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Small-Rooms dedicated to Music: from Room Response Analysis to Acoustic Design

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ABSTRACT

Reviewing elements of on-field professional experience gained by the authors in the analysis of small-rooms dedicated to music, case studies offered by the everyday working practice allow to deal with specific situations, these are seldom described by usual theoretical models and literature. Using the analysis procedure developed and refined by authors, it is possible to investigate the characteristics of the acoustic response of the small-rooms with more detail. In this paper case studies of particular interest will be described: different small-room phenomena will be shown in the reported measurements.

1. INTRODUCTION

This paper reviews elements of 15 years of on-field professional experience gained by the authors in the analysis of small-rooms dedicated to music (project and recording studios, mastering studios, audiophile rooms, home theaters, dubbing rooms and more). The acoustic analysis of small-rooms dedicated to music has become more and more important over the past decade because of the dynamics of the music industry: different phases of music production have been moved from the big recording studios to small ones, even in domestic environments. These spaces have often geometric dimensions smaller than those recommended by international standards such as EBU 3276 [1] and ITU-R BS.1116-1 [2]. In [1] the minimum floor area requested for a reference listening room is 40 m^2 while for high-quality sound control room is 30 m^2. In [2] the minimum floor area for monophonic or two-channel stereophonic reproduction is 20-60 m^2. These requirements are rarely fulfilled in music-related rooms used nowadays.

The in-depth knowledge of the acoustic response of these spaces still has several shortcomings because the subject is seldom reviewed by scientific and technical literature. For the analysis of these spaces the acousticians cannot trust entirely the classical acoustic models (reverberation time and acoustical parameters analysis, standard frequency response analysis through third octave band equalization or Fast Fourier Transform): it is necessary to use specific tools, tailored to the situation. It is also necessary to spread among acousticians, musicians and field experts the concept that the scientific measurement of room acoustic properties is the best way for an efficient acoustic design. Every room has unique characteristics related to its shape, boundaries, furniture and its specific requests for the intended use: it is difficult to solve this equation without an in-deep knowledge of the room response.

Moreover, in small-rooms dedicated to critical listening of music material, there are problems (often related with wrong geometrical dimensions) difficult to solve with acoustic treatment: it is important that those who will work in such environments (sound engineer, musician, producer) will be conscious of their rooms' issues, in order to avoid to take decision influenced by the room response and loose quality in the production. This awareness can only pass through the room impulse response measurement and analysis. In order to reduce acoustical problems in small-rooms dedicated to music, different active room equalization methods have been proposed in the last decades, ranging from simple approach (loudspeaker equalization through frequency response inverse FIR filtering) to more complex ones. These techniques can lead to side effects in the temporal response [3], degrading the perceived response depending on the amount of equalization used. We should remember that an unbreakable bond between frequency and temporal response is established: rapid temporal phenomena are not easy to manipulate with automatic systems that, often, provide acceptable results only in limited portions of space. As recommended in [1] electrical equalization should be used carefully.

For this reasons, a different approach, based on listener awareness and solid passive acoustic correction systems is preferred by the authors, as long as the design process starts with objective measurement and analysis of the room response: Digital Room Correction can be added at the end, it should be never used as a 'total solution' in a poorly treated room.

The authors have developed their methodology of investigation whose elements have been described in previous publications [4], [5] and [6]: the main elements of this procedure are reported in this paper, each of them followed by real cases on-field examples.

2. ROOM IMPULSE RESPONSE MEASUREMENT

The first step of the analysis is the measurement of a series of room impulse response, measured around the sweet-spot listening position. The sweet-spot is usually referred as the vertex of the equilateral (or slightly isosceles) triangle that has on the other vertex the left and right channel loudspeaker positions. Different room impulse responses are measured around the sweet-spot position, to perform accurate averages in frequency and phase domains: in this way, local effects related to the single impulse can be avoided and a response similar to the one perceived by the listener can be obtained. The measurement method used in the authors' procedure is the logarithmic sine-sweep method [7], that produces a good S/N ratio, allowing precise measurements of the system's linear impulse response even if the loudspeaker is working in a non-linear region. The impulse responses are recorded using, as sound source, the loudspeakers present inside the room and, as receiver, an omnidirectional linear measurement microphone: for a stereo configuration, the impulses are recorded for each speaker separately and then using both speakers at the same time. In this way is possible to compare left and right channel response with the stereo response. Ad hoc configuration for room impulse responses measurement are studied when a sub-woofer is present inside the room, or when a multi-channel playback system is installed (5.1 systems ore 7.1).

3. STEREO SYMMETRY CONTROL AT THE LISTENIG POSITION

The first control is to ensure a good stereo image. Once left and right channel room impulse responses have been recorded, an analysis of the symmetry of the listening system is performed. The Fast Fourier Transform of the left channel response is overlapped with FFT of the right channel, focusing on the low frequency range (usually ranging from cut-off frequency of the speakers to 300-500 Hz). It is important to ensure that what is "seen" by the left channel matches what is "seen" by the right channel. If this balance is guaranteed, no shifting in the stereo image reproduction will occur. To ensure this balance, in the acoustic treatment design, is necessary to place the same amount of furniture, equipment, absorbing and scattering panels, on the left and on the right side of the room. Often, traditional FFT analysis does not extend beyond this preliminary control (indeed, it is often performed in one-third octave frequencies band, reducing further the observation accuracy). The FFT spectra have the embedded limitations of showing the steady state response of the room, i.e. valid while listening long lasting sounds and notes. This analysis method is not suitable to take into account the transient nature of music.

3.1. Accurate symmetry in small rooms

For the MSC mixing room the authors design the acoustic treatment from scratch in a previously built room (it was not possible to modify the room sizes). The room has the following dimensions: 3.15 x 3.65 x 2.73(h) m, for a 31.5 m^3 volume and 11.5 m^2 floor surface. The dimensions are far below the recommendations contained in [1] and [2]. In rooms with this kind of geometry, low-frequency problems are always to be expected. Starting from this assumption, it is necessary for the acoustic design of the room to avoid any other possible issue. For example, it is possible to arrange the acoustic treatment and the position of equipment and furnishing to maintain the best symmetry for left and right channel. The results can be seen on Figure 1, with an average difference of 2.0 dB in the range from 30 to 500 Hz.

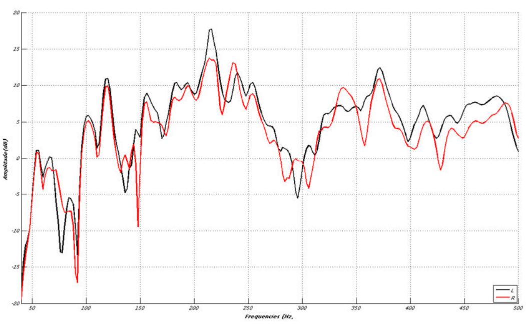

Figure 1 Room MSC. Left and right symmetry

3.2. Furniture effecting stereo symmetry

The second example concerns with a project studio (MNC) where the authors designed the acoustic treatment. The room has 3.00 x 3.65 x (h) 2.10 m dimensions with a volume of 23 m^3. Inside the room is placed a two-seat sofa. This 1.42 x 0.76 m sofa is placed on the back of the sweet spot position, on the left part of room. The impulse responses for left and right channels have been measured with and without the sofa inside the room. As can be seen in the comparison between Figure 2 (with the sofa) and Figure 3 (without the sofa), the presence of the sofa has a negative effect on stereo symmetry, particularly at 128 and 198 Hz where the left channel (black line) has a different behavior compared with right channel (red line).

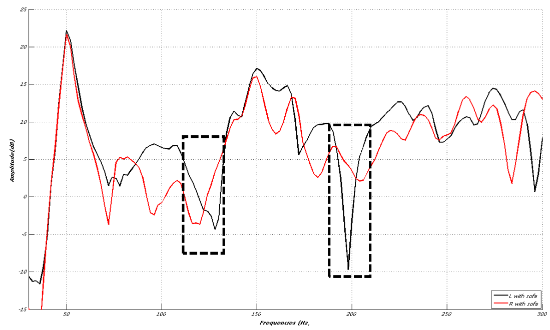

Figure 2 Room MNC. Left and right comparison with the sofa

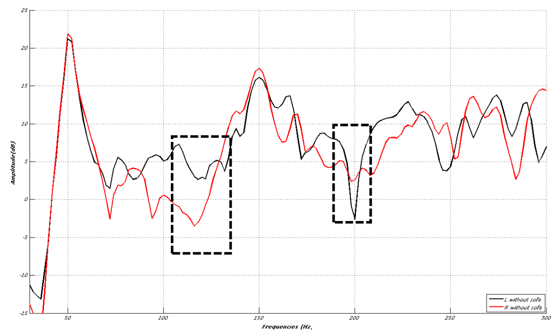

Figure 3 Room MNC. Left and right comparison without the sofa

With a maximum dimension of 1.42 m, the sofa begins to interact with sound through diffraction at frequencies which have wave-length greater than 60 Hz, since for that frequency $\lambda/4$=1.42 m. Removing the sofa, the deep valleys at 128 and 198 Hz are reduced, helping the left/right symmetry. Note that 128 and 198 are related to the second and third harmonic of 64 Hz. It can be assumed that the asymmetrically positioned sofa leads to an excessive absorption to frequencies related with its dimension for the left channel. The residual asymmetry showed by both graphs, is due to other furniture present in the room, required by the client (two outboard racks of different dimensions placed at left and right of the mixing desk and a bookshelf placed behind the listening point).

4. MODAL ANALYSIS

It is a well-known assumption that the low frequency behavior of small rooms is dominated by the standing waves forming at definite frequencies. In “shoe-box” shaped rooms their resonance frequencies can be calculated from their geometrical dimension L_x, L_y, L_z:

$$f_{n_x,n_y,n_z} = \frac{c}{2}\sqrt{\left(\frac{n_x}{L_x}\right)^2 + \left(\frac{n_y}{L_y}\right)^2 + \left(\frac{n_z}{L_z}\right)^2}\ \text{Hz} \qquad (1)$$

It seemed useful to authors to observe the superposition of resonance frequencies positions on the spectral FFT graphs. Particular attention is given to axial modes, i.e. the frequency modes that travel between two opposing surfaces in the room. These modes entail major contributions in building the room frequency response due to their energetic content. In this way it is possible to perform a conscious analysis of peaks and valleys in the frequency response. The possibility to associate a resonance peak to a particular axial mode allows the acoustic consultant to select the best strategy and the best positioning of acoustic treatment for that particular issue.

It is important to underline that modal resonances significantly affect the response also for non-regular rooms, with un-parallels walls. The problem with this kind of rooms is that the resonances still occurs, but they are less predictable. For example, the DRM room C is an acoustically treated professional dubbing room with maximum dimensions 4.00 x 3.60 x (h) 2.75 m. This room, for which the authors has been charged to correct the acoustical issues, has an oblique wall. As can be seen on Figure 4, observing the superposition between axial modes and frequency response, there are response peaks (at 114, 168 and 200 Hz) uncorrelated with mode positions also in the low frequency end of the spectrum, where the axial modes energy contribution is more relevant.

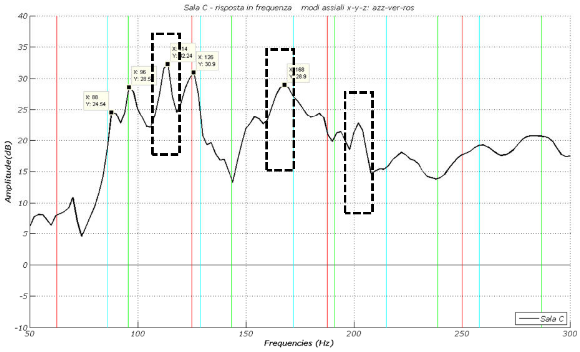

Figure 4 Room DRM C. Modal analysis.

4.1. Room geometry and modal distribution

The DRM room B is another professional dubbing room with dimensions 3.50 x 3.60 x (h) 2.75 m for a 34.6 m^3 volume and gypsum board walls. This room has an almost squared layout. It is a well-known matter of fact that this type of layout has to be avoided in order to reduce the modal overlapping. The room was already acoustically treated for high frequencies, but, because of the poor performance of the room, the authors have been charged to correct its acoustic issues.

The modal analysis applied in this room allowed to observe very clearly this phenomenon, as can be seen on Figure 5. In the following Figure the frequency response (in black) is plotted with the axial mode stems, the color of which varies according to the reference axis (blue for x-axis modes, green for y-axis modes and red for z-axis modes).

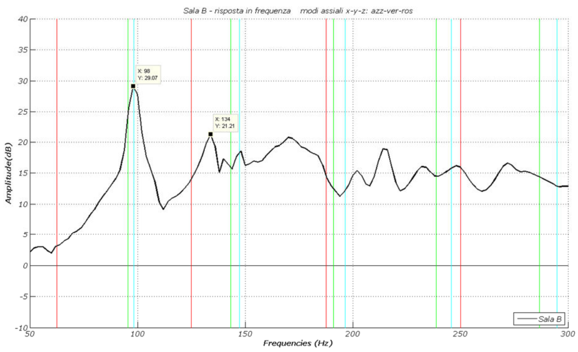

Figure 5 Room DRM. Modal analysis.

The stereo frequency response of the room shows a strong resonance peak around 100 Hz, where the room modes (2,0,0) and (0,2,0) overlap. It is also interesting to notice that this peak is followed by a deep valley caused by the lack of modal support.

It has to be noticed that the perfect correspondence between the calculated axial mode positions and the actual peaks and valleys behavior is gradually less accurate from 120 Hz up. This shift is mainly due to the presence of tangential and oblique modes. It is a well-known assumption that axial modes are dominant in the very low-frequency part of the spectrum.

It has been observed that the shift between theoretical and actual positions of resonance peaks is more evident where massive acoustic treatment has been arranged on the room, due to intrinsic limitations of equation (1) to consider the importance of reactive room boundaries.

4.2. Vaulted ceiling focusing effects

There are cases where the peaks and valleys behavior detected in the frequency response, cannot be closely associated with the position of room modes. For example, in the untreated PZZ room, a strong resonance peak, uncorrelated with axial modes position, was present. The PZZ room has 4.69 x 4.21 m floor and a vaulted ceiling with maximum height of 2.45 m. Walls and ceiling are all made of bricks. Inside the room is placed a vocal boot which breaks left/right symmetry. The authors were charged to design the acoustic treatment and the measurement session was done with the empty room. In Figure 6 is shown the 30-300 frequency response for left and right channel.

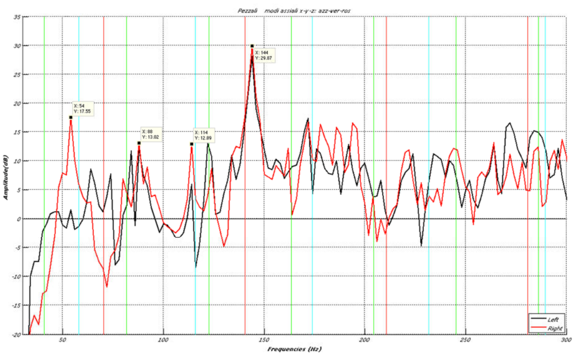

Figure 6 Room PZZ. Modal analysis.

As can be seen on Figure 6, there is a strong resonance peak placed at 144 Hz both for the left and the right channel in the sweet spot. This resonance peak does not correspond to any particular mode, so, in order to identify the reason behind that peak, considerations related to wave-length have been carried out. For a 144 Hz frequency, a 2.39 m wave-length corresponds: this distance is comparable with the vaulted ceiling radius. Thus the concave lens shape of the ceiling generates the acoustic focusing effect toward the listening position, showed by the FFT frequency response.

Since it is necessary to defend the stereophonic listening, and then the symmetry of the room, in order to reduce this focusing effect it is necessary to "break" the shape of the vault by the insertion of sound absorbing material hanged to the ceiling, near the lens focus.

5. TRANSIENT AND DECAY ANALYSIS

Because traditional FFT analysis is useful to explore the steady-state response of the room, that is the room response while listening to note and sound of long duration, different survey methods have been refined by the authors in order to investigate the transient response of the room at low frequencies.

The algorithm develops from AQT 2 procedure [8] and it creates short sine bursts at increasing frequencies, and synthetically convolves each one of them separately with the environment's impulse response. The output of each convolution (which, all together, create the 3D EFT plot) is the temporal evolution of each frequency in the room at the measurement positions. The envelope of these signals allows to see the transient behavior for short sounds which is important for level and tone perception.

The first version of this analysis method proposes the computation of decay times for all frequencies. This kind of accurate resolutions cannot be reached with traditional one-third octave band analysis. Decay times were computed for all frequencies with a Schroeder Backward Integration using the slope over a fall in amplitude of 20 dB from the steady state value and multiplied by 3 to estimate a 60 dB drop. The obtained curve is compared with the perceptual threshold of detection of modal decay proposed by Avis et al. in [9]. Further analysis on the topic has been recently presented by Fazenda et al. in [3]. The accuracy of this procedure is not comparable to that offered by traditional one-third octave band reverberation time analysis, where the important connection between a specific resonance mode and its intrinsic temporal decay is completely lost (small rooms can host two or more resonance problems in one single third octave band).

The authors' studies culminated in another paper proposed in this conference [10]: from a series of psychoacoustic test, it appears that, for short sounds, the classic frequency response is not so relevant regarding the perception of loudness. Instead, a new curve called "H(overshoot)" is proposed which shows the maximum value of the response envelope at each frequency. Therefore, the Overshoot Response shows the overshoot amplitude on valleys, and the maximum value reached on the peaks, making it greater than, or equal to, the steady state response at all frequencies Furthermore, the precision and definition of musical sounds is heavily modified by the convolution with the room and it appears to be strictly correlated with new temporal room metrics that the authors defined, called "Room Slowness" and "Room Inertia". The "Room Slowness" curve shows, for each frequency, the time passing between the instant when the test tone is started, and the moment when the response envelope reaches the steady state value minus a fixed value, while the "Room Inertia" curve shows, for each frequency, the time passing between the end of the tone burst and the moment when the response envelope reaches a fixed, "target" value (this curve allows to see intuitively which frequencies decay more rapidly). Further details can be found on [10].

5.1. Identification of problematic frequencies

Since the steady state frequency response is not able to show the transient behavior of musical sounds, the decay analysis allows to identify problems that are not visible observing the standard FFT plot. The case of ATR room can be taken as example. This acoustically treated mixing room is equipped with a 5.1 listening system. The room has gypsum board walls and internal dimension of 5.17 x 3.41 x 2.66 (h) m, for an overall volume of 47 m^3. In Figure 7 is reported the frequency response plot of the global 5.1 system (in black) and the response of the subwoofer (purple line). The profile of the curve is the one expected for a small room, with important contribution of modal frequencies distribution. The decay plot reported in Figure 8 shows that the decay lengths are well below the listening threshold proposed in [9]. A longer and outstanding decay can be found at 250 Hz frequency: this decay is above the listening threshold and no sign of its problematic behavior could be found observing the steady state frequency response, being at mid frequencies it could be considered also as a spurious resonance from an object in the room and so it needs an accurate on-site investigation.

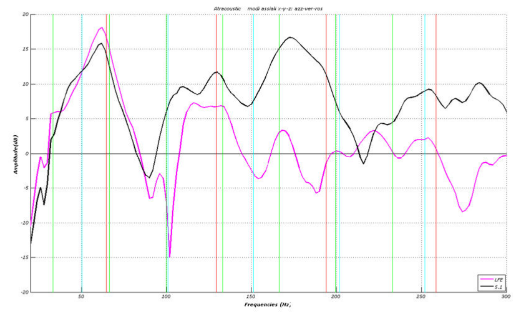

Figure 7 Room ATR. Modal analysis.

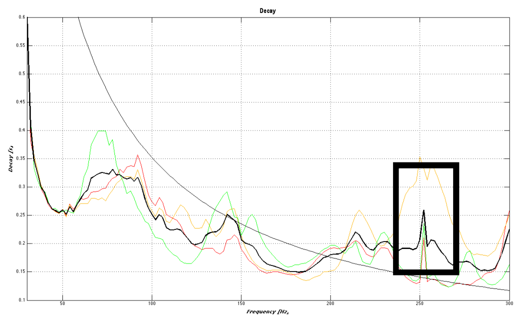

Figure 8 Room ATR. Decay analysis.

Knowing the exact frequency of longer decay time allows the acoustic consultant to elaborate the appropriate strategy to handle the issue: the first step is often to try to identify on site the source of the longer decay (in this case an ad-hoc sweep signal ranging from 200 to 300 Hz, has been used to actually search resonant cavities inside the room, they all are perceivable) and then subsequently take action to fix it, providing the correct arrangement of absorbing material.

5.2. Different decay response depending on the boundary materials

The decay analysis tool allows to observe also interesting behavior related to different response of the room according to the material with which the walls are built. In untreated rooms with similar dimensions, the modal decay response significantly varies for masonry walls or for gypsum board walls due to the different acoustic impedance offered by the boundary material. The rooms used for the comparison are GUD, a 4.70 x 2.73 x 3.09 m mixing room (volume 39.5 m^3) with gypsum board walls and ceiling, and CON, an editing room with tiled ceiling (height ranging from 2.13 m to 3.62 m) and 3.71 x 2.86 m plant (volume 30.5 m^3), with masonry walls. The rooms were non completely empty but without acoustic treatments during the measurement sessions. In Figure 9 the decay response for GUD room (gypsum board walls) is reported, while in Figure 10 the decay response for room CON (masonry walls) is reported.

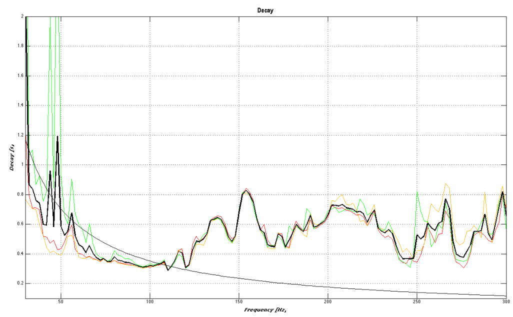

Figure 9 Room GUD. Decay analysis in a room with gypsum board walls

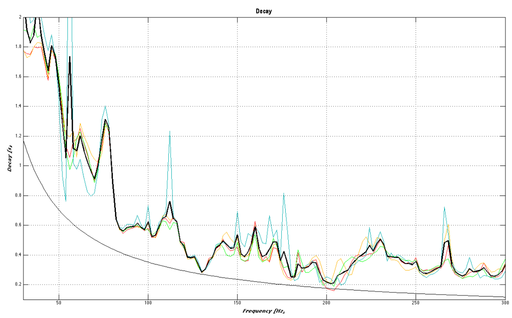

Figure 10 Room CON. Decay analysis in a room with masonry walls

As can be expected for untreated rooms, the decay lengths are generally above the perceptual threshold curve proposed in [9]. It is interesting to notice that with gypsum board walls, the decay lengths in the low frequency range (from 30 to 100 Hz) are much shorter. For the GUD room an average length of 0.55 s is obtained between 30 to 100 Hz, while for CON room a 1.20 s length is obtained in the same range.

