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Analysis of Dome Home Hall Theatre Acoustic Field

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The modelling of compartment in simulation software enables determination of acoustic parameters' distributions in a virtual compartment. The elementary question is how much the simulations reflect the actual state in a room. Analysing the acoustics of dome-shaped compartments, i.e. for instance various basilicas, a conclusion can be drawn that the acoustics of these objects is very good. Therefore the authors decided to analyse the influence of a dome shape on acoustic parameters of the compartment.

Keywords: dome home hall, acoustic field

1. Introduction

Taking into consideration the number of seats (188 seats in the auditorium), the Dome Home Hall of Theatre Groteska in Kraków can be classified to the group of small theatre halls. However for the sake of the atypical form, it is an interesting hall in respect of acoustics. It has a dome form of a diameter of 19 meters at the base. The total volume of the compartment is about 2800 m^3. The audience is placed approximately on a half-round plan in seven rows. The sound system consisting of two woofers SWA 1501 Mackie, two mid-tone SRM 450 Mackie column loudspeakers, and four mid-high-tone SRM 350 Mackie column loudspeakers is arranged in such a way, that woofers and SRM 450 loudspeakers are located in pairs symmetrically on both sides of the scene, and SRM 350 loudspeakers are located behind the audience.

According to relations of various type of spectators (both the classical theatre and musicals or concerts) the conclusion arises, that generally speech transmission and music perception is rather good. The only exception are the upper seats of the audience, where the stereo perception is difficult, especially in the meaning of perception of the music played.

The planned modernisation of the discussed compartment prompted the authors to carry out the analysis and to perform measurements. Verification of the accuracy of analytical results compared to measurements was to enable verification of how much the simulations reflect the actual state. Thereafter, the acoustic climate of the compartment was simulated only by changing its form. The use of the simulation software enabled the verification of distributions of particular acoustic parameters' in a virtual compartment. It should be emphasized though, that all simulation software is only reflecting the reality in a major or minor degree. On the one hand, it is an effect of methodology used by software to calculate acoustic parameters, and on the other hand – the effect of modelling [5, 7, 9, 10, 14].

Objective acoustic parameters provide the acoustical information specific for each hall, depending on the shape of room and the materials used in the object. All parameters can be measured as well as calculated in simulation softwared [2, 9, 12]. Acoustic parameters have specific values for each type of a hall – depending on the theatres are described at [2, 6, 13].

Model's correctness can be easily verified by comparison of the results obtained from the simulation, with the results obtained in the experiment in a real compartment.

2. Digital model

The actual view of the compartment the Dome Home Hall of the Groteska Theatre in Kraków, is presented in Fig. 1.

Fig. 1. View of the Dome Home Hall of Groteska Theatre.

Basing on the technical documentation, a model of the discussed hall was designed in AutoCAD software. Then specified materials were attributed to the particular surfaces (comparable to those in real conditions) with its reverberation absorption coefficients.

3. Simulation

To prepare a simulation, the RAYNOISE software was used, which forecasts and analyses acoustic conditions in both the closed compartments and open spaces. In its calculations, RAYNOISE is based on a geometrical cone method. Like the remaining geometrical methods, it relies on course of spherical wave front, which propagates in the compartment. Two primary geometrical methods are the ray method and the image sources method. They base on the following assumptions [3]:

- wave's reflection (similarly to optics) is in accordance with Snell's law, i.e. the reflection angle is equal to the incidence angle;
- wave path between two consecutive reflections is the straight line's section;
- the effects of wave phenomena are neglected, i.e. scattering, diffraction and superposition of the waves.

It should be pointed out though, that using the numerical proceeding in modelling enables the examination of wave effects.

The cone method, which was used in simulations, evolved from the ray method. In this methodology, the sound corpuscles' trajectories sent from the source create axis of energy bundles comprising the same solid angle, in which a spherical wave's sector runs. The reflection from walls proceeds, as it was mentioned above, in accordance with the geometrical acoustic laws. The observation point is stated as a geometrical point. At the moment of passage of the acoustic wave's sector through the observation point, the arrival time to this point is calculated, so is the wave energy density (its decreasing with a square of the travelled distance is taken into consideration in the methodology).

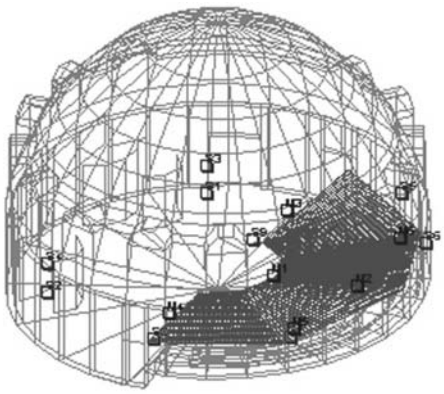

Fig. 2. Grid of the compartment in the Raynoise simulation software (S points – location of loudspeaker columns, U points – location of measurement points).

Materials used in the model (according to the real conditions) and its reverberation absorption coefficients are presented in Table 1.

Table 1.

Material	Absorption coefficient α					
	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Concrete floor with fitted carpet	0.04	0.04	0.15	0.3	0.5	0.6
Linoleum	0.2	0.15	0.08	0.05	0.03	0.02
Plaster	0.18	0.2	0.24	0.26	0.28	0.3
Chairs	0.384	0.483	0.509	0.66	0.803	0.817
Wooden door	0.15	0.1	0.06	0.08	0.1	0.05
Velour Curtain	0.05	0.12	0.35	0.48	0.38	0.36
Glass	0.1	0.07	0.05	0.03	0.02	0.02

The analysis was performed for an empty hall (without the audience and the stage scenery), so in the least beneficial acoustic conditions. Background noise in the compartment was assumed on the level of 35 dB.

The analysis was performed with use of the cone method, in which 2000 rays were used per every source and up to 6 surface reflections were examined. It was made in two versions: for electro-acoustic installation and for loudly speaking persons.

The reverberation time was calculated by the software in two ways (with a statistical Sabine's method and basing on the echogram obtained as a result of simulation with the use of cone method) – the results are presented in Table 2.

Table 2.

