All you need to know to build a small studio

Why size is important
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Size is important

The prospect of embarking on the acoustic build of a small room is daunting. Philip Newell discusses some of the problems encountered and explains some of the limitations to be anticipated when too much is expected from a small space.

I am writing this during a day off in Barcelona where I will be for about three months overseeing the construction of two rooms for compliance with the specifications for mixing in Dolby Digital. One room, the new Fig Tree studio, will be certified to Dolby Premier standard while the other is a rebuild for Audio Projects of an existing room in the ex-Duy studio complex. The first room is in a shell of about 85sqm, with a height of about 4m while the second occupies about 35sqm and has a height of only around 2.5m. This room cannot receive certification for mixing feature-film soundtracks, basically because acoustics and audio perception will not scale despite the fact that both rooms will be equalised precisely to exhibit the same ‘frequency’ response at the working positions. The acoustic differences are tied to distances and wavelengths. The smaller room will necessarily be restricted to the mixing of cinema commercials and trailers, although the premixing of the stems of dialogue, music and effects is a possible further use.

I have written several articles for Resolution, (V7.3, V8.4) outlining why these size differences give rise to such perceptual differences, even though the rooms may be quite precisely equalised to the standard cinema ‘X-Curve’ and may even use the same loudspeaker systems. I am building this big room big in Barcelona because it cannot be built small; at least not without sacrificing a great deal of its performance. These are big rooms and we are here to talk about small rooms. I first met Pablo Sanchez, the co-owner of Producciones Peligrosas in Peligros, near Granada, Spain, in 1994 when he and his partners wanted a recording studio. They had contacted a ‘general acoustics and sound isolation’ company to ask for a design, but before it was finished it became apparent to the owners that neither the isolation nor the internal acoustics were going to be adequate. I was asked to take a look at the situation. The control room was miniscule, and the studio (performing room) was rather uninspiring. What was more, although the isolation work was still not finished, a bass guitar and a drum kit playing in the designated area was producing 85dBc in the bedroom of the neighbour. There was just no way that it was going to be cut to 30dBA by the proposed isolation measures. Something drastic needed to be done.

The studio owners decided on a redesign so I pushed for a 30sqm control room and sacrificed much of the performing space. To allow the neighbours to sleep peacefully I had to insist on the subsequent triple shell construction, which consumed even more space. Initially, the owners were very worried that their available working area was shrinking so much, but the resulting control room was very neutral and the variable acoustics in the studio allowed much flexibility. Fifteen years later they are still in business, they are still on excellent terms with the neighbours, and they have a client list that they are very proud of. Unfortunately though, none of this could be achieved in a starting space the size of a shoe-box. The amount of space consumed can be seen in Figure 1.

In the studio in Peligros there were two saving graces that made it possible to make a good studio. First, the site for the studio was on solid ground so the weight of isolation materials was not a problem. Second, they had a height of almost 4m, which allowed the installation of 20cm of floated floor, and an adequate amount of wideband absorption in the ceilings to neutralise the room problems, even at low frequencies.

Pablo had called me to speak about some musicians with whom he was working who had just paid more than €15,000 to a ‘general acoustics’ company to design and build a studio in their home. The sound inside the rooms was said to be awful, the isolation between the rooms was poor, and the foot-falls of the people walking on the floor above could still clearly be heard. They asked me to travel down to see what could be salvaged.

The rooms, when finished, were tiny, only about 3m by 3m, with a height of just 2.2m. The basic layout is shown in Figure 2. If I had been asked to make a studio in such a small space from scratch I would have refused, because I would know that I could never build what they were expecting in a space so small. But I felt obliged to try to help his friends out of their situation.

I work for satisfaction as much as for financial survival, so if I cannot walk away from a room with the feeling of a job well done, then I prefer not to undertake the work. There is a definite trend, however, to go for marginally acceptable rooms and small rooms in general only tend to give satisfactory results...
if the standards that the owners are aiming for are not very high. Poor rooms and poor performances often go hand-in-hand. Poor sounds are rarely musically inspiring, and uninspired music rarely leads people to look for the highest quality of sound. You don’t do anyone any favours by making mediocre rooms, even if they are ‘workable’. In the case of Pablo’s friends there was just not the necessary space to make rooms that are as flexible as Pablo’s rooms, so the only possibility is to tailor the tiny rooms to a limited range of recording styles.

The current situation consists of suspended or floated sandwiches of plasterboard, with a dead-sheet damping layer in-between. The wall sandwiches are mounted on metal studs, and 70kg/cubic metre mineral wool has been placed in the cavities. There are also ‘acoustic’ doors and multiglazed windows. This type of isolation is great for most types of industrial noise as there are few processes outside the music business that regularly generate levels of 115dBC at low frequencies in small spaces, as do drum kits and bass guitars, for example. Conversely, there are few industries that are as sensitive to the ingress of noise as music recording studios. This is why designing to standard noise ratings/criteria is rarely appropriate in music studios. In fact, most isolation figures for doors and wall systems are only published down to around 125Hz, or sometimes 63Hz, and at these frequencies the isolation is usually diminishing. Unfortunately, it is exactly in this region where the musical power is frequently most potent. The only real options for isolating these frequencies are mass (weight) and distance. When faced with a studio in an office or light industrial building, the ability to load a lot of weight on the floors is often very restricted, and rarely, also, do people want to lose floor area ‘just’ for isolation. So, if the space is small and the floors are weak, good low frequency isolation is probably not an available option.

