Chapter 12

Stochastic Based Simulations and Measurements of Some Objective Parameters of Acoustic Quality: Subjective Evaluation of Room Acoustic Quality with Acoustics Optimization in Multimedia Classroom (Analysis with Application)

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/45950

1. Introduction

This chapter offers an original scientific research about stochastic based simulations and measurements of some objective parameters of acoustic quality and subjective evaluation of room acoustic quality, with acoustics optimization in multimedia classroom, complete scientific analysis, and application. The organisation of this chapter is very simple. After a short introduction that is an overview of completed research there are two main chapter parts with some definitions and explanations on the main subjects and research done. The conclusion to this research is contained in the final chapter segment, before the cited references.

According to http://www.answers.com/topic/convolution (2011/12/31), stochastic control methodology (SCM) is applied in a variety of fields including the computing, communications and acoustics optimization in multimedia environment. Also, SCT as a branch of control theory (CT) that deals with systems which involve random variables/signals and which occurrence can only be described in probabilistic terms attempts to predict and minimize the effect of these random signals through the optimization of controller design for acoustics optimization in multimedia room. Such deviations occur when random noise and disturbance processes are present in a control system, so that the system does not follow its prescribed course but deviates from the latter by a randomly varying amount. In contrast to deterministic signals, random signals cannot be described as given functions of time such as a step, a ramp, or a sine wave. The exact function is unknown to the system designer; only some of its average properties are known. A random signal may be generated by one of nature's processes, for instance, wind or multimedia wave-induced forces and moments on a antenna or a multimedia room. Alternatively, it may be generated by human intelligence, for instance, the contour to be followed by a duplicating machine. Outstanding experimental fact about nature's random processes is that these signals are very closely "Gaussian" that is a mathematical concept which describes one or more signals, i1, i2, …, in having the following properties: The amplitude of each signal is normally distributed and the joint distribution function of any number of signals at the same or different times taken from the set is a multivariate normal distribution. This experimental fact is not surprising in view of the fact that a random process of nature is usually the sum total of the effects of a large number of independent contributing factors. For instance, an ocean-wave height at any particular time and place is the sum of wind-generated waves at previous times over a large area. The underlying mechanism that generates a random process can usually be described in physical or mathematical terms. For instance, the underlying mechanism that generates shot-effect noise is thermionic emission. If the generating mechanism does not change with time, any measured average property of the random process is independent of the time of measurement aside from statistical fluctuations, and the random process is called stationary. If the generating mechanism does change, the random process is called nonstationary. Random noise is a type of noise comprised of transient disturbances which occur at random times; its instantaneous magnitudes are specified only by probability distribution functions which give the fraction of the total time that the magnitude lies within a specified range. Random noise represents: in mathematics a form of random stochastic process arising in control theory, or in physics noise characterized by a large number of overlapping transient disturbances occurring at random, such as thermal noise and shot noise, also known as fluctuation noise.

The room acoustics for multimedia room is complex problem which has to be take in consideration while designing the one, because it consists of several parts, like: analysing and calculating of acoustical parameters, measuring the real condition, simulating on computer, finding the cause and giving the solution for possible problems. Calculating and measuring methods, as well as their results, have to be analised and shown. At the end some proposals to obtain better conditions have to be given, and the simulation with proposed actions have to be made, to find out if those proposals solved the problem found out in the real room (Domitrović, Fajt & Krhen, 2009).

The room acoustic quality rating is at the end always subjective and influenced by stochastic (Simovic & Jr. Simovic, 2010) convolution (Uludag, 1998; Sobolev, 2001). The only question is how sharp is the criteria which should be met, what is the purpose of space and how important is the quality of listening for the listeners. With regard to this, judgment process is extremely complex (Fajt, 2000). On the other hand, it is possible to do objective measurement relatively easily and quickly. Following the above stated, the main idea of the first part of this chapter is that it offers an original scientific discussion with a conclusion concerning the relevance of making judgments about the subjective assessment of quality of space based on objective measurements of the room acoustic quality rating which is at the end always subjective and influenced by convolution, where information about the statistical correlation of subjective assessments and objective measurements of room acoustic quality is shown. In the first part of this work the results of statistical analysis of two acoustically differently treated spaces subjective testing are shown. The number of test participants was 33, of which 8 had musical education. The musical sample duration was 16.5 min. The loudness level has been calibrated, i.e. it was identical in both rooms. Eighteen parameters were evaluated in two ways: with and without the impact of musical memory. These results were compared with hypothetical results based on the experience of the authors. The comparison of subjective judgment and objective measuring results is shown. The possibility of making judgments about the subjective assessment of quality of space based on objective measurements is also given. At the end, information about the statistical correlation (Žužul, Šimović & Leinert-Novosel, 2008) of subjective assessments and objective measurements (Kosić, 2008) of room acoustic quality is shown (Krhen, 1994). Room acoustics is a characteristic of a room in which sound is well transferred and well received (heard), i.e., sound depending on type (speech or music, that is, type of music) and purpose (listening or recording). The development of acoustics – acoustic science, and especially its subcategories, architectural acoustics, is founded on defining objective parameters of spatial room acoustic quality and finding new methods (von zur Gathen & Gerhard, 2003) of their measuring and identifying their relationship with subjective parameters of spatial acoustic quality obtained through subjective testing (Everest & Pohlmann, 2009). That is why the task of this simulation research was to make an estimate, a simulation and measurement of the acoustics of a representative multimedia classroom (classroom at the Department of Electroacoustics, Faculty of Electrical Engineering and Computing, FER). The main idea of the second part of this chapter is that it offers an original scientific discussion with a conclusion concerning the relevance of making a prediction, stochastic based simulations and measurements of (some objective parameters of) acoustic (quality) in a sample multimedia classroom (classroom at the Department of Electroacoustics, Faculty of Electrical Engineering and Computing, or FER). Measurements and simulations of some objective parameters of acoustic quality were conducted in order to determine whether the representative multimedia classroom was acoustic or not, and if not, what measures (with stochastic optimization) should be taken in order for the mentioned room to meet optimal conditions for being acoustic.

2. Introduction to analysis

Subjective rating of acoustic quality is always the most important result which must be as high as possible, and it depends on several factors, such as: training of the listener, familiarity with the topic, musical memory and even the expectations of the listener. These ratings, however, always affect the same parameters, which were assessed in our studies. The statistical based analysis of these results has been made. On the other hand, objective parameters are much easier to measure. Measurements of objective parameters of acoustic quality were made, and at the end their mutual correlation is shown. Why? Because possible convolution problems. See visual explanation of convolution and its applications.

