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Practical Acoustic Treatment, Part 1

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PRACTICAL ACOUSTIC TREATMENT

PART 1: PAUL WHITE examines the basic principles of acoustic treatment in order to help you improve your recording and monitoring environment. This is the first article in a five-part series. Read Part 2, Part 3, Part 4 and Part 5.

There is a lot of confusion between soundproofing and acoustic treatment, but hopefully the recent series on Soundproofing (*SOS* February '98 to June '98) will have helped to explain the difference. Soundproofing is simply concerned with reducing the amount of sound getting into or out of a room, but the degree of soundproofing in no way defines how the room behaves as a space for listening to music. Indeed, it is very unlikely that it will function as a good listening (or performing) environment without further treatment.

A good listening room invariably combines appropriate absorption with scattering to break up strong reflections. Both these subjects will be covered as this series (which follows on from the one on soundproofing) progresses.

PRAGMATISM

The accurate acoustic treatment of a room cannot be undertaken based purely on theory, because, as we'll see later, the formulas used are not precise for small rooms, and the building materials involved may not have the same acoustic properties as stated in the tables of standard values you sometimes find in textbooks and materials catalogues. Professional studio designers use a combination of maths and measurement to arrive at a satisfactory solution, and the measuring equipment requires specialised operator knowledge, as well as being expensive.

If you interpret this as advice not to tackle the job yourself, you'd be both right and wrong. I'd never undertake a rigorous acoustic design project because I have neither the specialised knowledge, nor the tools required. But fortunately, it is possible to make significant improvements to a listening space by applying a few basic rules. What's more, because home recording tends to rely heavily on nearfield monitors, the contribution of the room's acoustic isn't as significant as it would be in a larger room with the monitors positioned further away from the listener.

DESIGN TRENDS

Over the past 20 years or so, a number of control room design philosophies have enjoyed 'flavour of the month' popularity. For example, early studios were often constructed like padded cells with mineral wool-lined walls covered with hessian. But we now know that this treatment produces a very dead acoustic, often with inadequate absorption at very low frequencies. The result is a room that booms at low frequencies, but sounds unnaturally dead to speech.

Then we had the flirtation with the so-called 'live end, dead end' approach, where the end of the control room with the monitors was made to sound dead using a combination of absorption and geometry, while the back of the room was allowed to contribute some reflections.

We've also seen rooms with carefully designed scattering surfaces, virtually anechoic rooms (ie. those with having a low degree of reverberation) with huge monitoring systems... and just about everything in between. Today's control room tends to incorporate a number of techniques with the aim of producing a better-balanced result.

The secret is to improve the room by doing as little as possible to it. Fortunately, most carpeted domestic rooms with just a few items of furniture are already pretty close to being acceptable listening environments. The purpose of this series is to explain some of the basic rules of acoustics so that you know what you're dealing with, and hopefully also to dissuade you from doing anything that might make the situation worse. For example, readers have phoned *SOS* after covering the entire surface of their studio with foam, mineral wool or even carpet to complain that the room sounds even worse than it did before (such distress is something that Nick Whitaker and Roger D'Arcy know all about -- see last month's interview on their approach to acoustic treatment) Once you've learned the basic rules, you'll know exactly why this might be the case, and you'll have a number of options to try that have a far higher probability of success!

STUDIO AREA

While a control room should be designed to provide the best possible environment in which to listen to and evaluate the music being recorded and mixed, the performing area or studio may have quite different acoustic properties. These might be dictated, as much as anything, by current fashion. For example, we have stone or wooden live rooms, rooms with variable acoustics, neutral rooms, and, occasionally, fairly dead rooms. Of course, some kind of compromise has to be reached in the project studio, where the recording and mixing is carried out in the same room.

A relatively dead recording environment excludes nearly all natural room ambience, enabling the engineer to start with a clean slate when it comes to adding artificial effects. However, most leading engineers and producers would agree that instruments that require a live acoustic setting invariably sound better in a sympathetic live room than when processed with artificial ambience from a digital reverb unit or echo plate. It's probably fair to say that a reasonably dead room is more useful than a very live one if it's the only room you have.

Separate live rooms remain popular for drums or certain other acoustic instruments, and a typical live room might consist of an untreated stone or tiled room with an exposed concrete or wooden floor. If space permits, it is possible to create a more general purpose recording room by designing an area that is live at one end, but damped at the other. Acoustic screens that are reflective on one side and absorbent on the other may then be used to create localised areas with the desired acoustic characteristic as well as providing some separation between instruments. Such studios should not be confused with live end/dead end control rooms (see the 'Design Trends' box), which will be discussed later. Movable carpets or heavy drapes may also be used to deaden a naturally live room.