Fortunately, in the case of the two small rooms in question, the owners of the studio are also the owners of the floor above and the purpose of the studio is to record, almost exclusively, Flamenco music. This type of music consists principally of voices, Spanish guitars, and the odd cajon. Generally, there is not much low frequency content in this music so high LF isolation between the rooms is not likely to be very necessary. Nevertheless, this would not make a good Rock studio as the LF leakage between the rooms would interfere with the LF from the loudspeakers during a recording. Achieving good low frequency isolation in small spaces in domestic buildings is not always practicable. What is more, the possibilities for a Rock band playing together in such a small space would be limited but then small spaces do tend to be very limited in what they can do well. In terms of the general low frequency isolation in this studio, if low frequency noise were to enter from the outside of the studio it would clearly disturb the recordings. Acoustic solutions to this problem are not easy to find. In such circumstances many sound engineers would resort to the use of high pass filters but the filters affect the time response accuracy of the transients and can definitely affect the timing and the rhythm, and also the tonal quality of the wanted bass. Unhappily, though, these changes are often unnoticeable in rooms with LF resonance problems and inadequate loudspeakers. In the case in question, the...
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The best solution to the LF noise ingress problem is to control it at source; the occupants of the house would need to be conscious of not making too many thumps when recordings are in progress. As the upper floor is also owned by the studio owners, the noises from foot-falls can probably be reduced by the installation of a floated floor on the upper level, but the low frequency ‘thuds’ from children jumping about would be very difficult to isolate. With a starting height of only 2.6m, isolating these noises from inside the room is simply a non-starter.

With regard to the internal acoustics of the rooms, the plasterboard structure will provide a considerable amount of low frequency absorption, but the middle and high frequencies will be quite reflective. Hence the boxy sound in the rooms and the bass-light characteristic. These characteristics are not useful for control rooms or for studio performing spaces and sticking bits of foam on the wall is only likely to make the response even less flat.

In Resolution V6.5, I wrote an article about rooms for voice-overs. The same technique explained there can deal with the middle and high frequency reflections — to mount a wood/cement/air, composite board, either glued over an open-cell polyurethane foam or screwed to studs with a fibrous infill. Along with the LF absorption due to the plasterboard sandwiches, this does go a long way to killing the entire acoustic of the room, but at least the colouration goes with it. For the live, acoustic performance of Flamenco music this would be awful but in the case of recordings, if they are made while wearing headphones, the necessary reverberation for the performance can be added artificially, and at least a clean, uncoloured sound can be recorded ready for whatever postprocessing is deemed appropriate.

Any sense of excessive deadness in a room can often be alleviated by the use of a hard floor, which does not affect what is captured by microphones very much. You'll hear a lot of criticism about rooms, such as those being described here, as being oppressive, but, in reality, musicians very soon become accustomed to them. After a couple of weeks they won’t remember what it was that they found so initially disturbing. Obviously, such rooms do not make inspiring performing spaces, but as already mentioned this can be assisted by the foldback. The crucial point is that spaces like these can yield very good quality recorded sounds, and they are also capable of allowing microphones to be placed at appropriate distances from sources without the risk of colouration from the rooms.

In the case of Flamenco singers, who tend to move about very much during the emotion of a performance, and who can produce 125dB SPL or more at the microphones if they are too close to them, such rooms are very useful. When a studio, limited as it may be, begins to work in a consistent and predictable manner and achieves good quality recordings of good performances, then despite its small size it can still be considered to be professional.

Small rooms, by their very nature, return whatever reflected energy there exists very rapidly, and this also goes for the reflections of the reflections, leading to a high reflection density and a characteristically ‘closed’ and ‘thick’ sound. Diffusion will not deal with this because it will still return the energy to the microphone, just in a different form. In my opinion, diffusers at close distances can lead to very unnatural sounds and in small rooms I would never use them. The only reliable way to achieve clean recordings is via wide-band absorption. I have removed many diffusers from small rooms, where people were complaining about undesirable colouration, and after replacing them with absorbers none of my clients has ever wished to put back the diffusers. Internet chat rooms are full of a lot of dross on this subject; the practical realities tend to tell a different story.

Of course, whether all this struggle to achieve the best attainable quality matters or not will depend largely on your attitude. Is the studio a professional studio or merely a business? If it is a business then the optimum point on the price/quality/profit scales will determine the levels of performance. If the studio is professional, then all efforts will be made to achieve the best recordings, even if doing it more cheaply could yield a bit more profit.

The big commercial studios, which are
disappearing, have the size necessary to be good at many things; they are truly multifunctional. When we deal with much smaller spaces we need to think more about specialisation if we are to keep the quality level high. The unavoidable reality is that acoustic control measures take space and they also need to be tailored to their circumstances of use. In my experience, especially in the multimedia industries, not only do people want to use whatever space is available, but they also, often and quite unrealistically, want it to be multifunctional. They rarely want to spend any significant amount of money on acoustic treatment or to lose more space than would be taken up by a coat of paint. Hopefully, what has been discussed here will serve to highlight some of the problems and explain some of the limitations to be expected when too much is expected from small rooms. The large and small cinema rooms in Barcelona and the two recording studios in Granada highlight some of the differences of scale.

Finally, I am reminded of another situation that involved a domestic studio in the house of a famous musician. His vocal room had an undesirable sound so I was asked for solutions. I proposed an acoustic treatment costing about €5,000 for design, materials and labour, but this was considered to be too expensive. Perversely, the owner’s solution was to buy different microphones, costing, in total, even more than the proposed acoustic work, but these ‘solutions’ still only worked at very short distances. As soon as the singer moved slightly away from the microphone (as they tend to do when performing) the room sound problem returned.

I have never been able to understand how the relatively subtle differences between microphones could be expected to solve the non-subtle problem of the boxy sound of a resonant room. After all, any high quality microphone would not be worth its reputation if it could not capture accurately the room sound. Nevertheless, nowadays, there is a great tendency to believe that more equipment is always the answer. In reality, good acoustics tend to trump an entire truckload of microphones and preamplifiers.

The moral of this story is that you cannot expect too much from small rooms without risking disappointment. They cannot be all things to all people, and there are no electronic miracles to perfect them. I am building the aforementioned Dolby Digital soundtrack mixing room in a 340 cubic metre shell because the requirements for achieving the most neutral acoustics and the best compatibility with public cinemas cannot be achieved in much less. Yes; size is important.

