well, w. The integer m describes the order of diffraction, with 0 being the specular direction. As the number of periods increase, the energy is focused into the diffraction directions and the diffration lobes become narrower, thus decreasing the diffusion coefficient.

$$\sin\theta = \frac{m\lambda}{Nw} - \sin\Psi; m = 0, \pm 1, \pm 2, \ldots$$

When the whole sample cannot be tested because of geometric constraints on source and receiver distances in the goniometer, a scale model sample should be used. Figure 2 shows the normalized diffusion coefficient from 5 different periodic arrays of semicylinders. The plots show that one semicylinder is not representative of the scattering from an array of semicylinders. Later in the Virtual Education Lab, we will describe in detail how the modulation with optimal binary codes can allow coverage over a wide area with minimal grating lobes.

A detailed discussion of the near and far field, as well as periodicity effects, is provided in Chapter 5 and 10 of my book with Professor Trevor Cox, "Acoustic Absorbers and Diffusers: Theory, Design, and Application," 3rd Edition, CRC Press (2017).

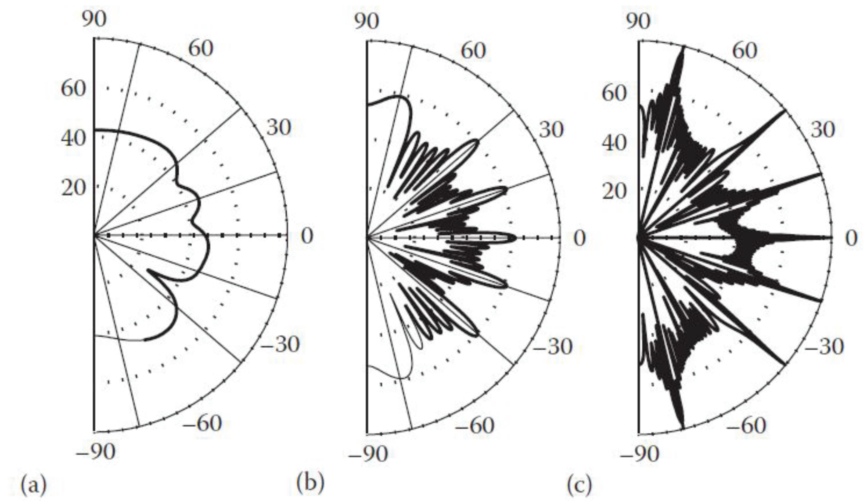

Figure 1. The scattering from N=7 QRDs at 3000 Hz for a different number of periods. (a) 1 period; (b) 6 periods; (c) 50 periods. Locations of diffraction lobes and directions of similar level are marked by radial lines at ±76ª, ±40ª, ±19ª, and 0ª.

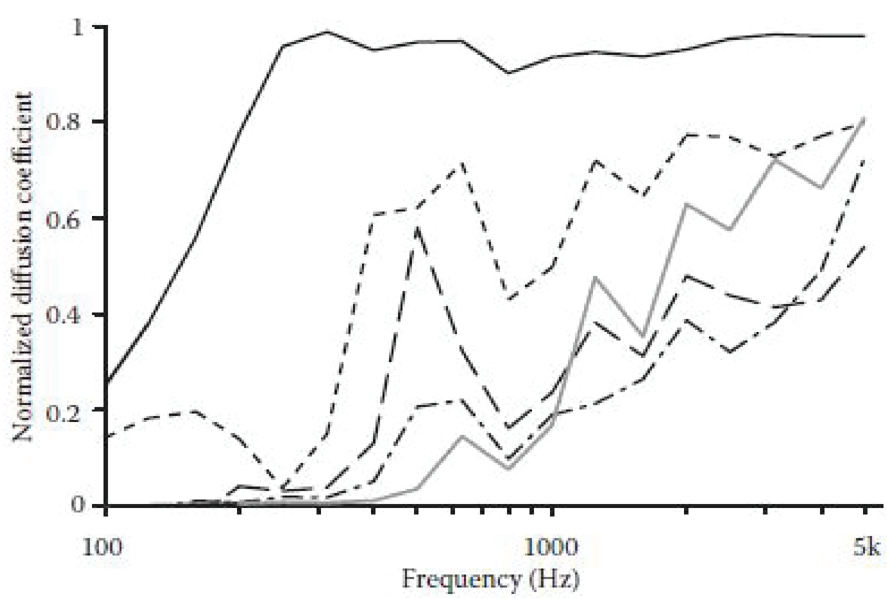

Figure 2. The normalized diffusion coefficient for various repeats of semicylinders. The number of semicylinders in each array we tested are:

—— 1, ‐‐‐‐ 2, – – – 4, ‐·‐·‐· 6, and —— 12.

Thus far, we have described a 2D or boundary layer goniometer, which can be used in a reverberant space. ISO 17497-2 also specifies the measurement procedure for a 3D goniometer. In the next post, we will compare the results from a 2D and 3D goniometer for a square-based pyramid and introduce a new wave-based program called Virgo, which can accurately simulate the scattering of any surface from a 3D CAD file. We will then leave the Experimental Measurement Lab and enter the Virtual Simulation Lab!

Dr. Peter D'Antonio
Director of Research
Acoustical Research Center