Multichannel Control Room Acoustics and Calibration

After discussing control room layout, loudspeaker position and interaction of loudspeakers with room boundaries, Genelec's Christophe Anet highlights the challenges in designing multichannel control rooms, practical issues when flush mounting speakers, the home theatre paradigm and some acoustical calibration recommendations.

Room Acoustics for Multichannel Audio

The design of a multichannel control room is constrained by the fixed recommended speaker placement. In the horizontal plane the compromise is often with the rear speakers, which implies that adjustable delays have to be inserted in the audio monitoring path to achieve equal direct sound arrival time for all loudspeakers. In the vertical plane the European Broadcast Union recommends same height and vertical tilt for rear and front speakers while other recommendations allow only rear speakers to be placed higher than the ear height. It is clear that very few rooms have five identical speakers in an ideal surround setup, and that rear speakers are typically smaller than front speakers.

There is a significant discrepancy between speaker placement recommendations and what actually happens in multichannel control rooms. Standards usually discuss room sizes and speaker placement angles but exact speaker locations relative to the room are not discussed. A minimum distance for free-standing speakers to neighbouring walls is given and the goal of a symmetric placement is emphasized. Recommendation for placing free-standing speakers at least one meter away from walls appears too optimistic, especially for full range speakers. This rule can only be applied (as discussed in a previous article) for speakers used with a subwoofer/bass management system. Then, the distance to the wall behind the main speakers should be at least 1.1 meters. Flush mounting will be discussed later.

Reflections actually form what we perceive as room acoustics. Reflections in the control room will occur not only from the single wall behind the speakers but also from other boundaries and directions (side walls, floor, ceiling, console top, equipment racks, etc). The resulting irregularities depend from the distances between speakers and each of these surfaces. Nobody wants to work in an anechoic chamber, and therefore we want to control the reflections in such a manner that their effect to the monitoring work is sufficiently small. Ideally we should eliminate reflections which cause severe cancellations and thus affect the frequency response balance. Practically we can also minimise such strong reflections, compared to direct sound, that arrive in a time window where the ears perceive them as smearing of the direct sound. Positioning speakers as far as possible from reflecting surfaces will move reflection-induced irregularities to as low a frequency as possible, which is beneficial to the imaging. The further away from the listening position we set the speakers, the more, in general, reflected signal we will listen to.

© Genelec Oy, 2004. Published in Resolution Magazine, Sweet Spot, pp 58-59, Jan/Feb 2004, Volume V3.1

If reflection levels in the room are too high compared to the direct sound, the multichannel sound field and the dynamic sound object panning become smeared. So, by increasing the direct-to-reverberant sound ratio in the room, the localization and the uniformity of the sound field will be improved. To achieve this, speakers used for multichannel work should have controlled directivity.

Concerning reverberation characteristics we have to differentiate between small rooms with typical free standing speakers and large rooms with flush mounted systems. In small multichannel rooms, the reverberation time is usually similar to stereo rooms due to similar type of room volumes. In larger rooms, after analysing more than 160 control rooms, we found that the mean reverberation time (RT_{60}) was 380 ms from 200 Hz to 4 kHz. Considering that most of these rooms were quite large, this measured mean RT_{60} is reasonably short and controlled. However, when strong diffusion is used to control the reverberant decay field, the reverberation time usually increases.

The very low frequency damping is an issue all of its own. Its implementation does not vary much from standard stereo room design. However, conventional rear wall absorbers are often insufficient to damp modes between sidewalls. These modes are excited by the rear speakers and additional damping is usually necessary. In general, lack of bass trapping becomes more problematic in multichannel control rooms, as there are multiple low frequency sources in different locations. This should stress to designers the importance to carefully control the low frequency energy decay and modal behaviour of multichannel control rooms.

Flush Mounting Speakers

Flush mounting speakers for hemispherical radiation is usually only implemented with large speakers. The benefits are many including improved low frequency efficiency, no rear wall cancellation nor cabinet edge diffraction. As a result of the improved low frequency efficiency, adjustment of the speaker's frequency response is necessary to keep the response flat below few hundred Hz.

Front walls are usually made hard in order to enhance the low frequency reproduction. This is ideal for two-channel rooms. In multichannel rooms the front wall may form a large reflective surface on which rear-speaker sound reflects. In certain room sizes these reflections may cause image instability. It is then wise to cover such large front surfaces with absorbing material efficient enough at mid and high frequencies but not able to absorb low frequencies. A 50mm sheet of rock wool or similar is suitable. In some cases the large speaker baffles themselves offer reflective surface for mid and high frequencies. As a separate note, the space between the speaker cabinet edge and the soffit cavity should never be left open without a facing panel. This small cavity can form a resonator, which will only adversely affect the speakers' frequency response and perceived sound quality.