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Fig. 3. The general acoustic construction. The difference between this treatment and that shown in Figure 1 is clearly apparent. In no way could the two treatments lead to similar results. As the treatment in Figure 1 could not possibly fit in the small space shown in the above figure, it follows that the small room could never expect to attain the same degree of isolation from the upper floor.
Optimisation is just part of the equation

Should loudspeaker/room optimisation be used to improve sound reproduction? In which situations can it help? What are its limitations? How does it work? Does it work? Trinnov’s FELIPE AVILA-REYES answers these questions based on the experience of installing Trinnov loudspeaker processors in studios.

Can room equalisation help to improve the sound of the control room? Is acoustic treatment the only real solution to acoustical problems? Trinnov’s experience shows that the best results can be achieved by combining all the three approaches: acoustic treatment, loudspeaker placement and optimisation. Most of the top acoustic designers today use some form of equalisation to complement the work done by acoustic panels and loudspeaker placement.

Certainly acoustic treatment and loudspeaker placement come first, and optimisation comes next. Optimisation is an integral part of the holistic sound system design process, which includes acoustic treatment and loudspeaker placement as essential steps.

The first industry that started to use equalisation was motion picture: all cinemas around the world are equalised according to SMPTE standards. Most of them use 31-band graphic equalisers whose settings are based on pink-noise measurements of the loudspeakers’ frequency response in the room. This amplitude-only based technology is at least 30 years old. When digital processors became available roughly 10 years ago, the analogue equalisers were replaced with digital 31-band graphics, using exactly the same methodology to set them up.

While cinema continues to rely on 31-band graphics, studios have recently started to integrate digital parametric equalisers, which can be set automatically based on acoustic measurements.

We can see loudspeaker/room optimisation is gradually becoming a widely available technology for pro and consumer applications. Automated EQ is nonetheless a great scientific challenge that has been addressed with very different approaches and mixed results, which explain why sound engineers and end users have such mixed opinions about it.

When we first released the Optimizer we offered some unique features valuable to sound engineers and producers: automatic sound system alignment, based on our findings in acoustics and 3D acoustic fields processing. As a pioneer in surround sound recording and mixing, the first user of the Trinnov was Florian Camerer at Austrian broadcaster ORF. Florian needed to solve a non-trivial problem to ensure that his 5.1 mixes would translate well for a majority of viewers and listeners.

The goal was to follow the ITU R-775 recommendation for 5.1 sound reproduction. This paper defines with great detail how the loudspeakers should be positioned, although it doesn’t explain how to achieve such a positioning in practice. Furthermore, it is quickly apparent to any engineer wanting to mix in 5.1 that achieving a consistent timbre from every loudspeaker is a real challenge, as well as attaining a proper stereo image between each pair of loudspeakers.

After many listening tests in different control rooms and OB trucks conducted by Florian and leading acoustic designer Peter Willensdorfer, it became clear that our automatic equalisation algorithms were suited to professional use. With the unique ability to measure in 3D the position of each loudspeaker, the Optimizer is the only tool that can align delays and levels for the whole system in minutes. Florian used these features to his advantage.

We then turned towards postproduction studios and found that the methodology and tools used to calibrate mixing theatres hadn’t changed for more than 30 years and pink noise and 1/3-octave graphic EQs were still being used. With version 2.0 of the Optimizer software we addressed these issues. Mixing theatres are different environments to broadcast control rooms. Target Curves were added to provide an automatic tool that helps studios meet the X-Curve SMPTE standard with accuracy. Automatic Crossover Alignment was added to fully integrate monitor controller/compensation with complex speaker arrays.

Our technology has also been applied to the home and is available in the latest Sherwood R-972 AV receiver and once the system is setup, the listener can be confident that he’s never been closer to the sound that was produced in the studio.

As can be seen, optimisation can be used in a variety of acoustical situations. Its benefits range from alleviating the problematic bass response of a small room to improving further a good sounding room. In fact, you can look at loudspeaker/room EQ in two almost opposite ways: as a problem solver; or as a tool that can turn a good control room into an outstanding control room.

Most engineers have a list of rooms where they would prefer not to work in, and a good portion of them are probably small rooms. To mix in a small room, you need to feel confident that your mixes will translate well and a combination of acoustic treatment and carefully applied EQ can truly improve the response in the low and mid ranges.

On the other hand, you could build a great sounding room and wonder whether there is anything left to be improved. Group delay compensation of the speaker drivers is one possibility for improvement and will dramatically improve the phase response of the loudspeakers, resulting in a more defined stereo image and more focused phantom sources between the loudspeakers. Many sound engineers have found that phase optimisation is a worthwhile improvement to their monitoring system.

You can make your own evaluation of optimisation by doing a mix in a non- equalised room, doing the mix again with the Trinnov activated and finally listening and comparing the two versions of your mix in different rooms. Our experience shows that users will find that the Trinnov mix translates better in a majority of other rooms.

Let’s talk about the specifics and what makes loudspeaker/room optimisation so complex and why is it such a subject of controversy. A lot of it’s to do with the lure of the ‘flat response’. If you focus on only one point in the room, for example at the engineer’s mixing position, it is theoretically possible to achieve a flat frequency response within 1dB. However, instead of making any improvement, this approach creates several problems. While the sweet spot measures flat, it will sound terrible. This is due to the fact that such correction can only work on one cubic centimetre around the measurement point and all other points, even 5cm from the measurement point, will sound worse and since the ears are at least 15cm apart this approach simply does not work.

What are you measuring and what does ‘flat response’ mean? This concept is closely related to the measurement technique that you use. Usually ‘flat response’ assumes that if you send pink noise to the loudspeaker, your 1/3-octave analyser will display a flat curve. However, pink noise has one major limitation: it can’t differentiate the difference between the loudspeaker’s sound and the room’s response. Does ‘flat’ mean that your loudspeaker’s response is flat or that the room’s response is flat? In fact, it may well be that your loudspeaker has a 3 to 6dB dip in the overlapping region of its crossover and that your pink noise measurement will read flat. In other words, if you only use pink noise you can’t really tell where the acoustic problems come from. You need a more powerful measurement technique that differentiates between the loudspeaker and the room.

