ON THE USE OF A NON-ENVIRONMENTAL CONTROL ROOM AS A
5.1 SURROUND LISTENING ROOM ¹

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Torres-Guijarro, Soledad¹; Pena, Antonio²; Sobreira-Seoane, Manuel A.²
¹Laboratorio Oficial de Metrología (LOMG); Parque Tecnológico de Galicia; San Cibrao das Viñas; 32900-Ourense, Spain; marisol@gts.tsc.uvigo.es
²Sonitum, E.T.S.E. Telecomunicación, Universidade de Vigo, 36310-Vigo, Spain; sonitum@uvigo.es

ABSTRACT

Whilst 5.1 surround systems are nowadays common in domestic audiovisual systems, surround sound still has fields to conquer in the audio world: broadcast, internet, portable devices… New audio codecs are consequently being developed for 5.1 formats, and listening tests are mandatory to prove their quality. Such tests, when performed over loudspeakers, require special listening rooms. A number of standards or recommendations outline the requirements to be imposed to these rooms. The control room of the ‘Universidad de Vigo’ follows a non-environment design that minimises the influence of the room and tries to preserve the sound of the recording during both the mixing and production processes. This goal is achieved by installing broadband absorbers in the ceiling and also in the side and rear walls.

In this contribution, the usability of such a room will be analysed according to international recommendations. This research includes the study of the electro-acoustic behaviour of loudspeakers, geometric and acoustic properties of the room, and sound field conditions. A detailed discussion of the divergences and implications for the usability when performing surround listening tests follows the measurement results.

1. INTRODUCTION: DESIGN OF SOUND CONTROL ROOMS AND INTERNATIONAL RECOMMENDATIONS FOR SURROUND LISTENING ROOMS

The design [1] of sound control rooms follows different approaches and there is no international standard, either official or de facto. The interest in having a better control room began in the mid-fifties, after the introduction of stereo recordings, but most of the adjustments were made using the ear as the key instrument. Nevertheless, the need for symmetry along the median plane, in order to keep a stable stereo image, started a new generation of control rooms. In the ‘60s Tom Hidley, one of the most important designers, started the design of control rooms with the following common features: high degree of symmetry along the median plane, minimal low frequency reflections coming from the back wall or ceiling, monitor loudspeakers flush mounted in the front wall and a short reverberation time down to low frequencies. Later designs (Live-End Dead-End (LEDE), “reflection free zone” principle, “controlled image design”, etc.) all tried to avoid an uncomfortable anechoic characteristic, whilst avoiding disturbing resonances and reflections.

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The non-environment design was proposed around 1982 by Tom Hidley, where the goal was having an acoustical environment with the minimum of room sound. Sound radiates from the monitor loudspeakers with barely any sonic influence from the room. This basic principle allows a reflective floor and a diffuse reflecting front wall where the loudspeakers are flush mounted. Huge absorbers cover the side walls, rear wall and ceiling, creating an almost hemi-anechoic space for the monitoring while keeping some comfortable working conditions because of the reflecting front wall. This design is supposed to preserve the sound characteristics of the mixing and production studios when taking the product to other control rooms, a fact that seems more and more important nowadays.

The origin of the standard listening rooms was largely based on the idea of providing rooms which are sufficiently similar in their acoustic performance to allow subjective judgements of equipment quality to be made on a reasonably representative and repeatable basis. One of the earlier specifications of a listening room was provided by the International Electrotechnical Commission (IEC), originally developed in 1985 and updated in 1998 as IEC 60268-13 [2]. The basic guidelines of this technical report were subsequently included, with minor changes, in other recommendations and technical documents, such as ITU-R BS.1116-1[3], EBU Tech.3276 [4] or AESTD1001.1.01-10 [5].

In the following, the results of the measurements carried out in the control room under test are compared with the requirements that the abovementioned documents impose to listening rooms. These requirements can be grouped into three categories: first, those that characterise the listening room (Section 3); second, those that apply to the reproduction systems (Section 4); and third, the properties of the sound field (Section 5). Section 2 introduces the room, audio equipment and measurement instrumentation. Section 6 closes this communication with some conclusions.

2. CONTROL ROOM AND INSTRUMENTATION

The non-environment control room whose properties are to be analysed in this contribution was built for the purpose of assessing audio codecs, as a high definition laboratory, according to the principles outlined in [6] and expanded in [7]. The room was based on a philosophy of stereo control room design, as these concepts had been shown to offer the highest degree of detail resolution. A wood surfaced reflective floor and a diffuse reflecting front “Rosa Porriño” granite wall, with huge absorbers covering side walls, rear wall and ceiling, complete the non-environment design (a detail of the front wall is shown in figure 1). The room was also equipped for 5/5.1 channel reproduction, using flush-mounted front loudspeakers and sub-woofer, with the provision of optional, stand-mounted rear loudspeakers, which could be either conventional loudspeakers or Distributed Mode Loudspeakers (DML).