CONTROL ROOMS

The control room is the part of the studio where sounds are evaluated both during recording and mixing. So a control room must provide an acoustic environment in which valid musical decisions can be taken. However, because of the multiplicity of different monitor speaker systems and the widely differing design philosophies of control rooms, the aim of creating anything approaching a universal standard has yet to be realised. Indeed, it was once said that if you were to take a sample of domestic living rooms and compare their acoustic performance, the results would be more consistent than a similar survey of studio control rooms. It may be an exaggeration, but it serves to show that virtually all studio control rooms sound different -- though it's also true that most acoustic designers agree in broad terms what constitutes a good listening room.

But before looking at the possible fixes for acoustic problems, let's look more closely at their causes.

ROOM PARAMETERS

The first thing to appreciate is why a room should have 'a sound' in the first place -- after all, it's the speakers that you're listening to. But sound bounces or reflects off all solid surfaces, so that when the sound source such as a loudspeaker stops producing sound, the reflections continue for a period of time until the energy is absorbed. Or to put it another way, the room functions as an energy store, returning the acoustic energy to the air at some point after the initial event.

Because of these reflections, we don't just hear the direct sound from our monitor loudspeakers, we also hear an appreciable amount of reverberation as the sound bounces around the room. In a good listening room, the reverb time will be too short to be perceptible under normal circumstances -- although you'd

BOLT-ON ACOUSTICS

If you don't have a room acoustics analysis software package and you don't fancy spending time with a calculator, you might be interested in Bolt's graph (he presented a paper on the subject in 1946), where the shaded space denotes acceptable room ratios. This isn't foolproof though, as some 2:1 room ratios fall into Bolt's area and some perfectly good rooms fall outside it. However it is a useful guide if some care is exercised -- just check the figures after you've decided on your room dimensions to make sure there are no problems.

Several sets of preferred ratios have evolved which work well practically as well as theoretically. Three of these are:

- ***1 : 1.14 : 1.39***
- ***1 : 1.28 : 1.54***
- ***1 : 1.6 : 2.33***

notice a huge difference if it were removed altogether. However, different materials and structures reflect different parts of the audio spectrum more efficiently than others, and the dimensions of the room cause resonances or modes to be set up (more on these later), so the reverb we hear is 'coloured' -- ie. it doesn't have a flat frequency response.

HOW MUCH REVERB?

The ideal listening room needs a touch of reverb to help increase the perceived loudness of the monitors and also to prevent the room sounding unnaturally dead. But the reverb time also needs to be roughly equal at all frequencies across the audio spectrum if coloration is to be avoided. Reverb times of between 0.3 and 0.5 seconds are normally chosen for control rooms, though it is also common for the very low frequency reverb time to be slightly longer (apart from in very sophisticated designs, where elaborate bass-trapping techniques have been employed).

An even reverberation time can only be achieved by the careful deployment of different types of sound-absorbing material and structures, and formulas exist that enable the areas of treatment to be calculated. However, as stated in the introduction, relying purely on calculations is likely to lead to inaccurate results, because of variables in the performance of the materials, combined with the effect of reflective and resonant studio equipment introduced after the design is complete, and the presence of people in the studio. It is also likely that the existing building has acoustic properties that can't be accurately calculated. It's for this reason that professional studio designers use very sophisticated measuring equipment and not just simple spectrum analysers to calculate room acoustics. Moreover, competent designers will generally measure the room after treating it, then make fine adjustments to ensure the measured result matches the target figures.

Because much of today's actual recording is done in the control room rather than in the studio proper, the design may be a compromise between ergonomics and acoustics, especially when equipment is regularly being moved in and out of the studio. However, once the most serious problems have been ironed out, such changes generally make less of a practical difference than you might imagine.

Once the room performance has been brought within acceptable parameters, the choice and location of loudspeakers can still have a dramatic effect on the overall monitoring accuracy of the room. This subject will be covered later in the series.

MODES

Earlier I mentioned room modes or resonances, which cause the spectrum of the reflected sound to vary at different points in the room. Assuming you have solid walls, room modes are directly related to room dimensions and, because the same physical laws apply, they will affect both control room and studio acoustics. If a sound wave is generated that has exactly the same wavelength as the longest dimension of a room, it will be reflected back and forth from the facing walls in phase with the original, thus reinforcing it -- a phenomenon known as a standing wave. Accepting the value for the speed of sound as being roughly 1100 feet per second, an 11-foot room would correspond to a half wavelength at 50Hz, the result being a strong 50Hz mode.

Any music signal played in the room would, therefore, undergo an artificial reinforcement or colouration of sounds at, or around, 50Hz -- although not only at 50Hz. Two half wavelengths at 100Hz also fit neatly into 11 feet, three at 150Hz, four at 200Hz, and so on. Introducing sound into the room at any of these frequencies will cause standing waves, giving us a potential trouble spot for every 50Hz increase in frequency.

TRIPS AROUND THE BAY

One architectural feature to avoid where possible is any form of concave structure such as a bay window or curved wall. These tend to focus reflected sound into one place, just like a parabolic reflector, which can seriously affect the room's acoustic performance when you're anywhere near the focal point. Convex or irregular surfaces, on the other hand, are generally desirable, as they help to diffuse high frequencies leading to a more even sound field.