Impulse response is an acoustic measurement technique that provides the time behaviour of your loudspeaker/room. However, measuring the time behaviour is one thing, and analysing it in a meaningful way is another challenge. An important portion of our research effort has been put into time-frequency analysis
techniques that can tell the difference between the loudspeaker and the room. Once you manage to do this you are already half way to the solution. Wavelet transforms are a powerful representation to better explain loudspeaker/room interaction.

Figure 1 shows a wavelet transform of the impulse response of a loudspeaker in a control room. An early reflection is clearly visible at 2ms. This is also a strong cancellation above 100Hz, due to a standing wave. The 'L' shape of the impulse (at 0ms) is evidence of the group delay of the loudspeaker: each driver produces higher frequencies first and lower frequencies later. Also notice the large amount of energy in the mid range, from 3ms to 6ms.

Figure 2 shows the same loudspeaker with Trinnov correction. The mid range is greatly improved: most of the energy comes from the loudspeaker, not from the room. This will make a huge difference for the translatability of the mixes done in that room.

Also, the group delay of the loudspeaker has been compensated. This will greatly improve the stereo image that the monitors are able to render. However, the early reflection is not touched in the high range because it arrives too late, so the algorithms don't even try to compensate for it.

The design philosophy of the Trinnov is to offer a loudspeaker processor that complies with and goes beyond current audio reproduction standards and industry practices. It combines automatic processes with fine-tuning tools that allow the sound system designer to reach the best results, while making the whole process easier and faster.

We have built a database of impulse response measurements of hundreds of rooms, ranging from ultra small audio rooms in OB trucks to some of the largest postproduction studios in the world. This has allowed us to continuously improve our algorithms and to develop a methodology that covers impulse response measurement of every loudspeaker from one or more listening points, automatic time-frequency analysis of the measurements, and computation of the automatic EQ for every loudspeaker, and manual fine-tuning with FIR, parametric and graphic EQs, based on listening tests and human analysis of the measurements before/after automatic EQ. In some cases, the sound engineers will suggest additional fine-tuning after a few weeks of working on their new system.

Instead of using pink noise the Optimizer uses MLS signals to measure the full impulse response of every loudspeaker in the room. This adds the time dimension to the frequency response and enables the Optimizer to see the full picture of the loudspeakers’ behaviour in the room. In multichannel setups the Trinnov’s cal mic identifies the real positions of the loudspeakers in 3D.

While many other measurement tools can perform impulse response measurements, none tell you how to analyse the measurements. This is where we have focused our research and come up with time-frequency analysis algorithms to identify room modes, first reflections and late reverberation. Every acoustic aspect is analysed and compensated for with a specific technique. The subtlety of our Optimizer resides in knowing which defects can be corrected with acoustic transparency.

Once the Trinnov’s acoustic analysis engine has done its job, it automatically computes FIR and IIR filters to improve the consistency of direct sound against late reverberation. A selectable feature of the Optimizer is to compensate the loudspeaker’s group delay and very early reflections by applying full-phase, time domain techniques (deconvolution). However, later reflections are left untouched.

The last step is to use the integrated acoustic analysis tools and make listening tests. This allows the pinpointing of certain frequencies that require additional equalisation to meet target curves, personal or project requirements. The fine-tuning may be performed within the Trinnov with manual FIR, parametric and graphic EQs.

Given the big acoustical problems encountered in most small rooms and the limited improvements that acoustic treatment can offer within the constraints of the space, loudspeaker/room equalisation can make all the difference in making a small room into an acceptable mixing environment.

Let’s take a look at one of our recent projects: the audio room of ORF’s U1D OB truck, which we recently updated in collaboration with Peter Willensdorfer. It is a typical small room: the dimensions of the empty space are 4m depth x 2.80m width, but once filled with the equipment the depth is reduced to about 3m. Also very typical for an OB truck, it uses Genelec 1031 and 1029 monitors.

For this particularly difficult environment we decided to try our latest multipoint algorithms. We measured five different points: the central mixing position of the sound engineer sweet spot, 20cm towards the front of the sweet spot, 20cm to the right, 20cm to the rear, and 20cm to the left.

To make the reading of the curves easier, only the first three points are displayed in Figure 3. The centre point is shown in green, the front is in red, and the right is in blue. The low range has strong peaks of as much as +5dB at more or less 45Hz and 100Hz and strong cancellations of as much as -12dB occur at 60Hz, 300Hz, 700Hz and 1800Hz.

The point 20cm to the right is the one that has more issues, and the point to the left (not displayed) looks very similar. Therefore the main problem in this room is the strong variation in tonal balance when the engineer moves his head only 10cm to the left or to the right.

As discussed earlier, the goal of optimisation is not to make a speaker respond better, but to reduce the inconsistency when the engineer moves sideways. As you can see in Figure 4, our algorithms manage to reduce the peaks and dips by 3 to 6dB on all the three points. This will make a huge improvement to the quality of the mixes produced in this small room. And it’s a result that an experienced engineer will probably not be able to achieve even after many hours of repeated measurements and manual equalisation.
The home studio

So you’ve chosen your space and want to turn it in to a miniature recording empire. NEIL GRANT of HGA suggests you remember that it’s a creative space first and a technical exercise second.

Since 1984, in fact, since 11 September 1984, it has been possible to assemble the components of a control room design — reliably and repeatedly — for those willing to undertake some basic research in the archives.

Unusually for the acoustics of control rooms and studios of the time, papers became available based on competent scientific method as a development of the experimental work of Don Davis, who had hypothesised in 1979, correctly, that the then current generation of control rooms and critical listening rooms were being designed and built back to front.

Davis had argued that the early recombination with the direct signal of specular reflections from side walls, ceiling soffits and console surfaces, and the slightly later recombination of rear wall lateral and contra-lateral reflections, superimposed artificial listening cues on the information being monitored. This had led to the design development of the LEDE Control Room, an approach refined by D’Antonio in his September Nashville presentation as the RFZ, or reflection free zone approach to monitoring.

With the reliable mechanics of design set in place, it needed only the inexpensive availability of computer-based measurement equipment to allow the analysis of these small (non-statistical) acoustic spaces, to encourage the repetition of standard design concepts.