Method		Reverberation time in octave bands [s] as a result of simulation							
		63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Sabine's method		2.49	2.48	2.05	1.26	0.96	0.88	0.79	0.63
Basing on the echogram	p1	2.2	2.2	1.9	1.3	1.1	1	0.9	0.6
	p2	4.3	4.3	3.6	2.3	1.6	1.4	1.2	1
	p3	2	2	1.7	1.2	0.9	0.8	0.8	0.7
	p4	2.5	2.5	2.2	1.5	1.2	1	0.9	0.8
	p5	4.5	4.5	3.8	2.3	1.7	1.4	1.2	1
	p6	4.8	4.8	4	2.3	1.6	1.3	1.2	1

Example echograms obtained in Raynoise software by the cone method are presented in Figs. 3 and 4. In Fig. 3, an echogram of 63 Hz octave band is presented for the first measuring point located in the first row in the centre of audience.

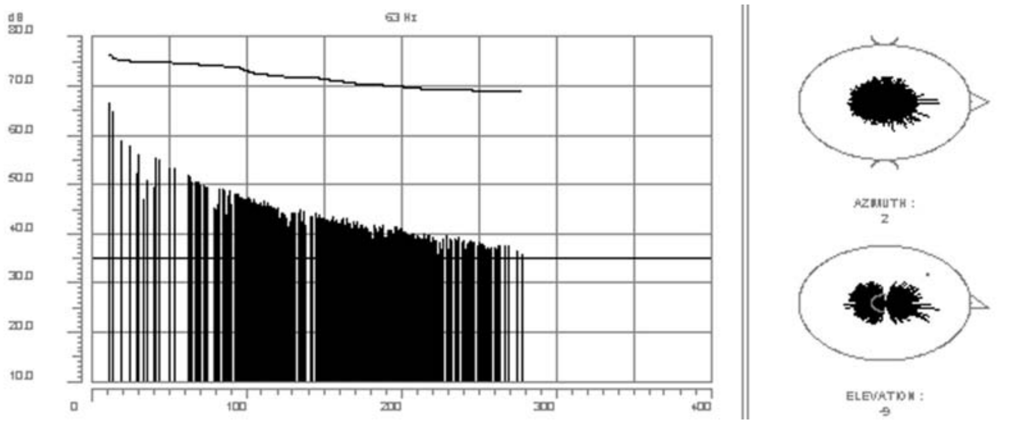

Fig. 3. Echogram for the first measuring point obtained in Raynoise software.

In Fig. 4 an echogram of 63 Hz octave band is presented for the point located on the stage.

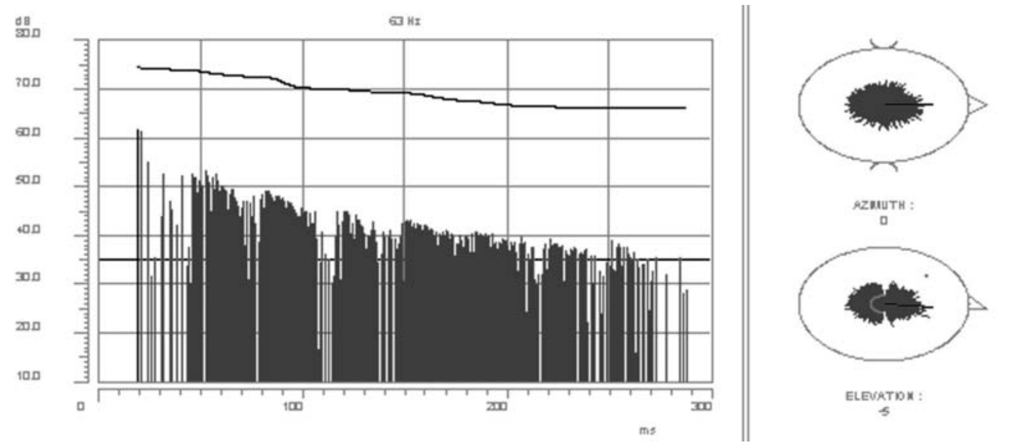

Fig. 4. Echogram for the point located on the stage obtained in Raynoise.

Because the reverberation time is only one of the aspects of compartment's acoustic climate, distribution of other acoustic parameters was determined by simulation [8,11]:

- Sound pressure level (SPL) was defined as:

$$SPL = 10 \log \frac{p_{\text{eff}}^2}{p_0^2} \ \ [\text{dB}], \tag{1}$$

where p_{eff} – the acoustic pressure; p_0 – the reference pressure, $p_0 = 2 \cdot 10^{-5}$ [Pa].

The acoustic pressure is the result of superposition of pressures of all reflections in the examined point.

• Speech transmission index (STI). It is an objective criterion characterising the speech transmission. Loss of speech signal transmission is caused by reflections, interference and background noise. Singular sinusoids, as a part of speech signal, has to be kept to maintain the clarity of sound. Modulation Transfer Function (MTF) is the equivalent of a curve expressing the sound reduction through a compartment (or generally limiting surfaces).

With the assumption that reflection process is strictly expotential, the modulation transfer index has the form of:

$$m(F) = \frac{1}{\sqrt{1 + (2\pi F * RT/13,8)^2}} - \frac{1}{1 + 10^{-\frac{SNR}{10}}}, \tag{2}$$

where T – reverberation time [s]; SNR – Signal-to-Noise Ratio [dB]; F – modulation frequency [Hz].

Generally, MTF was accepted as a normalized Fourier's transform of impulse response in scope of 0.25–32 Hz frequencies

$$MTF(F) = \frac{\left|\int\limits_0^\infty e^{2\pi Ft} p^2(t)\,\mathrm{d}t\right|}{\int\limits_0^\infty p^2(t)\,\mathrm{d}t} \cdot \left[1 + 10^{-\frac{SNR}{10}}\right]^{-1/2}. \tag{3}$$

STI is an average and normalized value of MTF.

• Direct SPL as a level of acoustic pressure without sound pressure from all reflections.

• Clarity. C_{80} clarity uses an index of 80 ms value as a threshold of music comprehension. It is defined as a common logarithm of a quotient between an E_{80} sound energy incoming to the receiver up to 80 ms after direct sound and energy incoming after 80 ms ($E_\infty - E_{80}$).

$$C_{80} = 10 \lg \frac{E_{80}}{E_\infty - E_{80}} \quad \text{[dB]}. \tag{4}$$

It is assumed that in compartments of proper acoustic conditions, differences between C_{80} values in various points should not exceed the level of 3 dB.

• Definition. It is one of the measures of a speech transmission. It compares "usable" sound with a total one. "Usable" sound is such a sound, which arrives to the receiver not later than after 50 ms after direct sound. Definition D_{50} is a ratio between the E_{80} sound energy incoming to the receiver up to 50 ms after direct sound and E_∞ is the total energy. Its value is given in [%].

$$D = \frac{E_{50}}{E_\infty} \quad [\%]. \tag{5}$$

$D = D_{50} \geq 50\%$.

The acoustic field parameters' distributions are presented in Figs. 5–9 (*a* variant – for electro-acoustic installation, *b* variant – for human speech). These are distributions of acoustic parameters on receivers' surfaces, so in this case, at the level of spectators' heads (1.4 m).

a) b)

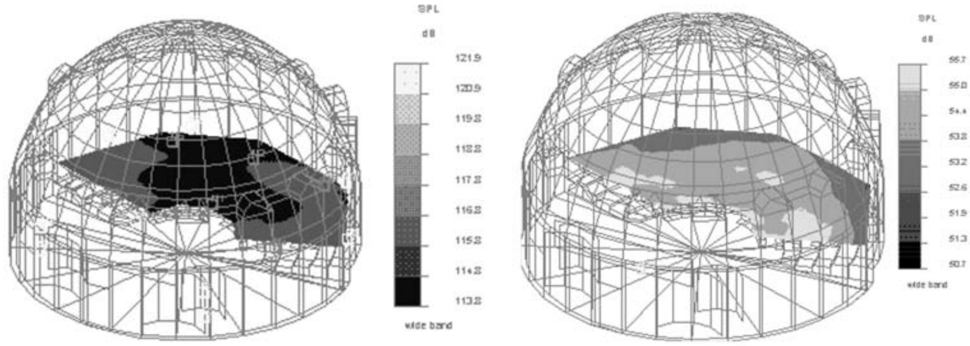

Fig. 5. SPL distribution on the audience for: a) electro acoustic installation, b) human speech.

a) b)

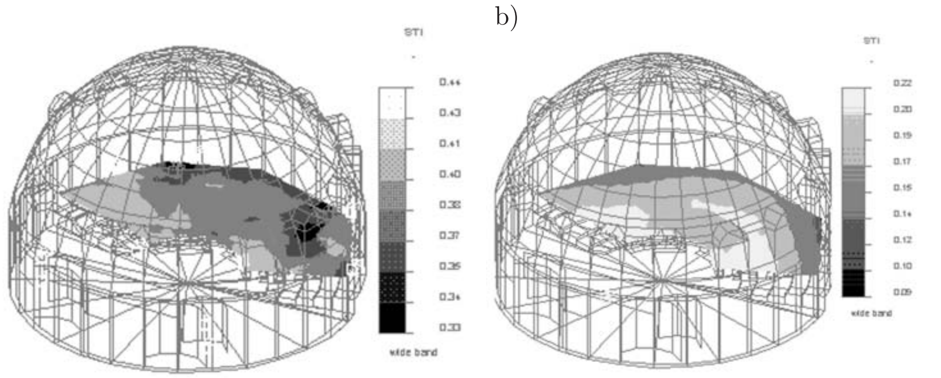

Fig. 6. STI distribution on the audience for: a) electro-acoustic installation, b) human speech.

a) b)

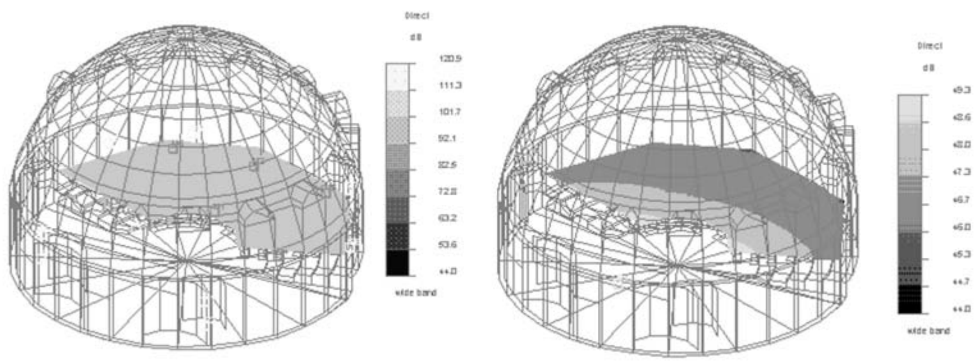

Fig. 7. Direct SPL distribution on the audience for: a) electro-acoustic installation, b) human speech.

a) b)

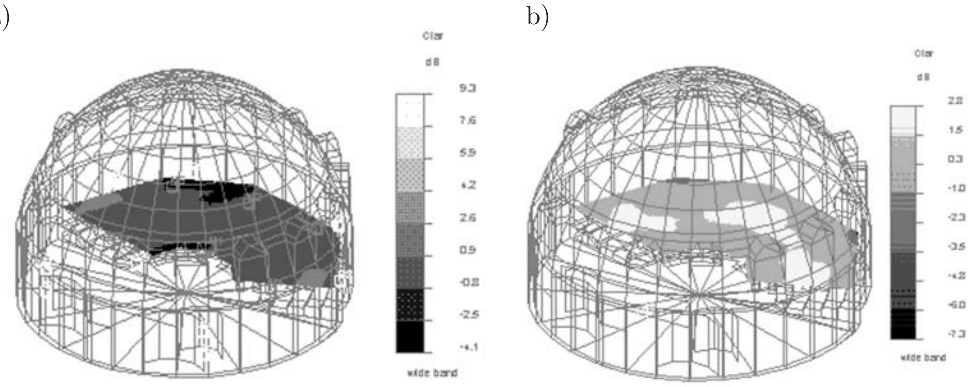

Fig. 8. Clarity parameter distribution on the audience for: a) electro-acoustic installation, b) human speech.

a) b)

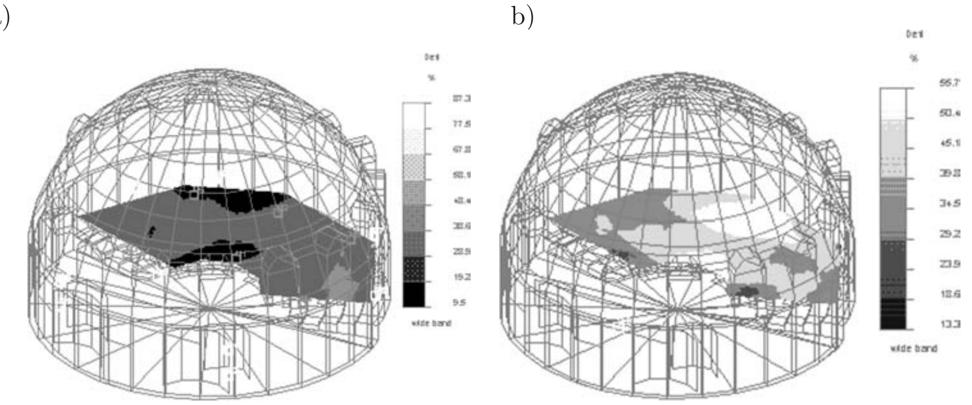

Fig. 9. Definition parameter distribution on the audience for: a) electro-acoustic installation, b) human speech.

