Acoustic essentials: sound on surfaces

Walters-Storyk Design Group's DIRK NOY explains how sound is bounced, absorbed and dispersed from surfaces.

When sound waves hit a surface we can observe one of three things or a combination thereof: the sound is geometrically redirected (reflection); the sound is attenuated (absorption); or the sound is distributed more or less uniformly (diffusion) (Figure 1). This is assuming we disregard the transmission of sound when sound partially travels through the surface. These fundamental behaviours are very much connected as absorption can be understood as an 'attenuated reflection' and diffusion is just a 'redirected reflection'. So let's look at these phenomena in more detail.

REFLECTION — Have you ever played pool billiards? If you have then the concept of reflection will certainly not be unknown to you. Just as a billiard ball bounces off a cushion (and hardly loses any energy) incident sound bounces off an acoustically reflective or 'acoustically hard' surface. Whether this is a good thing or a bad thing differs — targeted reflection of sound energy to the rear of an auditorium theatre can be great but, on the other hand, the focused reflections of a glass dome ceiling can cause an acoustical mess.

CONSOLE REFLECTION (FIGURE 2) — A major area of concern in setting up nearfield loudspeakers or desktop audio workstations is the creation of comb filtering. Comb filtering occurs when a sound wave interferes with a copy of itself that is slightly delayed in time, such as the direct sound leaving the loudspeaker interfering with a reflected copy of the same sound.

This situation can be greatly enhanced by simply moving the loudspeakers away from the listening position and therefore changing the local geometry and minimising the console being hit by sound energy (Figure 3).

SIDE WALL REFLECTIONS — Side wall reflections are another excellent way of creating unwanted comb filtering. Again, the reflected sound is interfering with the direct sound at the listener position. Using absorption, this situation can be greatly optimised (Figure 4 & 5).

ABSORPTION — When sound hits an absorptive material some part of the acoustical energy is transformed to other types of energy (mostly heat). Examples of acoustical absorbers include porous foams or perforated/slotted surfaces. In

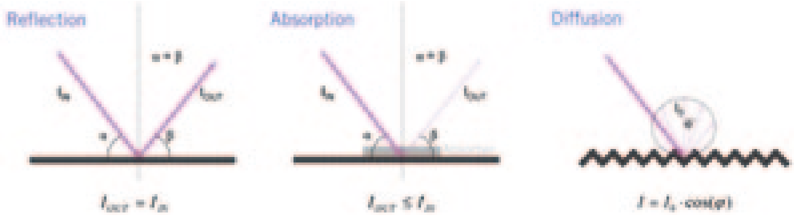

Figure 1. Reflection, Absorption, Diffusion.

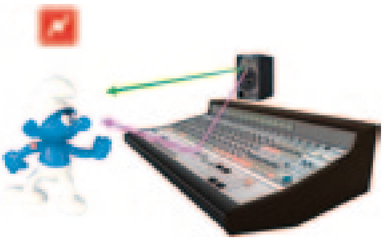

Figure 2. Console reflection comb filter.

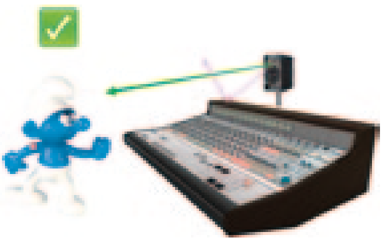

Figure 3. Console reflection minimised by relocating loudspeaker.

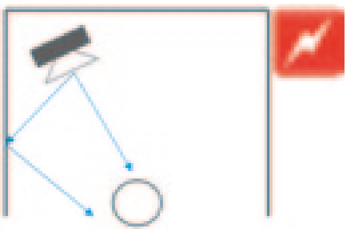

Figure 4. Side wall reflection interfering with direct sound.

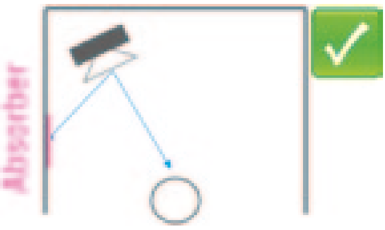

Figure 5. Side wall reflection minimised by absorption.

both cases the underlying energy transformation mechanism is the friction of air molecules. Absorption is useful to control unwanted reflections and consequentially to decrease excessive reverberation (Figure 6).

An alternative method to minimise side wall reflection is a change to the room geometry by the angling of the walls. This will steer the reflected sound clear of the listening position and on to areas where it can be absorbed or dealt with in another way (Figure 7 & 8).

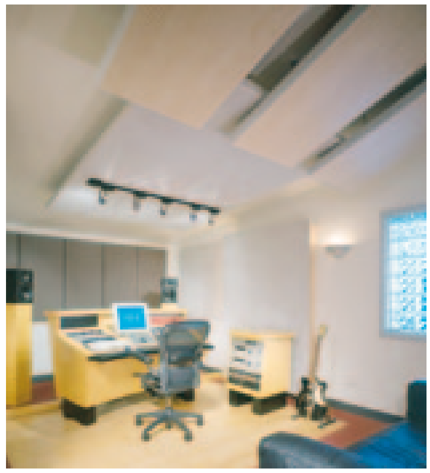

Figure 6. Engine Room Mastering, New York City USA, side wall absorber.