With hindsight, this commoditisation of control rooms was almost as bad a thing for the recording industry as the design hegemony that had existed in the previous decade. These had not been the most creative of spaces: these were technical, mechanical, sharp, angled, masculine areas, with client and artist segregation built in as part of their structure. Despite deconstructing the acoustical mechanics of these spaces, many remained dominated by the technology, with players isolated in lifeless, dead, fabric wrapped booths, and a feeling that any lack of a creative or analytical process would be fixed — after the event — through brute force.

What happened was that rooms were built and designed with technology in mind first and foremost. Rooms were quite deliberately built to accommodate ever more intrusive hardware, and much of the creative process was abandoned in the process. Twenty years ago, it took an exceptional artist to break out of this framework and demonstrate that the studio facility was only an incidental tool in a creative process that could involve a group of people, including the engineering and production staff, absolutely including the artist and players, and re-establishing that the creative process was an ensemble joint effort.

Returning the studio facility to the control of the artist as an integral part of this process was a major step at that time. Nowadays with the accessibility of demonstrably powerful recording equipment with a tiny footprint, it seems extraordinary to consider the process in any other light. Recording has moved from large purpose-built facilities to rooms and venues where the business of creation and collaboration assume a more realistic proportion of the budget available.

How come so many extraordinary records have been made in so many poor rooms with such technology? It is much more because the engineers and producers working in conjunction with the artists have been brilliant at their jobs, and in themselves immensely creative musicians, than they were helped and aided as they should have been by their environment. How much more successful they would have been if they had worked within a more supportive environment instead of battling with inadequate monitoring, cramped and acoustically dead spaces, no large ensemble space, and the truly extraordinary invention of the 1970s, the drum booth. It has been despite, rather than because.

There will always be a necessity for larger recording facilities, because there will be a requirement to deal with larger groups of people and larger genuinely competent acoustic spaces. It is just that the recording industry has found it hard to balance supply and demand, and establish what the point of the exercise actually is. Since so much can be accomplished within the size of a room that we would once have regarded as merely adequate as a ‘writing room’, it is worth looking anew at the priorities for working in smaller spaces. What are the genuinely important issues in working in small rooms, and do we need to have recourse to the conventional building block methodology of the last quarter century?

More powerful computers have given us access to surface optimisation, and it is at least possible for us to specify a diffusion coefficient in a plane, and optimise room surfaces to provide the response required. This at least moves the aesthetic and architectural environment instead of battling with inadequate monitoring, cramped and acoustically dead spaces, no large ensemble space, and the truly extraordinary invention of the 1970s, the drum booth. It has been despite, rather than because.

How come so many extraordinary records have been made in so
The room decay time — a room of this volume fails the Cremer-Müller criteria, there is insufficient reflection density to generate a statistical sound field. Simply put, the T60 decay of the room will be position dependent and will need to be measured at multiple locations to be considered valid. The natural decay of the room should be compared with a notional ideal, and treatment assessed.

The room modal response — since it is unlikely that most people will re-build the rooms available to them to optimise the room's low frequency response, the modal response must be accommodated with loudspeaker positioning.

The room early reflections — as noted previously, early specular reflections can corrupt the cues that provide localisation, image, and upper mid frequency balance. Monitor speaker selection and location could be used to mitigate this.

Let's briefly look at this room's details — one door, one window, carpeted floor, plastered board on timber frame walls and ceiling.

What is the predicted decay of this room? A T60 of 0.39 seconds, comfortably below the BB93 criteria of <0.5 seconds Tmf with no further absorption than a fitted carpet on the floor.

What of the room response? What you listen to is the convolution of the loudspeaker response and the room, and it is not possible to separate them. It is possible to optimise the location of the stereo pair to minimise fluctuations in the magnitude of the frequency response, and at the same time provide a recommendation for the listening position, using a proprietary computer program. This models the room's modal response and seeks a best fit for criteria in the low frequency response of the cabinet as far as 300Hz, while predicting an optimal location for listening.

The model predicts a listening position on the centre line of the room in plan, elevated 1.14 metres from the floor level. Speakers are located symmetrically about the centre axis, 0.67 metres from the forward wall, 0.86 metres from the side walls, and lifted 0.33 metres from the floor. The predicted response is very reasonable, and we have yet to place any acoustic treatment in the room, merely optimise location.

An appropriate loudspeaker choice is important; clearly there is little sense in looking to mount a cabinet in half space. Given the inconsistencies in the decay field in the room itself, it seems essential that the on-axis response is as nearly identical to the direct field as is practicable. In other words, the device should be omnidirectional.

What of low frequency absorption? The room itself will provide the best low frequency absorption in the space available to us. In the office used thus far as an example, low frequency energy leaves by the single two square metre window and does not return. Similarly, this is a timber frame building, and once low frequency energy has left the room, it will not come back to us. There is no room for large-scale absorption and there is little necessity.

When a room is this small, real world considerations outweigh conventional acoustic treatment, which would otherwise take over, and there are better choices in search of a workable environment. Sometimes it may well be better to invest in artwork for the wall and not a diffuser. Perhaps spending the money on a Velux should be considered before buying another rack of outboard equipment? It would not be the first time that rain on the roof or bird song complemented an impeccable recording.
Monitor placement in small rooms

The increasing use of small rooms as audio production environments needs careful consideration of the acoustic behaviour as well as correct loudspeaker placement. Genelec's Christophe Anet outlines the impacts of using a small room (a typical 3m x 4m) and the challenges of setting up a 5.1 monitoring system.

Every room (with the exception of a perfect anechoic chamber) has a set of resonant frequencies. These frequencies and how much they are boosted are defined by the room geometry and the surface materials. In rectangular rooms, as well as most other rooms, the mode density increases rapidly with increasing frequency. The colouration of sound caused by the modal resonance depends on the spacing of the modes in frequency and how much the modes are excited by loudspeakers. Only if the room dimensions are smaller than half the sound wavelength no mode can exist, and sound pressure in the room depends only on the loudspeaker output capability.