Some of convolution applications are cited bellow. Citation from: http://www.answers.com/topic/convolution (2012/12/31):

"Convolution and related operations are found in many applications of engineering and mathematics:

- In linear acoustics, an echo is the convolution of the original sound with a function representing the various objects that are reflecting it.
- In artificial reverberation (digital signal processing, pro audio), convolution is used to map the impulse response of a real room on a digital audio signal (Krhen, 1994).
- In electrical engineering, the convolution of one function (the input signal) with a second function (the impulse response) gives the output of a linear time-invariant system (LTI). At any given moment, the output is an accumulated effect of all the prior values of the input function, with the most recent values typically having the most influence (expressed as a multiplicative factor). The impulse response function provides that factor as a function of the elapsed time since each input value occurred.
- In digital signal processing and image processing applications (Pap, Kosić & Fajt, 2006), the entire input function is often available for computing every sample of the output function. In that case, the constraint that each output is the effect of only prior inputs can be relaxed.
- Convolution amplifies or attenuates each frequency component of the input independently of the other components.
- In statistics, as noted above, a weighted moving average is a convolution.
- In probability theory, the probability distribution of the sum of two independent random variables is the convolution of their individual distributions."

3. Subjective evaluation of room acoustic quality parameters

For the purposes of subjective acoustic quality evaluation, we examined the following parameters:

1. Noise volume;
2. Intimacy, Presence;
3. Loudness;
4. Reverberance;
5. Tonal Reproduction, Timbre;
6. Sound Definition, Clarity;
7. Echo Disturbance;
8. Speech Intelligibility;
9. Spectral Uniformity, Balance;
10. Sound stage imaging;
11. Dynamics;

12. Distortion;
13. Stability of performance;
14. Brilliance;
15. Bass reproduction;
16. Resonance;
17. Ambience Reproduction, Diffusion;
18. Overall Acoustic Impression.

Express each function in terms of a dummy variable τ.
Reflect one of the functions: $g(\tau) \to g(-\tau)$.
Add a time-offset, t, which allows $g(t-\tau)$ to slide along the τ-axis.
Start t at -∞ and slide it all the way to +∞. Wherever the two functions intersect, find the integral of their product. In other words, compute a sliding, weighted-average of function $f(\tau)$, where the weighting function is $g(-\tau)$.
The resulting waveform (not shown here) is the convolution of functions f and g. If f(t) is a unit impulse, the result of this process is simply g(t), which is therefore called the impulse response.

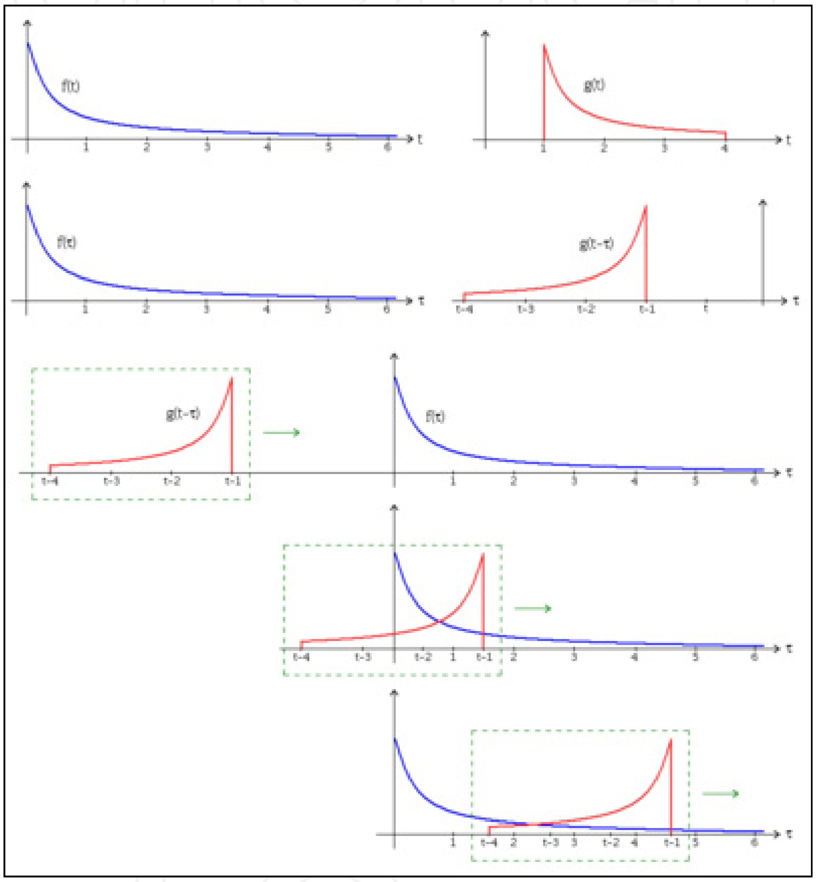

Figure 1. Visual explanation of convolution - according to: http://www.answers.com/topic/convolution (2011/12/31)

One room was acoustically untreated (Room 1), while the other was acoustically treated as a listening room (Room 2). All subjects evaluated parameter values as numeric values in the range from 1 to 5. In each room two tests were made. The goal was to determine the effect of listener's music memory on test results.

For this purpose, a group of subjects first heard a music test pattern, and the evaluation process began 1 minute after the end of the test pattern – Measurement Type A.

After that a 15 min pause was done, and subsequently after the pause the following test started in which subjects entered their ratings during the test sample listening – Measurement Type B.

It is interesting to note that for Room 1, for all parameters except for (3) at least one subject had given the worst score when they did test with the impact of musical memory, while in Type B test, only 4 parameters are not given the worst score.