To achieve the best possible results all five speakers should be flush mounted in a similar way. The requirement to have all speakers on equal distance, on the circle radius, leads to new control room shapes and geometry. Other issues such as ceiling design, low frequency absorption and diffusion, midrange definition and clarity have to be addressed separately by a studio designer.

The International Telecommunication Union has issued a recommendation ITU-R BS.775-1 to determine the vertical location of speakers in high quality monitoring spaces, and defines this as "the listeners' ears height" specified as 1.2 meters above the floor. Despite the fact

© Genelec Oy, 2004. Published in Resolution Magazine, Sweet Spot, pp 58-59, Jan/Feb 2004, Volume V3.1

that recommendations do not discuss speaker size and front baffle size as parameters affecting speaker placement, it is recognized that large speakers may in reality have to be placed higher than this. Often when large speakers are positioned too low close to the floor, their responses will have notches in the 80 Hz to 120 Hz frequency region, causing deterioration of the bass reproduction. In stereo control room design, speakers' height has always depended on room geometry, equipment layout and listening distance, and it should continue to be so for multichannel control room design. In reality, the larger the speaker, the higher it should be placed to reduce these cancellation phenomena. However, for these elevated placements, the vertical tilt angle is usually kept smaller than 20 degrees.

Home Theatres and Professional Production Rooms

Home theatres differ somewhat from professional production rooms in terms of acoustics and layout requirements. Basic reverberation time criteria and furniture reflections are generally taken care of in most home theatre designs, but room modes, standing waves, low frequency absorption and speaker placement are usually neglected. Most of these entertainment systems are installed in existing rooms having parallel walls and acoustically less acceptable dimension ratios. Only high-end home theatre rooms have controlled acoustics integrated with the entire design. The paradox of the common simple home theatre room is that it does not necessarily replicate the production environment and acoustics at all. The professional audio industry tries to follow an ITU standard for speakers' layout, but it is not the case amongst home theatre installers and designers (see figures 1 & 2).

This aspect was considered in the film industry very early by building large mixing theatres which were proportionally and acoustically exact copies of public theatres. In that way audio could be produced with assurance that replay would sound similar. With the improved audio

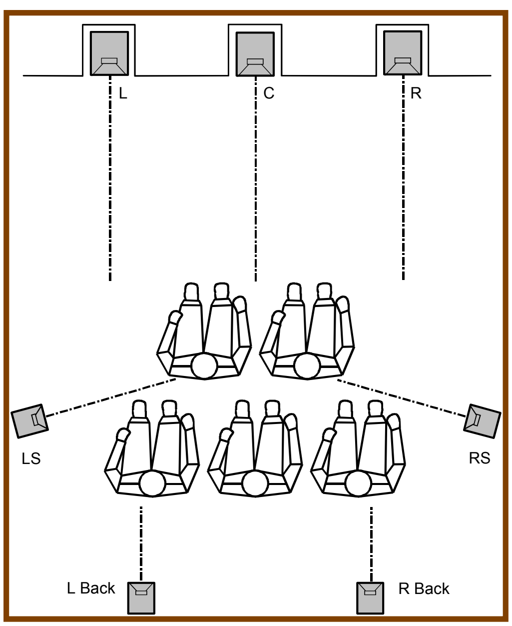

Figure 1: Typical home theatre speaker layout and room arrangement.

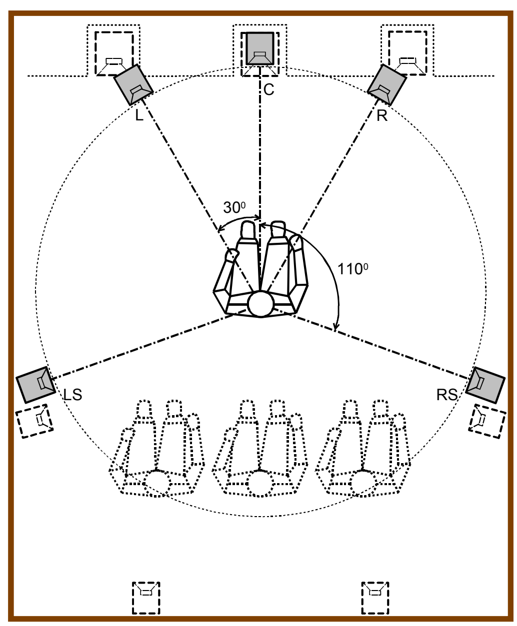

Figure 2: A professional ITU speaker layout overlaid on a typical home theatre room.