Frequencies below about 1000Hz are the most critical as the density of modes is fairly small with wide spacing between the modes. This favours using a larger space as long as the reverberation time of the room remains sufficiently low. The exact distribution of the modes also depends on the relative proportions of the room dimensions. The worst case is a cubical room. There the identical dimensions lead to a coincidence of the three axial sets of modes, and the mode resonances along the three axes of the room amplify each other. As a general rule, you should avoid precise integer ratios in room dimension proportions. We are already beginning to see that using small rooms involves some acoustical compromise.

Radiation space boosts bass level at low frequencies — A loudspeaker or subwoofer produces a certain volume flow and at low frequencies this volume flow spreads in all directions. If we limit the space by walls while keeping the sound output power identical, the energy density (also called intensity) in the limited radiation space increases. Every halving of the radiation space doubles the sound pressure level.

Fig. 2. Loudspeaker bass boost is influenced by the radiation space size.

At high frequencies the loudspeaker no longer radiates in all directions because the higher the frequencies the more directional they become. Placing the loudspeaker on the wall doesn't increase the high frequency sound level but low frequencies are boosted and the frequency response of the loudspeaker is no longer flat. The loudspeaker sounds boomy or bass-heavy. It is important to correct this problem in the loudspeaker or subwoofer response to keep the frequency response flat in the room.

The wall behind the loudspeaker can cause cancellations — Two signals with the same level but in anti-phase (180 degrees out of phase) can cancel each other out, resulting in silence. If the loudspeaker is placed a quarter sound wavelength away from a sound reflecting wall the wave reflected off the wall arrives back at the loudspeaker drivers in anti-phase. This totally or partially cancels the signal radiated by the loudspeaker at that particular frequency. How complete the cancellation is depends on the distance of the wall and the ability of the wall to reflect sound. The sound level dips down at the frequencies where the reflected sound is in anti-phase. The depth and width of a cancellation dip varies but in most cases such dips are audible. No loudspeaker equalisation cures this problem; increasing the level of the loudspeaker at the dip frequency also boosts the reflection and their sum remains low. The dip is not removed.

The best cure to cancellations is to flush-mount the loudspeakers in a hard wall. This places the loudspeaker in an infinite baffle. This can totally eliminate the dipping phenomena as no reflections are present. In our small-room case we must place the loudspeaker very close to the walls in order to raise the frequencies where such dips are audible. No loudspeaker equalisation cures this problem; increasing the level of the loudspeaker at the dip frequency also boosts the reflection and their sum remains low. The dip is not removed.

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Free standing loudspeakers are affected by nearby walls — Using a subwoofer with a crossover filter (typically at 85Hz) between the loudspeakers and the subwoofer can improve the monitoring system. The high-passed loudspeakers (sometimes called satellites) do not reproduce low frequencies. They can now be placed at the walls more freely at distances where low frequency nothing does not occur in their pass-bands. The ‘acceptable’ distance extends now out to 1.1m. The loudspeakers can be placed even further away (1.1m-2m) without seriously compromising the sound quality. The satellite loudspeakers should not be placed too far from the subwoofer (a maximum distance 2m). If the distances are larger the tonal balance between the various loudspeakers playing with the subwoofer may differ considerably due to differing excitation of the room modes. In practice freestanding loudspeakers
always suffer from some irregularities in their frequency responses, usually caused by cancellations.

One common location for the subwoofer is in the front middle of the room, equidistant from the sidewalls. This position is often problematic and compromises the acoustical performance. The subwoofer sits in the first pressure minimum of the lateral standing wave. The frequency response for a subwoofer in that location will most likely display serious irregularities.

The recommended positions for subwoofer(s) are on the floor close to the front wall (maximum distance from a wall is 60cm) and slightly offset from the middle of the room to avoid the first pressure minima position, or in a corner close to the front and side walls. The latter position maximises the subwoofer efficiency due to corner loading but may also excite strongly the axial modes in the room. Both solutions eliminate the most likely sources of cancellation dips in the subwoofer response.

Remember that the adjustments of gain (input sensitivity) and frequency response (Bass Roll-off) in a subwoofer are necessary during the final in-situ calibration. The acoustical loading must be compensated for. Crossover phase adjustment is also important to achieve and maintain flat frequency response across the crossover region.

**BASIC CHOICES FOR LOUDSPEAKER PLACEMENT AND ROOM SETUP** — The majority of audible problems in monitoring quality are due to the effects of the room on the sound radiated by the loudspeakers and subwoofers. Proper placement of the loudspeakers and subwoofer in the room is critical. Let's return to our small room on the sound radiated by the loudspeakers and subwoofers. Proper placement of the majority of audible problems in monitoring quality are due to the effects of the room on the sound radiated by the loudspeakers and subwoofers. Proper placement of the loudspeakers and subwoofer in the room is critical. Let's return to our small room on the sound radiated by the loudspeakers and subwoofers.

**Loudspeaker Placement**

**Straight placement (or possibly in a front corner (1/8th space).**

**Alignment circle). This implies placing loudspeakers against or very close to walls, as well as placing the subwoofer on the floor and against the front wall (you have a quarter space radiation then) or possibly in a front corner (1/8th space).

With such guidelines applied to our small room the monitoring setup circle radius (listening distance) becomes 1.38 m with a recommended listening area of 1.4m x 0.6m (hatched area). Note that the desk on the drawing is 1.2m wide and 0.6m deep.

**PLACEMENT OF EQUIPMENT INFLUENCES SOUND QUALITY** — The vertical positioning of the loudspeakers is also important, but less critical than the horizontal positioning. Ideally, the three front loudspeakers should be positioned at the same height. The brain has a high capability to localise information on the horizontal plane. In the vertical plane the precision is (zenith angle) about 3 degrees above ear level horizon and 5 to 10 degrees below ear level horizon (azimuth angle). Because of the behaviour of the ear/brain, human vertical localisation tolerance is about 7 degrees.