From the maps presented above one can infer, that the level of sound pressure reaches high values (above 110 dB), particularly in cases when the sound system is used. Values of Direct SPL are similar. In case of music reception, situation is also comparatively good (difference between the values is close to 3 dB). Whereas obtained STI values are anxious, so is the Definition, what speaks of speech comprehension. From the determined reverberation time and from SPL value it could be assumed that speech transmission would be good (reverberation time in scope of 1s and above in human voice band). Unfortunately, values contain below 0.4, even with an extra amplification of the speaker with an electro-acoustic installation (for "clean" speaker's voice in the scope of 0.2), so in case of electro-acoustic installation are merely weak, and for the person speaking without any amplification are even unacceptable. These results are anxious also for the reason of, as it was mentioned in the introduction, spectators' opinions of rather fair speech transmission.

4. Experiment

Measurement in real conditions was performed basing on the standard [4]. A random-type signal in form of a Maximum Length Sequence (MLS) was used in reverberation time measurements. There were only two persons performing the measurement present in the hall. There were no requisites placed on the stage. The discussed hall has no curtains on the stage. Measurements were performed in 6 points, and its distribution is presented in Fig. 10.

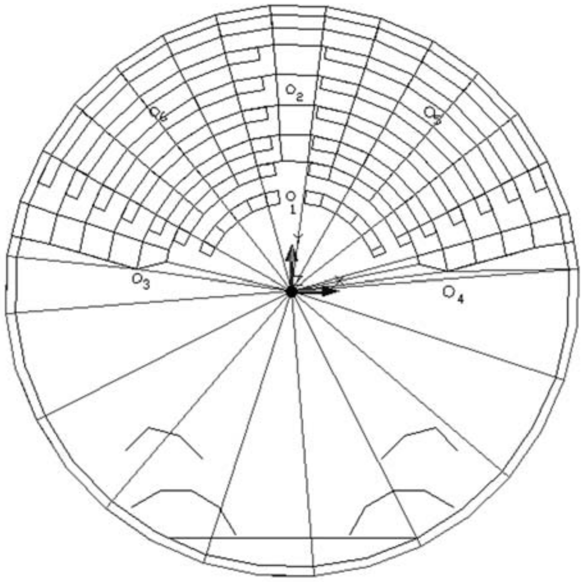

Fig. 10. Distribution of measurement points.

To generate MLS noise and to record impulse responses, the Sample Champion software was used, which serves to perform acoustic measurements and for real time data processing. It enables to determine both the compartment's impulse responses and loudspeaker's frequency responses using a MLS sequences. During the measurement, the following instrumentation was used: Behringer ECM 8000 microphone, GU 50 Beyma loudspeaker column, Elmuz Stereo Power 2158M amplifier, PreSons Firepod 24 Bit/96 kHz sound card and a computer with Sample Champion software installed. During the measurement, the loudspeaker was located in the middle of the stage (in view of a small compartment's size, measurements were performed in only one sound source location). A scheme of a measurement stand is presented in Fig. 11.

Reverberation time values in octave bands for every measurement point were obtained from the Sample Champion software. Basing on these, with the use of an arithmetic averaging, the average reverberation time of the compartment was determined. The results matching are presented in Table 3.

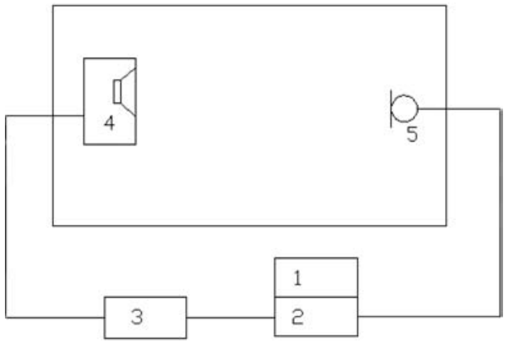

Fig. 11. Scheme of measurement stand: 1 – PC-class mobile computer with Sample Champion software, 2 – PreSons Firepod 24 Bit/96 kHz sound card, 3 – Elmuz Stereo 2158M Power Amplifier, 4 – GU 50 Beyma loudspeaker column, 5 – ECM 8000 Behringer microphone.

Table 3.

Measurement point	Reverberation time [s]							
	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
1	2.397	2.113	1.778	1.124	1.067	1.033	0.882	0.594
2	3.238	2.751	2.681	1.583	1.503	1.119	1.059	0.652
3	2.115	2.100	1.501	1.266	1.131	0.917	0.787	0.649
4	2.340	2.242	1.756	1.480	1.163	0.978	0.795	0.665
5	2.593	2.349	2.315	2.013	1.586	1.167	0.852	0.648
6	2.924	3.788	2.239	2.170	1.480	1.226	1.125	0.64

Average reverberation time for discussed hall in octave bands is presented in Table 4.

Table 4.

	Mid frequencies of octave bands							
	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
RT[s]	2.6012	2.5572	2.045	1.606	1.3217	1.0733	0.9167	0.6343

5. Definition of "Q" quality of the model

To define the model's correctness, which is dependent on real conformity of conditions and on precision of software's simulation, reverberation time values in octave bands obtained from the simulation were compared with the reverberation time values in octave bands obtained from the real compartment measurements.

Diagram of a reverberation time for a measurement and a simulation is presented in Fig. 12.

