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Practical Acoustic Treatment, Part 2

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PRACTICAL ACOUSTIC TREATMENT

PART 2: In his second article on acoustic treatment, PAUL WHITE tackles the absorbing subject of acoustic traps. This is the second article in a five-part series. Read Part 1, Part 3, Part 4 and Part 5.

Last month's introduction to acoustic treatment pointed out the importance of room dimensions in achieving an even modal response, but that doesn't help much if your room is already built. Fortunately, by taking a pragmatic approach, combined with the use of nearfield monitors, you can produce well-balanced pop music in a relatively unsophisticated room. When recording, there's usually a lot of close miking employed, and even then much of the sound subscribes more to fashion rather than to pure fidelity. It's really when recording speech, vocals or acoustic instruments that well-behaved acoustics are most important in the actual studio area. Equally, an apparently problematic control room can usually be set on the road to workability by choosing appropriate monitors and mounting them in a suitable position. Further improvements can be made by placing suitable acoustically absorbent materials within the room to absorb sound that would otherwise be reflected by the room boundaries, so that you hear more of the direct sound from your monitors (reflected sound is misleading, as it will be coloured -- effectively, EQ'd -- by whatever it has bounced off before it reaches your ears).

ABSORBING STUDIES

Having introduced our main enemies in acoustic design last month, it's now time to check out some of our allies. Absorbing mid and high frequencies is not much of a problem.There are several proprietary acoustic tiles, foams and heavy drapes that can effectively soak up frequencies above 300Hz. However, dealing with the bass end requires a more rigorous approach.

The reason for this is that low-frequency sounds have long wavelengths and a purely absorptive bass trap needs to be at least one eighth of a wavelength deep to do any good. At a frequency of 50Hz, that's approaching three feet and there aren't many studios that can afford the space to cover one or more walls with a three-foot thickness of mineral wool (such as Rockwool) with a density of 150 to 175 kg per cubic metre. That said, this type of trap has the advantage of working equally well at all frequencies down to its lower cut-off point.

"...it's now possible to treat a completed room by adding just a few well-chosen panels in the right places."

The other, and understandably more popular, approach is to build a damped, resonant structure that will absorb a significant proportion of a specific frequency band by converting it to heat via frictional losses. As the sound energy expended by a Wembley football crowd during an FA cup final (including extra time!) would be barely sufficient to warm a pot of tea for the teams at half-time, you don't have to worry about thrash metal bands setting fire to your walls during over-zealous guitar solos!

RESONANT TRAPS

There are two commonly used traps, both of which are easy to build. They are the panel absorber and the Helmholtz resonator. However, to be successful you first have to know precisely where your problem frequencies are and then you have to build these traps accurately to ensure that they work at the right frequency. I've included them here more for academic interest, as in a nearfield monitoring situation you can probably solve your worst problems by less complex means.

Both types of absorber take up a large area, but have the advantage of being only a few inches deep. Even so, you must bear in mind that these are tuned traps and so are normally used to reduce specific resonances. They are not suitable for use as broad-band absorbers, with the exception of a panel trap constructed with a highly damped, limp membrane.

PANEL ABSORBER

The panel absorber is the easiest and most predictable bass trap to design and build. It consists of a simple wooden frame over which is fixed a thin, flexible panel such as plywood, hardboard, barrier mat or even roofing felt. Fibreglass or mineral wool is often fixed inside the frame to help damp the system by absorbing energy, since the more the trap is damped, the wider the frequency range over which it will work. The resonant frequency is a function of cavity depth and mass per square foot of the panel material, so it's easy to calculate the necessary dimensions using a simple formula (shown in the box elsewhere in this article).

The actual area doesn't make any significant difference to the operating frequency, but obviously the more you want to reduce the low-frequency reverberation time, the larger the area of panel you'll need in the room. To understand better the effect of a given area of absorber, consider that a perfectly efficient full-range trap would affect the sound in the same way as an open window of the same size (but obviously without the associated problems of sound leakage).

Filling the cavity with fibreglass or mineral wool tends to lower the resonant frequency by up to 50 per cent as well as doubling the effectiveness of the trap. It also lowers the Q of the trap so that it is effective over a wider frequency range. A typical panel-type trap is effective for frequencies around one octave either side of the centre frequency, which at least has the advantage that you don't have to be absolutely accurate to get results.

