

# Auralization of Speech-Communication Cues

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## Introduction

Auralization is becoming a common technique in simulating different acoustical environments with laboratory control [1]. Furthermore, auralization provides a means of presenting binaural stimuli to a listener through some transducer. This study utilizes an auralization system to acoustically simulate a small test chamber (17.42'x12.92'x8.83') and present binaural speech babble to a listener as heard from this simulated room.

The room was simulated using a commercial auralization hardware and software package from Tucker-Davis Technologies (TDT). This system automatically calculates the direct sound and first-order reflections, assuming all walls behave as 100% reflective. Further components were supplemented to the software to increase the accuracy of the simulation. These components include the implementation of an approximate reverberant tail, and wall absorption filters.

## Reverberant Decay

An approximate reverberant tail was created to represent the higher-order reflections that the TDT system ignored. To create this reverberant tail, the reverberant decay curve of a small test chamber was measured using the MLSSA system V9.0. From the decay curve, the reverberation times (RT) per octave bands were calculated. Table 1 presents the RT values for the different octave bands.

Table 1: Averaged Measured Reverberation Times for the Small Chamber per Octave Band

Octave Bands (kHz)	.125	.250	.500	1.00	2.00	4.00	8.00
RT (sec)	0.72	0.94	0.85	0.56	0.55	0.48	0.49

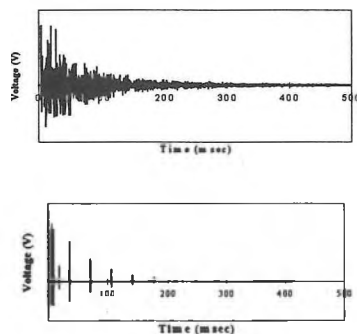


Figure 1a and b The measured and simulated impulse response for the small test room.

For simplicity purposes, the RT value of 0.6 seconds was chosen as the average RT over all octave bands accounting for the power in the low frequencies and the speech intelligibility contributed by the high frequencies. Using this RT value, the reverberant tail was made. The reverberant tail approximates an exponential decay curve using the decay processors built in to the TDT system. The set up consists of a feedback loop with one decay time variable,  $x$ , and one attenuation constant programmed on the delay processors. This particular arrangement creates a series of pulses separated by time  $x$ . Figure 1 displays both the measured test room impulse response and the simulated test room impulse response obtained by the TDT system.

## Surface Absorption

In calculating the first-order reflections to simulate the wall properties, speech signals were convolved with several finite impulse responses (FIR) that describe the relative reflective characteristics of the surfaces of the room. The values for these characteristics were obtained using a room-prediction technique, which involves manipulating the absorption values for each surface until it yields the proper RT for the room. Table 2 shows a list of the calculated absorption coefficients per octave band for the different surfaces in the room.

Table 2: Absorption Coefficients per Octave Bands for the Room's Surfaces

Surface	.125 kHz	.250 kHz	.500 kHz	1.00 kHz	2.00 kHz	4.00 kHz	8.00 kHz
Floor	0.02	0.02	0.01	0.03	0.03	0.04	0.04
Ceiling	0.35	0.22	0.23	0.30	0.35	0.50	0.55
Wall	0.09	0.06	0.04	0.05	0.07	0.07	0.07

## Simulation Validation

Once the room was simulated, the localization perception of listeners in the real and virtual environments were compared to validate the sound-field simulations [2]. In the real room, localization was accurate with feedback; without feedback, front-back confusions occurred. The performance of the localization tests in the virtual test room were comparable to the performance in the real room.

- [1] M. Kleiner et al., "Auralization - An Overview", *J. Audio Eng Soc.* 41 861-875 (1993)
- [2] M. K. Pichora-Fuller et al., "Localization in Real and Virtual Rooms", *Can. Acoust.* (Abstract)