But note that this is only in relation to one room dimension. The width and height of a room also give rise to their own series of standing wave frequencies. Because they are related to the three axes of the room (length, width and height) modes caused by standing waves between parallel room surfaces are known as axial modes. There are other more complex modes caused by sound bouncing off more than one wall and travelling round the room: these are known as tangential and oblique modes. Because the sound bounces off more surfaces to produce these modes, some of the energy is absorbed or scattered, so the intensity of the modal peaks is less than for axial modes. To be more precise, tangential modes produce half the energy of axial modes whereas oblique modes produce one quarter of the energy of the axial modes.

These modes decay at different rates, so to damp a mode, absorbing material must be placed in an area of high pressure. For example, to damp a mode produced by two opposite walls, the absorbent material must be placed on one of the walls, rather than on the floor or ceiling.

OPTIMUM DIMENSIONS

Unless you make at least one of every opposing pairs of surfaces completely absorbent across the entire audio spectrum, modes will exist. In other words, if a room has dimensions, it has modes, though the absorbency of the walls will influence the intensity of the modes. The question is, how do we reconcile all these apparently nasty resonances with a flat reverb spectrum?

The best-sounding rooms tend to have their modes fairly evenly distributed, so there are no drastic peaks or dips in the room's response. In practice, modal problems are most serious at lower frequencies, and unfortunately, smaller rooms tend to be worse affected than larger rooms because the low frequency modes are often strong, with little happening between them. One approach is to use tuned absorbers to damp down the energy peaks at the main modal frequencies, although a lot of this can be avoided at the planning stage by picking room dimension ratios that produce the most evenly spaced modes. Alternatively, nearfield monitors with a restricted bass response could be used to avoid exciting the rogue room modes.

"...much can be deduced about a room's mid-range performance simply by holding a conversation in it..."

It's also possible to improve the situation at low frequencies by a combination of monitor positioning and maybe even a little monitor equalisation -- though equalisation is rarely helpful at higher frequencies.

To learn a little more about the best shape for a room, let's first consider the worst possible shape -- a cube. Inside a cube, all three axial modes will occur at exactly the same frequencies and so will reinforce each other to form very noticeable peaks in the room response. Non-cuboid shapes are obviously more suitable, but if one dimension turns out to be exactly twice one of the others, then modes will still occur at the same frequencies. Even apparently unrelated dimensions can cause modal pile-ups at some frequencies purely by chance. Much research has been undertaken in the past to find sets of ratios that minimise these undesirable peaks. Currently you can buy computer programs, such as Pilchner-Schoustal's *Acoustic X*, that work out the room mode distribution from your room dimensions. Though no substitute for an experienced designer, such programs can be both educational and useful.

Large gaps between modes are also a problem because the room response will dip noticeably in these places. In practice, you might find that musical notes coinciding with these inter-mode gaps sound quieter compared with the rest of the spectrum. Clearly this is a bad thing because it will upset your perception of what you're hearing over your monitors, leading to a less accurate mix.

In most rooms, above the 300Hz mark, the modes become so closely spaced that we don't need to worry unduly about peaks or gaps. Below this frequency, the ideal situation is not to have gaps between modes of more than around 20Hz. At the same time, you should avoid closely packed or coincident modes. In a typical studio, the modal resonances tend to be around 5Hz wide, and the more reverberant the room, the narrower the modal bandwidth. However, if a room is below a certain minimum size, it is impossible to arrive at dimensions where the low frequency modal behaviour is ideal because the modes are too widely spaced.

THE RIGHT ANGLE?

It is a common misconception that building non-parallel walls will improve the standing wave situation. In practice, this has minimal effects at low frequencies: the low frequency modes will develop much as before based on the mean distance between walls.

What is true is that splaying the walls by as little as 1:10 or even 1:20 will help reduce high-frequency flutter echoes caused by mid- and high-frequency sounds bouncing between two facing walls or floor and ceiling. However, this particular problem is solved even more easily in most rooms with parallel walls by using small areas of acoustically absorbent material.

An approximation to the modal behaviour of a room can be arrived at by plotting just the three axial modes against frequency and ignoring the tangential and oblique modes. Calculating the tangential and oblique modes is much more complicated, and a number of textbooks stress that the practical results seldom bear out the mathematical predictions. Figure 1 shows how the axial modes may be calculated for each opposing pair of surfaces in a room. By substituting the numbers one, two, three, and so on for the value of n, a whole series of modes can be calculated, though the most significant are those falling below 300Hz.

As modal problems invariably have an adverse effect on the quality of speech in a room, much can be deduced about a room's mid-range performance simply by holding a conversation in it and checking the intelligibility of the speech. As a rule, if a room sounds good for speech, it will sound good for music, though there may still be low frequency problems below the natural frequency range of the human voice.

Next month, I'll look at some of the traditional solutions to the problems I've outlined so far.

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