**SMALL ROOM SUPPLEMENT**

**HIGH FREQUENCY RESPONSE IS SENSITIVE TO LOUDSPEAKER ORIENTATION** — High frequency information is of the utmost importance for the listener to evaluate subtle movements and variations in the audio stage. If room reflections are too high compared to the direct sound the imaging becomes poor. Loudspeakers should have well controlled directivity. It leads to a high direct-to-reflected sound level ratio and reduces the effects of nearby sound-reflecting boundaries. This helps the engineer to hear the programme material content and reduces the room effects. The purpose of the Genelec Directivity Control Waveguide (DCW) is to control the radiation angle of the tweeter and midrange drivers such that diffractions from the loudspeaker enclosure and room surfaces are minimised. Localisation, imaging, and flatness of the frequency response are improved irrespective of the loudspeaker location.

**CALIBRATION IMPROVES QUALITY AND CONSISTENCY** — To provide the best possible reproduction quality every monitoring system should be calibrated in its final installation (as already specified in the N12 Nordic Broadcast recommendation of the 1970s). Today DSP processing is integrated in monitoring loudspeakers. The most important benefit of this technology is the possibility for automated calibration of a loudspeaker system within a given room. Calibration tools like Genelec AutoCal, featured in GLM and GLM.SE, measure and determine the system response and calculate all the correct acoustical compensations and correction parameter settings for each and every loudspeaker and subwoofer. The automatic system determines acoustical settings to give a flat frequency response at the listening position (or over an area using spatial averaging) using notch and shelving filters available in each loudspeaker and subwoofer. It also aligns loudspeakers in time for an equal delay from all loudspeakers to the primary listening position, aligns output levels of loudspeakers and sets the subwoofer crossover phase. The entire calibration process takes less than five minutes for a full 5.1 system.

As more small rectangular rooms with strong modal resonances at low and midrange frequencies, low ceiling heights, and non-symmetrical equipment layouts are used as audio production rooms, the need for proper loudspeaker placement and consistent system calibration is more essential than ever. A well engineered monitoring system, containing DSP equalisation and supported by an automated equalisation method, can bring these difficult and challenging environments close to the quality of properly designed control rooms. In all cases correct loudspeakers and subwoofer placement is essential.
Big principles for a small room

DAVID BELL of White Mark Limited considers the acoustic issues relevant to setting up a smaller project studio or production space and shows that the same principles apply to the choices that need to be made, whatever the size of a monitoring environment.

The basic guidelines of any design process should be to assess what is required, understand the constraints on achieving this requirement and then produce a solution that produces the best balance between these influences that is possible. The simple aim in designing a monitoring environment is to produce a listening space that allows the user to hear what is recorded, via the loudspeakers, with as little distortion or colouration as possible.

The influences that any enclosing space has on the reproduction of sound are based on the same science whether the space is a vast auditorium, a state of the art recording studio or a small preproduction room or home theatre and whether the budget for dealing with the problems is high or low. The differences lie principally in what methods are practical and affordable to employ in the minimisation of the adverse effects that are inevitably produced by the chosen room.

The design of acoustic monitoring environments can be divided into two fundamentally different areas — those of isolation of the space and those of its internal acoustic treatment. The absorption existing in a room will reduce the overall sound level in the space by a small amount but, if the monitoring system has sufficient headroom, this will usually result in the operator merely advancing the volume control to compensate. Acoustic treatment has no significant part to play in increasing a room's isolation performance.

When choosing a room for use as a project studio or small mixing environment, consideration should be given to the way that the layout of the building in which it is housed can offer assistance in creating sound locks or other separation from its neighbours. Where space is small and budgets are tight it is often impractical to significantly increase isolation by adding sufficient mass to walls or by the creation of a separate isolation shell. The practical approach is to look for ways in which the space can be separated from its neighbours by using corridors or other rooms as buffer spaces. Significant improvement can also be achieved by ensuring that there are no weak points within the room walls through which sound can pass easily. Such features as mains power sockets let into the wall are breaches of the walls integrity and can easily be replaced by surface-mounted units allowing the recessing hole to be filled and the wall thereby improved.

Care should be taken that walls pass from floor slab to ceiling slab and that elements such as drop ceilings or decorative plaster ceilings do not mask significant gaps over the top of walls through which significant sound passage could be achieved. Similarly, floor voids will also create paths through which sound can leak bypassing the wall structures. All such voids should be closed off by extending the walls to the floor or ceiling slabs or by copious use of mineral wool slabs (50kg/m²) or similar. Doors should be solid core where possible and sealed with proprietary seals to render them as airtight as possible. Where possible, the room should be separated from other spaces by corridor space or other, outer room space and the same care should be taken with the walls and doors in these areas.

Where ventilation is required to the now sealed space, care should also be taken with the route taken by any fresh air ducting. This should be boxed in, where it passes through other spaces, or be routed directly into the space directly from outside. Where it has to pass through walls within the building, consideration should be given to fitting silencers at each point of wall penetration.

Having achieved the best level of separation for the proposed monitoring room, consideration needs to be given to the acoustic treatment of the space. Sound is coloured by its interaction with its environment and the measures taken to treat a room should minimise this as much as possible. Principal among these destructive colourations are the effects of standing waves and the interference effects generated by the many paths the sound can take from the monitors to the ears.

The basic dimensions of the room and the position chosen for the loudspeakers can be fundamental. The room I am sitting in currently, is a typical domestic size being 2.5m(h) x 4.1m(l) x 2.9m(w) and has a good chance of being reasonably neutral as a basic space because of the ratio of its principal dimensions not being a simple one. The room discussed in the brief for this article was suggested as 3m x 3m in plan with a height of around 2.5m. This is significantly less likely to be a good monitoring environment because of the simple ratio between its principal dimensions. This is further exacerbated by the practicalities of a standard equipment layout. Consider a workstation with nearfield loudspeakers set on stands each placed, say, 250mm from the front wall of the room. This arrangement would, almost inevitably, put the listener in the centre of such a space where standing wave effects would be at their maximum. When you consider that a normal chair puts the listener's ears at around 1.2m from the floor this means that the listening point is in the dead centre of the space. The choice of a room to be used for monitoring should be influenced by its shape with the complex relationship between the principal dimensions exhibited by my office being much preferable to the near cubic dimensions of the second space discussed.

