Placement and Room Acoustics Interaction

Multichannel audio production still has many challenges to face up to. We are constantly updated on the equipment involved and enlightened with techniques and aesthetics, but the various technical and practical issues that need to be considered before starting a multichannel recording or mix are less well addressed. Genelec's Christophe Anet presents some technical and practical issues for a multichannel control room.

To gather the right equipment in an acoustically decent control room is only part of the multichannel challenge. The issues that I will present here do not consider equipment choices or production techniques, but highlight the speaker placement in relation to boundaries, furniture design and layout, calibration of sound sources and room acoustics.

Equipment and Layout

Most of today's multichannel control rooms are not originally designed for multichannel production. Also equipment layout and installations vary significantly from one room to the next. The physical location of the equipment in the room has direct consequences on the quality of the reproduced audio and inevitably on the final production.

First, the general rule that the control room layout should be symmetrical is still valid. With the quantity of additional equipment, their symmetrical positioning is even more crucial.

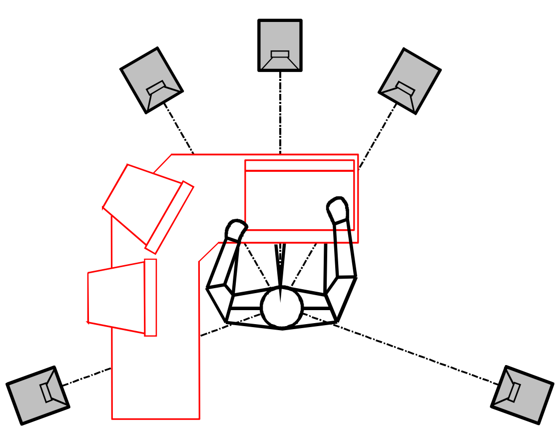

Figure 1: Non-symmetrical equipment layout leading to compromised sound field.

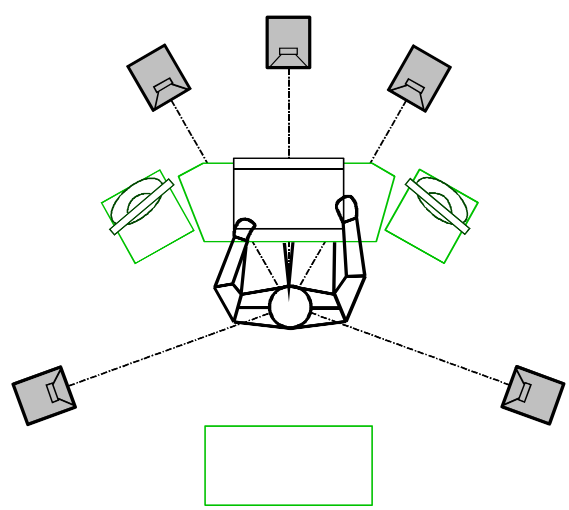

Figure 2: Example of a symmetrical equipment layout for a multichannel control room.

As the largest and heaviest piece of equipment in the control room is of course the mixing console, its location along the middle axis of the room is highly important. All other pieces of furniture added around and behind the console should also be spread in a symmetrical manner.

Early reflections, with high amplitude in relation to the direct sound, can smear the coherence of the spatial information and compromise sound source localisation. To avoid this, all reflecting surfaces (19” outboard racks, keyboard racks, computer tables, etc) placed between the speakers and the listening position should be removed, or at least minimised (see Figure 1 & 2). Furthermore, tables or outboard racks placed inside the speaker circle should be lower than the typical mixing console control surface height. With DAWs, the insertion of large screens into the work surface reduce significantly first order reflections from the centre speaker. Making the tabletops from non-reflecting material such as perforated steel would reduce the reflections further. However small the remaining surfaces can be, reflections in the time domain should be identical from both the left and right half of the room. Furniture could be designed so that there are no additional surfaces beyond the job needs. If each speaker faces a direct path with different reflection patterns, it will be quite impossible to measure five identical responses at the mix position. Even with proper symmetry, everything possible should be done to remove the reflecting surfaces, especially those close to each speaker.

For the placement of the listening position in the room, most research works indicate that the reference point should be located in the front half of the room, so that the engineer gets the best direct-to-reverberant signal ratio in listening. However, as there are now rear speakers involved as well, the acoustic design of the front half of the room becomes more complicated. If the room has, for example, hard and reflective front wall surfaces, direct sound from the rear left speaker will bounce on the front right speaker and nearby boundaries. This situation should be avoided as these strong first reflections will alter the front speaker’s direct sound. This calls for some planning in room geometry and location of absorptive surfaces in the mid and high frequency band.

