FH MMA SALZBURG – MUSIC PRODUCTION

RECORDING STUDIO DESIGN

1. INTRODUCTION

The planning and construction of acoustic spaces for recording studios, film mixing studios and broadcasting facilities (control rooms, recording rooms, post-production screening facilities, etc.) requires very specific know-how in several scientific and artistic fields, including room acoustics and design, electric and light installation, HVAC systems, etc.

The acoustic behavior of acoustic spaces depends on a lot of different factors, including:

- **type of wall/ceiling/floor construction** (affects sound proofing and amount of sound reflected, so also the reverb time)
- **room shape and proportions** (affect the distribution of the resonance modes and diffusion)
- **room size** (affects the reverb time and the frequency of the resonance modes)
- **choice of materials** (affects the absorption factor, that usually varies across the frequency range)
- **acoustic modules** (can further affect the room acoustic adding absorption, reflection or diffusion).
- **placement of speakers** (main monitors, midfield, nearfield)

In large concert halls or theatres reverb diffusion (a smooth, pleasant reverb without flutter-echoes) is almost guaranteed by the size of the acoustic space alone. Also, there are usually no problems related to the room resonance modes (the strongest modes are, for very large rooms, in infra-sound range and they are already evenly distributed in the critical low frequency range).

One of the challenges is to keep the acoustic behavior of the hall constant, no matter whether it is empty, half filled with public or full; this can be achieved for example designing seats that, when empty, have an absorption factor like that of a human body with clothes.

Properly designing small rooms (such as control rooms, sound booth, small live recording rooms) is more difficult, as the strongest room resonance modes are usually in the critical bass frequency range (between 20 and 200 Hz) and can become a problem if the room proportions are not chosen properly. Also, because of the small room size and relatively high frequency of the room modes, it is more difficult to achieve reverb diffusion.

When planning and building studio rooms we are mostly dealing with two categories of problems:

- **Soundproofing** (this means, simply put, to keep inside sound in, and outside sound out)
- **Acoustic Control**: the optimization of the inner acoustics (frequency response, reverb time) which will ultimately affect the "sound" of the rooms.

In addition to this we are dealing with these construction challenges:

- An efficient HVAC system (Heating, Ventilating and Air Conditioning): when the rooms are really sound-proof, they are also air-tight; forced ventilation is therefore required to keep the air fresh and CO_2 levels low, which is essential for a pleasant working environment (especially for performing musicians). A studio HVAC system must provide adequate heating, cooling and ventilation, it must operate as quietly as possible (ideally it should be completely silent) and it should not compromise the sound insulation between rooms (silencers are required between ducts supplying air to different rooms, and between the rooms and the HVAC main machine).
- Planning and laying out the whole electrical, lighting, audio and video cabling system: particular care has to be taken to supply all components with clean current (usually a star-shaped connection: all components are connected through a common source) and to connect all gear with symmetrical cabling, avoiding ground loops or other sources for undesired noise.
- Proper installation of all the required equipment, particularly monitors (nearfield, midfield, main monitors), mixer, outboard effects, recording and editing devices, etc.

Larger commercial studio facilities may include several rooms and areas:

- A control room, where the main monitors, mixer and outboard are placed (required)
- A main live recording room (required)
- Additional recording rooms with different acoustics characteristics (optional)
- One or more isolation booths (vocal booth, drum booth, etc.)
- Sound locks between the control room and the recording rooms (to reduce sound transmission between the rooms in the complex)
- A machine room (for all noisy studio gear such as tape machines, hard disk recorders, computers, amplifiers, etc.)
- A lounge/kitchen area for the artists to relax between sessions, or for visitors (required)
- A recreational area with a billiard table, table-tennis and other indoor-games (optional)
- Bathroom/WC facilities (required)

2. SOUNDPROOFING

A studio facility should obviously be as much as possible isolated from the outside world to allow recording at any time of the day or night, without external sounds *leaking* in (for example traffic and environment noise). At the same time, the sound of the instruments performed (including very loud ones, like drums) and the studio monitors output should not leak outside the facility, where it could disturb neighbors or other people nearby. Regarding this matter, please note that in Germany and Austria there are quite restrictive laws concerning *acoustical pollution*: the sound emissions from the studio should not go beyond the average noise level of the area where the studio is built. Normally residential areas are subjected to more restrictive regulations than commercial areas.

Sound isolation is generally considered *bidirectional*: the amount of insulation from inside to outside is usually same as from outside to inside. Careful planning of the required Sound Transmission Loss (measured in dB) at all different frequencies and in both directions, must be done to achieve the desired results, as different types of noise and styles of music can have very different sound spectrum characteristics, and therefore require specific types of insulation.

Most manufacturers of construction materials for walls and floors (for example Knauf – www.knauf.de) include detailed information about how to use these materials and about the transmission loss you can achieve at different frequencies (typically 125, 250, 500, 1000, 2000 and 4000 Hz).

The *average efficiency* of a sound barrier at blocking sound can be represented by a single number rating called *STC* or *Rw*.

- **STC** (Sound Transmission Class) is a noise barrier rating used in USA: it is a measurement of how much noise will be prevented from passing through a material or construct. A STC of 60 (in a laboratory) would stop 60 dB of noise. Example: if we have a noise source of 100 dB SPL on one side of the sound barrier, and the barrier is rated STC 60, there will be 40 dB SPL residual noise on the other side.

- **Rw** (Weighted Sound Reduction Index) is a noise barrier rating used in Europe: it is similar to STC, however it is more restrictive due to different weighting of low frequency transmission. Therefore it is possible that a wall achieving 55 STC might only be rated 53 Rw.

2.1 THE MASS PRINCIPLE

There is a direct relation between a sound barrier mass and the amount of insulation achieved: theoretically, doubling the mass we should achieve double as much insulation (+ 6dB, or +6 STC/Rw). We can double the mass using denser materials, or doubling the wall thickness. However, due to flanking transmissions (for a wall: transmission through the floor and ceiling), the effective improvement in insulation doubling the mass is only 4-5 dB.

TYPICAL STC VALUES FOR MASSIVE CONCRETE WALLS	
100 mm thick concrete	STC 48
200 mm thick concrete	STC 52
100 mm thick concrete blocks	STC 40
200 mm thick concrete blocks	STC 45
200 mm thick concrete blocks, filled with concrete and plastered both sides	STC 56

2.2 THE MASS-SPRING-MASS PRINCIPLE

As seen from the examples before, adding mass alone is not a very efficient way to increase the insulation. To achieve the amount of insulation required by a professional studio (STC 85 and more) with a single partition massive concrete wall, the wall should be over 2 m thick!

A more efficient principle is *decoupling* two separate wall partitions, which create a *Mass-Spring-Mass* system. The advantage of this system is that much higher insulation ratings can be achieved with a lighter construction, and without losing too much space due to the wall thickness.

The *spring* in the M-S-M system can be simply an air space (partially filled with rock wool), decoupling pads using a visco-elastic material (for example *Sylomer*, manufactured in Austria by *Getzner* www.getzner.com), or actual steel springs (for example used to decouple a floating floor from the supporting concrete slab).

The disadvantage of a M-S-M system is that at the resonance frequency the insulation is *worse* than a massive single partition wall. Only about 2 octaves above the resonating frequency the insulation becomes significantly better than a single leaf wall. It is therefore necessary to move the resonance point as low as possible. If good insulation is required starting from 32 Hz, the resonance freq. of the system should be only 8 Hz.

