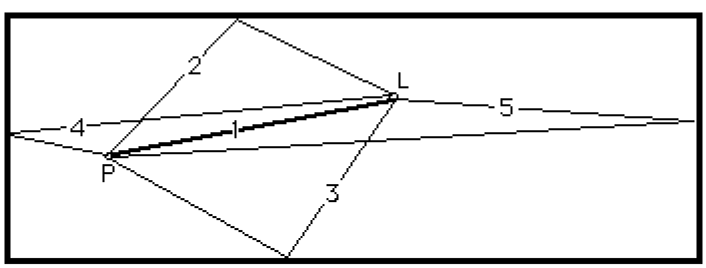
Acoustics for Music

Most of our music making is carried out indoors. In such a situation, the listener's experience is formed almost as much by the room itself as by the instruments. For a successful performance (or recording), the concert space (or studio, or living room with recorded sounds) must fulfill the following:

- The audience must clearly hear all of the music with the proper balance between instruments, and the proper tonal balance for each instrument.
- The performer must clearly hear himself and the other performers.
- Reverberation should be appropriate to the style of the music.
- Extraneous sounds must be inaudible in the concert space.
- The sound of the concert should be inaudible outside of the concert space.

These goals are more or less in order of importance. The last requirement will not affect the concert itself, but may affect the possibility of holding future concerts. With these criteria in mind, we will examine the important structural factors of the the room which control them.

SOUND IN A ROOM



Paths of sound from performer P to listener L

Fig.1 Direct sound and early reflections

Figure 1 shows the paths taken by the sound as it travels from the performer to the listener. (The wavefronts of the sound are not shown, they would be perpendicular to the lines drawn.) The heavy line, number 1, shows the shortest path, the direct one. The other paths all involve one reflection, so must be longer than the direct path, although their relative lengths will change as the performer and listener move about the room. Since sound travels at a steady 1 foot per millisecond, the sound of a single event is going to arrive at the listener's ears several times as determined by the different path lengths. We can chart the arrival times on a graph:

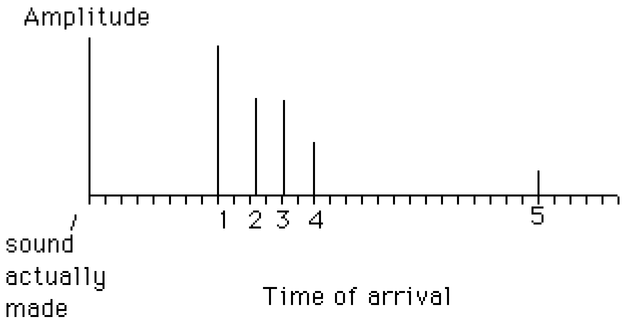


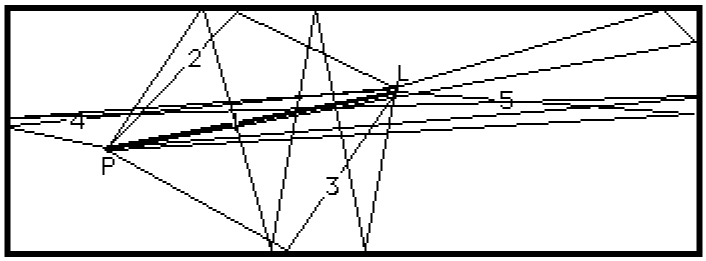
Fig. 2 Arrival times of a single sound

The amplitude of a particular reflection is determined by the path length and the efficiency of the wall in reflecting sound. That efficiency is described as the **coefficient of absorption** (any sound not reflected is absorbed). The coefficient of absorption is a number between 0 and 1, with 1 representing total absorption (an open window) and 0 representing total reflection.

We are very used to hearing sounds indoors, so we have learned not to be confused by the multiplicity of sounds arriving from various directions. We almost always realize the sound comes from the direction of the first arrival. (The whole issue of localization is too involved to get into here. It depends a lot on the number and shape of our ears.) Any reflections that arrive within 20 milliseconds of the first add to the impression of loudness of the sound. Any reflections that arrive more than 40 milliseconds after the first may be heard as a distinct echo, but are usually accepted as reverberation. Reflections that arrive between 20 and 40 milliseconds after the direct sound can be confusing and interfere with understanding if the sounds are speech.

Reverberation

Sound does not stop at the listener's ears of course, it continues and is reflected again by the other walls of the room. If the coefficient of absorption is low, a sound may bounce several dozen times before it fades away.



