Room Acoustic Properties of the New Listening-Test Room of the Fraunhofer IIS

Andreas Silzle[1] and Michael Leistner[2]

[1]*Fraunhofer-Institut für Integrierte Schaltungen IIS, E-Mail: andreas.silzle@iis.fraunhofer.de*
[2]*Fraunhofer-Institut für Bauphysik IBP, E-Mail: michael.leistner@ibp.fraunhofer.de*

Abstract

The room acoustic properties of the new listening-test room of the Fraunhofer IIS follows the strict recommendations of ITU-R BS.1116-1. The results of the qualification measurements regarding direct sound, reflected sound, and steady state sound field are shown. Comments to the subjective room assessment are given.

1. Vision and Requirements

The Fraunhofer IIS is one of the most active and innovative audio research organizations contributing to many of the commercially successful open standards-based audio compression schemes such as MPEG Layer-3 and MPEG Advanced Audio Coding (AAC). Many technologies that are developed in the audio and multimedia business field are based on psychoacoustic principles. Consequently, a large number of listening tests are conducted. These tests have to be performed in a standardized listening room built according to the ITU-R BS.1116-1 [1]. The recommendation describes the proportions of the room controlling room modes, the noise floor, the reverberation time over frequency, the operational room response of the loudspeakers to the listener position, and the early reflections.

Figure 1: Main listening-test room with the set-up of 9 main loudspeakers, 2 subwoofers, and 43 loudspeakers on the walls and the two circular trusses on different heights.

2. Room Dimensions and Room Modes

Length (l), width (w), and height (h) of the room should be such that the net floor area is between 30 and 70 m² for the intended multi-channel reproduction, and should fulfill the relationships

$$1.1\frac{w}{h} \le \frac{l}{h} \le 4.5\frac{w}{h} - 4 \quad \text{and} \quad \frac{l}{h} < 3, \quad \frac{w}{h} < 3$$

By choosing $l_n = 9.3$ m, $w_n = 7.5$ m, and $h_n = 4.2$ m, where the index n denotes net values including acoustic lining, the net floor area turns out to be 70 m², and the lowest room mode lies at 18 Hz. For low frequency reproduction this very low frequency and the equal distribution of the first room modes is as beneficial as the high density of 6 modes per third octave in the 50 Hz band, and over 30 modes per third octave in the 100 Hz band.

3. Sound Insulation and Noise Floor

The listening conditions will be influenced by the background noise within the room. Background noise has its origin in any kind of building services (e.g. ventilation, heating, air conditioning, etc.) or studio equipment (e.g. amplifier, computer, etc.). Airborne and structure-borne sound insulation, muffling and absorption measures as well as the application of low noise equipment must ensure that the background noise level in the room does not exceed the NR 10 curve imposed by ITU-R BS.1116-1. For this reason it was decided to build the listening-test room as a room-in-room structure. It rests on damped spring pads, which form together with the room a spring mass system with a resonance frequency of ~10 Hz. The inner room has a mass of about 200 metric tons, indicating the massive design of the construction.

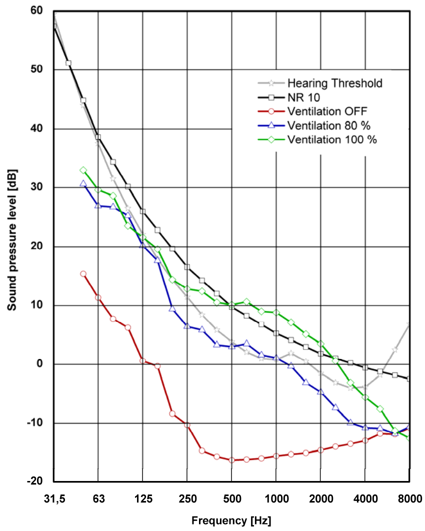

Figure 2: NR10, background noise levels in different operating states and the threshold of hearing of narrow band noise in a diffuse sound field.

Due to the fact that the listening-test room will be used by up to ten persons simultaneously, it is essential to install an efficient and very quiet heating, ventilation and air conditioning (HVAC) system. An important precondition to achieving a quiet system is a low air velocity within the HVAC system. Since low air velocity depends directly on the cross section many ventilation openings were employed. (See the black holes in the ceiling in Figure 1.) Figure 2 shows that the measured noise levels fulfill the NR 10 requirement for the HVAC system. Also the self-noise of the many loudspeakers is in all important cases below NR 10.

4. Reverberation Time

The reverberation time of a listening-test room should be low and relatively frequency independent. Human hearing is adapted to a reflective environment. Therefore listening tests have to be executed in a slightly reverberant environment. ITU-R BS.1116-1 requires a room volume dependent reverberation time T_m with an average value, measured over the frequency range from 200 Hz to 4 kHz, of

$$T_m = 0.25(V/V_0)^{1/3}$$

where V is the volume of the room, and V_0 is a reference volume of 100 m³. In this frequency range a deviation of only 0.05 s from T_m is allowed. Applying the actual volume of the listening-test room (293 m³) to this formula gives a desired T_m of 0.36 s. The measured reverberation time, shown in Figure 3, has a T_m of 0.33 s (0.03 s or 8% less than the desired value which is acceptable) and fits nicely into the tolerance band specified by the standard.