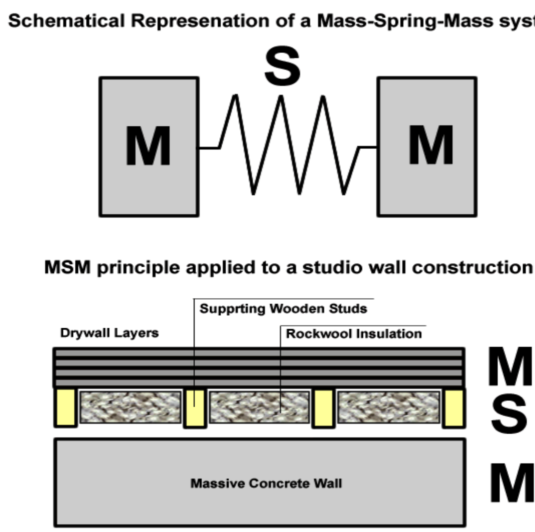

Figure 1: Example of a Mass-Spring-Mass system

Light studio walls can be made from 2 partitions of relatively light construction materials, decoupled from each other. In a single stud, single frame wall construction the insulation can be improved decoupling one of the two partitions with a *resilient channel*. This is a sort of metal rail which is elastically mounted on one side to the wall frame: the gypsum boards are then mounted onto the rail, instead of being fixed directly to the studs. On the other side, the gypsum can be mounted directly to the studs.

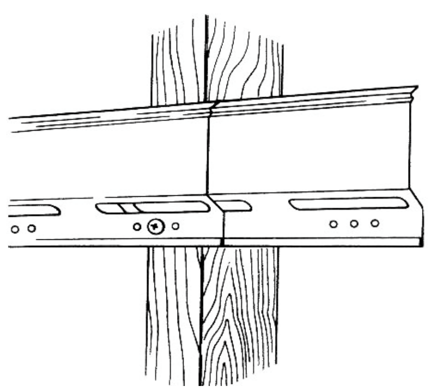

Figure 2: Detail of a resilient channel, for the elastic mounting of a gypsum board to a wooden frame

All boundaries between boards and corners must be sealed with acoustical sealant. The whole wall or ceiling should be mounted on elastic pads to avoid flanking transmission. All cavities of the wall should be filled with rock wool, glass wool or similar isolating material (best is wood fiber wool).

The factors that contribute to improve sound proofing are:

- **The mass of each partition** (how many layers of gypsum board are used, or the thickness of the massive wall leaf). Higher mass is better.
- **The distance between the partitions** (in a single stud wall, this is the stud dimension, for example 10x10 cm). Bigger distance is better.
- **The decoupling of the partitions** (resilient channel, double studs or separate wall frames; spring decoupling in floor systems).
- **Whether the air cavity** (between partitions) **is filled with rock or glass wool insulation** (ideally, about half to 2/3 of the cavity should be filled with 40kg/m³ insulation).
- **The resonance frequency of the M-S-M system**: lower frequencies are better. Effective insulation is achieved about 2 octaves above the resonance frequency F (= 4F).

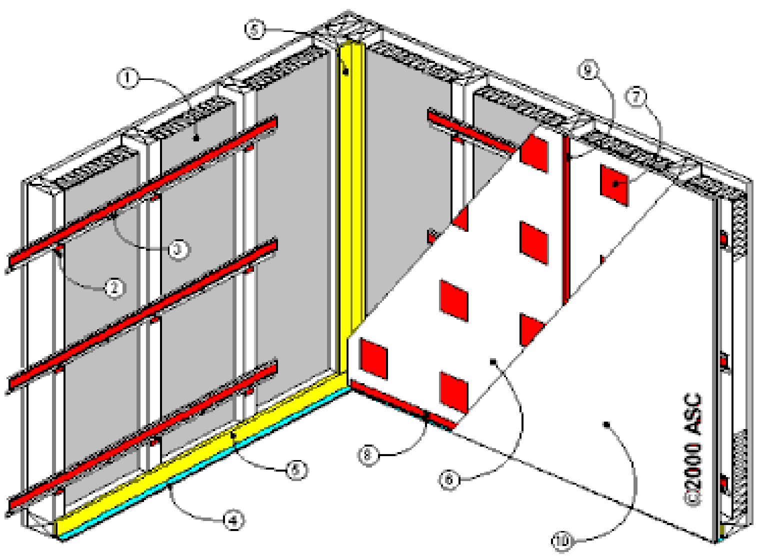

Figure 3: A typical light studio wall using resilient channels and multiple layers of gypsum applied on special damping pads – STC 60-65 (http://www.asc-soundproof.com)

TYPICAL STC VALUES FOR *DRYWALL CONSTRUCTION* (WOODEN FRAME + GYPSUM BOARD)	
Single frame, 16 mm gypsum board on each side	STC 34-35
Single frame, 16 mm gypsum board on each side + rock wool insulation	STC 36-38
Single frame, 16 mm gypsum board on each side with resilient channel	STC 38-40
Double studs, one layer soft fiber board + one layer 16 mm gypsum board on each side	STC 42
Double studs, one layer soft fiber board + one layer 16 mm gypsum board on each side + rock wool insulation	STC 47
Double frame, 16 mm gypsum board on each side	STC 43
Double frame, 16 mm gypsum board on each side + rock wool insulation	STC 48
Double frame, 16 + 25 mm gypsum board on each side	STC 55
Double frame, 16 + 25 mm gypsum board on each side + rock wool insulation	STC 60
Double frame, 16 + 25 mm gypsum board on each side + rock wool insulation and with additional resilient channel	STC 65-68

2.3 *ROOM WITHIN A ROOM* CONSTRUCTION

To achieve the best sound insulation possible, commercial studio facilities are often built using the *room within a room* principle: the outer shell is made from massive concrete or masonry walls and floors, taking care of most of the sound containment and isolation from the outside world. The inner studio spaces are constructed as *floating rooms* with their own supporting concrete floors, decoupled from the outer shell using elastic pads or springs. For the inner walls and ceilings lighter materials can be used (wood or metal framing with gypsum and/or plywood panels). Great care is taken in avoiding sound transmission at the boundaries between floors, walls and roofs, and in the installation of electrical and HVAC systems.