Paths of sound from performer P to listener L

Fig. 3 More reflection paths

This drawing would be solid black if all of the possible reflections were shown. The arrival time graph is more informative:

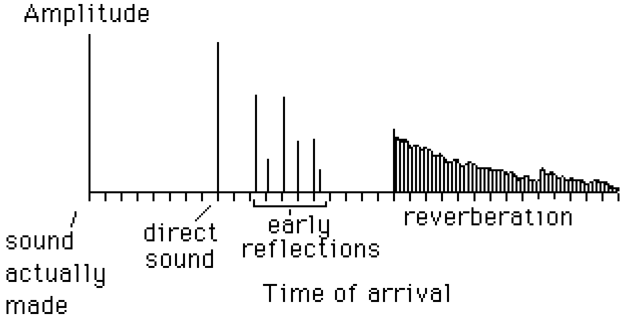


Fig. 4 Time and amplitude of sounds at listener's ear

This shows the complete picture of what is heard if a single, short sound is produced in a room. Most of the sound energy that is reflected twice or more is heard as reverberation, a sort of stretching of the sound event. The actual amplitude of reverberation is not very important (unless it is strong enough to obscure following sounds) but the time that it persists is. Short reverb times (a half to a full second) are comfortable for speech, whereas moderate times (1 to 3 seconds) work well with various kinds of music. Some music was written for very reverberant environments such as large stone churches, and should be heard that way.

Coloration

Reverberation time is the most often quoted description of a performing space, but it is not really the most important. The frequency response of the reverb should be reasonably flat, or slightly low pass, which is sometimes described as "warm reverb". That means that low partials of sounds will persist a little longer that high components, matching the decay characteristics of most instruments. The opposite effect, where high pitched sounds linger, can be very annoying. This is the situation in many indoor swimming pools.

The envelope of the reverberation should match that in figure 4, a fairly even decay, with no "lumps" of sound. A rectangular room with flat walls will not provide such an envelope; the reverberation will occur in bursts, often with distinct echos ("slap-back). To provide even reverberation, the shape of the walls should be complex, but not very regular. A regular structure, such as a staircase, will often produce a series of echoes called flutter echo.

Isolation

Control of reflections and reverberation can satisfy the first three goals on our list. Isolation is a matter of the materials and techniques used to build the room. The walls must be heavy and solid, and for really excellent isolation, all walls, doors, floor and ceiling must be doubled; literally one room within another. Attention must be paid to such details as air ducts and holes for electrical cables, for sound can leak through any opening. Once an adequately isolated structure is finished, noise generating devices must be kept out. Light fixtures, (especially fluorescent), heaters, and backstage equipment can all create noise and must be chosen for quiet operation.

Adequate isolation is almost impossible to achieve after construction if it was not built in in the first place, but since it is an issue that is very important to low budget recording and electronic music, here are a few things that can be tried.

- First, find the leaks that sound follows between the studio and the outside world. Edges of doors, vent ducts, electrical outlets are all suspect. They can be treated with the materials sold for heat insulation, if the heavy, expensive versions are used.
- Direct attachment of sound sources to walls, floors or ceiling should be avoided. Swing speakers from ropes or mount them on stands. Put three layers of carpet on the floor, or set things on the canvas part of camp stools.
- Hang absorptive materials. Heavy curtains or rugs from floor to ceiling work well, as does four inch thick fiberglas insulation. (Thinner fiberglas has poor frequency response) There are plastic foams designed for this purpose, but they are expensive and a fire hazard. Egg carton material has a nice shape for diffusion, but is not particularly absorptive. If the above procedure makes the room too dead, hang some light hard panels in front of but not touching the absorption

Building for good acoustics

A small concert hall was given acoustical treatments in a recent renovation. Here are the visible features that were added:

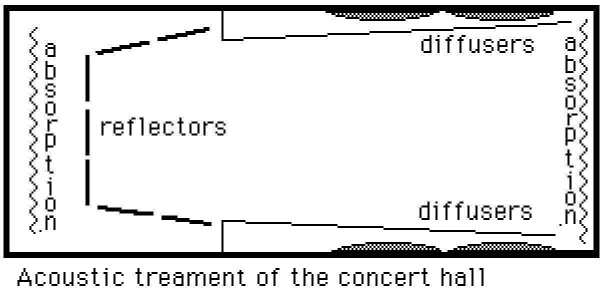


Fig. 5 Some structures to control reflections and reverberation

The diffusers smooth out the reverberation and make the sound reasonably uniform at different seats. The absorptive curtains allow the reverberation time of the room to be adjusted to control the loudness of ensembles of various sizes. Movable panels behind the performers serve to group the early reflections into the "sooner than 20ms" range and also (probably more important in this small hall) help the performers hear each other.

The issue of architectural acoustics is very complex, and often not handled well. It seems that most concert halls are constantly being tinkered with and occasionally rebuilt at fantastic costs; perhaps our expectations are unrealistic now that we are used to hearing every note and nuance in our living room.

Source: http://www.co-bw.com/Audio_Acoustics.htm