Audio programme is matrixed using a Surround Sound Controller Audient ASP510. Crossovers and power amplifiers for the front loudspeakers are from Neva Audio. A Reflection Arts horn and a 15 inch JBL drive are used in the two-way frontal loudspeakers, with a 18 inch McCauley subwoofer. At present, MiniPro MP80 (from Fane Acoustics) DML panels are temporarily installed as the surround loudspeakers, driven by a Neva Audio amplifier.

The measurement instrumentation included a Tascam CD-RW2000 professional CD player as the analogue source. Half-inch free-field microphones and a conditioning amplifier were from Brüel&Kjær. Brüel&Kjær’s Investigator 2260 combined with a Type 3595 sound intensity probe were used to perform the intensity measurements. Signals were digitally stored in a Fostex D-5 DAT recorder. A Tektronix CSA7404B Communications Signal Analyzer was used to estimate delays down to a few microseconds. A hemi-anechoic chamber equipped with IAC Metadyne Anechoic Wedges was used to measure the pannels. Matlab and an Adobe Audition sound editor were used as post processing software.
3. ROOM MEASUREMENTS

3.1. Geometric properties

In the ITU, EBU and AES recommendations, there are several restrictions in the ratios between the dimensions of the room, to ensure a reasonably uniform distribution of the low-frequency modes. Rooms should be symmetrical relative to the vertical plane on the mid-perpendicular of the stereo base, and the floor area should preferably be in the shape of a rectangle or quadrilateral with one pair of sides parallel.

The control room in Vigo is embedded in a rectangle of 7 m wide and 5 m deep. Left and right loudspeakers are separated by three meters with the centre one brought slightly nearer to the sweet spot in order to minimise a horn effect from the front rigid walls. Rear panels are located close to the rear and side fabric-covered interior surfaces, according to the ITU reference listening arrangement. The fabric hides multi-layered absorbers, whose component parts behave differently at different frequencies. As a consequence, the dimensions of the room depend on frequency in a progressive way, as in any high definition room. Thus, it is not clear how to face the specifications in listening room standards regarding dimensions, apart from the symmetry requirement, which is in general fulfilled. In this type of rooms, low frequency modes are very well damped, ensuring good room behaviour at low frequencies despite its proportions. Taken to its extreme, the shape of an anechoic chamber has no effect on modal response.

3.2. Reverberation time

Standards agree about a nominal value $T_m$, computed as the average measured over the frequency range 200Hz-4KHz, which is linked to the volume of the room as $T_m = 0.25(V/V_0)^{1/3}$, with $V$ the volume of the room, and $V_0$ a reference volume of 100 m$^3$. Variations of $T_m$ over the 63 – 8000 Hz frequency range should follow the most restricting mask (from the AES document) in Figure 1.

The following procedure was used to measure the reverberation time of the room: each loudspeaker was alternatively excited by three impulsive signals, and the room response was recorded in four points within the listening area. The computed reverberation times were then averaged. Figure 1 shows the resulting $T_m$ (around 160 ms) as well as the variation with frequency. This variation is well within the limits, with no sudden changes with frequency.

It should be noticed that despite the $T_m$ value being below the recommended lower limit (0.2 ms, to ensure a ‘natural’ acoustic environment), this room is deliberately dry to improve its definition. The formula that links both $T_m$ and the volume is not valid due to the hemi-anechoic design and the frequency-dependent nature of the absorbent mechanisms.
4. MEASUREMENTS OF REPRODUCTION DEVICES

The front loudspeakers are flush mounted and therefore have been measured in situ. The results in the previous section show that the sound field in the control room is close to free-field, except for the reflecting floor, which was covered with 50 cm foam absorbers. The microphone was positioned at a distance of 2 m, instead of the standard of 1 m, because of the overall size of the source, and faced towards the acoustic centre which is defined by the manufacturer. Test level was fixed to 84 dB SPL.

The rear flat panels were measured in the hemi-anechoic chamber. The measuring point was set 1 m from the middle of the radiating surface, and the test level was 90 dB SPL.

4.1. Transient fidelity and amplitude versus frequency response

Transient fidelity requirements force the decay time (to a level of 1/e of the original level) to be less than 5/f (2.5/f in EBU document). Figure 3 shows the decay times for the loudspeakers when excited with a set of frequency-varying sine bursts, together with the 5/f restriction.

The following main violations of the 5/f restriction can be seen in the figure: The frontal speakers show a peak in 125 Hz which is not due to a slow transient decay, but to the burst response, which suffers a destructive interference probably caused by a reflection in the room (see Figure 4). The origin of this reflection still needs to be clarified with more measurements in different points of the listening area. However, at the intended listening position for critical assessment the reflection is less evident.

The influence of the room may explain why the 5/f requirement is not achieved above 400 Hz: at 400 Hz, the measured reverberation time is 194 ms, which means that the room response will be attenuated by a factor 1/e in 14 ms, and at this frequency the limit 5/f equals 12.5 ms. That is to say, the room decay time and the speaker decay time are comparable. The central loudspeaker was not included in this measurements, as it showed an anomalous behaviour and will probably have to be replaced.
Finally, one of the rear panels has a peak around 400 Hz, which is reported by the manufacturer as a notch in the frequency response.