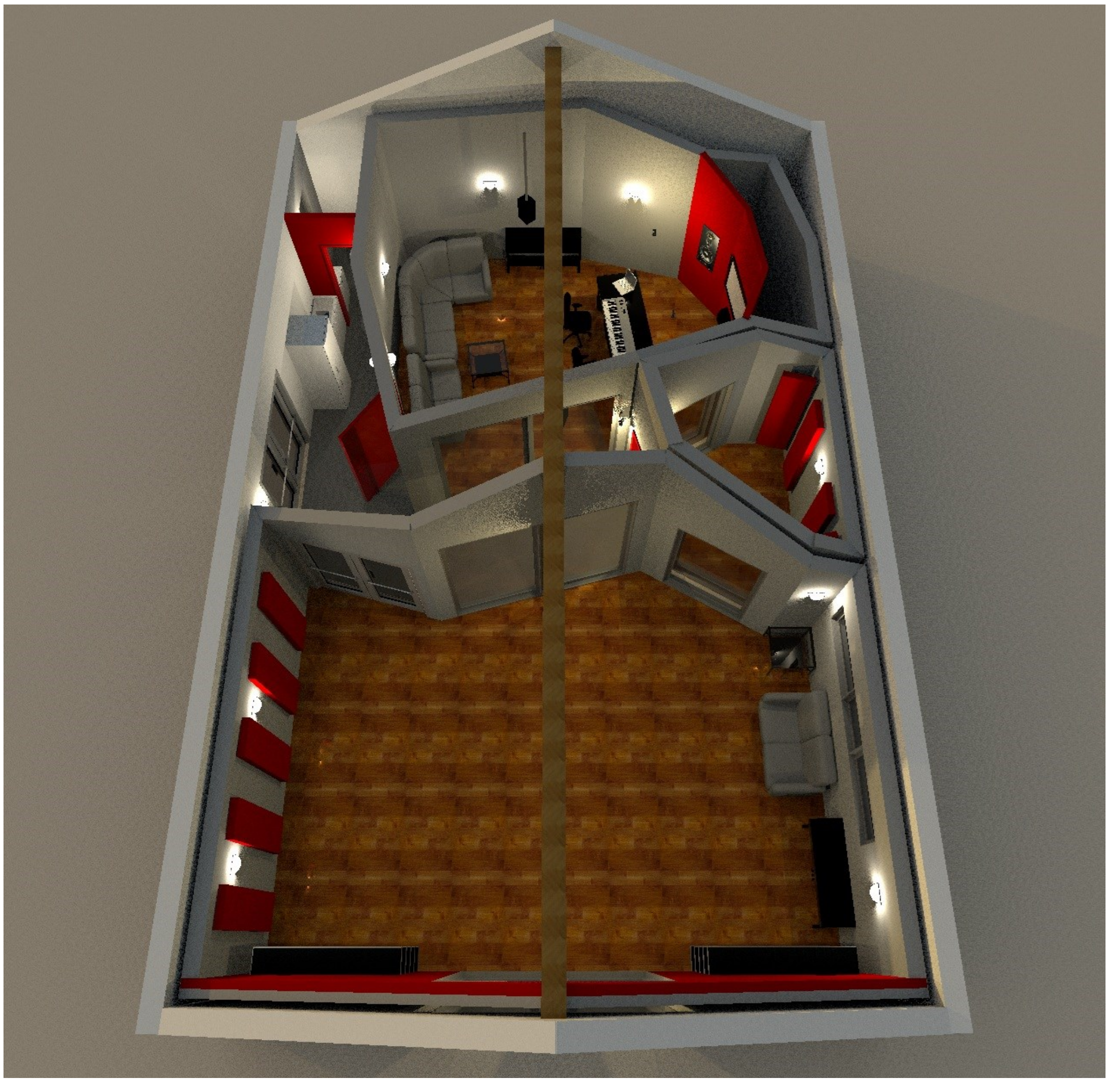

Figure 4: Example of studio facility using room-in-room construction for every room
(from top: control room, vocal booth, live room) – DNS Studios, 2012

2.4 COMPARISON BETWEEN DIFFERENT WALL CONSTRUCTIONS

To better understand how is the acoustic performance of a M-S-M system compared to a massive wall construction, we will compare a few wall partition types using *Insul*, a software designed by *Marshall Day Acoustics Ltd* to accurately simulate the acoustic performance of different types of single and multi-leaf partitions.

EXAMPLE A (MASSIVE, RW 43)

This is a massive single partition wall, made of 6 layers of 12.5 mm gypsum board and supported by metal studs framing (not shown).

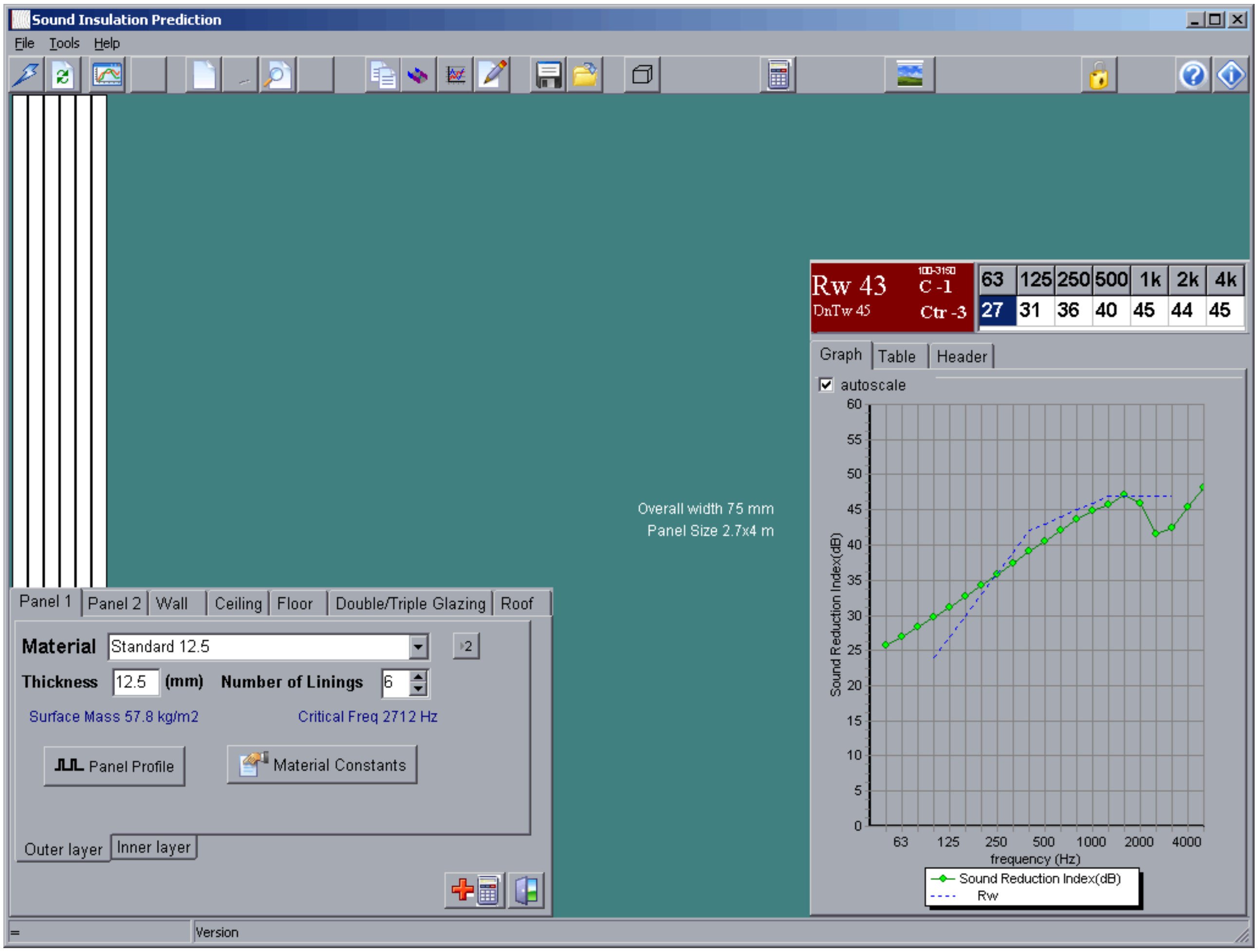

Figure 5: A massive single partition wall, made of 6 layers of 12.5 mm gypsum board and supported by metal studs framing (not shown).

This wall has a rating of **Rw 43**. This does not sound like much, however notice how the Sound Reduction Index graph has a gentle slope of only 6 dB per octave (= only 6 dB insulation loss for each lower octave). The insulation provided at 63 Hz is still 27 dB.

The insulation loss of about 10 dB at 2.7 kHz is caused by the gypsum board own “critical frequency”. Using gypsum boards of different thickness (for example 12.5 and 15 mm) would minimize this problem.

EXAMPLE B (M-S-M, RW 65)

This is a M-S-M double partition wall with 3 layers of 12.5 mm gypsum board on each side of the metal studs framing; a resilient channel is mounted on one side for better decoupling. The 100mm air cavity is filled 80% with rock wool (33 kg/m³ density).