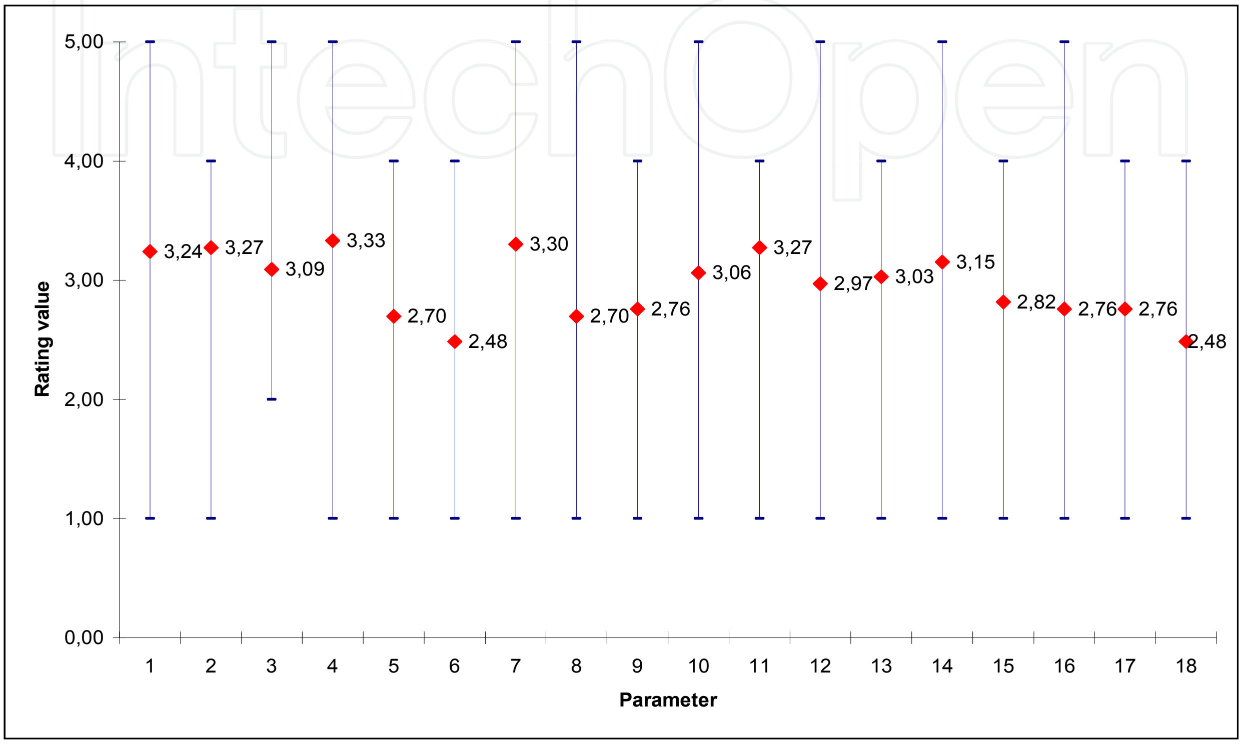

Figure 2. Feedback results for Room 1 / Measurement Type A – Minimum, Maximum and Average Value

Parameter	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
σRoom 1, Type A	1.07	0.83	0.93	1.03	0.83	0.93	1.22	0.80	0.74
σRoom 1, Type B	0.99	0.61	0.83	1.02	0.81	0.78	0.99	0.86	0.57
σRoom 2, Type A	0.98	0.58	0.55	0.88	0.59	0.58	0.36	0.69	0.65
σRoom 2, Type B	0.64	0.72	0.55	0.85	0.46	0.59	0.17	0.55	0.46
Parameter	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*
σRoom 1, Type A	1.13	0.75	1.29	0.80	1.02	0.87	1.02	0.85	0.78
σRoom 1, Type B	1.02	0.71	1.03	0.72	0.91	0.95	1.15	0.77	0.82
σRoom 2, Type A	0.70	0.64	0.73	0.72	0.74	0.90	0.59	0.86	0.67
σRoom 2, Type B	0.90	0.67	0.53	0.66	0.65	0.89	0.52	0.80	0.67

Table 1. Standard deviation for all feedback results

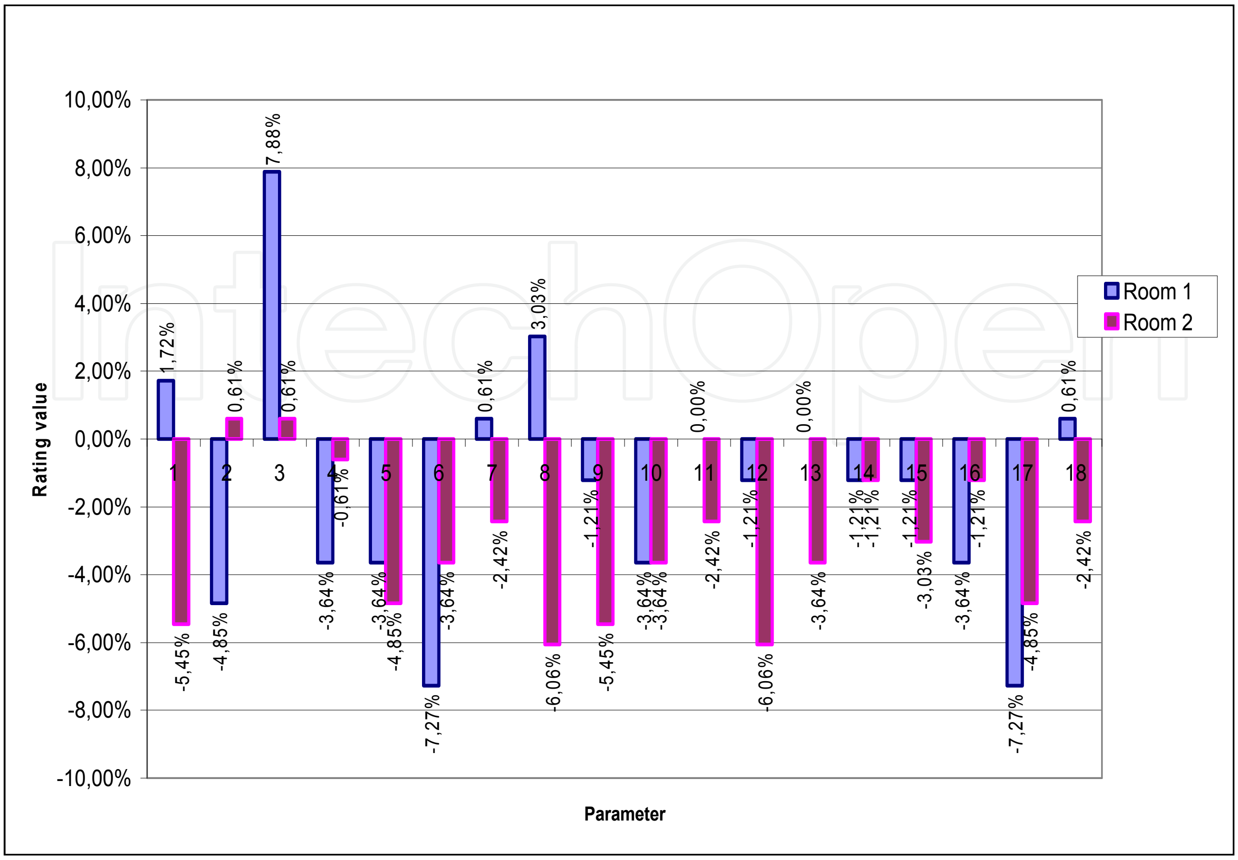

Figure 3. The feedback difference depending on musical memory (Meas.Type A – Meas.Type B) – Positive value: better result without memory effect; Negative value: better result with memory effect

In this evaluation, 8/18 (44.4%) of the parameter (Meas.Type A) and 10/18 (55.5%) parameters (Meas.Type B) also received the best value. This clearly points to a very large dispersion of results, and points (and confirms) the problem that always exists in the subjective assessment of acoustical quality parameters. Standard deviation shows us also the relatively large dispersion of results (Table 1).

In the most cases, individual results are significantly below average: Room 1 – Meas.Type A: 26/33 (78.8%); Meas.Type B: 23/33 (69.7%) and Room 2 – Meas.Type A: 18/33 (54.5%) ; Meas.Type B: 23/33 (69.7%).

Musical memory definitely has an impact on making assessments about the acoustical quality, and we can see (Fig. 2) that the results are in the most cases better with memory effect. This is especially outlined in the Room 2 (16/18 – 88.8%), compared with Room 1 (11/18 – 61%).

When we compare the subjective assessment of the average acoustic impression (18) with an average value of all parameters, we can see that these values are in Room 1 - acoustically untreated room: Meas.Type A: 2.48 / 2.98; Meas.Type B: 2.45 / 3.06 much more different than in Room 2 - acoustically treated room: Meas.Type A: 3.97 / 4.03; Meas.Type B: 4.09 / 4.18.