Thus far the design of the small listening environment has centred on choosing rooms of the correct position within a building and of a suitable shape to offer the best basis for treatment to be applied. Nothing so far has been suggested that reduces the size or significantly increases the cost of the creation of the room.

The interference between differing paths that the sound can take from loudspeaker to ear is the next aspect that must be considered. To understand the mechanism let's consider a sound that is fed to the loudspeaker being mixed with a sound that has been delayed a short time. As the time delay of the second sound is increased from zero the two sounds will interfere with each other. At any given delay period there will be a frequency at which the original sound and the delayed sound are out of phase and the one will totally cancel out the other. At frequencies above and below this exact figure the cancellation will be partial. At frequencies that are a multiple of this exact frequency at which the original sound and the delayed sound are out of phase the one will totally cancel out the other. When sound reaches a room wall and finds its way to the ear of a listener, this is exactly the effect that takes place when it is mixed in the ear with the direct sound from the loudspeaker. The delay of one sound with respect to the other is...
set by the difference in path lengths and the nature of the reflections off wall surfaces is important if the listener is to hear a good representation of the original signal when seated in the monitoring position of the room.

It should be understood that all spaces will affect the sound in some way but what is very important, in design terms, is the way in which the reflections relate to each other and to the sound being monitored and the extent to which their interference is destructive. Rooms are evaluated by listeners based on the way the many reflections that occur within them add up in cumulative effect. A room in which many reflection paths have similar or identical delays would result in the effects of each path being closely spaced in the frequency domain and the monitoring quality being badly affected by deep holes in the frequency response. This is further evidence in favour of a room with irregularly related dimensions. The way the room is driven by the loudspeakers and the methods used to suppress the most direct reflection paths can have fundamental effects on the quality of the listening experience.

In a high-end studio design, the monitors are often flush-mounted which, effectively, places the front surface of the loudspeakers into the wall. Care should be taken to minimise radiation from the other surfaces of the loudspeaker but when this is done the front wall is eliminated from early reflection consideration and the side walls, floor and ceiling become the main sources.

Early reflection is an important consideration because the path length differences have effects in the crucial areas of the frequency range and the relative intensity of the sound waves is most equal (and thus their interference capabilities with the direct sound path are maximised). A high-end studio design would suppress the early reflections off the ceiling and side walls by the introduction of deep treatments to attenuate them and the geometry of the monitor placement. These deep acoustic treatments would also reduce room standing waves by offering low frequency absorption in all three principal planes of the room. Further, they would offer broadband absorption to reduce the reverberation time of the space by suppressing multiple reflections off the walls. Excessive absorption of high and mid frequencies would be countered by the addition of diffusion elements at the rear of the room to bring the high frequency reverberation time up to match the other areas of the frequency range and prevent colouration by uneven decay times.

Where the room size is small (and the budget matches) there is neither the space nor the funds to treat the room in this way. The principles, however, remain identical and should be addressed systematically in the same way. It is not usually practical to flush-mount monitors and so these are usually on stands in free space. This has two principal effects. First, and of benefit, the nearer the monitors are to the listener the higher the ratio of direct radiated sound to reflected sound from the boundaries. This means that the room will have less effect on the sound heard because the reflected sounds will be lower in level. Second, and disadvantageously, the sound radiated from the rear and sides of the loudspeakers will have an early interaction with the nearest boundary and thus be delayed by a short period and mix with the direct sound at the listening position. This often results in a strong change to the sound heard at bass and low mid frequencies. This can best be minimised by moving the speakers to positions where the effects are spread throughout the spectrum and have a less noticeable effect. This can be done by listening or by using measurement software to illustrate what is going on. The use of absorption in the corners of the room behind the loudspeakers can also help to attenuate the reflections from the rear and side walls behind the monitors.

Suppression of early reflections from the side walls and ceiling can be achieved by the use of absorptive panels. Consideration of the mechanism of absorption illustrates why absorptive panels should be at least 100mm thick with some claiming that treatment should be a minimum of 150mm thick to have an acceptable effect. The absorber should have a high density absorptive material (mineral wool or fibreglass at 60kg/m3) of a thickness around 50mm set off the wall with an air gap behind it. Space constraints often influence these elements to be sloped with a deeper air gap towards the front wall of the space when used on walls and ceilings. It’s my opinion that the gluing of thin acoustic foam panels directly to walls has limited application to monitoring environments based on the limited frequency range over which these have absorptive properties.

Where budget allows, the addition of diffuser panels at the rear of the room can be very beneficial, particularly those based on quadratic residue theory whose bass absorptive characteristics will further enhance the room.

In conclusion, it should be noted the principals that govern acoustic design apply whatever the size of room or budget and the aim should always be to perform meaningful treatment that is targeted at the room’s specific shortfalls. No one method or solution will work in all rooms and so treatments should be aimed at broadband effect and tuned devices should not be employed. Where possible, measure the room and adjust its performance based on the results obtained. If measurement is not possible then listen to known programme material and only make changes one at a time, noting the effect of each alteration and noting whether it improves matters or not. Fundamental changes can be wrought by moving free-standing monitors and finding the best position for these should usually be the first step towards setting up a listening environment.
Some Questions are Easy to Answer

“Where do these lumps in the lower midrange come from? Should I move my furniture or get a smaller display?”

“How can I add more bass trapping in my small room to avoid this boominess?”

“All this with a 5.1 system! How am I supposed to find the time to calibrate my system accurately?”

“I should just get a Genelec DSP system!”

When you are building or fine-tuning your audio monitoring environment there are many aspects to consider: the design and geometry of the room, loudspeaker placement, acoustical treatments, the type of equipment to use and making sure everything works well together. When it comes to optimized audio reproduction and proper adjustments of your response curves, the decision is easy. Genelec DSP systems with AutoCal™ automatic calibration can attack common problems in your room response with just a few mouse clicks. Get familiar with our DSP systems at www.genelecDSP.com