Virtual Education Lab: What type of scattering behavior is exhibited by triangles and pyramids?

In the previous post, we examined the scattering from a semicylinder. In this post, we discuss the scattering from triangles and pyramids, which can display a wide variety of scattering behavior. As we will show, it depends on the geometry. Single triangles are not that useful because generally large areas need to be covered and then the surface becomes too deep. The reflection from an array of triangles or pyramids is very much determined by the steepness of the side slopes. For simplicity, the analysis here considers only a 2D case with triangles, but the arguments can easily extend to a 3D surface, such as a pyramid, which we will also discuss.

Simple ray tracing yields much information about how a triangle reflects sound. Figure 1 shows some examples. As the angle (χ) of the triangle varies, the reflection characteristic shifts between a notch response, diffuse reflection lobes, and a specular response. For this discussion, only the center position of two triangles at high frequencies will be considered at normal incidence. For shallow angles (χ ≤ 30°), the ray tracing shows only a single reflection from each side as shown in Figure 1. The far-field scattering polar, determined with a BEM analysis, results in two distinct lobes being generated at angles of ±2χ, shown in Figure 2. This then forms a notch response, with the energy in the specular direction being reduced. This is effectively a redirecting surface that generates two strong reflections in different distinct directions, similar to the 3D scattering shown later for a square-based pyramid. For a 30º < χ < 45º, a mixture of single and double reflections is apparent in Figure 2 (40º). The single reflections will again form lobes in the directions of ±2χ, the double reflection will be in the directions of ±(180 – 4χ). Figure 2 (40º) shows four distinct lobes in the polar response. By choosing an appropriate angle for the triangle, it is possible to have a notch in the specular reflection direction, but now, the reflected energy is spread over four lobes, which is often more desirable.

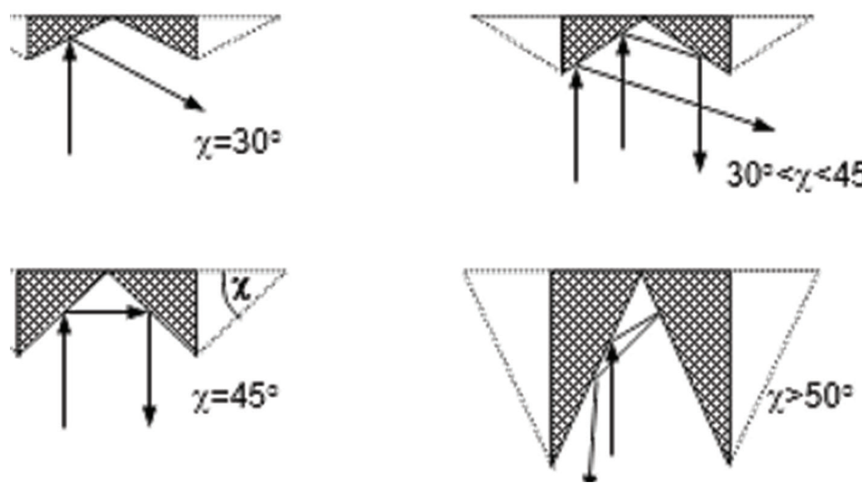

Figure 1. Ray tracing of normally incident sound to the center of pairs of triangles with differenct interior angles.

χ = 45° is a special case, because the energy is returned back towards the source, as shown in Figures 1 and 2. This is sometimes termed a *corner reflector,* a topic we will discuss in the next post. For 45º < χ < 54°, double reflections always occur, but these generate only two lobes, as seen in Figure 2 at χ = 50º. As χ increases beyond 54º, the number of reflections that a ray undertakes before escapting the surface rises. A varying number of clear distinct lobes are still generated, and simple ray tracing techniques can still be used to locate the directions of the most significant lobes. The relative level of the lobes varies, however, depending on the reflection paths. When the angle becomes exceptionally large (χ > 85º), a single fairly borad lobe appears. The surface is acting like a

