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ACOUSTICAL EVALUATION METHOD OF A CLASSROOM OF THE TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

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Abstract: In this paper, a method of measuring and interpreting acoustic quality in a classroom is presented. The acoustics of the classroom are described by the reverberation time and the objective acoustic parameters that derive from it. The measuring points were chosen in accordance with ISO 3382-1, so that to obtain an accurate acoustic characterization of the listening area. At each measurement point, the impulse response was measured and then critical distance, reverberation time, clarity and definition were extracted. Finally, the values of the objective acoustic parameters were mapped and the results were analyzed.

Keywords: *acoustic measurements, reverberation time, objective acoustic parameters, critical distance*.

I. INTRODUCTION

The paper, structured in four sections, proposes a method for evaluating the acoustics of a classroom at the Technical University of Cluj-Napoca. The first section is an introductory one, which describes the motivation of the importance of the assessment of acoustics in an enclosed space as well as the acoustic parameters that are taken into account in such an assessment. The second section describes the proposed measurement method and the used measurement setup. The third section presents the experimental results which are analyzed in the fourth section.

Current classroom teaching methods are different from those of 20 years ago. The teacher no longer gives a monologue in front of the students. The teaching is now an interactive activity, involving all students. The students' ability to concentrate should not be diminished by the poor quality of classroom acoustics. So it is necessary to know the sound quality in the students' listening area and where it is necessary to make changes in the architecture of the classroom to improve the acoustics. In 2018, at the Euronoise 2018 Conference, Room acoustics and learning Environments section, Professor Gerhard Tiesler stated that: "*Good acoustics is a measurable ergonomic factor and contribute to better human working conditions in school environments*" [1]. The assessment of the acoustics of an enclosed space takes into account the noise level and the reverberation time.

Acoustic characterization of enclosed spaces is a general concern of researchers in the field and requires dedicated special equipment [2].

The noise level of the classroom at rest must be below 35 dB [3].The optimal reverberation time value is not clearly specified because it depends on room's destination. There are recommendations for level of the reverberation time according for each destination. In general, in classrooms, the energies of high-frequency sounds are more absorbed than those of medium-low frequencies. For this reason, reverberation times at medium-low frequencies are longer. Sounds with frequencies between 100 Hz and 1 kHz are the most critical because the human ear has a growing sensitivity in this area. In this frequency range is the teacher's voice frequency fundamental. So, measuring the reverberation time in this frequency range is very important in assessing the intelligibility of sound [4]. Thus, for classrooms with the size of an amphitheater, with a volume of approximately 600 m^3, the recommended reverberation time is 0.8 s.

The reverberation time specific to the empty room can be calculated using Sabine's formula [4] (1) :

$$T_r = \frac{0.161 \cdot V}{\sum_n \alpha_n \cdot S_n} \quad (1)$$

where:
V = room volume (m^3);
α_n = the absorption coefficient of the absorbent material in the room;
S_n = the surface of the absorbent material in the room (m^2);
S = the total surface of the walls (m^2);
The constant 0.161 is s/m.

There are many factors that influence the duration of the reverberation, namely, the absorbent surfaces in the space (which form the envelope of the space), the furniture and the number of people present in the room. Sabine's formula is very popular, but in the case of large enclosed spaces, the value of the Sabine's reverberation time can deviate even by one second from the actual reverberation time of the

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room. This is because the formula does not take into account the absorption of sound energy by the air through which it is propagated, nor the geometric shape of the room, nor the existing furniture, nor the level of energy absorbed by people in the closed space. Developed in 1922, this formula has undergone a number of corrections to date, such as the addition to the equation's denominator of a factor for large halls (Knudsen 1929, Millington 1932, Sette 1933, Kuttruff 2009) that takes these elements into account [5].

The acoustics of a room depends a lot on the number of people occupying the space. In [6] the author specifies that the volume of an enclosed space is projected according to the maximum number of people who will occupy that space. Thus, a unit volume is established for each person. The unit volume is between 4-6 m^3. The listening quality of these people depends on their position in relation to the sound source but also in relation to the reflective surfaces around them.