As the surface of the panel may also reflect higher frequencies, curved panel traps have been constructed to simultaneously absorb bass frequencies and diffuse higher ones. However, it may be easier just to cover the front face of the trap with a layer of acoustic foam to extend its usefulness to the mid and high end of the audio spectrum. Figure 1 shows the construction details of a conventional panel absorber. Because the amount of damping affects the tuning of the trap, you may want to test the finished trap to see what effect it's actually having. You can discover the resonant frequency by sticking a cheap contact mic on to the panel's surface, then plugging the mic into a preamp or mixer with a VU meter. Play a test tone from an oscillator or test tone CD using loudspeakers, and vary this around the frequency the trap is designed for until you get a maximum meter reading. This will be at the trap's resonant frequency.

DAMPING

An undamped panel trap using a rigid membrane will radiate some energy back into the room after the incident sound has ceased. This is clearly an undesirable state of affairs, and so some degree of damping is generally included within the panel. Though panel traps are normally considered to be tuned absorbers, the use of a heavy, well-damped panel material lowers the Q of the trap so much that it may be considered a broad-band device, especially when combined with plenty of internal damping.

There are specialist materials such as mineral-loaded vinyl barrier matting, or even lead-loaded materials, that are heavy, flexible and highly damped and therefore lend themselves to wide-band bass trap design. You can also get good results from a trap which is between eight and 12 inches deep, filled with mineral wool and covered with a simple roofing-felt membrane. The only disadvantage is that the properties of roofing felt tend to change with age, so using barrier mat is probably a better long-term solution (if more costly). Apparently the BBC used to use roofing felt for their bass traps, but now they've replaced them with more up-to-date designs where the budget permits. Where the budget doesn't, their recommendation is to cover the fronts of the traps with carpet to reduce reflections and to increase low frequency absorption. I assume the carpet also acts as a membrane in conjunction with the roofing felt. You can also try experimenting with heavy vinyl floor covering as a membrane.

With such a high degree of damping, the action of the trap is less like a resonant panel and more like a floppy wall. In other words, sound energy is expended in trying to vibrate the felt which is so well damped that the energy is largely absorbed. Because the Q of such traps is low, the depth of the trap becomes far less critical. A broad-band trap is shown in Figure 2.

Many historic buildings feature wood-panelled rooms and these often have well-controlled acoustical properties because, in effect, a panelled wall with an air space behind acts as a tuned bass absorber. To a lesser extent, studio construction involving plasterboard fixed to a frame also acts as a trap for bass and mid frequencies, although the actual results depend on

THOSE FORMULAS IN FULL

PANEL ABSORBER FREQUENCY FORMULA

The formula for determining the frequency of a simple panel absorber is as follows:

F =170/√MD

F = the frequency you're aiming to absorb

M = the mass of the panel in lbs per square foot

D = the depth of the air space in inches.

The metric equivalent of this equation is:

F=60/√MD

where the mass is in kilograms and the unit of length is metres.

* HELMHOLTZ TRAP FORMULA

You can determine the operating frequency of a Helmholtz trap with the following formula:

R = 200 √P/DT

R = resonant frequency,

P = the percentage of perforation (total hole area divided by panel area multiplied by 100)

T = the effective hole depth in inches (thickness of panel plus 0.8 of the hole the depth of the air space behind it. In practical terms, it is easier to treat a room that has a lightweight construction than one that is solid, because a large proportion of the bass energy passes straight through the walls instead of being reflected back. Unfortunately, in this particular case, what is helpful for acoustic treatment is totally at odds with what is desirable for good sound isolation -- that is unless you are dealing with a lightweight inner shell built within a solid outer shell. If you have plasterboard walls, you can again try the sweep oscillator and contact mic approach mentioned above to establish the actual resonant frequency. If the walls are too resonant or resonate at the wrong frequency, adding a second layer of plasterboard, ideally one with a different thickness to the first, will damp the resonances and change the frequency of absorption. You can use the first formula shown in the box to establish what the new resonant frequency is likely to be.

diameter)

D = the depth of the air space in inches.

Note that it's easy enough to convert this formula into metric, but the numbers are more straightforward if you stick to imperial measurements.

HELMHOLTZ TRAPS

Another type of tuned trap, popular in broadcast studios and older recording studios, is the Helmholtz resonator. This is essentially an enclosure with an aperture, not dissimilar in terms of its physics to a bottle -- and just as a bottle has a very specific resonant frequency (which you can hear if you blow over the hole), so too does a Heimholtz resonator. A bottle has a very narrow bandwidth, but by introducing an absorbent material such as fibreglass or mineral wool into the neck to reduce the Q, the operating range can be widened. While you don't see many studios full of bottles (at least not ones being used as bass traps), it is possible to simulate the effect of hundreds of tuned bottles with a perforated panel over an air space.

By fixing a perforated wooden panel over a frame and putting an absorbent material inside the space created, a resonant bass trap is formed with each perforation acting as a single 'bottle' in our virtual bottle array. Again, there is a fairly simple formula to determine the operating frequency (see box).

Figure 3 shows the construction of the Helmholtz trap. By varying the percentage of perforation, the design can be applied to both the bass and mid range. However, predicting the performance of these traps is difficult because the Q or bandwidth varies depending on the amount of internal damping.

The other problem is getting the right perforation percentage. Common pegboard is usually used in mid traps rather than bass traps. For example, pegboard with 3/16-inch holes on a one-inch matrix has a perforation percentage of 2.75 per cent. Fixed over a four-inch air gap, this gives a resonant frequency of a little over 400Hz. Boards of different perforation percentages may be available from specialist acoustic suppliers, but are not readily available from conventional builders merchants.

Like a panel absorber, adding an absorbent material lowers the resonant frequency slightly and also broadens the resonant peak. Instead of employing perforated board, it's theoretically possible to use a series of slats to create a slotted panel with the correct perforation percentage, but the calculations for such an absorber don't always predict a precise result, so I'd recommend some form of test to verify the final resonant frequency.

Helmholtz resonators were once very widely used both in broadcast and recording studios, but panel traps with limp membranes seem more widespread in modern designs.

Tuned traps should be placed on the walls corresponding to the room modes that you wish to attenuate. Your can tackle floor-to-ceiling modes by placing a trap on the ceiling. Traditionally, bass traps are placed close to corners where there is an area of high pressure.

MID AND HIGH ABSORBERS

One of the simplest absorbers for use at higher frequencies is open-cell foam, such as that used in furniture. In fact, expensive acoustic foam tiles are often only sculpted versions of this same material. (Note that for safety reasons, you should always use fire-retardant foam.)

The lowest frequency that will be effectively absorbed is dictated by the thickness of the foam. One-inch thick foam is most effective above 1kHz, while four-inch thick foam is useful down to 250Hz. The low-frequency absorption can also be improved by spacing the foam a few inches away from the wall using a wooden frame.

A similar absorber can be made from two-inch mineral wool slab, fixed to a frame two inches away from the wall and covered with open-weave fabric to prevent the fibres escaping into the air. Again, this should be usefully effective down to 250Hz or so. A variation on this is the acoustic blanket used in broadcast work where layers of mineral wool reinforced with lightweight wire mesh are covered with fabric and hung from walls. The frequency down to which a blanket is effective is determined by the

MOVABLE SCREENS

Portable acoustic screens are useful because they can be used to modify the sound of a small part of a room for the recording of, say, a vocal, drums or acoustic guitar. These screens are generally built with a polished wood or synthetic laminate surface on one side and a mineral wool or foam absorber about four inches thick on the other. They are supported by simple wooden legs and, by turning either the hard or the absorbent airspace behind.

Carpet is not thick enough to be effective at anything more than the high frequency end of the spectrum -- its absorbency drops off noticeably below 2kHz. There is a slight advantage in using a foam-backed carpet, and once again, mounting this with an airspace behind will extend its effectiveness down another octave or so. However, it's less than ideal as a wall treatment.

Variable absorbency in the mid- and high-frequency range can be achieved by hanging heavy drapes a few inches from the wall. The width should be generous enough to allow the material to hang in folds rather than being tightly stretched. If they are hung on a rail in front of a reflective surface, it's a simple matter to draw them back when you want to convert a dead acoustic into a live one.

side towards the performer, a live or dead environment can be created. Drum booths can be made of a set of tall screens with another screen balanced on the top to form a roof. For drums, acoustic guitars and so on, the live side is normally used, and for vocals, the dead side. The diagram is this box shows the construction of a simple acoustic screen.

These screens are only effective down to around 250Hz on their absorbent side, but that's usually adequate for the purpose.

SUMMARY

Absorbent traps can be useful in producing a more even acoustic environment, but only if applied intelligently so as to produce a nominally consistent reverberation time across the audio spectrum. The most common mistake people make when building their own studios is using too much trapping, usually at mid and high frequencies, and this serves only to further emphasise low frequency resonances that are more difficult to cure. In any event, it's probably unwise to do anything irreversible before the carpets and equipment are installed in the studio as these invariably make the room sound totally different to the way it did when empty.

Numerous advances in trap design have been made by specialists in the field of acoustic treatment, with the result that it's now possible to treat a completed room by adding just a few well-chosen panels in the right places. It's also possible to build panels with variable absorbency so that they can be adjusted in situ. Understandably, the designers of these traps are reluctant to give too much away!
If you have a difficult room and you're planning to do commercial work, it could be cheaper to call in a proficient acoustic consultant than to tackle the job yourself and get it wrong.

Next month, I'll continue by looking at ways in which to calculate the amount of acoustic treatment required.

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