4. Objective measurements of room acoustic quality parameters

Objective measurements for Room 1 and Room 2 have been made with acoustical SW "ARTA". The measurements were done with 4 kinds of signal generator: sweep, pink noise, white noise and MLS. The sampling frequency was 48 kHz except for the speech intelligibility measurements, where the sampling frequency was 16 kHz for all signals. The correlation between the results is very good.

f [Hz]	T30 [s]	T20 [s]	T10 [s]	EDT [s]	C80 [dB]	C50 [dB]	D50 [%]
63	1.268	1.344	0.877	1.608	1.79	1.12	56.40
125	1.197	1.326	1.182	1.491	0.80	-3.17	32.50
250	1.027	1.165	1.305	1.400	0.58	-1.73	40.20
500	1.164	1.237	1.260	1.429	-0.51	-3.06	33.09
1000	1.139	1.240	1.100	1.315	1.61	-0.61	46.52
2000	1.059	1.101	1.114	1.170	2.30	0.00	50.01
4000	0.873	0.852	0.799	0.904	4.50	1.55	58.86
8000	0.710	0.694	0.697	0.699	6.82	3.35	68.38

Table 2. Objective measurement results for Room 1, sweep signal, sampling f = 48 kHz

Measured speech intelligibility (sweep signal, sampling f = 16 kHz)

for Room 1 is:

STI = 0.5044 (male),
0.4893 (female),
Rating:
FAIR,
%ALcons= 8.8092;
RASTI = 0.5146
Rating: FAIR,
%ALcons = 10.4877,

and for Room 2:

STI = 0.6668 (male),
0.6362 (female)
Rating: GOOD,
%ALcons= 3.2315;
RASTI = 0.7269
Rating: GOOD,
%ALcons = 3.3203.

5. Statistical based analysis - first conclusion

Since it largely depends on the audience and their real possibilities of making assessments, subjective evaluation of room acoustic quality parameters is always difficult to make, as well as to accurately assess the subjective room quality. The resulting dispersion of the results shows that even within a group of people from similar socio-economic groups, education levels and technical knowledge, there are differences. However, since there is still a very good correlation between subjective and objective evaluation of the measured parameters, we can say that there is a very high probability that the subjective evaluation of room acoustic quality will be consistent with objectively measured parameters, and that the majority of people agree with that assessment.

6. Introduction to application: Acoustics based optimization in multimedia classroom

Acoustics is a characteristic of a room where within that space sound is well transferred and well received (heard) according to the type of sound (speech or music, that is type of music) and purpose (listening or recording). The development of acoustics – acoustic science, and especially its sub disciplines, architectural acoustics, is based on defining objective parameters of acoustic quality of a space and in finding methods for their measurement and establishment of their interdependency with subjective parameters of spatial acoustic quality which were obtained through subjective testing. The traditional task of spatial acoustics was to ensure and form conditions which will enable better acoustic transfer from the sound source to the listener. Objective parameters of spatial acoustic quality are determined by the possibility of finding objective methods of measurement. The parameters that determine the acoustic quality of a room are: time of echo, time of early drop of sound energy, room constant, room radius, clarity, mean time, definition, relationship between the reflected and direct energy, support, relative level or power index, sound color, occasional diffusion, the assessed relationship signal/murmur, loss of consonant articulation, speech transfer index, the ratio of useful and harmful sound, fraction of lateral energy, inter-aural coefficient of cross correlation, direction index, and time of initial delay. All measurable parameters of acoustic quality of a room which are interrelated in some way due to the fact that they have basic characteristics of sound waves are mentioned here. It is not necessary to measure and use all parameters in spatial acoustics. Those which can be measured and those that give us reliable information even with subjective parameters on the acoustics of the room being tested should be selected. The results obtained will help take appropriate actions which will improve the acoustic quality of a particular area. Subjective parameters for acoustic quality of a room depend on whether we are referring to speech or music. When determining the acoustic quality of a room with respect to speech the subjective parameter is intelligibility. Subjective parameters for the acoustic quality of a room are: loudness, definition or clarity, reproduction of high frequencies or brilliance, reproduction of low frequencies or fullness, sparkle, sound imagery (stage), localization or locating the sound source, intimacy or closeness, echo, noise level, reverberation, tone reproduction, color of voice, tone or sound, intelligibility of speech, spectral equality, dynamics, area of soundness and transient response, deformities, equal distribution of sound pressure, reproduction of ambiance, spatiality, impression of space, diffusion, resonance audibility and entire acoustic impression.

7. Predicting measures for checking acquired acoustic quality in a classroom

The basic measurement of acoustic quality of a room is the measurement of reverberation time as the most important objective parameter of the acoustic quality of a room since it contains characteristics of a room such as dimension and volume and shape and absorption. Measuring reverberation time can be carried out in various ways and different types of measuring signals and sources of signal measurement are used. Basically, all types of measurement of reverberation time differ according to the principle of big difficulties created by the level of sound pressure of 60 dB above the noise level of the area which is needed according to definition for establishing reverberation time. The oldest way of measuring reverberation time is using the burst (pistol or similar) or noise (noise generator) which through frequency analyzer and logarithmic printer give a curve-like lowering of the sound pressure in a space. The Figure 4 graph shows the reverberation time measuring a protractor – a transparent board with scales for reading the reverberation time. In this type of measurement it is advisable that the level of actuation signal is at least 40-50 dB above environmental noise level.

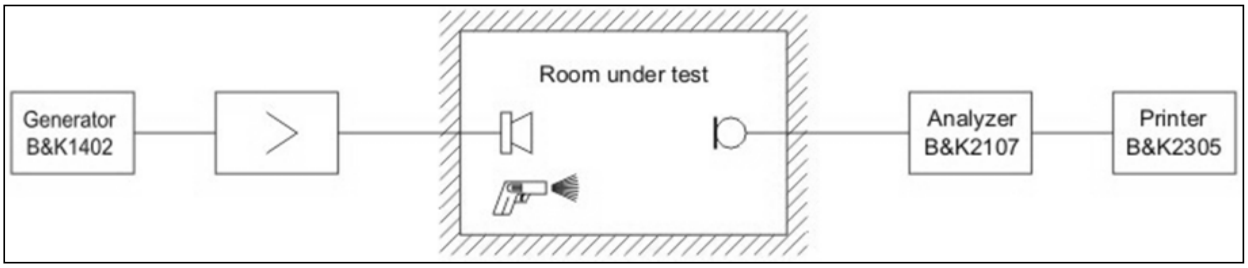

Figure 4. Graphical layout for direct reading of reverberation time using a protractor

Based on the Schroeder integration, a special way of measuring reverberation time from the impulse response possible to implement into a digital sound measuring device was developed (e.g. B&K 2231 using a module for measuring reverberation time BZ 7108). The results are directly read from the instrument according to the octal and terca (tertiary bands) within the set frequency area. Reverberation time is calculated (extrapolation) based on 10, 20 and 30 dB of lowering of the signal level and thus avoiding the need for a 60 dB signal dynamics. The digital sound measurer or SPL meter (B&K 2231 using a module for measuring reverberation time BZ 7108), depending on the environmental noise level, itself generates the required signal level sufficient for measuring, based on the signal received with appropriate indicators of a low level or pre–actuation, independently carries out level correction. Due to the lowered influences of possible mistakes in measurement, four subsequent measurements within the entire frequency area, whose results are stored in digital sound measuring device memory and through statistical analysis can yield results of proper accuracy.

8. Predictions, stochastic based simulations and measurements in the sample multimedia room

The task is to make a prediction, stochastic based simulations and measurements of (some objective parameters of) acoustic (quality) in a sample multimedia classroom (classroom at the Department of Electroacoustics, Faculty of Electrical Engineering and Computing, or FER). Measurements and simulations of some objective parameters of acoustic quality in order to establish opinion whether the sample multimedia classroom is acoustic (according to some rules and conditions) or not, and if not, what measures should be taken in order for that classroom to meet the condition of acoustics. If the same measuring conditions are ensured, objective parameters of must be repeatable and be direct indicators of acoustic quality. The first measurable parameter is the reverberation time (time necessary for level of sound pressure or sound strength is lowered for 60 dB as sound emission is stopped).

Figure 5 shows the layout of the sample multimedia classroom. The numbers refer to positions in the room where reverberation time was measured, and the sound source is also marked with a symbol. Table 3 shows the results of the measurement of reverberation time depending on various frequencies of sound source in the real system.

Frequency	Position 1	Position 2	Position 3	Position 2	Position 4	Position 5
62,5 Hz	1.14 s	1.44 s	1.24 s	1.44 s	1.22 s	1.33 s
125 Hz	1.32 s	1.50 s	1.37 s	1.50 s	1.22 s	1.54 s
250 Hz	1.67 s	1.55 s	1.62 s	1.55 s	1.59 s	1.67 s
500 Hz	1.50 s	1.55 s	1.48 s	1.55 s	1.57 s	1.56 s
1 kHz	1.40 s	1.38 s	1.38 s	1.38 s	1.35 s	1.36 s
2 kHz	0.99 s	1.18 s	1.14 s	1.18 s	1.14 s	1.17 s
4 kHz	0.89 s	0.82 s	0.85 s	0.82 s	0.83 s	0.83 s
8 kHZ	0.67 s	0.63 s	0.99 s	0.63 s	0.64 s	0.65 s

Table 3. Results of reverberation time measurement

The second measurable parameter is the distribution (division of the sound pressure). Sound pressure at a point in the room area is the result of the interference of direct and reflected sound and therefore in the spatial allocation of the sound pressure there are areas of minimum and maximum of sound pressure which are especially expressed in resonant frequencies. This parameter was measured at various frequencies in 30 points defined with introduced coordinates, shown in Figure 6. The results are shown in Table 4.

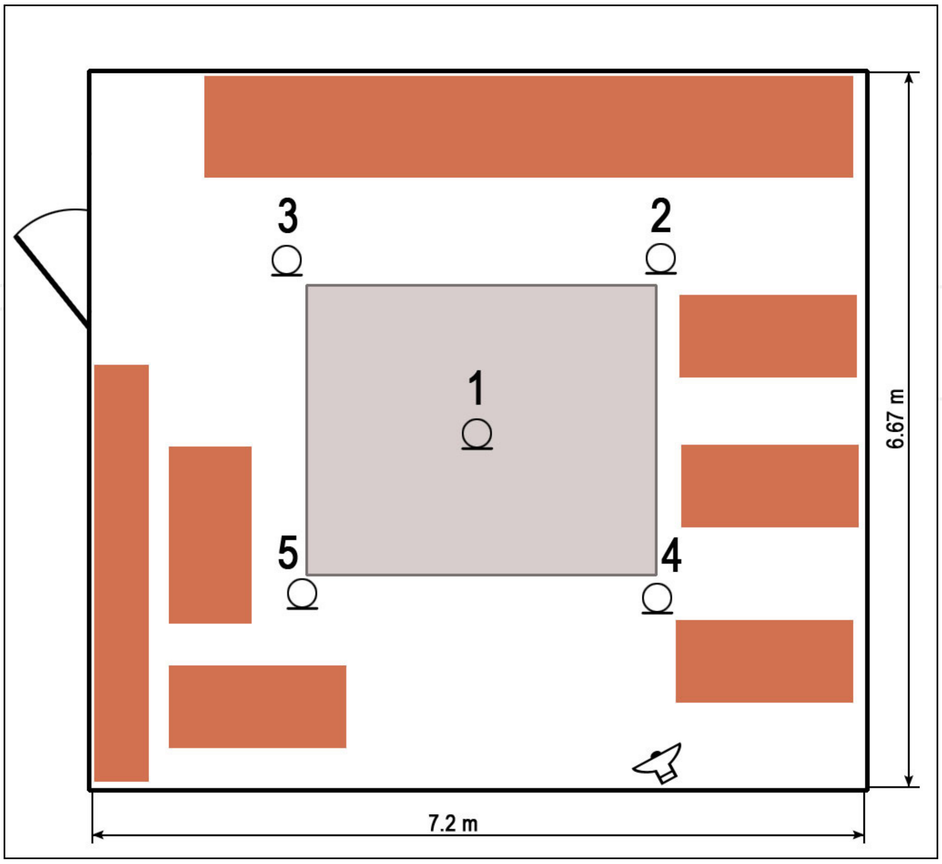

Figure 5. Room layout CX-15 (sample multimedia room)

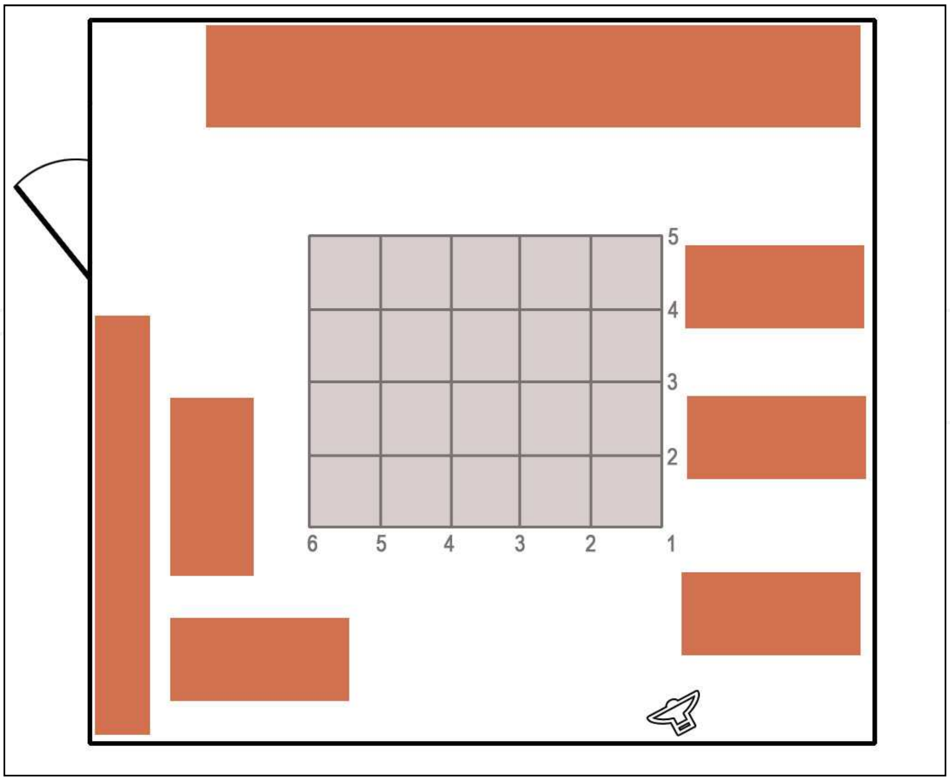

Figure 6. Measurement of sound pressure distribution

Position	31.5 Hz	63 Hz	125 Hz
(1,1)	63.5	80.0	77.5
(1,2)	64.5	82.0	81.0
(1,3)	64.5	82.5	66.0
(1,4)	64.0	80.5	79.0
(1,5)	64.0	78.0	83.0
(2,1)	63.0	71.0	78.0
(2,2)	63.0	74.0	74.0
(2,3)	62.0	78.0	73.0
(2,4)	61.0	79.0	75.0
(2,5)	58.0	77.5	79.0
(3,1)	63.0	79.0	74.5
(3,2)	61.0	74.0	72.0
(3,3)	58.0	65.0	71.0
(3,4)	54.0	74.5	74.0
(3,5)	51.0	76.0	73.0
(4,1)	63.5	83.5	70.5
(4,2)	53.0	78.5	74.5
(4,3)	49.0	74.0	76.0
(4,4)	52.0	75.0	73.0
(4,5)	61.5	76.5	70.0
(5,1)	67.0	84.5	70.0
(5,2)	62.0	79.5	73.0
(5,3)	64.0	75.5	74.0
(5,4)	68.0	77.5	73.0
(5,5)	67.0	77.0	73.0
(6,1)	65.5	80.0	71.0
(6,2)	58.5	79.5	62.0
(6,3)	56.5	77.5	70.0
(6,4)	65.0	79.0	75.5
(6,5)	68.5	83.0	77.0

Table 4. Level of sound pressure in dB for particular frequencies

The obtained results for sound level in decibel (dB) are relative, considering that they are only relevant for differences in levels for particular frequencies. Separate measurement was conducted using Bruel and Kjaer sound measuring device (SPL meter - B&K 2231 using a module for measuring reverberation time BZ 7108) which was attached to a spectral analyzer.

Measurement was conducted in the spot which is marked by number 1 on Figure 7 and the shaded area around that place. The speakers emitted a white murmur and the spectral analyzer recorded the situation for several spots in the area. The results were transferred

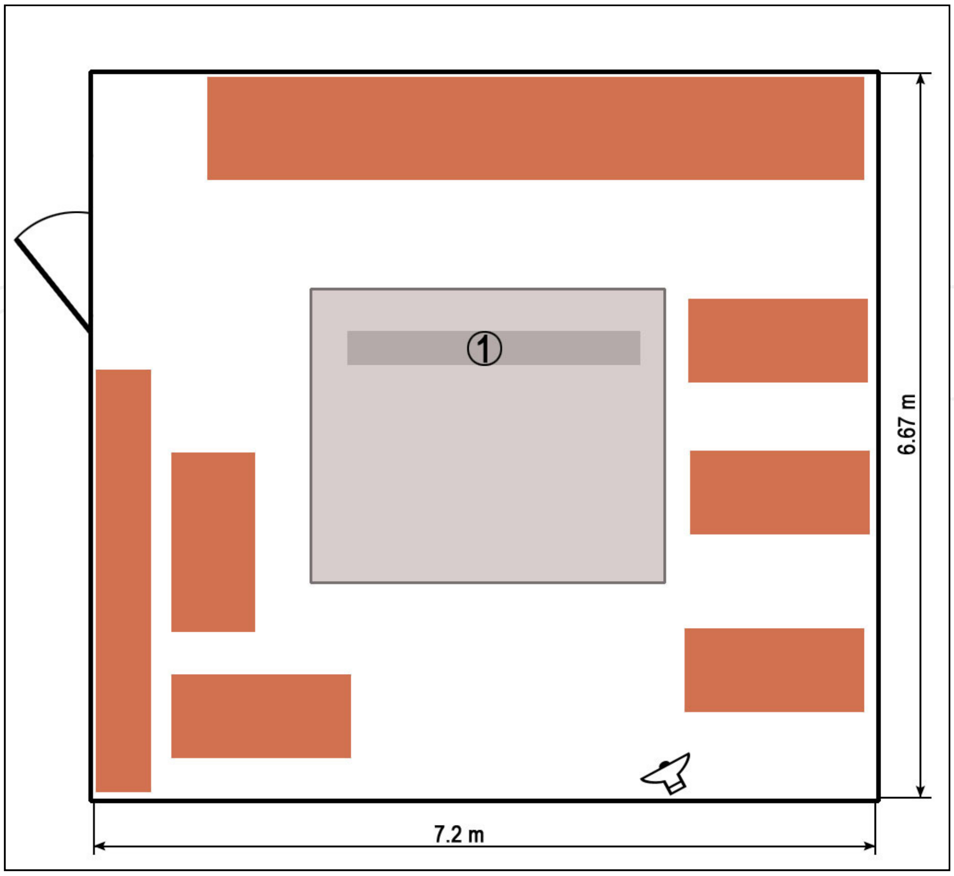

Figure 7. The measurement was carried out in the area marked with number 1 and the shaded area around that spot