Critical distance (CD) is the distance from the sound source at which the sound energy of the direct sound is equal to the sound energy of the waves reflected in the room [7]. Beyond the CD, the listener's sound perception is influenced by the acoustics of the closed space. The CD is approximated as follows:

$$CD \cong 0.056 \cdot \sqrt{\frac{V}{T_{60}}} \quad (2)$$

where:

V = the volume of the enclosed space (m^3);

T_{60} = the reverberation time of the enclosed spaces (s) in which the sound intensity decreases by 60 dB;

The constant 0.056 is s/m

From equation (2) it is obvious that in a closed space characterized by a long reverberation time, the CD will be one of small size and vice versa.

The reverberation time evaluates only the late reflection part of the decomposition curve. The objective acoustic parameters of quality and definition take into account all the reflections of the sound at the measurement point and are a ratio between the early and the late reflections. Thus, the assessment of the acoustic quality of the classroom is more appropriate to be made in terms of objective acoustic parameters [8].

For vocal sound, C_{50} clarity is the parameter by which the quality of human voice reception is assessed. The mathematical form of this parameter is:

$$C_{50} = 10 \cdot \lg \left[\frac{\int_0^{50} h^2(t)dt}{\int_{50}^{\infty} h^2(t)dt} \right] \quad (3)$$

For proper sound quality, the C_{50} must have values in the range of [0, 5] dB.

The objective clarity parameter C_{80} is a parameter specific to the complex signal and is calculated by:

$$C_{80} = 10 \cdot \lg \left[\frac{\int_0^{80} h^2(t)dt}{\int_{80}^{\infty} h^2(t)dt} \right] \quad (4)$$

Recommended values for C_{80} are in the range of [-3, 5] dB. The values of the clarity parameters that are below the recommended value range indicate a reverberant closed space and the values above the recommended range, indicate an attenuating closed space.

Parameter D_{50} is strictly related to parameter C_{50} and specifies the degree of intelligibility of the received voice signal (5). It is measured in percentages. The best intelligibility of the signal is recorded for the value of 50% of this parameter.

$$D_{50} = \lg \left[\frac{\int_0^{50} h^2(t)dt}{\int_0^{\infty} h^2(t)dt} \right] \quad (5)$$

II. THE PROPOSED METHOD AND EXPERIMENTAL SETUP

a. The proposed method

For the acoustic characterization of a closed space, it is necessary to know the reverberation time of that space, which is considered the mother of all objective acoustic parameters. In this paper, we extract from the impulse response the reverberation time and the clarity parameters C_{50} and C_{80} respectively, the definition D_{50} which will be the basis for assessing the acoustic comfort of the audience.

The closed space proposed for measurement and acoustic assessment is a classroom, with a volume of 576 m^3 (Figure 1). In the classroom, students are distributed in 130 places organized in 13 rows. Each row has 10 seats. The measuring microphone was placed on even rows, so as to cover a circular surface with a radius of 1 m, for capturing the measuring signal, at points P_1 ... P_{18}. In this way, the entire audition area was covered. The distances between the measuring points, respectively between the microphones and the sidewalls, comply with the provisions of the ISO3382-1 standard. I used only one microphone for the measurements, which I positioned in turn at each measurement point. The sound source is represented by the letter S. It is positioned in the middle of the teacher's table, 1m above it.

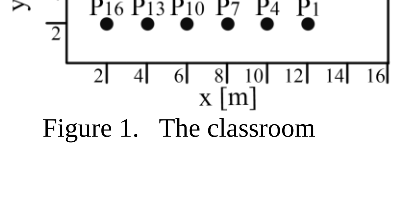

Figure 1. The classroom

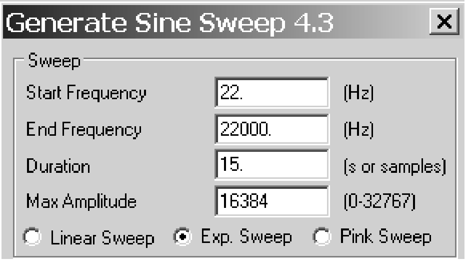

Figure 2. The LSS parameters

The used measurement signal is an LSS (Logarithmic Sine Sweep) signal [8], with a band of 20 Hz-22 kHz, with a duration of 15 seconds and an amplitude of -6 dBFS (Fig. 2). The LSS signal used is an exponentially increasing sweep signal, characterized by equation (6).

$$x(n) = \sin\left[\frac{T \cdot \omega_1}{\ln \frac{\omega_2}{\omega_1}} \cdot \left(e^{\frac{1}{T}\ln\frac{\omega_2}{\omega_1}} - 1\right)\right] \quad (6)$$

where ω_1 and ω_2 represent the initial frequency and the final frequency of the signal respectively, T its duration.

After mounting the equipment, before starting the measurement process, it is essential to know the response characteristic of the room at rest (lack of sound). The reverberation time is measured from the impulse response untill sound attenuation by 60 dB. If the room noise at rest is higher than -60 dBFS, then the reverberation time can be measured fractionally at 20 dBFS or 30 dBFS, the final value is then extrapolated to 60 dBFS.

In this paper, we extracted the impulse responses in 18 measurement points (Figure 1), then from these measurements the reverberation time was computed. The impulse response was obtained from the convolution between the signal recorded at the measuring point P_i and the LSS signal with the reverse filter. The reverberation time T60 of the room is the highest value obtained from measurements at several measurement points.

We checked the optimal number of students for the classroom volume and calculated the critical distance with equation (2). The next step is to extract the objective acoustic parameters from the impulse responses.

b. Experimental setup

The used sound source is an omni-directional source OmniSource 4295 Loadspeaker Brüel & Kjær. The measuring microphones used are PCB 130E20, located in the listening area at the measuring points, in accordance with the ISO3382-1 standard. There are 18 measuring points P_1 ... P_{18}, organized in 3 columns and 6 rows. The measurement signal is of LSS type and is created with the Adobe Audition application with the Aurora plugins [10] and played through the amplification system with the help of the Behringer Eurorack MX10 mixer. For the signal processing we used the ASUS-Lamborghini VX1 laptop. With the help of the ARTA application [11], the values of the objective acoustic parameters were extracted from the impulse responses.

III. EXPERIMENTAL RESULTS

We calculated the maximum number of students for the classroom in the experiment, dividing the classroom volume by 576 m^3 at the limits recommended in [6]. The result was that the hall could accommodate a maximum of 144 students. Of course, this information does not take into account the mood of the listeners in the room in relation to the place where the sound source is located, nor the geometry and reverberation time of the room.

The first measurement performed in the classroom was that of noise with the room at rest (lack of sound). The measurements showed that at low frequencies, noise peaks appear at -45 dBFS. For this reason, to validate the reverberation time values, we measured T30. The values corresponding to the 18 measuring points, obtained using ARTA software, were introduced in Table 1. As it can be seen, the highest reverberation time, 1.7 s, was recorded in the middle of the room, at points P_9, P_{10}, P_{11}, P_{12}. These measuring points completely cover rows 7, 8, and 9, ie 30 seats.

Knowing T_{60} value, we calculated the CD and found CD = 0.97 m. Inside a circle around the sound source, with a radius equal to the critical distance, the classroom does not influence the quality of the received sound reception. Outside this imaginary circle, the energy of the sound waves reflected inside the classroom is greater than the energy of the direct sound wave. Therefore, in this area, the audience perceives a sound distorted by the closed space. The higher the energy of the reflected waves than that of the direct sound is, the more the quality of the reception is lost.

All places in the classroom are positioned beyond the critical distance. Therefore, the acoustics of the classroom influence the sound directly between the sound source and the receivers. How great is this influence, we found out after extracting the objective acoustic parameters from the impulse responses at each measurement point. using the AURORA plugins attached to the Adobe Audition application. The values of the acoustic parameters are in Table2, Table 3 and Table 4, respectively.

The quality of the sound received by the students can be appreciated very well from the values of the parameters. For better visualization, we prepared Table 5, Table 6, Table 7, and Table 8, respectively for each parameter, in which we highlighted the measurement points where the quality of the sound is good.

For the voice signal, analyzing the objective parameter from Table 5, we notice that only in the first two rows of the measurement points the received sound has a good quality. The best sound is received in P2. Here only very high frequencies suffer, but being a vocal signal, we can say that at point P2 and within a radius of 1 m around this point, the highest quality acoustic signal is received.