The different response to decay lengths given by the wall materials is very important in the first steps of the room design: the association of cavities and gypsum boards acts as a reactive diaphragm, generally reducing low frequencies decay lengths, while masonry walls are purely reflective. Long decays above 100 Hz are related to the lack of acoustic treatment, it is interesting to note that GUD room still has some resonance problems at 50 Hz. This is another example of the unbreakable bond between temporal and frequency domain: different (temporal) decay lengths (in this case, due to wall materials) entail significant variations in the frequency response of the room.

5.3. New insights on decay analysis

In the other paper proposed in this conference by the authors [10] new insights on transient and decay analysis can be found. The application of the developed algorithm to real rooms, shows that there is strong correlation between peaks and “slow frequencies” (i.e. frequencies that are quite slow both in rising to and decaying from the steady state), and between valleys and “fast frequencies” (i.e. frequencies faster both in rising to and decaying from the steady state, that show an overshoot behavior, meaning that there is a peak higher than the steady state level in either or both the initial and final part of the response envelope). Psychoacoustic tests carried out for the research, show that listeners prefer “fast” room where resonances are not disturbing.

The application of the developed algorithms to two interesting rooms, is shown below. Other examples can be found on [10].

The first example is taken from the room CON described in the previous paragraph. It is an example of a “slow” room, because on the frequency response’s peaks, response envelopes grow and decay slowly, returning high values for Room Slowness, Inertia (Figure 12) and Decay Time. Frequency response peaks are present at 44, 76, 86 Hz, which do not reach steady state with 0.15 s bursts, while valleys at 82, 130, 250 Hz show moderate opening overshoot and little closing overshoot. While this room does not feature strong Overshoot behavior, Room CON is quite problematic, since it seems to react very slowly to frequencies on the frequency response’s peaks, returning high values for the Room Slowness parameter.

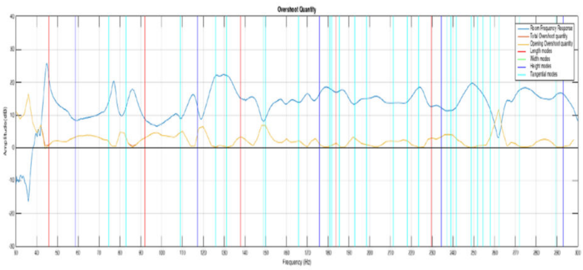

Figure 11 Room CON. Steady State and Overshoot Response.

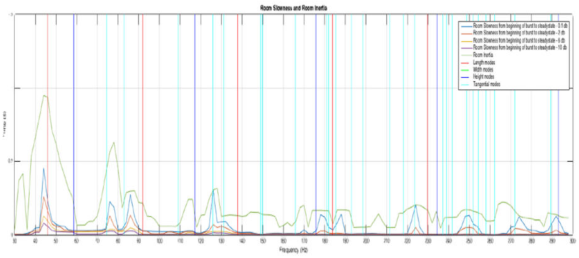

Figure 12 Room CON. Slowness and Inertia.

Room SGR has dimensions 4.6 x 3.6 x (h) 2.6 meters, with a volume of 43.1 m^3. It is a parallelepiped symmetric room and it is used as a mastering room. The walls are gypsum boards with specific correction. This room has a peak at 38 Hz which does not reach steady state with a 0.15 s tone and valleys at 64 and 100 Hz with strong opening overshoot and small closing overshoot.

With very low values of Slowness, Inertia and Decay Time parameters (Figure 14), this is an example of a “fast” room.

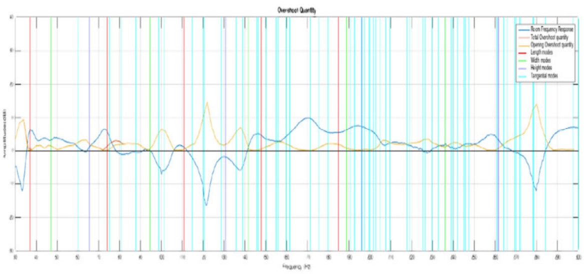

Figure 13 Room SGR. Slowness and Inertia.

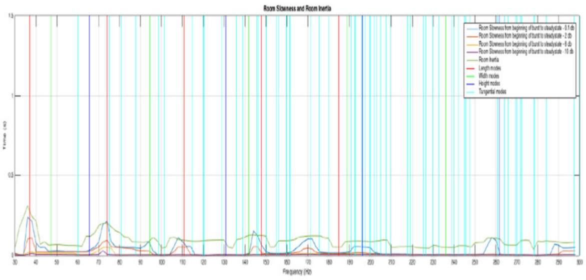

Figure 14 Room SGR. Slowness and Inertia.