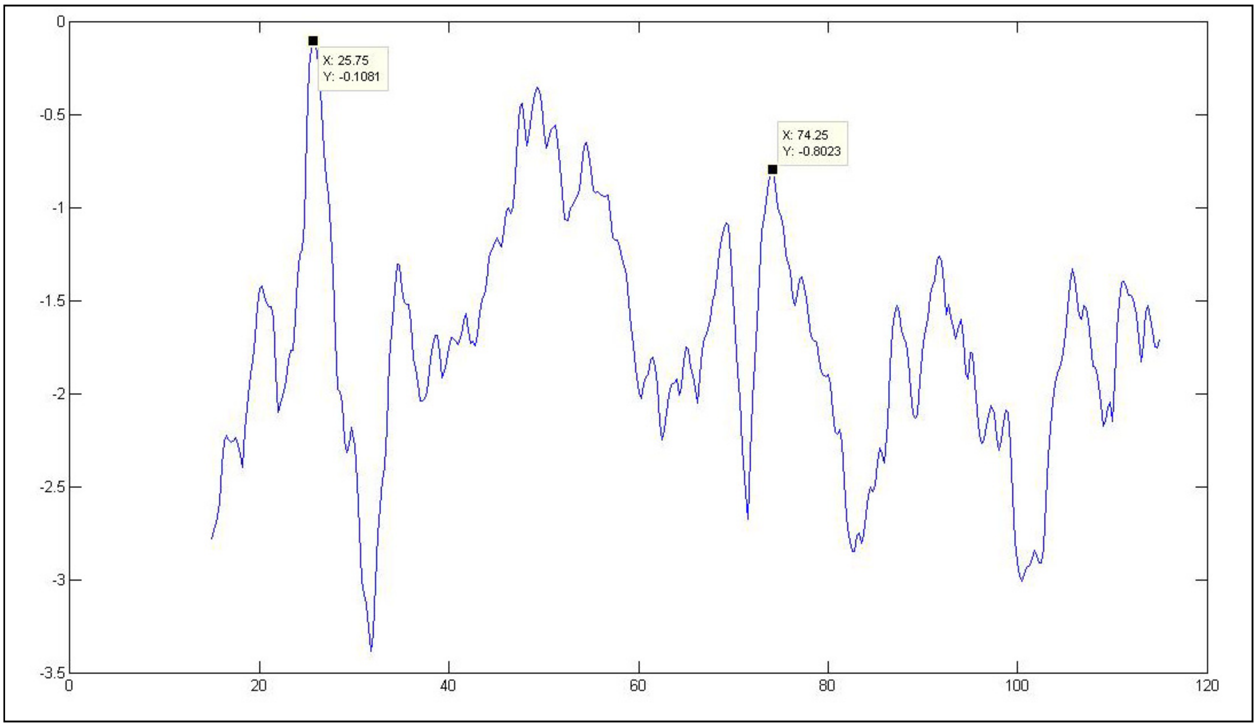

Figure 8. Measured resonances (points which represent maximum standing waves)

into the program Matlab which created a graph shown in Figure 8. Figure 8 shows the dependency of the sound pressure on frequency in spot 1. The results of the measurement in the area are rather similar to the results of measurement in that spot.

Figure 8 shows resonances, that is, points which represent standing waves maximum. The most prominent maxima are at the frequency of about 26 Hz, followed by 50 Hz and 75 Hz. Such maxima show up at resonant frequencies obtained by the formula:

$$f = \frac{c}{2}\sqrt{\frac{p^2}{A^2} + \frac{q^2}{B^2} + \frac{r^2}{C^2}}$$

The measure represents the speed of sound in the air which is c= 340 m/s, A, B and C are room dimensions, and p, q and r are natural, whole numbers. Room dimensions: A=6.7 m; B=7.2 m; C=3.2 m.

Table 5 gives the results of the calculation of resonant frequencies and it is evident that the calculated values coincide with the measured values. The most prominent frequencies are 26 and 74 Hz.

p	q	r	Mod (Hz)
0	1	0	23.60
1	0	0	25.37
1	1	0	34.60
0	2	0	47.20
2	0	0	50.70
0	0	1	53.00
1	2	0	53.60
2	1	0	56.00
0	1	1	58.10
1	0	1	58.90
1	1	1	63.40
2	2	0	69.30
0	2	1	71.00
2	0	1	73.46
0	0	2	106.25
0	1	2	108.80
1	0	2	109.20

Table 5. Resonant frequency calculation results

The following step was the acoustic simulation on the computer. For that purpose the EASE program (version 4.1) was used. The aim of the simulation was to show the reverberation time at various frequencies depending on the construction materials used. For calculating reverberation time, the Eyring formula was used and set with the following expression:

$$T_r = \frac{0.161V}{-S\ln(1-\alpha)}$$

Where V is room volume, S is the sum of all areas in the room, and α average absorption coefficient. The simulation of the current situation of the room was conducted first. The simulation results are presented in Figure 9, which shows that the situation is not satisfactory for frequencies lower than 2 kHz, considering that there is a large deviation in the reverberation time from normal values. Because of that some changes were necessary. In the area (virtual, used in the simulation) absorbers, materials used for "absorbing" sound waves, were used. To be more exact, they were placed on the only available wall in the room.

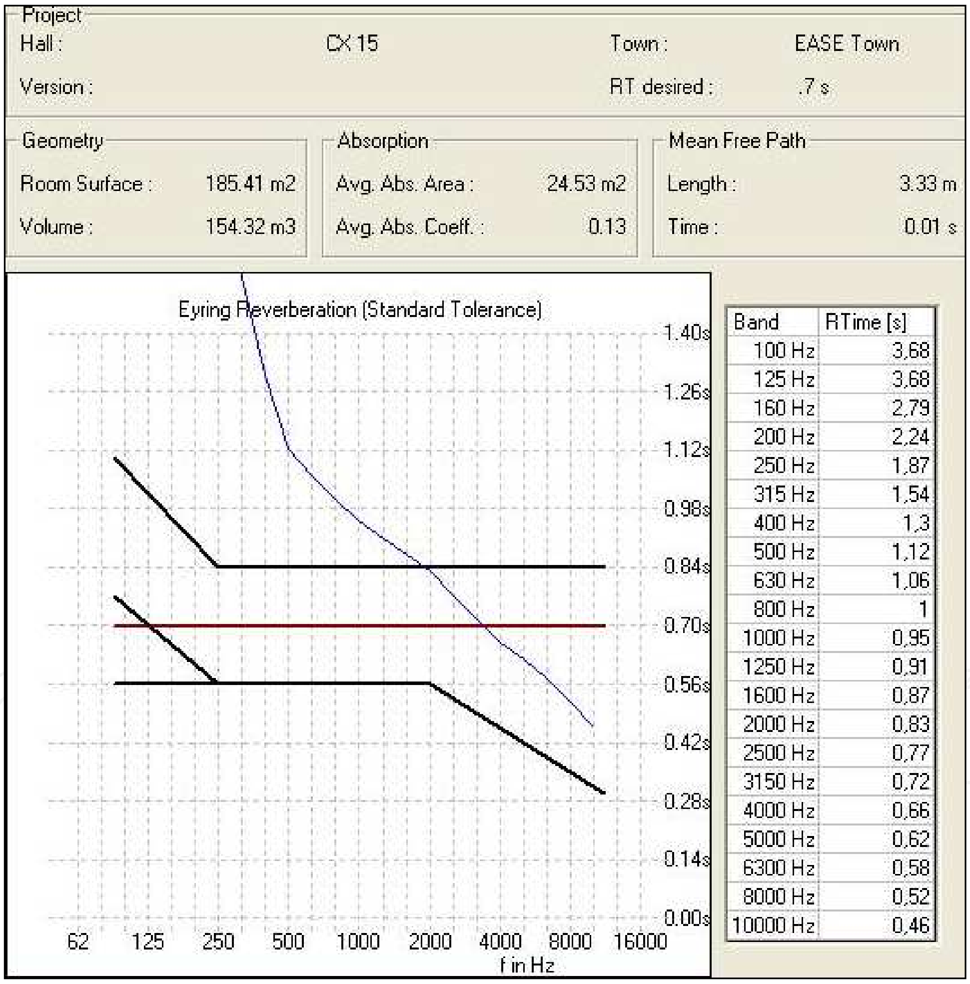

Figure 9. Results of the first simulation

After that, another simulation took place, the results of which are shown in Figure 10. As it can be seen on Figure 10, the results are rather satisfactory considering that there are no great deviations in the reverberation time from optimal values.