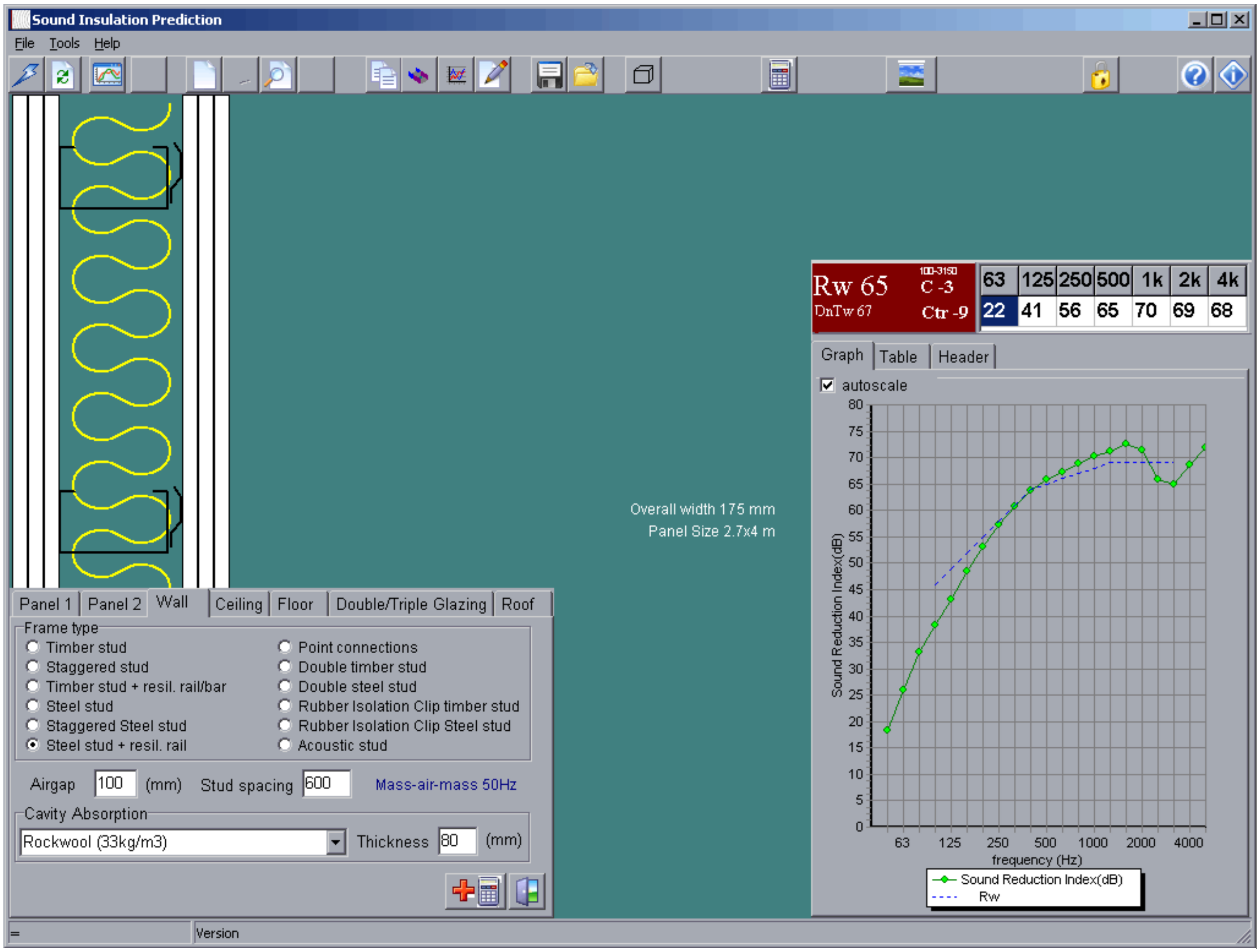

Figure 6: A M-S-M double partition wall with 3 layers of 12.5 mm gypsum board on each side of the metal studs framing; a resilient channel is mounted on one side for better decoupling. The 100mm air cavity is filled 80% with rockwool (33 kg/m³ density).

Now the rating of the wall has climbed up to **Rw 65**: this is a 22 dB improvement (= over 12 times the insulation) using the same gypsum boards and having the same mass as the wall in Example A!

However, there are also some negative side effects: notice how the Sound Reduction Index graph is now much steeper, with a slope of about 12 dB per octave (= 12 dB insulation loss for each lower octave). The insulation provided at 63 Hz is now only 22 dB, so it is about half as good as in Example A (27 dB). However, from 125 Hz and above this wall performs better.

CONCLUSION 1: comparing two walls that use the same mass and materials, (a single massive partition like in Example A, and a double M-S-M partition like in Example B) the M-S-M system will provide on average much better insulation (and have a much higher Rw rating), but might not perform as well in the very low frequency range.

Let's now find out how thick should a massive wall be to achieve the same Rw rating as the M-S-M wall in Example B.

EXAMPLE C (MASSIVE, RW 65)

This is a massive concrete wall, 300mm thick, plastered on both sides.

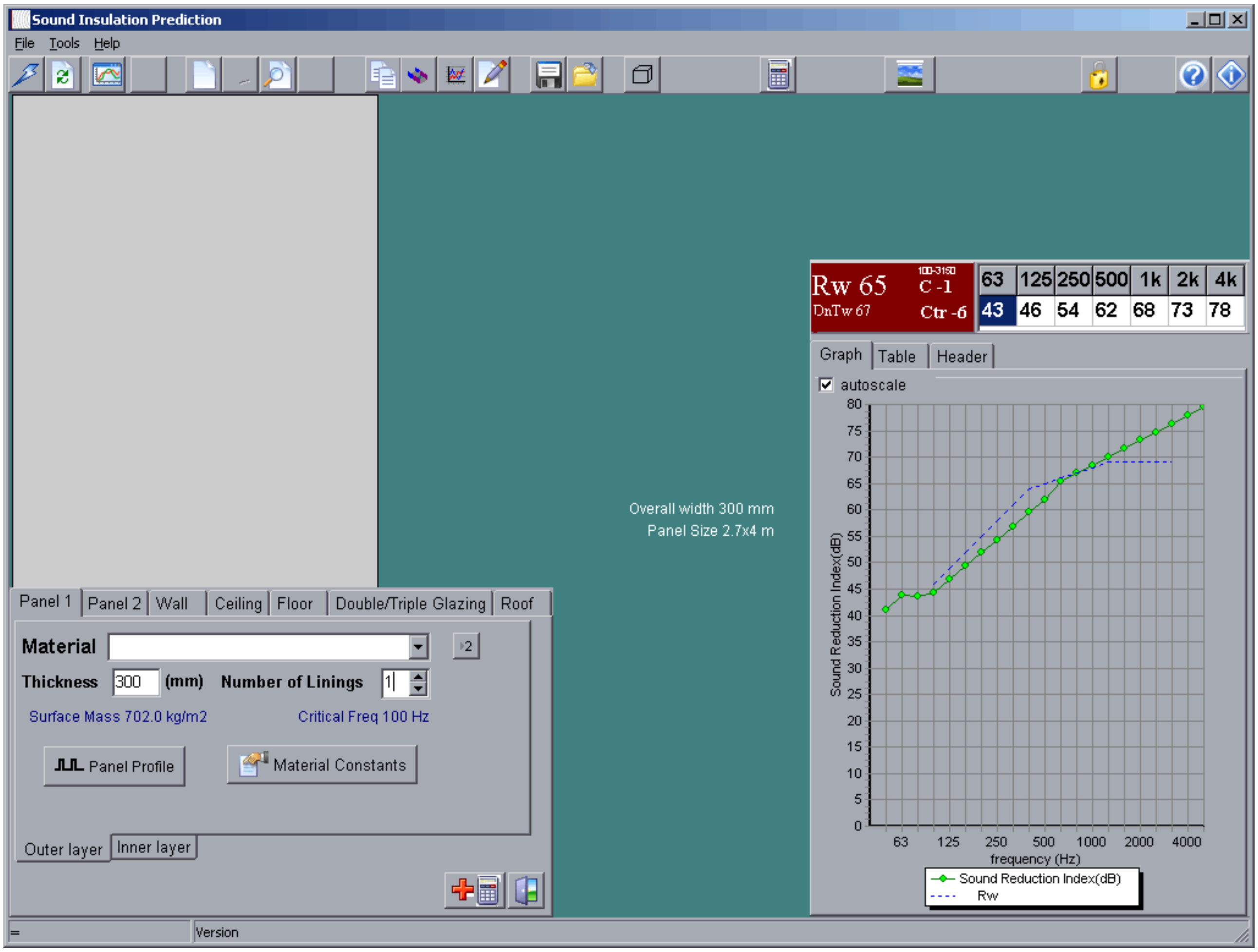

Figure 7: A massive concrete wall, 300mm thick, plastered on both sides.