After analysing the transient fidelity of the loudspeakers, the effect of the room in the measurements becomes apparent. For this reason, we need to further investigate the sound field in the room before presenting and discussing the amplitude versus frequency responses of the front speakers.

4.2. Directivity, harmonic distortion, time delay and dynamic range

The remaining electro-acoustic requirements are discussed below.

The directivity index C has been estimated using two measurements: total sound power source and axial sound intensity from 500 Hz up to 10 kHz. C is between 4 and 12 dB for most bands in the front loudspeakers, increasing smoothly with frequency, thus fulfilling the ITU specifications. The 500 Hz band shows a small value under zero, perhaps due to a notch in the low frequency loudspeaker directivity (the acoustic axis of the two-way speaker does not coincide with the low frequency loudspeaker axis). As expected, the rear panels exhibit an irregular behaviour in the acoustic axis as frequency increases. EBU and AES recommendations extend the restrictions to 16 KHz.

The non-linear distortion has been measured using a discrete set of pure tones sweeping the whole band. The front loudspeakers exhibit a good score under -50 dB in the whole band. ITU, EBU and AES threshold is -30 dB for lower frequencies and -40 dB for the higher ones. The rear panels show serious problems in reproducing frequencies below 125 Hz, being almost linear for higher frequencies, with the exception of a singularity at 400 Hz, reported by the manufacturer.

A pulse-like signal is used to estimate the time delay between channels, storing both the direct signal from the analogue source in one oscilloscope channel and the signal being played through the loudspeaker under test in the other channel. The delays between the front channels are under 6 µs, fulfilling both ITU (100 µs) and AES (10 µs) requirements, and the delay between the rear channels is 2 µs. When comparing frontal and rear channels the delay is around 20 µs. The EBU document has no comments about this if sound does not accompany pictures.

Finally, the loudspeaker system should fulfil the required dynamic range relating to the manufacturer's technical specifications.

5. SOUND FIELD CONDITIONS

The impulse responses measured from loudspeakers R, L and C show early reflections (those that arrive during a time interval up to 15 ms after the direct sound) which are attenuated by far more the 10 dB suggested by the standards, in the 1-8 kHz range. Floor reflections are reduced by 8.5 cm foam mats in the front part of the floor, which prove to be quite efficient in this frequency range. No anomalies are observed in the late part of the impulse responses.

However, the situation changes for the surround loudspeakers. Floor reflections are now clearly noticeable, their attenuation being in some cases less that the required 10 dB. Reflections from the front can also be identified, which may come from the wall, the front loudspeakers or the TFT display placed above the central monitor.

As a conclusion, the behaviour of the front loudspeakers is satisfactory in terms of reflected sound, while that of the rear panels may be improved with foam mats on the rear part of the floor. Reflections from the front wall are difficult to avoid due to the lack of directivity of DML panels, and are something we have to live with given the distribution of absorption in this kind of room. It should be noticed that the front wall reflections are not audible to expert ears, probably because binaural perception averages the sound field in two points (ears) with different reflection patterns.
The operational room response curve, which combines the response of the room and loudspeakers, cannot be presented. The possible presence of unwanted reflections in the room, and some misadjustments in the speakers need to be solved or at least further investigated before we can fully discuss this characteristic.

6. CONCLUSIONS

The control room of the ‘Universidad de Vigo’ generally complies with the requirements posed for surround listening rooms, with the following riders. The ratios between the dimensions of the room are irrelevant, as the dimensions of a semi-anechoic chamber vary with frequency, and its modal response at low frequencies is controlled through absorption. The reverberation time evolution with frequency is satisfactory; its nominal value is, however, smaller than recommended, to improve the definition of the room and allow the perception of small impairments introduced by codecs. Regarding the measurements of reproduction devices, additional work is needed in order to evaluate the frequency response of the flush-mounted speakers, because it is difficult to isolate their response from that of the room. Further measurements of the sound field in the listening area will help to explain the influence of the room on the speakers characteristic. With regard to directivity, harmonic distortion, time delay and dynamic range, in general terms, the equipment fulfils the specifications. An anomaly in the directivity of the three front loudspeakers was observed at 500 Hz, which may be due to the coincidence of the measuring point with a notch in the directivity pattern of the bass speaker (it should be noticed that the acoustic centre of the two-way monitor is not on the axis of the low frequency driver). Finally, regarding surround speakers, the 5.1 concept is sometimes claimed to be defined on the basis of five identical loudspeakers. However, DML panels are more convenient for this kind of room because the diffuse sources are less likely to give rise to specular reflections from the hard surfaces of the front wall. Furthermore, the diffuse rear sources tend to improve the sensation of envelopment in the highly absorptive rear half of the room.

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References:


