CHAPTER

11 Room design for loudspeaker listening

CHAPTER OUTLINE

In the light of various caveats about room and loudspeaker design, there are no precise answers to the questions: "What precautions should be taken in typical living rooms toward making listening to recorded music over loudspeakers as pleasant as possible?" and " How should loudspeaker outputs be adjusted to go with different room characteristics?" Sean Olive et al [1]. boldly state, "Given that today the sound quality of commercial phonograph recordings remains highly variable, there are always opportunities for good room corrections to sound bad and for bad room corrections to sound good." Added to this is what some call "Beranek's Law" [2]: "If one selects his own components, builds his own loudspeaker enclosure, and is convinced he made a wise choice of design, then his own loudspeaker sounds better to him than does anyone else's loudspeaker."

The following discussion is offered as a general guide to listening to recorded music with loudspeakers located in a living room.

PART XXXII: HOME ROOM DESIGN

11.1 CONCERT HALL ACOUSTICS

Because listening to music in your home is an alternative to listening to music in a concert hall, the acoustical factors that make a concert hall satisfactory must be considered when planning room and loudspeaker configurations. These concert hall factors include direct sound, loudness, adequacy of bass, degree of source spreading, reverberation time, strength and quality of the reverberant field, envelopment, freedom from distortion, freedom from echoes, and quiet.

Direct sound. Wherever one sits in a concert hall, the direct sound should be clearly heard before the energy in early reflections and reverberation have risen to the level that starts masking that sound. Freedom from masking of the direct sound is particularly important in the frequency region above 700 Hz. If the direct sound is not clearly heard, the music lacks impact and the listener may tend to go to

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sleep. This problem is particularly important in shoebox shaped halls with small seating capacities because the side walls that reflect early sound are nearer to the listener, which means that the reflections start masking the direct sound sooner. One possible design for a hall with limited seating is to make it fan shaped. This way, all listeners are nearer the stage, and the side walls do not reflect early sound toward the audience areas. In Boston Symphony Hall, which is shoebox shaped, the statues and niches and edges of high-up windows reflect sound above 700 Hz back toward the stage, which decreases the energy that would otherwise reflect from the side walls and thus preserves audibility of the direct sound.

Loudness. In a concert hall, the music must be loud enough as measured by the quantity Sound Strength G in dB. The magnitude of G is determined by the total overall sound-absorbing quantities of the audience, sidewalls, ceiling, and performers on stage. The greater their absorption the lesser is G.

Loudness of the bass sounds. A common complaint in concert halls is inadequate loudness of the bass sounds. A measure of bass loudness is a quantity called Bass Index, which is the strength of the sound G in the 125 Hz octave-frequency band *minus* the strength of the sound at mid-frequencies (average of the strength G in the 500 and 1000 Hz bands). Generally, if the walls are adequately heavy and the absorption of the audience seats at low frequencies is not too high, the bass loudness will be satisfactory.

Degree of source spreading. The sound in a concert hall is more pleasant if there are early reflections that come from lateral directions—the side walls in a shoebox shaped hall. Early lateral reflections spread the source, which results in a fuller tone. Of course, these reflections must not come so soon as to mask the direct sound, but they must occur in the interval between 30 and 80 ms after arrival of the direct sound. The optimum shoebox-hall width for meeting this requirement is about 24 m. It is difficult to achieve sufficient early lateral reflections in halls where the audience surrounds the orchestra. In fan-shaped halls, early lateral reflections are non-existent.

Reverberation time. Reverberation is part of the music that one hears in a concert hall. No symphonic piece sounds good outdoors where there is no reverberation. Optimum reverberation time for the current symphonic repertoire is 1.8 to 2.1 s. For chamber music the optimum time is 1.5 to 1.7 s. Reverberation does not contribute to loudness.

Strength and quality of the reverberant sound field. The quality of the reverberant field is enhanced if there are substantial irregularities on the side walls and ceiling. In some halls, this is accomplished by niches on the side walls above the top balcony and by coffers in the ceiling. These irregularities must be of depths of up to 0.5 meter. Such great depths are not desirable below the upper balcony, because lateral sound reflections of high quality are needed from there.