This wall has the same **Rw 65** rating as the M-S-M wall in Example B; to achieve this it must be over 12 times heavier (702 kg /m² vs 57 kg /m²) and much thicker as well (300 mm vs 175 mm). Obviously, it would be also much more expensive to build.

However, its performance in the low frequency range is much better: again, the Sound Reduction Index graph shows a slope of only 6 dB per octave. At 63 Hz this wall still provides 43 dB insulation, in other words 21 dB more (= about 11 times more) than the M-S-M wall with the same rating.

CONCLUSION 2: comparing two walls with the same Rw rating (a heavier single massive partition as in Example C, and a lighter double M-S-M partition as in Example B), the massive wall will provide much better insulation in the low frequency range.

2.5 NC CURVES

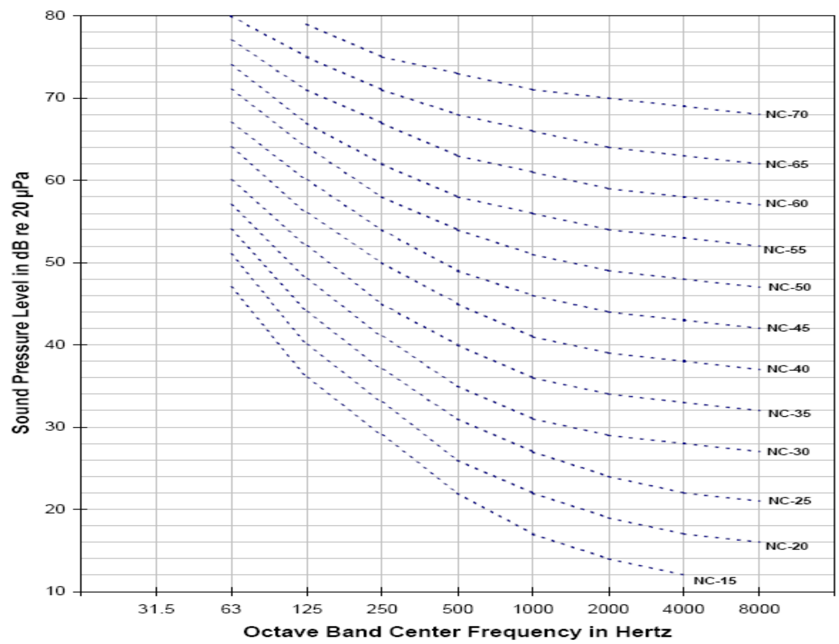

Figure 8:NC (Noise Criterion) curves

The goal for a professional studio facility should be a NC (Noise Criterion curve) value of 15 or less. NC curves weights middle-high frequencies more than lower ones, where we have reduced hearing sensitivity.

After a measurement of the environment noise in the area where the studio must be built, it is possible to compare that curve with the target NC curve: the difference is the amount of insulation required by the studio construction to achieve noise levels.

These NC values should not be compromised by a loud operating HVAC (Heating, Ventilation & Air Conditioning) system: this must be planned accordingly and operate at very silent levels under the target NC curve.

3. ACOUSTIC CONTROL

A lot of different factors can influence the acoustic properties and can contribute to the *sound* of a room:

- **Room size**: affects both the low frequency response and the room cutoff frequency, as well as rev. time.
- **Room shape and proportions** (room dimensions, parallel or non-parallel surfaces): affect the resonance modes and the frequency response, and the diffusion of the reverberation.
- **Reverberation time**: depends on the room size as well as the absorption coefficients of the materials used for all surfaces.
- **Frequency response**: depends from size, shape and absorption coefficients.
- **Doors and windows** construction and placement.
- **Acoustic Modules** (wide-band absorbers, bass traps, diffusers, resonators, etc.).
- **Furniture**, placement of **equipment** (mixer, effect racks, etc.), **instruments**, etc.
- In a control room, the placement of **loudspeakers** (flush mounted main monitors, midfield and nearfield monitors).

3.1 ACOUSTIC REQUIREMENTS

The sound requirements for control rooms can be very different from those of recording rooms.

Control Rooms should be as *neutral* as possible, in other words they should add no coloration whatsoever to the sound coming out of the monitor loudspeakers (in an ideal case, you should not hear the room coloring at all).

A more neutral *encoding* of the sound during mixing/mastering ensures higher chances that the *decoding* on any given system will be closer to the original. Any coloration added during mixing/mastering can potentially be made worse due to additional colorations during playback on other systems and cause extreme irregular frequency responses.

Recording Rooms on the other hand not only can, but should have character. Depending on the kind of instruments and musical style, the requirements might vary. Recording rooms do not need sound *neutral* like control rooms, nor should they always be symmetrical.

Usually larger studio facilities have a selection of different acoustic spaces with different characteristics:

- *live rooms*, with longer reverberation, for instrumental recording
- *dead rooms*, with little or no reverberation, for vocal or speech recording
- *rooms with variable acoustics* (using moving or rotating panels, curtains, mobile walls, etc. etc.)

Generally, **vocal** and **speech** recording rooms should usually offer a relatively *dry* and *uncolored* acoustic, to achieve maximum clarity. This can be both provided by a very absorptive small room, or in a neutral sounding larger room.

The acoustic of **instrumental** recording rooms might vary between relatively dry (0.5 – 0.8 sec reverb) to quite reverberant (1.2 – 2.5 sec) depending on the musical style.

Sometimes **classical** music instrument and choir require longer reverberation times that can only be achieved in concert halls or churches.

Isolation Booths should be as *dead* as possible to minimize transmission of sound across the rooms they connect. Here the sound and frequency response of the room is irrelevant.

Machine Rooms should also be as *dead* as possible, to avoid that equipment noise resonates or is amplified and in extreme case leaks in the adjacent rooms.

3.2 ROOM PARAMETERS

3.2.1 ROOM SHAPE AND PROPORTIONS – EIGENMODI

The room shape and proportions affect the pattern of the *Eigenmodi* (the room own resonance modes), and the amount of "diffusion" (density of the reverberation).

The room modes are classified in:

- **Axial Modes** — occurring between opposite parallel surfaces, therefore along the 3 main axis of the room: the *dominant* factor
- **Tangential Modes** — occurring among 4 surfaces, avoiding 2 that are parallel: can still be *significant* in rooms with hard/stiff surfaces
- **Oblique Modes** — occurring among all surfaces: are rarely significant

An easy way to calculate the Axial Modes of a room is:

$$f1 = \frac{c}{2 \times L}$$

- f1 = frequency of the 1st axial mode
- c = speed of sound and
- L = dimension of the room considered

The next axial modes of that dimensions are simply:

- f2 = 2x f1
- f3 = 3x f3
- …..

The Eigenmodi should be spaced as evenly as possible. Therefore, room proportions where one dimension is a multiple of the other (like a room with 10 x 5 x 2,5 m size), or with same dimensions for length, width and height (like a room with 5 x 5 x 5 m size), must be absolutely avoided: this would generate extreme strong resonances of certain frequencies that are supported by all three room dimensions (in example 1: waves resonating at the 2,5 dimension fit also the 5 and 10 m dimensions).