ABSORPTION COEFFICIENT — To characterise the properties of an absorbent material the Absorption Coefficient 'alpha' was introduced. This coefficient describes the material's conversion ratio of sound energy to other forms of energy as a normalised percentage (0% to 100%, or 0 to 1). Alpha varies with the incident sound's frequency — materials that have good absorption properties at low frequencies (alpha, for example, over 60%) often have little or no absorption at high frequencies (for example, less than 20%) and vice versa (Figure 9).

Absorptive materials are available in dozens of designs, shapes, colours and formats. A current summary would encompass the use of plastic, perforated or slotted wood panels, metal in various shapes, fabric, foam, various wall and ceiling plasters, microperforated foil, transparent laser cut panels and any combinations of the above. A selection is made according to the acoustical properties, the desired aesthetics and integration solution and the available budget.

LOW-FREQUENCY ABSORPTION — Low frequency control is a major problem in small acoustic spaces due to the wavelengths of these frequencies being similar to the room's dimensions. Membrane absorbers and Helmholtz resonators are absorber designs suitable for frequencies below about 125Hz.

A membrane absorber is a moveable rubber, wood or metal membrane mounted in a frame. At certain frequencies (or, depending on the type: below a certain cut-off frequency), the membrane starts to vibrate when exposed to sound pressure and thus transforms energy from the soundfield in to heat. Helmholtz resonators work like a coke bottle that can be used as a whistle: a given closed volume (the volume of the bottle) has an opening with a particular length (length of the bottle neck) and a particular cross-section (diameter of the bottle neck). Helmholtz resonators are easily incorporated in a space where otherwise unused volumes are available (e.g. a raised platform cavity in a home theatre, or a void above a suspended ceiling).

DIFFUSION — Diffusion is used to distribute sound in space uniformly. Diffusors are available in a range of shapes and sizes. At the moment there are two metrics to measure and characterise scattering surfaces — the Diffusion Coefficient d, and the Scattering Coefficient s — and both are frequency dependent.

A commonly used approach is the so-called QRD Diffusor, or Quadratic Residue Sequence Diffusor. The device's geometry is based on a prime number which determines the length after which the sequence repeats periodically and thus also the number of wells the diffusor consists of. Typically one of the prime numbers 7, 11 or 13 is used. One-dimensional diffusors contain depth variation in one dimension, thus forming linear divided wells or steps of varying depth, whereas two-dimensional diffusors offer depth variation in two perpendicular directions, thus forming a lattice of divided cells or steps of varying depth — looking a bit like a skyscraper skyline.

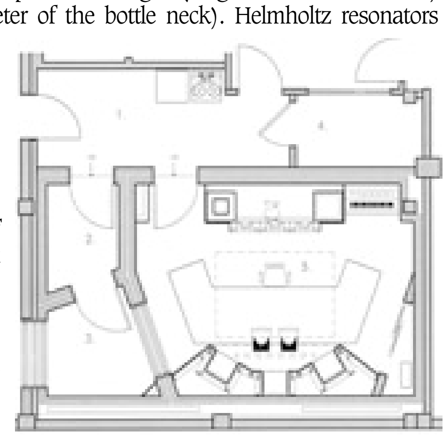

Figure 8. KIFF Aarau, Switzerland; side wall reflection minimised by room geometry.

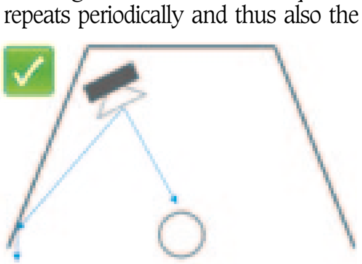

Figure 7. Side wall reflection minimised by room geometry.

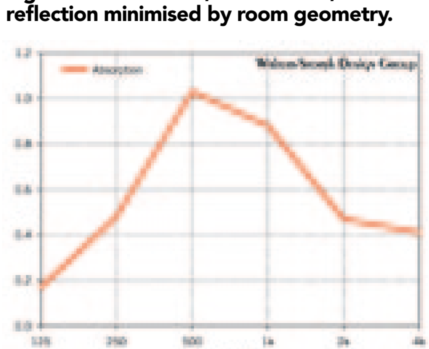

Figure 9. Absorption Coefficient of a slotted wood material.

Figure 10. CDM Productions, Switzerland. Finished recording room with diffusors, ceiling and wall absorbers.

Diffusion can be used to control reflections when the placement of further absorption is not desired, for example when the reverberation times are already on the low side (Figure 10).

FINDING THE BALANCE — A large amount of design time is spent on the complex issue of balancing reflection, absorption and diffusion in a room. Besides finding the optimal acoustical solution these are surfaces that are actually exposed to the eye and so a pleasing aesthetic is asked for as well.

To preview and study the acoustics of a space before construction a number of tools are available. These allow for the prediction of certain acoustical parameters such as Reverberation Times and Standing Wave distribution. These and other parameters will be touched on in the next article in the series. ■

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