Recommended Speaker Placement

The widely accepted professional standard is the ITU–R BS.775–1. The recommendation states clearly a few well-known points: the positioning of the reference listening point is at the centre of an imaginary circle having a radius between 2 m and 4 m (min. and max. radius defined in the ITU-R BS.1116–1 recommendation).
Concerning positioning angles, in the horizontal plane, there should be 60 degrees between front left and right speakers, with the centre speaker in the middle. Both rear speakers should be placed within 100 to 120 degrees from the centre line. If more than two rear speakers are used, they should be symmetrically placed between 60 and 150 degrees from the centre line. The acoustical axis of the front speakers – as defined by the speakers’ manufacturer - should be approximately at the listener’s ear height, meaning 1.2 m for the ITU. The height of the rear speakers is less critical and an inclination of up to 15 degrees is accepted.

Many layout variations are possible within the ITU recommendations. Despite the fact that most recording engineers choose the ±110 degrees for the rear speakers, there are differing views about these angles. Depending on the source material and the type of surround effects desired, the surround channels location becomes an open issue. The general practical goal, however, should be to follow these recommendations to achieve compatibility in the overall production chain.

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Since all sources are placed on a circle, the speakers have to be precisely positioned to avoid amplitude and signal arrival delays (as an example, if an audio element is panned from centre to left, and the centre monitor is offset forwards or backwards by 25 mm (1"), one can expect amplitude ripples in the 500 Hz region due to arrival time delays). The ITU also allows positioning the centre speaker along a straight line between left and right speakers, but then a time delay is needed to retrieve equal arrival times.

The rear speakers often have to be placed higher than ear level, but not beyond 15 degrees of inclination; otherwise coherence of the front-back image and of the surround field is lost. In many cases the elevation of the rear speakers is an elegant solution that frees the floor space.

Once the array is in place, the speakers must be pointed towards the engineer's listening position to obtain the optimal on-axis reproduction. Even if the reference listening area with a standard 5.1 speaker's arrangement might be slightly larger than with a stereophonic arrangement, it is crucial that each speaker is orientated properly. If large reflective surfaces cannot be removed, the five main speakers could be placed slightly higher than listening level on separate stands, all at the same height, and then slightly tilted down towards the listening position.

The brain has much higher capability to localise information in the horizontal than vertical plane - our ears' location explain that fact very easily. The ear/brain vertical localisation resolution is about 3 degrees above ear level horizon and 3 to 10 degrees below that line. Hence our vertical localisation tolerance is roughly 7 degrees in the normal vertical working window, and there two sources can be positioned at different heights without the ear/brain noticing the difference. This useful human hearing tolerance can be exploited when placing the centre speaker. Also, with a non-acoustically transparent screen, the better position for the centre speaker is above the screen and not below as some paper suggest – the ITU included. Placing the centre speaker below the screen means the speaker cabinet is closer to the floor and floor reflections will strongly colour the critical midrange band. Above the screen the centre speaker might suffer from low ceiling reflections but applying effective, i.e. reasonably thick, damping materials in the ceiling is easier than on the floor. A thin carpet does not help.

Speakers and Boundary Interferences

Probably the majority of the audible problems in monitoring are due to the effects of the room acoustics. A large majority of multichannel rooms use a combination of speakers/subwoofer/bass management system to reproduce the 6 discrete channels. With that set-up the bass management will direct the low frequencies of each main channel and most of the LFE channel to the subwoofer.

To determine the practical correct location for the subwoofer and the main speakers, let's assume a crossover frequency of 85Hz between them. Since all speakers and subwoofers are omni-directional at low frequencies, cancellation effects, standing waves in the room and the proximity of boundaries will affect the speakers/subwoofer performance.

When a speaker having flat anechoic (4π) response is placed against one solid boundary - which is large compared to the wavelength - the radiation space becomes 2π, and the theoretical amplitude gain is 6 dB for frequencies below a few hundred Hz. This applies typically to flush mounted speakers or speakers placed with their back against a wall. In all cases, this amplitude change has to be compensated to retrieve a flat and neutral frequency balance.

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Typical subwoofer location is on the floor and against a wall. Here are two large boundaries (radiation space π), which cause a +12 dB amplitude gain compared to free field. This gain is beneficial, as it provides additional headroom and/or less distortion.
Dual subwoofers are suggested for certain multichannel formats and most of such installations place the subwoofers in the control room front corners. The radiation space is further halved and the amplitude gain becomes then +18 dB for each subwoofer. Adjustments of such systems can become difficult due to the strong excitation of room modes from the corners. A fully symmetrical subwoofer placement is then less recommended, as a slight layout asymmetry can minimize the room modes excitation.