There are several studies about **optimal room proportions**, for example:

- L. W. Sepmeyer (1965): 1 : 1.14 : 1.39
1 : 1.28 : 1.54
1 : 1.60 : 2.33
- M. M. Louden (1971): 1 : 1.40 : 1.90
1 : 1.30 : 1.90
1 : 1.50 : 2.10

Check this post by Eric Desart (designer of *Galaxy Studios* in Belgium and moderator of the *Studiotip Acoustic Forum*) about the **Acceptable Room Ratios** for more information: http://forum.studiotips.com/viewtopic.php?p=5570

EXAMPLE OF ROOM MODE CALCULATION

Here an example of room mode plot for a control room with dimensions 6.7 x 5.3 x 3.5 m:

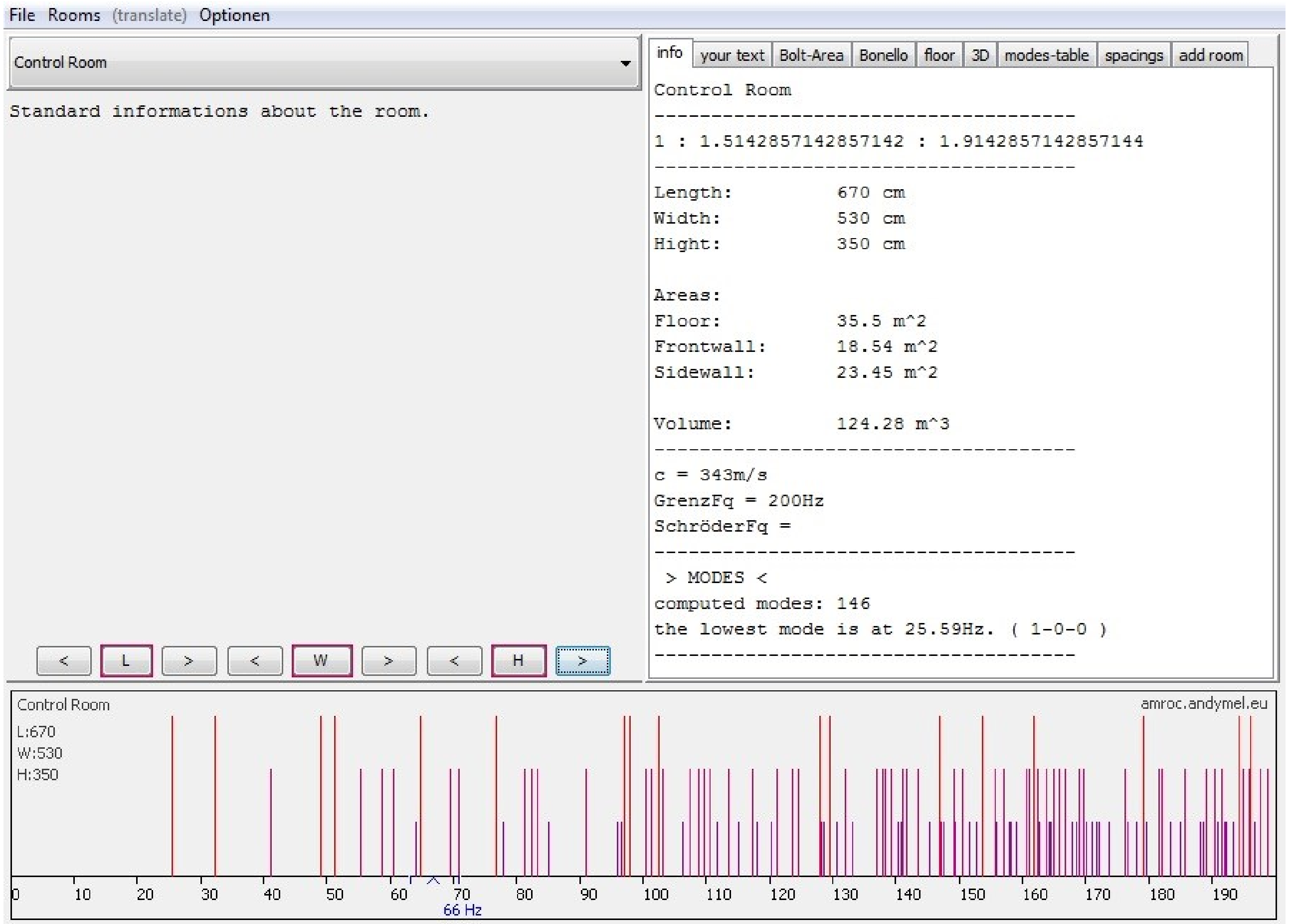

Figure 9: Example of room mode plot for a control room with dimensions 6.7 x 5.3 x 3.5 m,
using the room mode calculator at http://amroc.andymel.eu/

The highest lines in the plot are *axial modes* (strongest), the mid ones are *tangential*, and the lowest are *oblique* modes (weakest). The plot shows a rather even distribution, with good spacing and no axial or tangential modes overlapping. Fine tuning of the modal distribution is possible by adjusting the room dimensions in centimeter steps.

3.2.2 BOLT AREA

Richard H. Bolt (1911-2002) found an area of cumulative good room ratios, including his own and those suggested by L. W. Sepmeyer, M. M. Louden. The room shown in Fig. 9 (dimensions: 670 x 530 x 350 cm) fits quite in the middle of the *Bolt Area*.

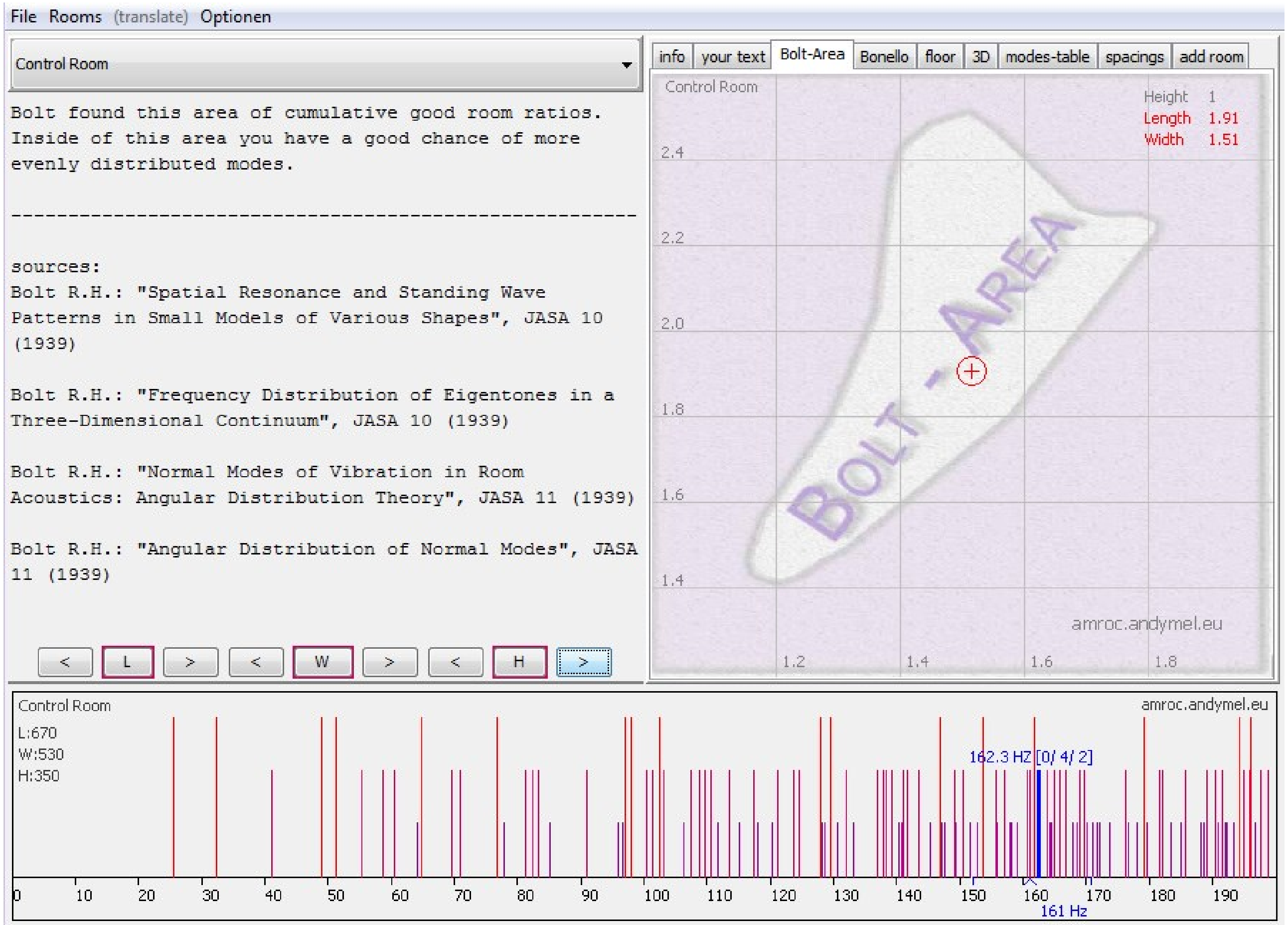

Figure 10: Graph showing how the chosen room proportions fit quite in the middle of the *Bolt Area*:

Of course, when the room layout is not based on parallel surfaces, like in modern RFZ control rooms, it is not easy to predict the exact behavior of room resonances. A good approximation can be achieved using the average between the bigger and smaller dimension for the calculations. For example, if a Control room is 6 m wide in the back and 4,6 m wide in the front, the average would be (6 + 4,6) : 2 = 5,3 m.

Only very expensive acoustic design software can currently give an accurate prediction of the Eigenmodi is rooms with complex geometry.

3.2.3 ROOM SIZE AND REVERBERATION TIME

Room size affects the lowest frequencies that can be played back with support from the room own resonance modes (Eigenmodi), as well as the reverberation time.

In larger rooms, the natural resonating modes start from a lower frequency; therefore, the Eigenmodi are less spaced apart (= denser) in the critical range between 20 and 200 Hz compared to small rooms. As there are less resonance peaks and gaps, a more even frequency response is easily achieved, and besides the rev. time can be relatively constant across the sound spectrum.

Reverberation time is generally longer in a larger room, as it takes longer time for sound waves to travel from one surface to another, and more time for the sound energy to be dampened/absorbed by these surfaces. The effective rev. time depends on both size and the absorption coefficient of the materials used.

A Control Room should ideally not be smaller than about 100 m³ (like in the example above, 6.5 x 5.3 x 3.5 m = 124 m³), if frequencies down to 25 Hz must be played back with natural mode reinforcement. Unfortunately, many control rooms do not even meet this basic requirement.

Recording Room sizes can vary, depending from what should be recorded: a booth for dry vocal or drum recording could be a few m³ size (for example, 3,5 x 2 x 2,5 = 17,5 m³), while a room for ensemble recording should be at least 150-200 m³ in size (for example, 9 x 5,5 x 4 = 198 m³), to provide adequate diffusion and a rev. time of about 0,5 – 0,7 sec.

3.3 CONTROL ROOMS

3.3.1 BASIC REQUIREMENTS

In modern design of Control Rooms, the tendency is towards a symmetrical layout, but without parallel surfaces: slanted walls contribute to diffusion (denser reverberation) and avoid slap-back and flutter-echo effects, as the sound waves cannot bounce back and forth between the two parallel surfaces. For the same reason, the ceiling of a Control Room is not parallel to the floor, but usually is lower near the front wall, and higher towards the back wall.

Slap-back and flutter-echo are undesired phenomena which would greatly compromise the acoustic of the room, so they should be avoided in any case.

SIZE

The standard size of a modern Control Room is about 7 m length by about 4 to 6 m width (4 m for the front wall with flush mounted speakers, and 6 m for the back wall with diffusors). The height varies between 2.5 (front) and 3.5 m (back). The effective height of the structure is often a higher value, if large amounts of wide-band absorbers are to be fitted in the ceiling.

It is important that the back wall is about 3 – 3.5 m away from the mixing position, so that the reflections from that wall (usually fitted with diffusers) arrives about 18-22 ms after the direct sound from the main speakers. This time gap is important to avoid comb-filtering and smearing of the stereo image. Larger time gaps are undesired, as it would be perceived as a distinct echo reflection.

REVERB TIME

In a control room the reverb time should be as short as possible, and in any case shorter as the reverb time of the recording rooms; otherwise it would mask the sound of the acoustic spaces being recorded.

The standard reverberation decay time RT_{60} (the time the sound energy of the reverb takes to drop 60dB from the direct sound emission) for a modern Control Room is between 300 ms (LF) and 200 ms (HF). Larger Control Rooms (over 60 m² area) might have higher RT_{60}, but it is important that the level of the reverberation remains as low as possible.

This requires large amount of wide-band absorbing elements, usually placed on the ceiling (rock, glass or wood fiber wool, between 10 and 50 cm thick depending on the lowest target frequency to be absorbed, enclosed in supporting wooden or metal frames). If some surfaces are using materials that absorb only in the mid and high range (like carpets or curtains), special low frequency absorption elements must be used to compensate and achieve a linear response (bass traps, Helmholtz resonators).

A completely dry room is not desirable, as it causes listening fatigue: the ideal goal would be to receive dry, coherent sound from the monitor loudspeakers within the first 20 ms, undisturbed by any early reflection, followed by a diffused room reverb with about 200-300 ms decay time.

3.3.2 CONTROL ROOM LAYOUTS

The most common design types to achieve this goal are LEDE (*Live End, Dead End*), RFZ (*Reflection Free Zone*), Non-Environment and ESS (*Early Sound Scattering*)

LEDE

Figure 11: A typical "old style" LEDE room (The London 12)

Live End / Dead End Control Rooms are built on the following principles: the speaker front walls and ceiling (the Dead End) are very absorptive, to eliminate secondary paths from the monitors to the listening position; the back wall (the Live End) is rather reflective and can include a set of *diffusors* to provide pleasant reflections back to the listening position. These diffused reflections do not color the sound, as they come after about 20 ms delay and are reduced in intensity; if properly directed they can even improve stereo imaging. The Live End removes the unpleasant feeling one would have working in a completely *dead* room, while the Dead End guarantees precise monitoring.

RFZ

Reflection Free Zone Control Rooms are an improvement over LEDE, where a special room geometry is used instead of an absorptive front wall and ceiling to avoid secondary paths and early reflections from the speakers.

The main monitors are always soffit or wall mounted in this type of room; the front walls and ceiling are constructed at specific angles that disperse the sound in the direction of the back wall. This guarantees precise stereo imaging and clear, uncolored sound.

The back wall usually has a large array of Quadratic Residue Diffusors (QRDs, like from the company RPG), which provide pleasant diffused reflections without interfering with the direct sound from the monitors. Like with the LEDE design, the optimal distance from the mixing position to the back wall should be about 3,4 m to get the diffused reflections after a time delay of about 20 ms:

(2 x 3,4 m): 340 m/s = 0,020 s = 20 ms

Values between 18 and 22 ms are optimal. A shorter time delay may cause *comb filtering*, while a longer delay might be perceived as a *slap-back echo*, neither of which is desirable.

Because the parquet wooden floor is also quite reflective, in RFZ rooms it is necessary to have an extremely absorptive ceiling (wide band, full range absorption + bass traps) in order to keep reverberation time under the desired limit of about 0.3 sec (for a 35-45 m² room) and avoid floor/ceiling flutter echo.

Figure 12: A large RFZ control room (The Mushroom, Austria) with flush mounted main monitors (ADAM S7 mk I), absorptive ceiling, wooden floor, and rear diffusor array

NON-ENVIRONMENT

Non-Environment Control Rooms are basically *hemi-anechoic chambers*, where all surfaces except the speaker front wall and the floor are extremely absorptive. The speaker front wall is constructed like in a RFZ design and disperses the reflections towards the absorptive back wall and ceiling.