Table 1 The reverberation time values

T60 [s]		Octaves [Hz]						
		125	250	500	1000	2000	4000	8000
Measuring Points	P1	1.4	1.5	1.5	1.6	1.5	1.3	0.9
	P2	1.3	1.4	1.5	1.6	1.6	1.3	0.8
	P3	1.3	1.5	1.4	1.6	1.6	1.3	0.9
	P4	1.3	1.6	1.5	1.6	1.6	1.3	0.8
	P5	1.2	1.6	1.4	1.6	1.6	1.3	0.9
	P6	1.3	1.5	1.5	1.6	1.6	1.3	0.8
	P7	1.2	1.5	1.4	1.6	1.6	1.3	0.9
	P8	1.2	1.5	1.4	1.6	1.5	1.3	0.9
	P9	1.3	1.4	1.5	1.7	1.6	1.3	0.9
	P10	1.2	1.4	1.4	1.7	1.7	1.3	0.9
	P11	1.2	1.6	1.4	1.7	1.5	1.3	0.9
	P12	1.2	1.6	1.5	1.7	1.6	1.3	0.8
	P13	1.3	1.5	1.5	1.6	1.6	1.3	0.9
	P14	1.3	1.5	1.4	1.6	1.6	1.3	0.9
	P15	1.3	1.4	1.4	1.6	1.7	1.3	0.9
	P16	1.4	1.5	1.5	1.6	1.6	1.3	0.9
	P17	1.2	1.6	1.5	1.6	1.6	1.4	0.9
	P18	1.4	1.4	1.4	1.6	1.6	1.3	0.9

Table 3 The C_{80} values

C80 [dB]		Octaves [Hz]								
		63	125	250	500	1000	2000	4000	8000	16000
Measuring Points	P1	2.0	0.8	-3.3	0.4	-0.3	0.2	2.0	3.0	3.8
	P2	4.9	2.0	2.6	1.6	1.9	1.4	4.0	6.4	8.0
	P3	4.7	1.6	2.1	0.8	-0.1	-0.2	2.6	5.7	5.6
	P4	3.2	1.9	-1.5	-1.1	-0.5	-0.1	2.2	3.1	4.9
	P5	3.9	3.1	1.0	1.8	0.1	0.6	2.3	5.1	6.9
	P6	0.3	1.0	1.5	1.2	0.4	0.7	1.8	3.5	5.4
	P7	0.1	0.5	-0.2	-0.3	-0.2	-0.1	0.8	2.9	5.0
	P8	2.4	2.0	0.9	0.2	-0.1	-1.3	1.1	4.6	6.6
	P9	0.8	-1.6	-3.4	-0.7	-0.9	-1.8	0.6	3.5	4.9
	P10	2.2	-0.5	0.7	0.2	0.1	0.2	1.1	4.2	5.1
	P11	2.6	0.2	-5.1	0.1	0.4	-1.0	1.0	3.6	5.1
	P12	3.2	-1.3	-3.4	-0.4	-1.0	-0.9	0.6	3.2	4.2
	P13	-2.9	0.5	0.8	-0.3	-1.6	-0.3	0.7	3.5	5.0
	P14	-0.5	-5.1	-2.5	-0.4	-1.4	0.4	1.4	2.9	4.7
	P15	-1.1	-0.1	-1.7	0.1	0.0	-1.4	0.5	2.9	4.2
	P16	-0.8	-0.6	0.3	0.3	-1.3	-0.6	1.5	4.3	5.4
	P17	-3.2	2.5	2.4	0.4	-1.8	-0.9	0.9	2.7	4.5
	P18	5.6	1.0	0.1	-2.1	-2.0	0.0	1.0	3.8	4.9

Table 2 The C_{50} values

C50 [dB]		Octaves [Hz]								
		63	125	250	500	1000	2000	4000	8000	16000
Measuring Points	P1	1.1	-2.8	-4.0	-2.3	-2.2	-1.5	0.2	1.0	1.7
	P2	1.5	1.5	1.3	0.5	-0.2	0.2	2.6	4.9	6.4
	P3	2.5	-0.6	1.5	-0.9	-2.1	-1.7	1.1	3.9	3.6
	P4	1.5	1.5	-4.1	-3.2	-3.0	-2.0	0.2	1.3	2.6
	P5	2.1	1.6	-1.9	-0.1	-1.5	-1.0	0.2	3.0	5.0
	P6	-0.6	-0.4	-4.0	-0.4	-1.0	-2.0	0.1	1.6	3.5
	P7	-3.5	-0.6	-2.7	-3.5	-2.7	-3.2	-1.2	0.6	2.7
	P8	0.4	-0.1	-1.8	-2.6	-2.6	-4.2	-1.0	1.2	4.0
	P9	-2.1	-2.8	-7.0	-3.2	-2.9	-4.4	-2.1	1.1	2.5
	P10	-2.2	-2.5	-2.2	-2.6	-2.2	-2.0	-1.0	1.4	2.8
	P11	-1.2	-3.2	-7.2	-2.0	-2.8	-3.2	-1.2	1.9	2.9
	P12	-0.7	-2.9	-4.9	-4.1	-3.7	-3.5	-2.0	0.5	1.5
	P13	-9.1	-3.4	-3.4	-4.2	-4.3	-2.2	-1.6	1.2	2.5
	P14	-1.3	-7.4	-5.9	-3.3	-2.9	-2.8	-0.8	0.6	2.3
	P15	-2.5	-4.6	-3.8	-2.5	-2.3	-5.0	-1.9	0.7	1.9
	P16	-3.1	-3.7	-0.7	-2.8	-3.2	-3.3	-0.9	2.4	3.3
	P17	-4.1	-5.0	1.0	-3.4	-3.6	-4.5	-1.9	0.0	2.2
	P18	3.5	-4.2	-1.4	-3.7	-4.0	-2.5	-1.0	1.9	2.9

Table 4 The D_{50} values

D50 [%]		Octaves [Hz]								
		63	125	250	500	1000	2000	4000	8000	16000
Measuring Points	P1	56	34	29	37	37	41	51	55	60
	P2	58	59	57	53	49	51	65	76	81
	P3	64	47	59	45	38	41	56	71	70
	P4	59	59	28	32	33	39	51	57	64
	P5	62	59	39	49	41	44	51	66	76
	P6	46	48	28	48	44	39	50	59	69
	P7	31	47	35	31	35	32	43	54	65
	P8	52	50	40	36	35	28	44	57	71
	P9	38	34	17	32	34	27	38	56	64
	P10	37	36	37	36	38	39	44	58	65
	P11	43	32	16	39	34	32	43	61	66
	P12	46	34	24	28	30	31	39	53	59
	P13	11	32	31	27	27	38	41	57	64
	P14	43	15	21	32	34	35	45	53	63
	P15	36	26	29	36	37	24	39	54	61
	P16	33	30	46	34	32	32	45	64	68
	P17	28	24	56	31	30	26	39	50	62
	P18	69	27	42	30	28	36	44	61	66

Table 5 The measuring points where the C_{50} values are in the recommended range

Frequency	C_{50} The recommanded values are between [0, 5] dB																	
63 Hz	P1	P2	P3	P4	P5	P6		P8				P12						P18
125 Hz		P2	P3	P4	P5	P6	P7	P8										
250 Hz		P2	P3													P16	P17	
500 Hz		P2	P3		P5	P6												
1 kHz		P2				P6												
2 kHz		P2			P5													
4 kHz	P1	P2	P3	P4	P5	P6		P8						P14		P16		P18
8 kHz	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
16 kHz	P1		P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18

Table 6 The measuring points where the C_{80} values are in the recommended range

Frequency	C_{80} The recommanded values are between [-3, 5] dB																	
63 Hz	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16		
125 Hz	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13		P15	P16	P17	P18
250 Hz	P1	P2	P3	P4	P5	P6	P7	P8		P10			P13	P14	P15	P16	P17	P18
500 Hz	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
1 kHz	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
2 kHz	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
4 kHz	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
8 kHz	P1			P4		P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
16 kHz	P1			P4			P7		P9			P12		P14	P15		P17	P18

Table 7 The measuring points where the D_{50} values are in the range of [45, 55] %

Frequency	D50 The values between [45, 55] %																	
63 Hz						P6		P8				P12						
125 Hz			P3			P6	P7	P8										
250 Hz																P16		
500 Hz		P2	P3		P5	P6												
1 kHz		P2																
2 kHz		P2																
4 kHz	P1			P4	P5	P6								P14		P16		
8 kHz							P7					P12		P14	P15		P17	
16 kHz																		