Another boundary interference to consider is the so called 'back wall' cancellation effect, generated by the single reflection from the wall behind the speaker. When two identical signals are in anti-phase, they cancel each other. If the speaker is a quarter wavelength away from a reflective wall, the reflected wave comes back to the speaker with half a cycle phase difference and thus cancels the original signal at that frequency. The importance of the cancellation depends on the distance and the reflection coefficient of the wall, but it is usually well audible.

For a multichannel set-up using an 85 Hz crossover between speaker and subwoofer here is a set of practical placement solutions:

First, the distance between the radiating subwoofer driver and the wall providing part of the low frequency loading must not exceed a conservative 90 cm. If the subwoofer is placed further than 90 cm, cancellation and comb filtering will start to occur below 85 Hz, degrading the subwoofer response.

Secondly, there are three practical alternatives for the main speakers reproducing the remaining frequency range above 85 Hz:

- First, the speakers are flush mounted in a hard wall (or 'infinite baffle') eliminating the rear wall reflection problem. With two-way speakers this option is rarely implemented, but is almost inevitable with large full-band speakers.

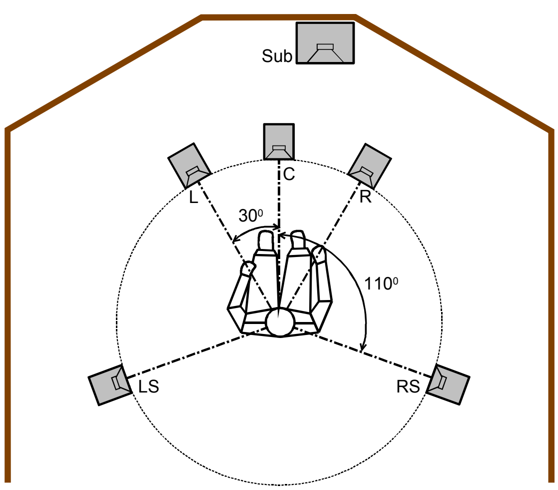

Figure 4: ITU R BS.775-1 speaker placement with each main speaker placed at least 1.1m from the wall behind.

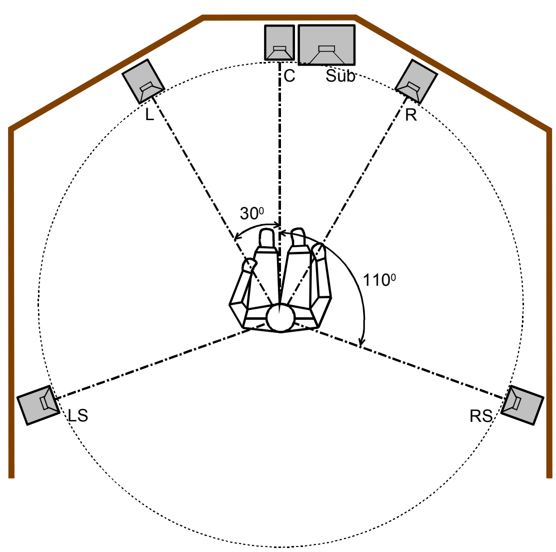

Figure 3: ITU R BS.775-1 speaker placement with each main speaker placed against a wall. (hemispherical loading)

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- Second best is placing the speaker very close to the wall, which raises the cancellation frequency. However, with very small speakers, inherently less directional in mid frequencies, the dip just moves to the low mid-band and might cause even worse coloration. Nevertheless, in most cases distances between 0 and 20 cm between the front radiating driver and the wall behind can be considered as safe (the directivity of the speaker should be high enough so that the rear radiation cannot cause a severe cancellation).

- The third logical cure is to move the speaker away from the wall, and in our example case it is at least over 1.1 m. In doing so, the cancellation frequency goes down below the 85 Hz cut-off of each main speaker. In the meantime, of course, distances to other room boundaries become smaller and reflections from these other surfaces might start to dominate the response. This third placement solution is the most common layout for multichannel control rooms that are not equipped with large flush mounted speaker systems.

The acoustical adjustment of the interaction between speakers and room is highly important before doing any kind of level calibration, so that the frequency response of the whole system is consistent across the entire spectrum without cancellation dips.

Most of the above practical suggestions require some common sense and some advanced planning. A well laid out control room is a necessary starting point for any multichannel production.

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