Acoustics of Small Rooms, Home Listening Rooms, Recording Studios

The acoustical properties of small rooms – used *e.g.* for listening to music, watching movies, *etc*. in a person's home, or *e.g.* sound recording studios – differs considerably from that of large rooms – auditoriums, concert halls, cathedrals, lecture halls, *etc*. primarily in the reverberation times (typically T_{60} < ½ second for a small room) and also room resonances. The "mix" of direct sound *vs*. early reflected sound vs. reverberant sound is different for small *vs*. large rooms. In a large room, first-arrival times of the early reflected sound are typically on the order of ~ 50-80 ms after the direct sound, whereas for small rooms, the first-arrival times of the early reflected sound are typically on the order of ~ few *ms* after the direct sound. Additionally, and especially so in home environments, the sound absorption properties of the room often are significantly higher than in large rooms, due to the presence of carpeting on the floor, window curtains on walls, *etc*. Thus, the acoustic "intimacy" of the small room often makes it difficult to emulate the acoustics associated with that of a larger space, *e.g.* when listening to recorded music.

The Sabine formula $T_{60} = 0.161V/A$ holds for small rooms, and shows that for fixed small volume *V*, the reverberation time can be increased by reducing the absorption *A* of the room. However, if you've ever been in an empty room in a house, *e.g.* with no carpeting or drapes/curtains present, because of the short first-arrival times associated with a small room, the reverberant properties of a small empty room are starkly different than that of an auditorium. The short *vs*. long decay time associated with sound in small *vs*. large rooms provides important auditory information/clues to the listener about the size and nature of the room.

For rectangular rooms, the eigen-frequencies associated with the axial, tangential and oblique-mode room resonances $f_{lmn} = \frac{1}{2} v \sqrt{\left(l/L_x\right)^2 + \left(m/L_y\right)^2 + \left(n/L_z\right)^2}$ with $l, m, n = 0, 1, 2, 3, 4, 5, ...$ will also be commensurately higher than those associated with an auditorium, also contributing to the perceived acoustic differences between small *vs*. large rooms. The higher-frequency room resonances accompanying small *vs*. large rooms thus "color" the sound of recorded music being listened to in a small room differently than *e.g.* in an auditorium-type live-sound environment.

Most listeners in a small room will likely be situated such that they are ~ 2 *m* or more away from loudspeakers located in the small room. At low frequencies, the directivity factor *Q* of loudspeakers is reduced {due to diffraction effects} and the room absorption, *A* is typically low in small rooms at low frequencies {*e.g.* carpeting absorbs sound relatively poorly at low frequencies}, thus a listener in a small room is often in the reverberant field of the room at low frequencies, *i.e.* typically $Q/4\pi r^2 < 4/A$ at low frequencies. At higher frequencies, the directivity factor *Q* of the loudspeakers increase as well as the sound absorption *A* of the room such that for a typical listening distance of *r* ~ 3-4 *m*, $Q/4\pi r^2 > 4/A$ at higher frequencies, further contributing to the listener's perception that small rooms are "dead"-sounding, relative to large auditorium/concert halls, *etc*.

In a small listening room such as in a house, an audiophile likely enjoys listening to music recorded in stereo (*i.e.* L & R-channel sound), or perhaps a enjoys watching a movie, or recordings of live music *e.g.* on a DVD with the 5.1 surround-sound – *i.e.* requiring a multiple channel/multiple speaker home theater sound system.