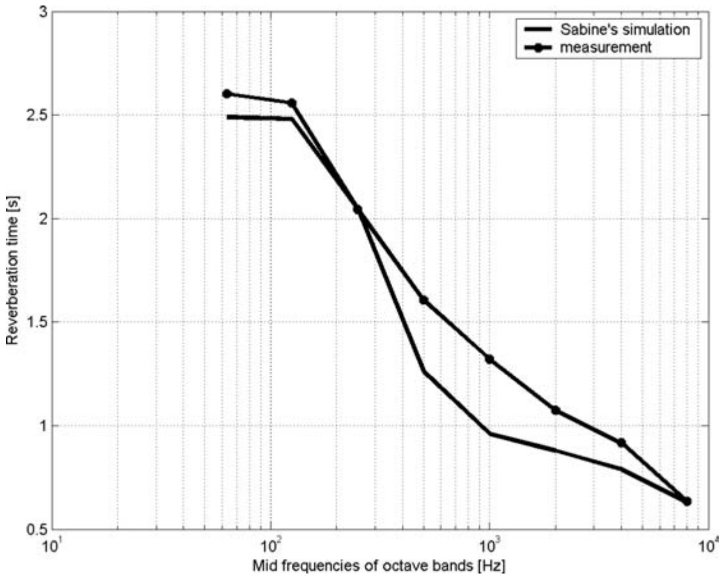

Fig. 12. Diagrams of reverberation time in octave bands for measurement and simulation by statistical method and an average reverberation time obtained from measurements.

Quality (effectiveness) of the model can be determined by the following formula:

$$Q = \left|\frac{\Delta x}{x}\right| \cdot 100\%, \tag{6}$$

where

$$\Delta x = x - x_{\mathrm{real}}, \tag{7}$$

x_{real} – reverberation time value obtained from measurement, x – reverberation time value obtained from simulation.

Results for particular bands are presented in Table 5.

Table 5.

		Mid frequencies of octave bands								
		63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	Σ
Q1 (Sabine's method) [%]		4.47	3.11	0.24	27.46	37.68	21.97	16.04	0.68	**13.96**
Q2 (echo-gram) [%]	p 1	8.96	3.96	6.42	13.54	3	3.3	2	1	**5.27**
	p 2	24.67	36.02	25.53	31.17	6.06	20.07	11.75	34.8	**23.76**
	p 3	5.75	5	11.71	5.5	25.67	14.63	1.63	7.29	**9.65**
	p 4	6.4	10.32	20.19	1.33	3.08	2.2	11.67	16.88	**9.01**
	p 5	42.38	47.8	39.08	12.48	6.71	16.64	29	35.2	**28.66**
	p 6	39.08	21.08	44.03	5.65	7.5	5.69	6.25	35.7	**20.62**

6. Identification of the model

It was assumed, that the quality of a scope Q=1±20% speaks of a very high model's conformity with the reality. Because in both cases a deviation calculated for the whole band is smaller than 20% (for Sabine's method it amounts to 13.96%; for reverberation time determined from an echogram method – average is 16.16% in the whole band for all points, whereas for frequencies above 500 Hz – average is 12.58%) it can be accepted that the model is created correctly. Relatively considerable deviation for the frequency of 8 kHz can be an effect of using a material of high absorption coefficient for this frequency band in the real compartment, which could not have been used in a digital model.

7. Verification of STI calculation correctness in Raynoise software

Low STI values calculated in Raynoise software, with a reverberation time speaking of rather fair speech comprehension in the discussed compartment, inspired the authors to compare STI values obtained from Raynoise software with STI values obtained in other simulation software, based on geometrical methods. To verify the correctness of calculation of the speech transmission parameter, a simple rectangular compartment's model was built, with a single sound source located in it – a loudly speaking person. Approximately it can be stated, that it is a small auditorium hall with a carpet lying on the floor, having its walls and ceiling finished with a plaster and velour curtains mounted on the rear wall. Dimensions of this compartment are 5.5 m × 7.5 m × 4 m (geometric proportion [1]). Approximately 50 seats were provided in this compartment – these are hard, wooden chairs. Without analysis it can be supposed that speech transmission in this compartment should be fair. Results of the analysis in Raynoise software and EASE software's AURA module confirmed the hypothesis put forward before. Distributions of acoustic parameters obtained in both software are presented in Figs. 13–15.

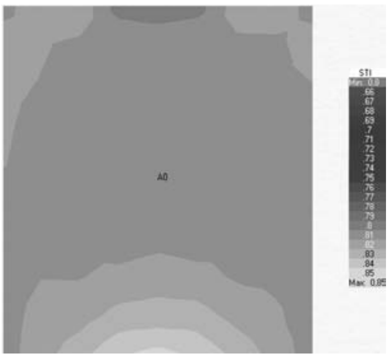

Fig. 13. STI parameter's distribution calculated in EASE software (AURA module); example of rectangular compartment – a 50 seats lecture hall.

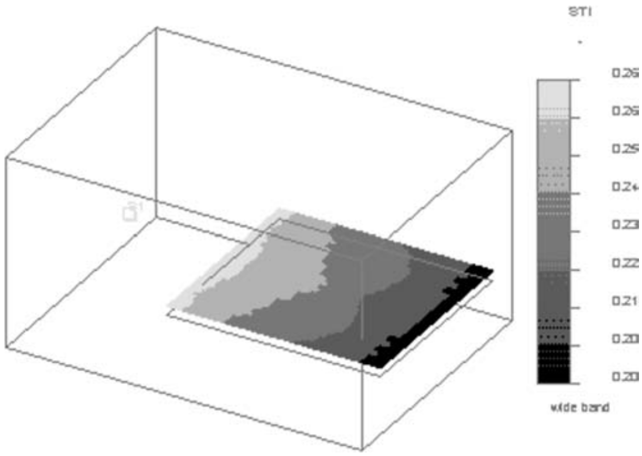

Fig. 14. STI parameter's distribution calculated in Raynoise software (using a cone method); example of a rectangular compartment – a 50 seats lecture hall.

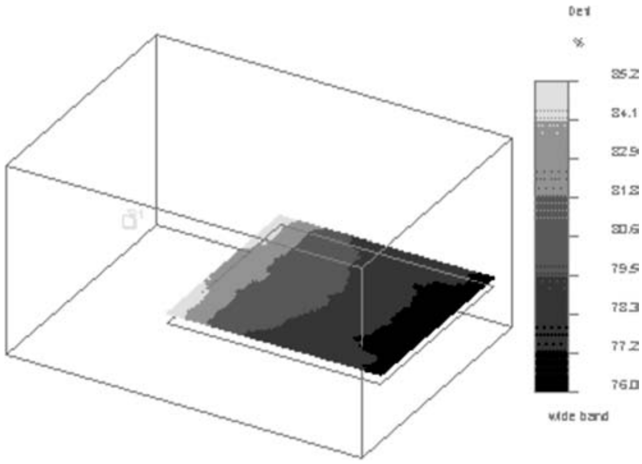

Fig. 15. Definition parameter's distribution calculated in Raynoise software in a example rectangular compartment – a 50 seats lecture hall.

From the Definition of parameter's distribution a conclusion can be drawn that because on the whole area examined D>75%, this parameter suggests a fair speech transmission. Results obtained in the EASE software also demonstrate that speech transmission in the analysed compartment is very good (STI = 0.8–0.85). Nevertheless, completely different results were obtained in case of STI parameter calculated in the Raynoise software – the results are much lower (in scope of 0.2–0.25), which can suggest definitely unfavourable acoustic conditions in the compartment and of a very poor speech transmission.

Basing on the above, a conclusion can be that values of the STI parameter calculated in the Raynoise software are significantly underrated, which is tantamount to the fact that they are wrongly determined.

8. Dome shape influence on acoustic parameters of the compartment

Except the compartment's analysis in the present form, an analysis of dome's influence on the hall's acoustic parameters was performed. The analysis of a compartment shape's influence on acoustics consisted in reducing of dome's size (decreasing the compartment's height), until the moment of assuming a cylinder form of the compartment.

In comparison, an analysis of a compartment of cylinder form and with a height equal to the real dome's height was performed. Results obtained for RaSTI parameter (with use of sound system) are presented in Figs. 16–17.

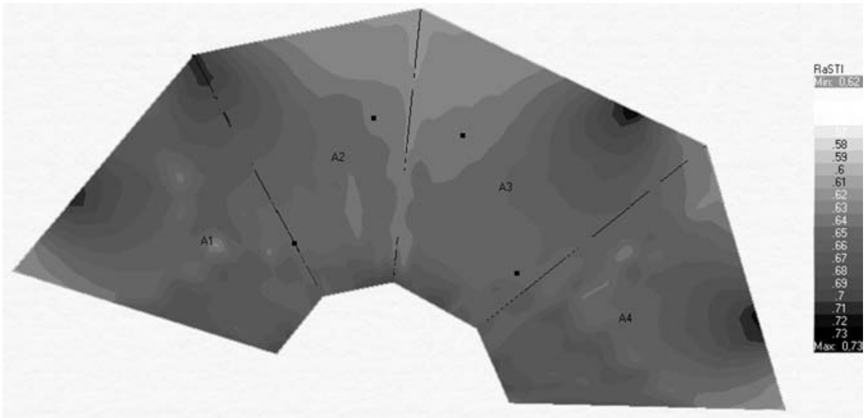

Fig. 16. RaSTI parameter's distribution in a real form compartment.

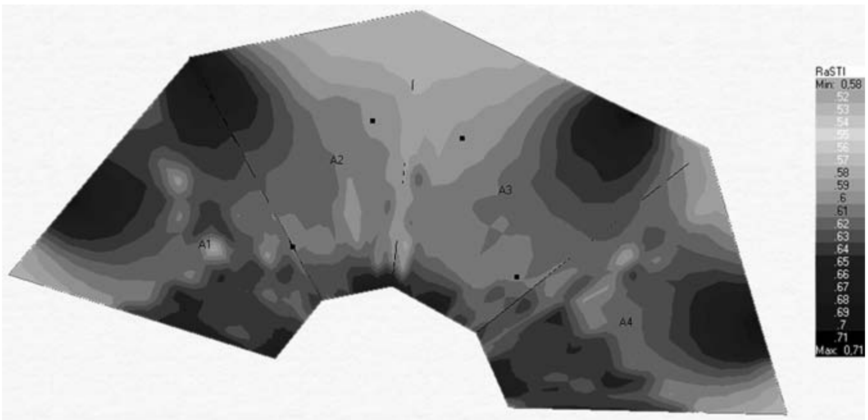

Fig. 17. RaSTI parameter's distribution in a cylinder form compartment and a height of a real dome.

Basing on above maps, it can be stated that in case of this specific compartment – the Dome Home Hall of the Groteska Theatre, a dome form reduces the values of speech transmission parameter only in the slightest degree. However, what results from the analysis, a cylinder-shaped compartment of height of 5 m could have better acoustic properties than its current shape. A dome shape of compartment achieves slightly better speech transmission values only in case of a cylinder-shaped compartment, but of height equal to the current hall's dimensions. As far as a dome shape above the stage has a positive influence on compartment's acoustics (for the sake of sound amplification for the auditorium), use of reflective surfaces or scattering structures are recommended above the audience rather than using a dome shape.

Analysing the acoustics of other dome-shaped compartments, i.e. for instance various basilicas, a conclusion can be drawn that the acoustics of these objects is fair or even outstanding in some cases. Therefore, except for symbolic meaning in case of sacral buildings, which as a whole had to symbolize the Universe, and its particular elements – cubical temple's body – the Earth, half-dome – semicircular dome of the Firmament, these domes were increasing the acoustics' quality of these buildings. A fact should be underlined yet, that the above-mentioned buildings are incomparable with the discussed hall, and furthermore in almost every case a cubicoidal part's volume is greater than a dome part's volume. Whereas in case of the Dome Home Hall of the Groteska Theatre, these proportions are distributed the other way – the dome part's volume, and so a vault's bowl of the compartment is much higher than a cylinder part's volume of the compartment. Undesirable reflections do not have a possibility to diffuse on the compartment's cylinder part's walls and practically are again reflected from the vault's bowl in a large scale, what intensifies the echo impression.

9. Analysis of acoustics on the stage

The character of theatre halls is based not only on very good acoustics in the audience, but also on very good acoustics on the stage. To achieve a smooth proceeding of the performance, assuring a fair audibility of both the music emitted from the electro-acoustic installation and a fair speech transmission for each actor is necessary. Statements of actors performing on the discussed stage indicate that the sound monitoring quality and speech transmission between actors is not good.

All the above-discussed factors brought about the decision to realise an acoustics analysis of the stage in the Dome Home Hall. Results obtained by means of a cone method in Raynoise software are presented in Figs. 18–21.

As it is visible in the above figures, admittedly the Sound Pressure Level values and Direct SPL values are high, but their distribution is fairly irregular. The situation of other acoustic parameters is similar, their distribution is also irregular. Values, which the Definition and Clarity parameters reach, are not satisfactory as well. The Definition reaches values above 50% merely in a small area, in addition to a high irregularity.