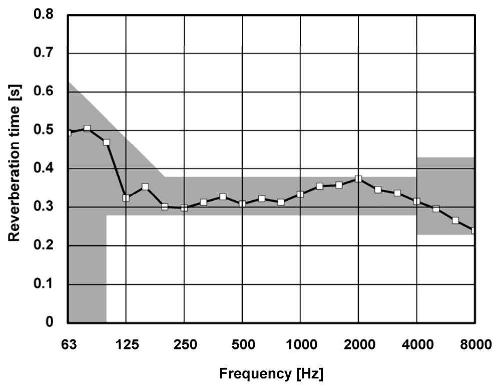

Figure 3: Measured reverberation time of the listening-test room. The gray shaded area is the allowed range of tolerance.

5. Operational Room Response and Early Reflections

According to ITU-R BS.1116-1, the operational room response curves are defined as the 1/3 octave frequency responses of the sound pressure levels produced by each monitor loudspeaker at the reference listening position, using pink noise over the frequency range from 50 Hz to 16 kHz. The measurement result for the main monitor loudspeakers belonging to the 5.1 set-up is presented in Figure 4. The values outside the range of tolerance allowed by the standard around 200 Hz correspond to a destructive interference, caused by the first reflection of sound from speakers to listening position via the floor.

6. Subjective Room Assessment

The floor reflection can be removed by absorbers around the listener. Figure 5 presents the tolerance range for reflections (from all directions) and the two impulse responses. Informal listening tests indicate that the audible influence of removing this reflection is not desirable – it sounds unnatural.

The listening-test room has been subjectively assessed by several audio experts by listening to various stereo and multichannel sound material and by listening to hand clapping and natural voice sounds. No anomalies in the sound field like flutter echoes or tonal colorations have been found. All listeners so far expressed their satisfaction about the achieved acoustic properties, especially neutrality, which is indispensable for the intended use. Although not visible in the reverberation time measurements, an unexpected positive audible influence is caused by the two large trusses with the large number of mounted loudspeakers. The room sounds by these early reflections more lively and natural, compared to the "empty" room before and to other ITU-R BS.1116-1 rooms, which often evoke a slight "under water" sound feeling, especially when the ceiling is low and highly damped. There were also some discrete resonance frequencies audible at the beginning. The most audible were caused by the metallic trusses. After filling them with sand (400 kg extra weight), the problem was removed.

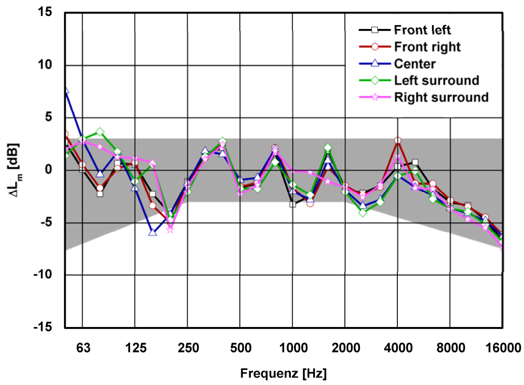

Figure 4: Operational room response of the five main monitor loudspeakers.

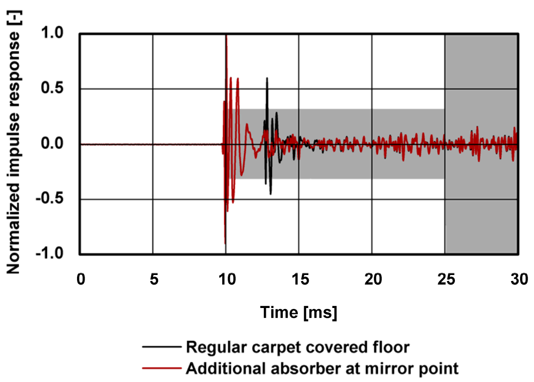

Figure 5: Measured impulse responses, band pass filtered from 1 kHz to 8 kHz, from the center loudspeaker to the reference listening position.

More details about this and other audio rooms and the belonging equipment is presented in [2].

7. References

[1] ITU-R Recommendation BS.1116-1, Methods for the subjective assessment of small impairments in audio systems including multichannel sound systems. 1997, Intern. Telecom Union: Geneva, Switzerland. p. 26.

[2] Silzle, A., et al. Vision and Technique behind the New Studios and Listening Rooms of the Fraunhofer IIS Audio Laboratory. 126th AES Convention, 2009, Munich, Germany. preprint #7672.