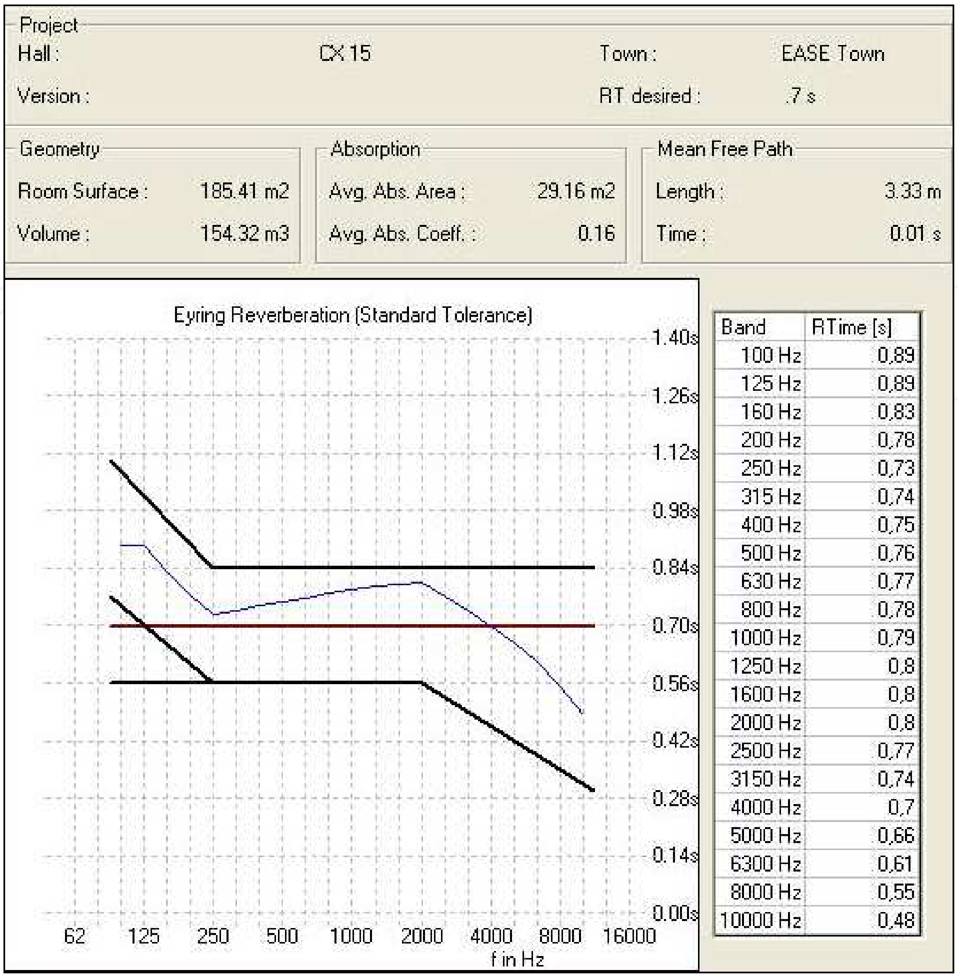

Figure 10. Second simulation results

Therefore, the back wall should be entirely covered with absorbing diffuser whose dependency of absorbency coefficient on frequency is shown in Figure 11.

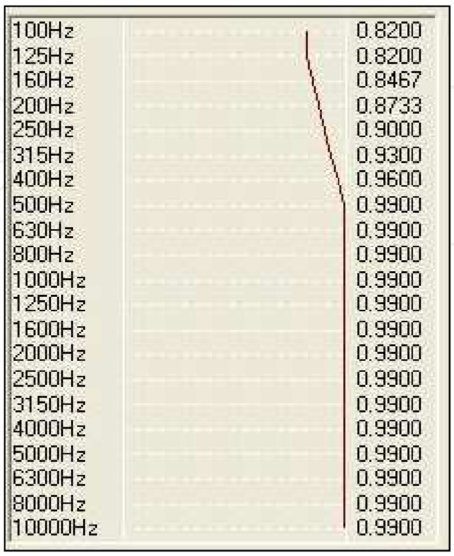

Figure 11. Overview of the dependency of absorbency coefficient on frequency

It is important to mention how in acoustic room simulation, some additional objects such as cupboards, board, etc. were not taken into consideration since they have a marginal influence on the end results constraint.

9. Acoustics optimization in multimedia classroom as an application - second conclusion

The presented procedure of the analysis, simulation and measurement of the sample multimedia classroom, indicates a need for professional design and supervision of the performance of multimedia classrooms considering their ever-growing use from the point of view of long life learning (LL) that is lengthy and frequent stay in them. Such a statement is very important in the case of adult education since they tire more quickly (especially if they are strained in order to hear better and understand speech) than the younger population involved in lifelong learning, that is, in-service teacher training. This is also very important for handicapped groups (partially sighted people and people with partial hearing abilities) involved in long life learning. Furthermore, all classrooms used for foreign language learning should have strictly defined adequate acoustic conditions, also confirmed by this simulation (optimization).

10. Conclusion

Since it largely depends on the audience and their real possibilities of making assessments, subjective evaluation of room acoustic quality parameters is always difficult to make, as well as to accurately assess the subjective room quality. The resulting dispersion of the results shows that even within a group of people from similar socio-economic groups, education levels and technical knowledge, there are differences. However, since there is still a very good correlation between subjective and objective evaluation of the measured parameters, we can say that there is a very high probability that the subjective evaluation of room acoustic quality will be consistent with objectively measured parameters, and that the majority of people agree with that assessment. The presented procedure of the analysis, stochastic simulation and measurement of the sample multimedia classroom, indicates a need for professional design and supervision of the performance of multimedia classrooms considering their ever-growing use from the point of view of long LL that is lengthy and frequent stay in them. Such a statement is very important in the case of adult education since they tire more quickly (especially if they are strained in order to hear better and understand speech) than the younger population involved in lifelong learning, that is, in-service teacher training. This is also very important for handicapped groups (partially sighted people and people with partial hearing abilities) involved in long life learning. Furthermore, all classrooms used for foreign language learning should have strictly defined adequate acoustic conditions, also confirmed by this simulation (optimization).

The suggestion for further development opens up a new area for improving the system of real simulation according to the effort in the organization of complex research. The system of analysis, comparison and monitoring has to be based on set and realistic stochastic procedures, control and values in both main chapter parts, and the results obtained are expected to open new areas for research and modelling. This research was a part of main Scientific research named "Analytical Model for Monitoring of New Education Technologies for Long Life Learning"conducted by Ministry of Science, Education and Sports of the Republic of Croatia (Registered Number 227-2271694-1699).

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