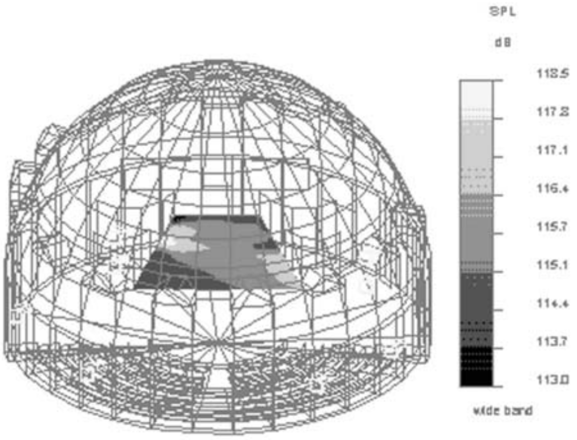

Fig. 18. SPL parameter's distribution in the area of the stage.

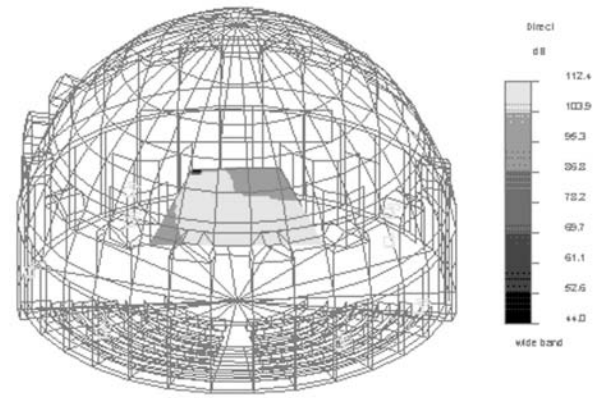

Fig. 19. Direct SPL parameter's distribution in the area of the stage.

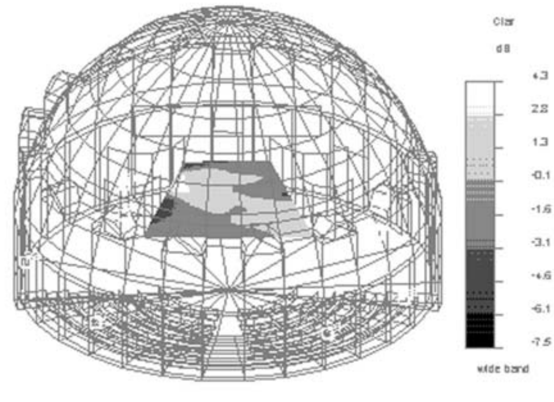

Fig. 20. Clarity parameter's distribution in the area of the stage.

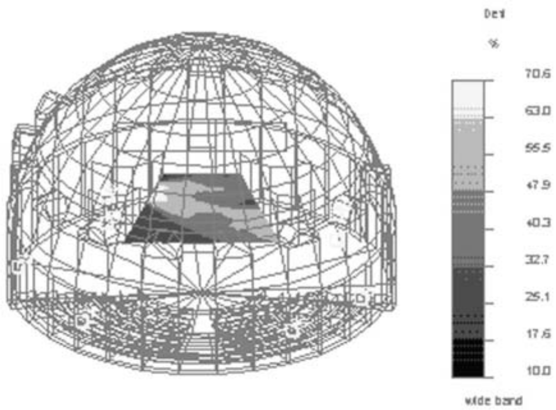

Fig. 21. Definition of parameter's distribution in the area of the stage.

A conclusion can be drawn that a fair speech transmission occurs solely in slight and very irregular stage area. A great problem is the fact that in the front of the stage, on its flanks, all parameters reach meaningfully different values. Therefore, the statements of actors concerning none too great acoustics on the stage are confirmed. Due to the obtained in Raynoise software STI results uncertainty, this parameter was not taken into account.

The problem of acoustics on the stage can be an effect of a dome form of the hall and its asymmetry.

10. Analysis of the potential of acoustic parameters' improvement in the discussed compartment

From the previous deductions it follows, that acoustics in the discussed hall is not at its best. Since there is no possibility of changing of the compartment's form – a dome over the audience can not be removed; the only and the simplest solution is application of an acoustic plaster work on the dome's part over the auditorium. A non-regular distribution of this plaster work over the analysed area was also proposed. Applied acoustic plaster work is a Sonacoustic plaster work produced by Asona (absorption coefficients in octave bands are presented in Table 6).

Table 6.

	α 125 Hz	α 250 Hz	α 500 Hz	α 1000 Hz	α 2000 Hz	α 4000 Hz
Acoustic plaster work Sonacoustic ASONA	0.68	0.92	0.73	0.71	0.84	0.88

The simulation of compartment's acoustics with applied acoustic plaster work using a cone method is presented in Figs. 22–25 (variant *a* – parameter's distribution on the audience, variant *b* – on the stage).

a) b)

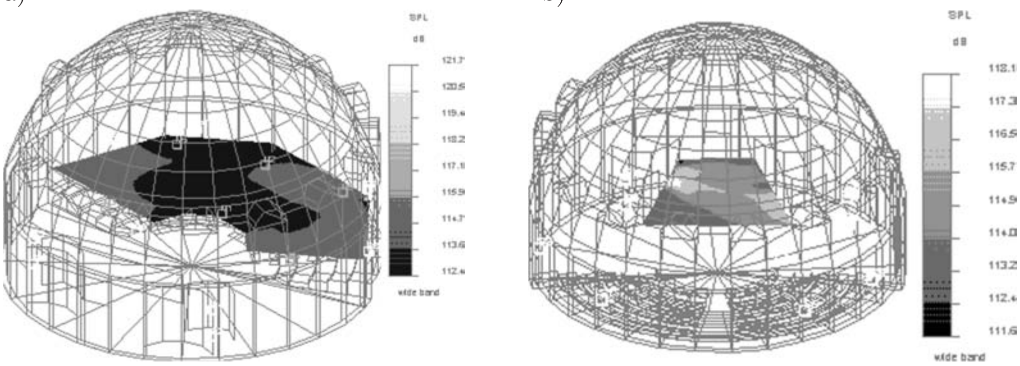

Fig. 22. SPL parameter's distribution: a) on the audience, b) on the stage.

a) b)