In the Non-Environment room, there are no QRD diffusors on the back wall: instead, a large wide-band / bass absorber is built using hanging elements. Therefore, there is no wash of diffused reflections after 20ms, like in the LEDE or RFZ designs. The ceiling is also built as a large wide-band / bass absorber (like in the RFZ design). The room does not sound unpleasantly *dead* when speaking, thanks to the reflective wooden floor and front speaker wall, which is often built out of stone slabs.

Non-Environment rooms can sound incredibly crispy and accurate: it is possible to perceive details that can otherwise be heard only over headphones. However, their *sound* is unlike any other typical listening environment, therefore they do not *translate* very well to standard listening environments. Also, because of the high levels of absorption, the monitoring system must supply very high power to provide the desired SPL levels.

As in Non-Environment rooms the natural room *Eigenmodi* die away very quickly, they do not influence much the frequency response of the room. It is therefore possible to build Control Rooms that are smaller than 100 m³ and still offer a quite linear playback. It is also possible to have the back wall closer than 3,4 m, as it is completely absorptive.

Figure 13: A typical Non-Environment control room (Lamiña Production Studios, Spain) showing stone front speaker wall, wooden floor, absorptive ceiling, side and back walls

ESS

Early Sound Scattering is in principle similar to LEDE with one important difference: instead of the absorbers used in the LEDE design, a large number of diffusors are installed not only in the back wall, but also in the front wall and ceiling. The early reflections are not completely eliminated, but have a smoother, diffused pattern that causes less comb filtering (and therefore less coloration).

Another argument to support this type of control room: the diffused reflections help masking the unavoidable reflections from the mixing desk.

Figure 14: Early Sound Scattering control room (Graceland Studios) with the typical diffusors installed on the front wall and ceiling

4. ABSORPTION COEFFICIENTS OF STANDARD BUILDING MATERIALS AND FINISHES

NRC (NOISE REDUCTION COEFFICIENT)

NRC is a sound absorption rating. It measures a percentage of how much sound will not be reflected from where it came. Based on a range from .05 to 1.0, where a NRC of 1.0 means that all the sound energy that hits that product passes through it and does not bounce back to its source. A NRC of .60 would reflect 40% of the sound back to the source, and let 60% of the noise pass through it.

4.1 FLOOR MATERIALS

MATERIALS	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 HZ
concrete or tile	.01	.01	.15	.02	.02	.02
linoleum/vinyl tile on concrete	.02	.03	.03	.03	.03	.02
wood on joists	.15	.11	.10	.07	.06	.07
parquet on concrete	.04	.04	.07	.06	.06	.07
carpet on concrete	.02	.06	.14	.37	.60	.65
carpet on foam	.08	.24	.57	.69	.71	.73

4.2 SEATING MATERIALS

MATERIALS	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 HZ
fully occupied - fabric upholstered	.60	.74	.88	.96	.93	.85
occupied wooden pews	.57	.61	.75	.86	.91	.86
empty - fabric upholstered	.49	.66	.80	.88	.82	.70
empty metal/wood seats	.15	.19	.22	.39	.38	.30

4.3 WALL MATERIALS

MATERIALS	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 HZ
Brick: unglazed	.03	.03	.03	.04	.05	.07
Brick: unglazed & painted	.01	.01	.02	.02	.02	.03
Concrete block - coarse	.36	.44	.31	.29	.39	.25
Concrete block - painted	0.10	.05	.06	.07	.09	.08
Curtain: 10 oz/sq yd fabric	.03	.04	.11	.17	.24	.35
Curtain: 14 oz/sq yd	.07	.31	.49	.75	.70	.60
Curtain: 18 oz/sq yd	.14	.35	.55	.72	.70	.65
Fiberglass: 2" 703 no airspace	.22	.82	.99	.99	.99	.99
Fiberglass: spray 5"	.05	.15	.45	.70	.80	.80
Fiberglass: spray 1"	.16	.45	.70	.90	.90	.85
Fiberglass: 2" rolls	.17	.55	.80	.90	.85	.80
Foam: Sonex 2"	.060	.25	.56	.81	.90	.91
Foam: SDG 3"	.24	.58	.67	.91	.96	.99
Foam: SDG 4"	.33	.90	.84	.99	.98	.99
Foam: polyur. 1"	.13	.22	.68	1.0	.92	.97
Foam: polyur. 1/2"	.09	.11	.22	.60	.88	.94
Glass: 1/4 plate large	.18	.06	.04	.03	.02	.02
Glass: window	.35	.25	.18	.12	.07	.04
Plaster: smooth on tile/brick	.013	.015	.02	.03	.04	.05
Plaster: rough on lath	.02	.03	.04	.05	.04	.03
Marble/Tile	.01	.01	.01	.01	.02	.02
Sheetrock 1/2" 16"o.c.	.29	.10	.05	.04	.07	.09
Wood: 3/8" plywood panel	.28	.22	.17	.09	.10	.11

4.4 CEILING MATERIALS

MATERIALS	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 HZ
Acoustic Tiles	.05	.22	.52	.56	.45	.32
Acoustic Ceiling Tiles	.70	.66	.72	.92	.88	.75
Fiberglass: 2" 703 no airspace	.22	.82	.99	.99	.99	.99
Fiberglass: spray 5"	.05	.15	.45	.70	.80	.80
Fiberglass: spray 1"	.16	.45	.70	.90	.90	.85
Fiberglass: 2" rolls	.17	.55	.80	.90	.85	.80
wood	.15	.11	.10	.07	.06	.07
Foam: Sonex 2"	.060	.25	.56	.81	.90	.91
Foam: SDG 3"	.24	.58	.67	.91	.96	.99
Foam: SDG 4"	.33	.90	.84	.99	.98	.99
Foam: polyur. 1"	.13	.22	.68	1.0	.92	.97
Foam: polyur. 1/2"	.09	.11	.22	.60	.88	.94
Plaster: smooth on tile/brick	.013	.015	.02	.03	.04	.05
Plaster: rough on lath	.02	.03	.04	.05	.04	.03
Sheetrock 1/2" 16"o.c.	.29	.10	.05	.04	.07	.09
Wood: 3/8" plywood panel	.28	.22	.17	.09	.10	.11

4.5 MISCELLANEOUS MATERIALS

MATERIALS	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 HZ
Air: sabins/100 cu. ft.				0.90	2.3	7.2
Water	0.008	0.008	0.013	0.015	0.020	0.025
People - adults	0.25	0.35	0.42	0.46	0.5	0.5

RECOMMENDED LITERATURE

- EVEREST, F. ALTON: *Master Handbook of Acoustics* – McGrav Hill (ISBN 0-07-136097-2)
- SHEA, Mike: *Small Budget Recording Studio* – McGrav Hill (ISBN 0-07-138700-5)
- GERVAIS, Rod: *Home Recording Studio: Build It Like the Pros* – Course Technology (ISBN-13: 978-1435457171)

RECOMMENDED INTERNET LINKS

- *Acoustic Treatment for Home Studios* – Peter Elsea
  http://arts.ucsc.edu/ems/music/tech_background/TE-14/teces_14.html
- Acoustic Forum StudioTips
  http://forum.studiotips.com

ACOUSTIC CALCULATORS

- *Eigenmodi Calculator*
  http://amroc.andymel.eu
- *Room sizes compliance with international standards and recommendations*
  http://www.acoustic.ua/forms/rr.en.html
- *Eigenmodi Calculator* – Hunecke
  http://www.hunecke.de/german/rechenservice/raumeigenmoden.html
- *Reverb Time Calculator* – Hunecke
  http://www.hunecke.de/german/rechenservice/raumakustik.html

WEBSITE

- http://www.digitalnaturalsound.com/fh-multimediaart/music-production.html
- www.digitalnaturalsound.com or www.dns-studios.com > FH | MultiMediaArt > Music Production