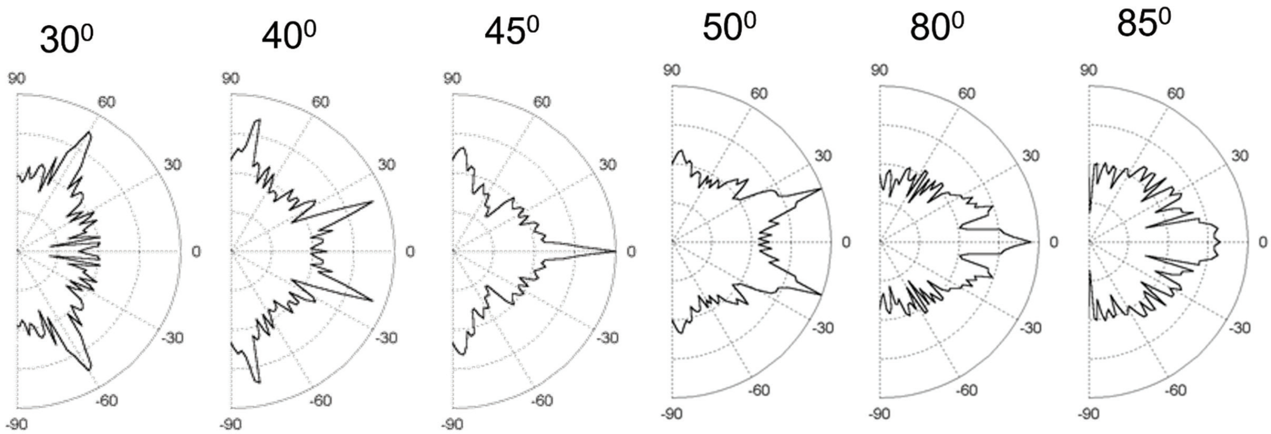

Figure 2. Scattered polar responses from triangles with various interior angles.

horn loudspeaker in that a highly directional response is obtained, but in a more diffuse manner than occurs with a $\chi = 45^\circ$ surface.

As alluded above, the scattering from a square-based pyramid for normal incidence, as simulated by VIRGO (DR 220526), specularly reflects incident sound from each face of the pyramid.

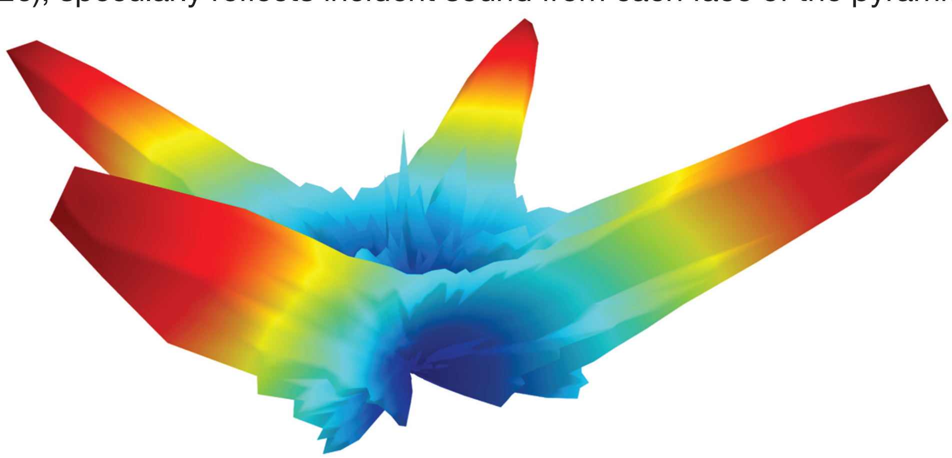

Figure 3. VIRGO simulated specular scattering from a square-based pyramid.

For a more thorough discussion, please refer to Chapter 11 in my book with Prof. Trevor Cox called Acoustic Absorbers and Diffusers: Theory, Design, and Application, 3rd Ed., CRC Press (2017).

In the next post, we will discuss the scattering where $\chi = 45^\circ$ from a corner reflector, and how this special case can be utilized to form a new device called a Returner, in which the scattered energy is returned back to the direction of incidence.

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