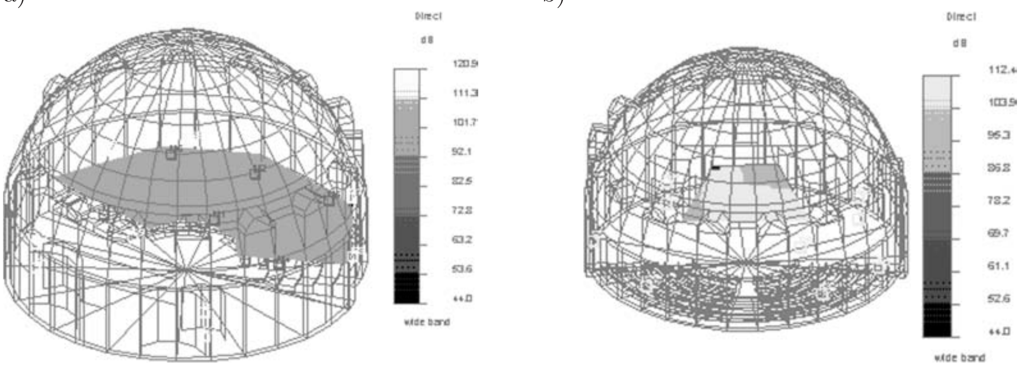

Fig. 23. Direct SPL parameter's distribution on the: a) audience, b) stage.

a) b)

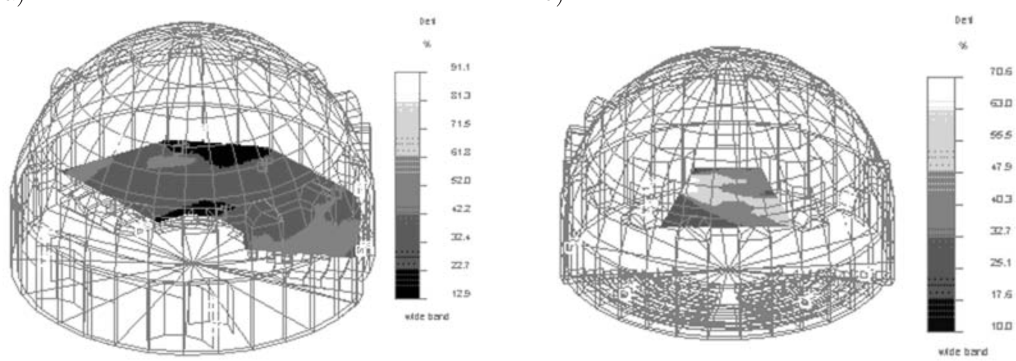

Fig. 24. Definition parameter's distribution on the: a) audience, b) stage.

a) b)

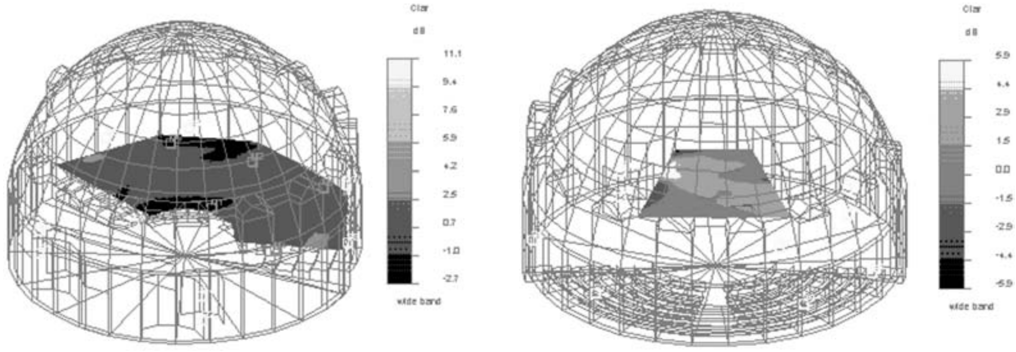

Fig. 25. Clarity parameter's distribution on the: a) audience, b) stage.

The approximate reverberation time in octave bands obtained with the use of Sabine's statistical method in Raynoise software is presented in Table 7.

Table 7.

Method	Reverberation time in octavo bands [s] as a result of simulation							
	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
by Sabine	2.02	2.02	1.64	1.20	0.94	0.83	0.74	0.60

As it can be seen, the reverberation time obtained with use of Sabine's statistical method was meaningfully reduced in scope of low frequencies (to 500 Hz). Thanks to a treatment incorporating the acoustic plaster work in the area over the audience, a Sound Pressure Level and a Direct SPL is similar to the original compartment, and simultaneously a dampening of low frequencies succeeded, which gives effect of increased average values of Definition and Clarity parameters, both on the audience and on the stage. The distribution of parameters is also more equalized. Summarizing this operation it can be stated, that even such simple treatment as application of proper plaster work can improve the compartment's acoustic quality.

11. Summary and conclusions

The modelling of a compartment in simulation software enables, with a high probability, determination of acoustic parameters' distributions in the analysed compartment. The occurring deviations are of the order of a few percent (in case of Raynoise software $< 12\%$), which is rather an effect of the simplifications used in geometrical methods implemented in the software and approximations of compartment's modeling. Several variants of arrangement of the sound-absorbing materials in the discussed compartment were performed and a couple of variants for other compartments. Variants of the same layout of similarly branded materials, but of different reverberation absorption coefficients, were also verified. The analysis of a minimal compartment's geometry changes were carried out as well. It consisted in keeping overall compartment's dimensions, and reducing the internal elements layout changes to a small degree inside these compartments. It can be stated, that all of the mentioned treatments have influence on model's sensitivity. Therefore, during modeling of compartment's acoustics, a particular attention should be paid to the types of applied materials and their layout. It is much easier in the compartment's design phase, because of simplicity of the earlier recommended materials used in a compartment which is being built later on, with keeping its interior's layout analogous to the design. The situation of already existing compartments which are subject to acoustic analysis is more complex. In this case, model's accuracy with the actual status will be greater if the precise data concerning used material layout and type can be received from architects and contractors.

In case of Raynoise software, the STI parameter values are underrated to a high degree.

A dome form is beneficial in its application over the stage (for the sake of auditorium's sound amplification), whereas over the auditorium application of other forms and sound scattering structures is recommended.

A dome form of the hall's vault, forming an acoustic mirror, causes non-beneficial echo on the stage and in its surroundings. In case of a dome-form compartments, a very substantial element is the proportion between a cylinder-formed part's volume and a dome-form part's volume – in case of large sacral buildings the volume of the first element is greater than the volume of the second one, so undesirable echo is dispersed on the walls and cylindrical part's elements. This effect cannot exist in case of the discussed Groteska Theatre's Hall, in which these proportions are distributed inversely – a cylindrical part is relatively small, and the dome part has a substantial volume. A conclusion can be drawn that in case of the discussed compartment (Dome Home Hall of the Theatre Groteska in Kraków), a dome form has more of a decorative character than compartment's acoustics improvement.

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