diffuse Bulletin

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OVERHEAD CANOPY DESIGN

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It is useful to define the cut-off frequency for a plane reflector, the transition frequency between specular reflection and significant diffraction. To continue with the filter analogy, the transition frequency can be taken as the -3dB point of the high pass filter. This gives acousticians an approximate frequency below which the panel most effectively scatters sound in all directions and above which the panel produces more specular-like reflections. Rindel has derived a simple and useful formulation for the cut-off frequency. Rindel used a simplified Fresnel solution method for the scattering from a plane surface, with the Fresnel integrals approximated by simple mathematical functions. Using this solution method, Rindel found a transition frequency above which the Fresnel integrals remain roughly constant. He defined this point as the cut-off frequency.

For a plane panel it is given as:

$$f_{-3dB} = \frac{cr^*}{8a^2\cos^2(\psi)} \quad (1)$$

Where r* is given by:

$$r^* = \frac{2rr_0}{r+r_0} \quad (2)$$

r_0 is the distance from the source to the panel centre;
r is the distance from the receiver to the panel centre;
2a is the panel width;
c is the speed of sound, and
ψ the angle of incidence.

The use of a cut-off frequency is most valid for receivers close to the specular reflection direction. A rough guide to the region over which the cut-off frequency representation works is therefore the region over which the geometric reflection point lies on the panel. Incidentally, to simplify the calculation of these angles, an image source construction is a good idea, as it greatly reduces the complexity of the trigonometry - this is shown in Figure 1 of dB Vol.1, Issue1.

For a plane panel, the case of scattering close to the specular reflection direction is usually of most interest, as this will have the largest amount of the scattered energy at high frequency. Nevertheless, with significant energy scattered into other angles at low frequencies, the use of a cut-off frequency should be used with caution. Equation 1 assumes either a square panel, where the azimuth and elevation incident angles are the same, or a two dimensional world. For rectangular panels, and arbitrary incidence angles with square panels, there will be two different cut-off frequencies to consider, due to the two different dimensions. For circular or odd shaped panels, the transition will be more complicated, but similar general principles to that shown in Figure 2 of dB Vol. 1, Issue 1 apply.

Figure 1 shows the total sound field impulse response - incident plus reflection sound - for plane wave scattering. The direct and reflected sound are clearly distinguishable, as is the edge scattering wave which has a negative magnitude, between 10 and 12 ms. Figure 2 shows the frequency response of the total sound field in Figure 1. The reflected sound from a plane panel is very similar to the incident sound field unless the panel is small. This means that the frequency response shows distinct comb filtering. Comb filtering is characterized by minima and maxima at a regular spacing in frequency. The ear is particularly sensitive to this emphasis and de-emphasis of frequency components, and when audible, listeners will complain of harshness or glare from these reflections. In diffuser design, the ability of a surface to disperse the sound spatially is often monitored. There is an equivalence between spatial and temporal dispersion.

In dB Vol. 1, Issue 3, we will investigate the spatial distribution of the scattered sound, shown as a polar response. As we will describe, this spatial response plays a vital role in canopy design.

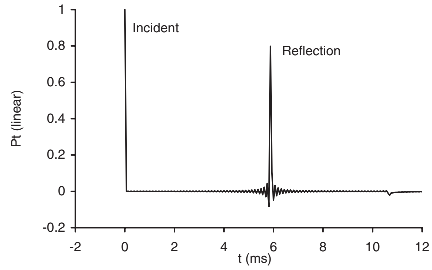

Figure 1. Time response for incident and scattered sound (reflection) from a plane surface. Note edge scattering between 10 and 12 ms, with a negative magnitude.

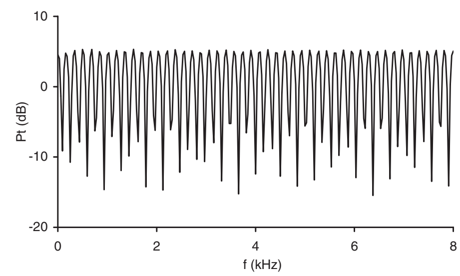

Figure 2. Total field frequency response for plane surface scattering. Note the regular comb filtering, leading to harshness and glare.