6. TIME DOMAIN ANALYSIS

For what concerns the time domain, the behavior of the first milliseconds of the room impulse response must be thoroughly analyzed in order to identify the presence of potentially disturbing specular reflections or particular patterns of reflections. It is also proposed a statistical analysis developed by the authors, described in [5] and [6]. The analysis of mixing properties of the sound field is proposed focusing on the transition between deterministic early reflections and stochastic diffuse sound field. Thanks to the kurtosis curve of segments of the impulse response, first and second order correlated reflections that can alter the balance of listening are highlighted. The measuring tool refined by the authors, starts from the work of Stewart and Sandler [11]. Kurtosis is calculated for a sliding window over the impulse response and the process creates a curve (called here *k(t)*). This curve, in its normalized version, starts with values around one and gradually goes towards zero as the degree of ‘Gaussianity’ of sample inside the window increases.

The developed tool ensures the possibility to verify clearly the effect of the sound-diffusing elements inserted inside a small-room such as the reduction of strong specular reflections. The attenuation of strong specular reflections is shown by the linearization of the profile of the kurtosis curves, displaying quickly the effectiveness of the scattering element presence

6.1. Acoustic treatment effectiveness analysis

Room SNT is a 46.67 m^3, non-symmetric listening room with tilted roof and gypsum board surfaces. For this room, it has been possible to follow all the steps of the acoustic treatment process, starting from preliminary analysis in the untreated room, until post opera impulse response measurement, made in order to verify the effectiveness of the proposed acoustic treatment. The first measurement session made for the acoustic design of the SNT listening room was made with a traditional loudspeaker system. The second session was made instead with a couple of electrostatic diffusers.

Electrostatic diffusers (ESL) are commonly recognized as the reference in the undistorted musical reproduction (distortions 100dB@1m are equal to: above 1000Hz: 0.15%; above 100Hz: 0.5%; above 50Hz: 1%). As per working principle are crossover and cabinet less and composed of full frequency emission elements (usually almost planar) made by thin membrane, the electrostatic diaphragm, that is practically massless allowing a precise timing in the reproduction of musical signal (despite piston loudspeakers that have inertial mass that causes several time delay to the reproduced signal). ESL are open diffusers and so the sound pressure is emitted also from the back with a phase shift of 180°. For this reason, it deserves a precise treatment of the back wall, in order to avoid out of phase reflection (usually ESL are placed far from to rear untreated wall for avoiding an interference of the reflected sound on the direct emitted sound).

The comparison between the kurtosis curve obtained for the right channel of traditional speaker and the kurtosis curve measured with electrostatic diffuser is shown below. Similar consideration can be made for the left channel but they are omitted for space constraint. Both measurement was done with the empty room (no acoustic treatment on walls or ceiling) but fitted carpet on the floor.

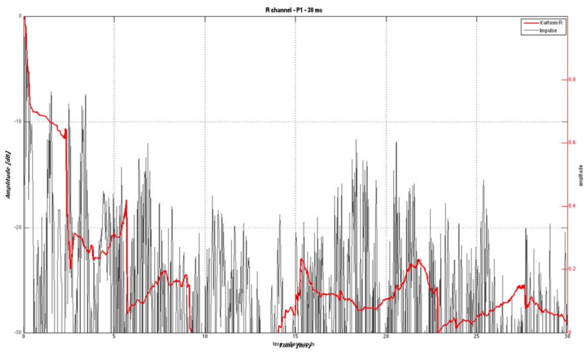

Figure 15 Room SNT. Right channel kurtosis curve for traditional loudspeakers. 0 to 30 ms.

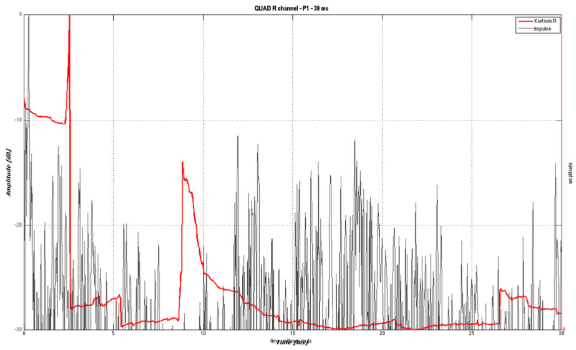

Figure 16 Room SNT. Right channel kurtosis curve for ELS loudspeakers. 0 to 30 ms.

As can be seen on Figure 15, in the first milliseconds of the impulse response, there is a wider spread of reflections due to sound diffraction caused by the cabinet of the loudspeaker. In Figure 16, with the electrostatic loudspeakers, in the milliseconds from 0 to 7 there is the contribution of direct sound and strong lateral reflection. After a reflection-free section, around 12 ms stronger reflections arise, due to the sound emitted by the rear part of the diffuser.