© Genelec Oy, 2004. Published in Resolution Magazine, Sweet Spot, pp 58-59, Jan/Feb 2004, Volume V3.1

quality of multichannel discrete productions we seem to have lost or neglected such consistency. Hence the discrete multichannel mixing work will almost never translate exactly at the reproduction end, and this should raise questions amongst designers and installers of home theatres.

It appears that the only solution for the mix engineer is to check the final DVD audio mix-down in a typical home theatre environment! This suddenly reminds us of early stereo production methods, where engineers checked their mixes on car stereo!

Acoustical Calibration

Finally, the general aim of multichannel speaker system acoustical calibration is to ensure that the output level of the band limited subwoofer is the same as that of the main speaker system. The question is then, what reference level to use? For 35 mm film mixing work, the SMPTE (Society of Motion Pictures and Television) reference monitoring level is 85 dB using full bandwidth pink noise as the sound source, with level read using a sound pressure level meter (SPL) set on C-weighting on slow response time.

For the release of film materials on television, various standards state that the operating mixing level should be somewhat lower. Then the low-level dialogues which are easily heard in a quiet and acoustically well treated control room are mixed on a slightly higher level. This is to ensure that when replayed in a home theatre, which has typically higher background noise level, dialogues will still be clearly heard. However, for music mixes, there are no standardised levels – as with stereo – because each engineer chooses the level based on personal need and taste, very much like the levels chosen by end users. Thus, one absolute reference level is not yet really applied to all multichannel surround sound applications.

Several methods can be used to calibrate the frequency response of each loudspeaker as well as their combined system response. Generally, individual loudspeaker frequency responses must be calibrated before adjusting speaker output levels. Furthermore, there is no point in trying to calibrate the loudspeaker frequency responses if there are fundamental acoustical problems in the room. Those should be solved first. Level calibration is the last step once all other issues have been resolved.

The acoustical response of the main speakers together with the subwoofer should be flat and linear over the full audio spectrum. If measuring equipment is available, MLS type impulse response will provide excellent information for detailed and precise speaker calibration. If no MLS measuring system is available, there are two other coarse alternative level adjustment methods. The accuracy of these methods depends greatly on the quality and frequency response of an SPL meter.

If a third-octave RTA is available, play broadband pink noise signal (20 Hz-20 kHz) through the subwoofer and one of the main channels (usually the centre). Read the third-octave RTA display and note the level of each 1/3 octave band in the subwoofer bandwidth. Set the subwoofer gain so that the 1/3 octave bands are at the same level as those on the main speaker range. Then set the other main speakers at the same level. The specific absolute SPL reference level depends on your type of application.
Another possibility is to use an SPL meter and two different types of filtered pink noise: a 500 Hz to 2 kHz and a 20 Hz to 80 Hz band noises. Both are two octaves wide. The first signal, well away from the subwoofer's bandwidth, will be used for the adjustment of the mid band frequencies of each main speakers. The SPL meter should be set to C-weighting and slow response time, and the same reading (say 83 dB) and adjustment should be done for all five

© Genelec Oy, 2004. Published in Resolution Magazine, Sweet Spot, pp 58-59, Jan/Feb 2004, Volume V3.1

channels. Next, the 20 Hz to 80 Hz filtered pink noise can be played through the subwoofer. The proper adjustment should give a reading about 3 dB lower than the one for the main speaker (in our example, 80 dB SPL). The reason for this difference in level reading is that most SPL meters have a built in high-pass filter, which ignores part of the subwoofer output. If there is no high-pass filter in the SPL meter, then the reading should be the same in both cases. This follows from the pink noise itself and the test signal two octaves' bandwidth.

Last, but not least, is the subwoofer phase alignment. An incorrect phase alignment between main speakers and subwoofer causes a drop in the frequency response of the whole system at the crossover frequency, and this is usually in the critical 70 Hz to 90 Hz region. Because the phase difference between main speakers and subwoofer at the listening position depends on their physical position in the room, the phase adjustment should be done only after the preferred positions for loudspeaker have been found. A proper crossover point phase adjustment has been achieved when a smooth and linear frequency response transition occurs between a main speaker and the subwoofer.

© Genelec Oy, 2004. Published in Resolution Magazine, Sweet Spot, pp 58-59, Jan/Feb 2004, Volume V3.1