Binaural Simulations and Measurements in an Optimized Room Acoustic Test Scenario

Julio Cesar B. Torres[1], José F. L. Naranjo[2], Roberto. A. Tenenbaum[2], Sönke Pelzer [3], Michael Vorländer [3]

[1] *PEU-COPPE, Federal University of Rio de Janeiro, Brazil, Email: julio@poli.ufrj.br*

[2] *IPRJ, State University of Rio de Janeiro, Brazil, Email: ratenenbaum@gmail.com*

[3] *ITA, RWTH, Deutschland, Email: mvo@@akustik.rwth-aachen.de*

Abstract

Nowadays, auralization is one of the most attractive tools for evaluating how people hear the sound in a given environment. Each software developer implements different methods and techniques to obtain the Binaural Impulse Responses (BIRs). In this work, we present a comparison of two acoustic simulators (RAVEN and RAIOS) for obtaining such BIRs. The main goal is to identify the main characteristics that distinguish these responses from measured ones in controlled environments and evaluate how significant are such variations. Finally, the results of such comparison are presented based on quantitative investigation, pointing out to useful indexes capable to evaluate the auralization quality.

Introduction

Several acoustic simulators have been developed along the last years based on several propagation methods and signal processing techniques. These differences may reside not only in the methods but also in the parameters. Variation on the reflection order or on the number of particles may produce significant differences in the impulse response. Besides, even using the same method, with the same parameters, simulators might use different signal processing techniques to synthesize the wave fronts. Considering binaural simulation, there are also the receiver and the auditory models, which may influence the results. Therefore, it becomes very important to investigate the results obtained by such simulators and identify such differences.

Acoustic Simulators

The acoustic simulator RAIOS is supported by a joint group research of two Brazilian universities [1]. This software implements an hybrid method for obtaining the monoaural (IR) and the binaural impulse responses (BIR). The sound sources are modeled as omnidirectional and the binaural impulse response is obtained by processing the energy of each ray hitting the receiver by the corresponding Head Related Transfer Function (HRTF).

The acoustic simulator RAVEN is developed at the Institute of Technical Acoustic (ITA) from RWTH Aachen University [2] and implements also hybrid methods to obtain the mono and binaural impulses responses. It this case, an image method is used to compose the early reflections, while, by superposition, the late part of the impulses response is provided by an stochastic raytracing method , simulating the diffuse scattered reflections (diffuse field). This simulator is also able to implement directivity for the sound sources using DAFF open source format.

Investigation Scenarios

The scenario used for such comparison was the reverberant chamber located at ITA-RWTH, used also for evaluating the quality assessment of room acoustic simulation [3]. A single loudspeaker and two receiver locations were selected (a microphone and the ITA Dummy Head). Two room configurations were selected for simulation and measurements. In the first scenario, no absorption material was introduced. In the second one, one of the walls was covered by an absorptive material.

According to the scenario setups, both simulators were configured to generate the mono and binaural impulse responses at the selected room locations. For both simulators, the receiver characteristics were the same, i.e., no correction or equalization was performed for the microphone and the same HRTF data were used for binaural synthesis. However, for the sound source, it was not possible to keep the same configuration, since RAIOS can only implement omni-directional sources up to now. Scattering coefficient of 5% was adopted by both simulators.

Simulation Results

The impulse responses (IRs) for the reverberant setup were simulated using the measured absorption coefficients. The T_{20} parameter obtained from the monoaural IRs presented deviations from the measurements, as can be seen in Fig. 1. In order to minimize the differences that might appear in the binaural IRs, due to a mismatch o the reverberation times, the absorption coefficients for both simulators were adjusted (tunned). The final T_{20} with the tuned coefficients are also presented in Fig. 1.

From Fig. 1 we observe a large mismatch of the T_{20} at the lower frequency bands. However, such differences are expected since both simulators implement geometric methods and the Schroeder frequency of the empty chamber is around 500 Hz. On the other hand, at the mid-high frequencies the differences can be neglected. The exact procedure was also performed for the absorptive case, where

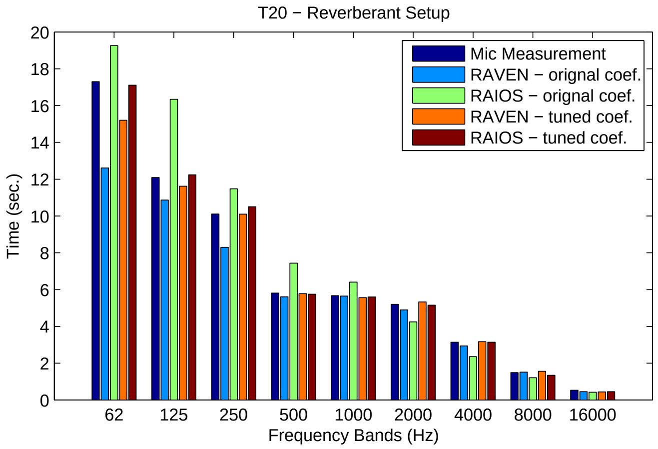

Figure 1: Comparison of simulated and measured T_{20}, for original and tuned absorption coefficients.