Envelopment. In the best halls, the audience feels enveloped by the reverberant sound. This is a matter of the strength G of the reverberant sound measured 80 ms after arrival of the direct sound—the higher the strength the greater the envelopment. However, the design of concert halls of the future may be influenced by a trend in modern phonograph recordings. In these, some of the recording microphones are placed near the performers. The others record the reverberant sound. The relative strength of the two is then adjusted by the tonemeister and the tendency is to make the strength of the reverberant field relative to the direct sound lower than is experienced in the actual concert hall. The strength of the reverberant sound field may be reduced in a hall by adding appropriate sound absorption materials in the side walls and ceiling.

Freedom from distortion, noise, and echoes. It almost goes without saying that these must be avoided in a concert hall. Distortion can come from repetitive small-scale irregularities on the side walls below the top balcony. This is sometimes called the "picket-fence" effect. Noise generally comes from the ventilating system. Echoes are easy to identify in computer simulation of a hall during the planning stage.

11.2 LISTENING ROOM ACOUSTICS

Typical space. The typical American living room has dimensions of, say, 7 by 9 m with a ceiling height of 2.7 m. Window frames, draperies and pictures on the walls provide diffusion of the sound field at high frequencies, but at frequencies below 1000 Hz the sound field is generally not diffuse. The reverberation times are often greatly different at different frequencies depending on the sound absorption qualities of furniture, wall hangings, and carpets.

Reverberation times. There is general agreement that reverberation times at mid-frequencies (500 and 1000 Hz octave frequency bands) should not exceed 0.5 s, and at low frequencies (62 and 125 Hz bands) it may rise somewhat, say to 1.25 times that at mid-frequencies. Control of the low-frequency sound is possible by selecting heavily-upholstered furniture. In other words, the room should not sound "dead," nor should it sound very reverberant, partly because the reverberation time of the recorded sound should come through in its pristine form.

Loudness. Loudness is generally not a problem, because the amplification of the playback system is easily adjustable.

Placement of loudspeakers. Of course, the answer to this question depends on the system purchased. A five-loudspeaker system will be handled differently from a two- or three-speaker system. Let us first talk about the interaction of room resonances with loudspeaker location.

The four lowest modes of vibration in the above-mentioned typical living room will have frequencies of 19.2, 24.5, 31.2 and 38.4 Hz. These will only be excited if the loudspeaker is put in the corner of the room. Even if the loudspeaker is in the corner, the listener would also have to be in another corner to hear those resonances. If either the loudspeaker or the listener is located in the center of the room, the four lowest modes that the listener would hear would be double in frequency, 38.2, 49, 62.4 and 76.4 Hz. Since neither the listener nor the loudspeaker will likely be in either place, the frequencies of the first four modes that are heard will probably lie between about 30 and 60 Hz.

From Fig. 11.1 we see that the lowest note of the double bass is 41 Hz and that of the Cello is 65 Hz, so these notes may be better served by their harmonics. It is well known that if the harmonics of a musical note are heard, the hearing mechanism will supply the missing fundamentals.

If the typical five- or six-loudspeaker system is employed, the woofer will be at the front of the room and the others will circle the listener. In this case, the question arises as to the directivity characteristics of the side and rear loudspeakers.

Directivity of loudspeakers above the cut-off frequency. This category includes all loudspeakers surrounding the listener. Some listeners prefer the sound to come from loudspeakers that have relatively narrow directivity patterns at all of these frequencies. The reason is that they wish to hear only the sound that is recorded. If the patterns are broad, they will overlap in the room, and the recorded sounds from the different loudspeakers will arrive at different times, and a "smearing" effect results. Others feel that the smear is equivalent to increased "envelopment" which they feel is a good thing.

Some subjective tests. There are electrical systems that are sold to "correct" the reproduced sound in the room. Olive et. al.[1] made subjective tests of several such electrical systems. For the tests, they used a high-quality loudspeaker operating above a crossover frequency at 80 Hz and a high-quality subwoofer. The woofer was located in a left-front corner, and the other loudspeaker was located in a direction about half way between the center of the room and the location of the woofer. Eight subjects were seated on chairs in the center. The reverberation time for the room was 0.4 s, and the levels for all

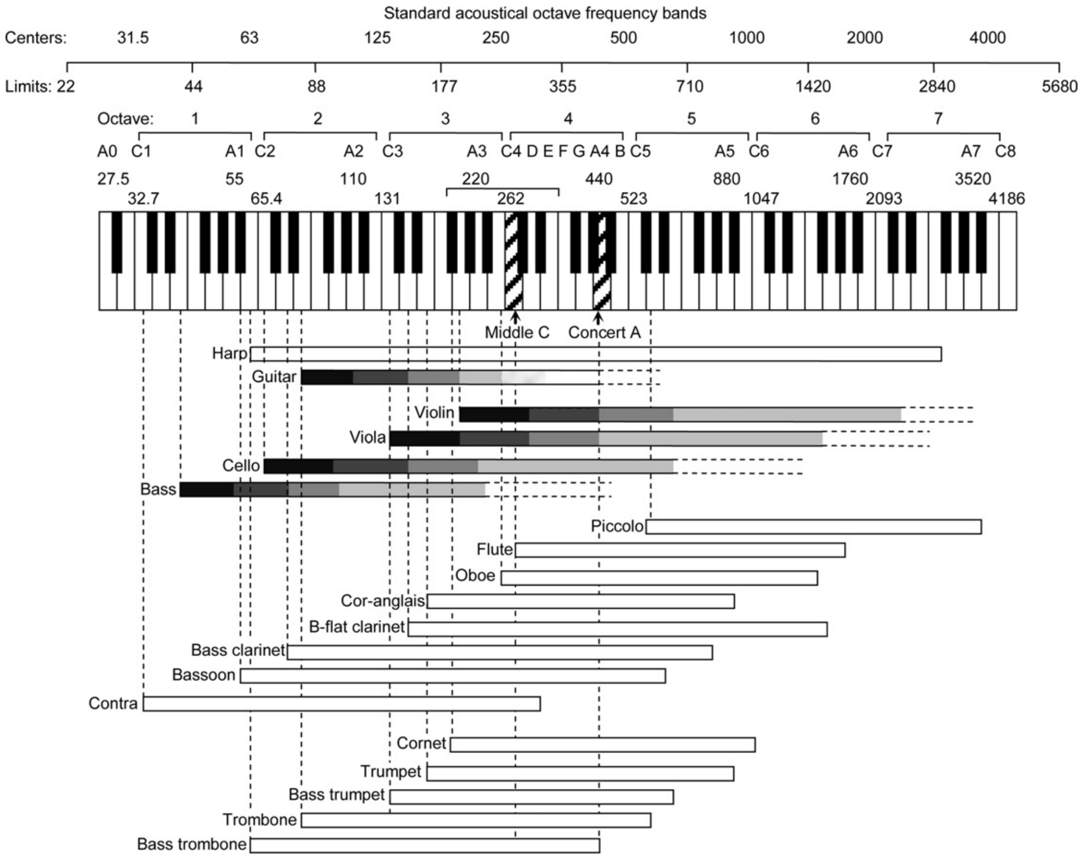

FIG. 11.1 Musical scale.

of the correcting systems being compared were adjusted to be the same as determined by dBA measurements at the listening positions.

According to the test subjects, the most preferred systems had the flattest spectral balances and they were rated as “full and neutral.” This could be accomplished by rolling off the response below the cut-off frequency by, say, 6 dB per octave, to compensate for the rise in reverberation time and loudness owing to uneven sound absorption in the listening room. The lowest preferred systems were rated as “colored, harsh and thin.” Surprisingly, the best rated systems had a downward-sloping frequency response toward the high end of the frequency spectrum.

A more elaborate system was described in some detail in the *Science Times* section of the *New York Times* (9/6/2011) as providing sound of the quality heard in the best shoe box shaped halls. To quote with some editing: The company Audyssey in Los Angeles said “That listening tests showed that speakers directly ahead and to either side of the listener provided the most attractive sound stage. The ‘wide speakers’ mimicked the reflections from the side walls of a concert hall. For ‘depth of stage’, listeners preferred speakers in front and high above. This sound—also slightly delayed—gave a sense of where the different instruments were. For full concert-hall-effect three speakers were in front; two were elevated; two were wide; two were slightly behind, and two were directly behind." Of course a subwoofer in the corner of the room was used. It was emphasized that the levels had to be adjusted so that a flat frequency response was achieved at the listeners' positions. No mention was made of how the loudspeakers were driven by present-day symphonic recordings.

Concluding remarks. There is not much more to be said. When setting up a listening system, it is recommended that a suitable room-correcting system be used to obtain the best response of the combined room/loudspeaker system.

References

[1] Olive SE, Jackson J, Devantier A, Hunt D, Hess SM. The Subjective and Objective Evaluation of Room Correction Products, in the 127th AES Convention 2009. paper no. 7960.

[2] Beranek LL. Acoustics. McGraw-Hill; 1954. p. 208.