It therefore seems necessary not only to deal with lateral reflections but also with the sound reflections coming from the wall behind the sound diffusers. For the lateral reflection a sound diffusing approach has been chosen in order to widening the stereo image while for the other reflections, a sound absorption strategy seems to be more appropriate. In Figure 17, the kurtosis curve obtained from the measurement made with all the acoustic treatment properly installed. Also in this case the right channel response is shown.

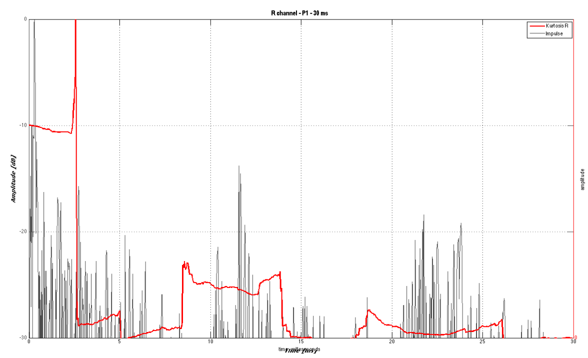

Figure 17 Room SNT. Right channel kurtosis curve for ELS loudspeakers and scatterers.

Observing the Figure 17 the linearization of the profile of the kurtosis curve obtained with the acoustic treatment is clearly shown. The lateral reflections (up to 7 ms) are more diffuse and their intensity is reduced compared to case depicted in Figure 16. The reflections coming from the wall behind the diffuser is strongly reduced and generate just a slight deviation from the achievement of diffuse field state (represented by kurtosis = 0).

7. CONCLUSIONS

Elements of on-field professional experience gained by the authors in the analysis of small-rooms dedicated to music have been reviewed in this article. The importance of accurate impulse response measurement for starting a room acoustic correction project has been founded with different examples, where traditional acoustic analysis methods fail because of the specific phenomena related to small-rooms. To address problems related with a specific frequency or with a specific reflection, it is necessary for the acoustic consultant to have ad-hoc tools like the ones described in this paper.

The unbreakable bond that links frequency and temporal responses forces the consultant to deepen more and more the small-rooms acoustic response knowledge: because of the complexity of this relationship, the active equalization tools available on the market should be used carefully and after a thorough acoustic set-up.

Often, it is more important for the sound engineer to gain through analysis an awareness of the strengths and weaknesses of a room rather than try to overcome limitations imposed by the physics themselves. The tools described in this paper are continually reviewed [12] in order to improve them and to verify their effectiveness, also under a psychoacoustic point of view.

8. REFERENCES

[1] EBU Tech. 3276 "Listening conditions for the assessment of sound programme material: monophonic and two–channel stereophonic" 1998.

[2] ITU-R BS.1116-1 "Methods for the subjective assessment of small impairments in audio systems including multichannel sound systems" 1997.

[3] B. Fazenda et al. "Perceptual thresholds for the effects of room modes as a function of modal decay" Journal of Acoustic Society Am. 137 (3), March 2015

[4] L. Rizzi and F. Nastasi, "Room Acoustic measurements in non Sabinian enclosures for music: echometry, modal analysis, sound decay analysis", Internoise 2010, Lisbon, Portugal, June 2010.

[5] L. Rizzi and G. Ghelfi, "Measuring Mixing Time in non-Sabinian rooms: how scattering influences small-rooms responses", 132nd AES Convention, Budapest, April 2012.

[6] L. Rizzi and G. Ghelfi, "Scattering effects in small-rooms: from time and frequency domain analysis to psychoacoustic investigation", 134th AES Convention, Rome, May 2014.

[7] Angelo Farina. "Advancements in impulse response measurements by sine sweeps". In: 122nd AES Convention, Vienna (May 2007).

[8] A. Farina et al – "AQT – A New Objective Measurement of The Acoustical Quality of Sound Reproduction In Small Compartments", Audio Engineering Society, 110th Convention, Amsterdam (2001)

[9] M. R. Avis, B. M. Fazenda, and W. J. Davies, "Thresholds of detection for changes to the Q-factor of low frequency modes in listening environments," J. Aud. Eng. Soc. 55(7–8), 611–622 (2007).

[10] L. Rizzi et al. "Perception of low frequency transient acoustic phenomena in small-rooms for music", Audio Engineering Society, 140th Convention, Paris (2016)

[11] R. Stewart and M. Sandler, "Statistical measures of early reflections of room impulse responses", Proc. of the 10th Int. Conference on Digital Audio Effects (DAFx-07), Bordeaux, France, 2007.

[12] www.tuneyourstudio.com