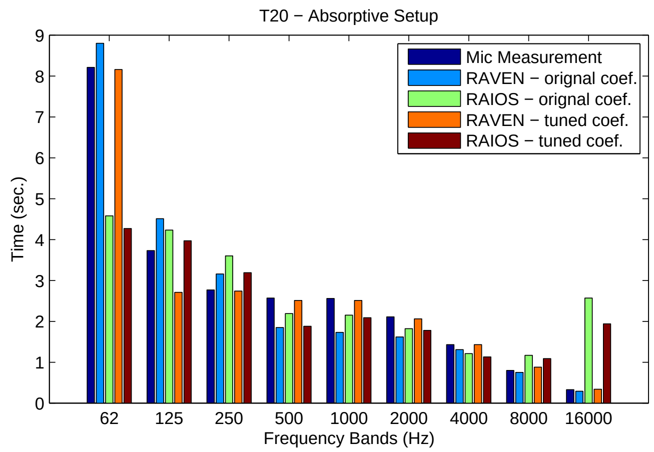

Figure 2: Comparison of simulated and measured T_{20}, for original and tuned absorption coefficients.

the T_{20} per band presented much lower values, as can be observed in Fig. 2. Binaural comparison was performed in terms of the Interaural Cross Correlation Coefficients (IACC), calculated over the full impulse response lengths. The IACC values for reverberant and absorptive setups are presented at Figs. 3 and 4, for tuned and original coefficients.

Conclusions

Considering the reverberant case, we observe that variation of the absorption coefficients and T_{20} does not affect significantly the IACC parameter. However, comparing the software, there is a large difference of IACC above 4 kHz. This might be related to the synthesis method used by the software to convert from energy (squared pressure) to pressure and to the use of a omnidirectional source by RAIOS, since the HRTF used were the same. For the absorptive case, the coefficient tuning interfered mostly at higher frequency bands and, in most bands, there was a correlation reduction. A valuable conclusion of this work is that T_{20} adjustment focusing on binaural simulation may introduce deviations at the full time IACC, mainly for absorptive cases. Therefore, even providing accurate monoaural impulse responses, whose T_{20} matchs well with the measurements, analysis of the IACC revealed not being an alternative to evaluate the binaural IRs.

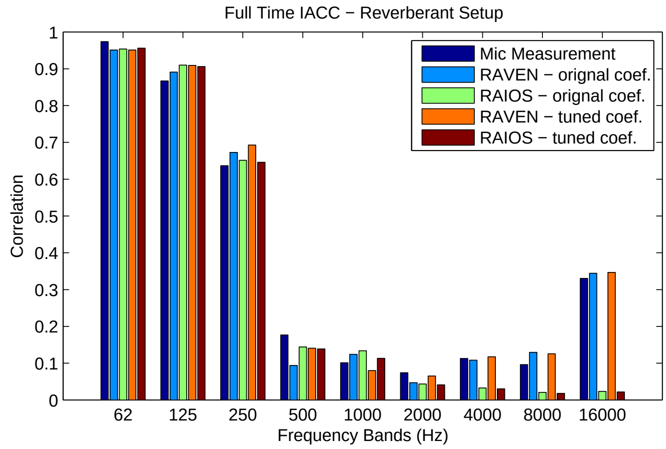

Figure 3: Binaural comparison of IACC for original and tuned absorption coefficients (reverberant case).

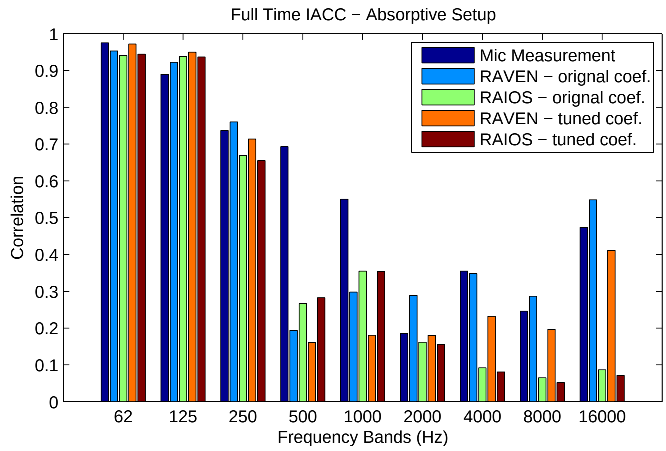

Figure 4: Binaural comparison of IACC for original and tuned absorption coefficients (absorptive case).

References

[1] R. A. Tenenbaum, T. S. Camilo, J. C. B. Torres, and S. N. Y Gerges. Hybrid method for numerical simulation of room acoustics with auralization: part 2 - validation of the computational code raios 3. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, 29:222–231, 2007.

[2] Dirk Schröder and Michael Vorländer. Raven: A real-time framework for the auralization of interactive virtual environments. In *Proceedings of Forum Acusticum 2011 : 27 June - 01 July, Aalborg, Denmark*. Spanish Acoustical Society, 2011.

[3] Sönke Pelzer, Marc Aretz, and Michael Vorländer. Quality assessment of room acoustic simulation tools by comparing binaural measurements and simulations in an optimized test scenario. In *Proceedings of Forum Acusticum 2011 : 27 June - 01 July, Aalborg, Denmark*. Spanish Acoustical Society, 2011.