Table 8 The measuring points where the D_{50} values are in the range of [40, 60] %

Frequency	D50 The values between [40, 60] %																	
63 Hz	P1	P2		P4		P6		P8			P11	P12		P14				
125 Hz		P2	P3	P4	P5	P6	P7	P8										
250 Hz		P2	P3													P16	P17	P18
500 Hz		P2	P3		P5	P6												
1 kHz		P2			P5	P6												
2 kHz	P1	P2	P3		P5													
4 kHz	P1		P3	P4	P5	P6	P7	P8		P10	P11		P13	P14		P16		P18
8 kHz	P1			P4		P6	P7	P8	P9	P10		P12	P13	P14	P15		P17	
16 kHz	P1											P12						

The next measuring point, where the received sound has a good quality is P3. Here, the sounds have a good quality less at the frequencies of 250 Hz and 1 kHz. The most problematic frequency is 250 Hz.

This frequency can often be found in the voice of a teacher during the lectures. The 1 kHz frequency is unlikely to be reached by a teacher with his or her voice during classes. In points P5 and P6, an acceptable sound is received, but in the rest of the class, because we far exceed the critical distance, we cannot receive a quality vocal sound. As we see in Table 2, C50 values at low frequencies reach values below 0 dB, which indicates that the classroom is a reverberant chamber at these frequencies. Because of this, the voice signal is deficient in most listening areas.

By observing the objective acoustic parameter D50, and knowing the value of 50% for an ideal intelligibility, we made two tables of values. In the Table 7, we illustrated the values that are very close to the ideal value of D50, namely we assess the range of values [45, 55]%. Thus, nowhere in the classroom we have a place to receive a perfect sound. In the Table 8 we widened the range between [40, 60]%. Far from ideal, but still intelligible, as it resulted from the interpretation of parameter C50, the measuring points P2 and P3 recorded the most intelligible sound received, followed by points P5 and P6 respectively. As in the case of parameter C50, an area is observed in the middle of the classroom where a lower quality sound is received. From Table 1 it can be seen that in that area the reverberation time has the highest value (1.7 s).

If parameters C50 and D50 respectively illustrate poor reception of the voice signal, the parameter C80 indicates a very good reception of the complex signal (Table 6). The complex signal is a signal specific to multimedia applications that uses other types of signals played back by sound equipment (a mix between music and speech). In this case, the points closest to the sound source (points P2, P3, P5, P6) lose from the high frequencies. Table 3 indicates that high frequencies (above 8 kHz) are absorbed in those audience areas. In general, the quality of the complex sound received by students is very good.

IV. CONCLUSIONS

In this paper we evaluated the sound quality in a classroom of the Technical University of Cluj-Napoca. The sound quality influences the students' ability to concentrate and assimilate information. Due to the pandemic, a statistic of the relative perception of the students could not be performed. Using equipment appropriate to the measurement process, we reproduced in the classroom an LSS-type measuring signal and received it in 18 measuring points covering the listening surface. By convolving the received signal with the LSS signal through the reverse filter, we obtained the impulse response corresponding to each measuring point. From the impulse responses we extracted the objective acoustic parameters and with their help we analyzed the quality of the acoustic signals received in the listening area.

We computede the critical distance from the sound source. This distance of 0.97 m indicated that the entire audition area is within the sphere of influence of the acoustics of the classroom. The highest value of reverberation time was recorded in the middle of the listening area.

We extracted the values of the objective acoustic parameters C50 and D50, specific to a voice signal and of the parameter C80, specific to complex signals (voice and music). The voice signal is received very well only in the area closest to the sound source. As we move away from the sound source, the signal quality becomes weaker and weaker, with the lowest quality signal being received in the middle of the audience area, where the reverberation time is also the longest. The complex signals, easily specific to multimedia equipment used by teachers, reach a very good quality in the whole listening area, except for the closest listening points to the sound source, where the high frequencies are absorbed.

The fact that the analysis performed in this paper indicates that the voice signal is not received at an appropriate quality, does not mean that it is not heard or understood at all. This analysis shows that in areas where the values of objective acoustic parameters are not in the recommended areas, the effort of concentration performed by the students to receive information transmitted by the teacher, is much higher and this directly affects the process of understanding and assimilating knowledge.

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