Positioning sound absorption – a comparative study based on different calculation methods (preliminary paper)

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Abstract

The effect of positioning of sound absorbing surfaces is studied in a number of simplified benchmark geometries using different calculation methods. Benchmark geometries have the same volumes and almost the same surface areas. Statistical formulas suggest, that positioning the same sound absorption in these cases would have no effect on the results. It is well known, however, that validity of statistical formulas depend on rate of diffusion and on the distribution of sound absorbing surfaces.

The aim of the study is to see how results from different room acoustic models correlate and to see how different room acoustic parameters relate to each other and the positions of sound absorption, with respect to the average scattering.

Keywords: room acoustics, scattering, comparison of methods.

1 Introduction

There are numerous calculation methods for basic room acoustic parameters and it is good to know exactly, when it is allowed to use simplified approximation and when creating a model is unavoidable. By the word "exactly" we mean physical parameters and limit values assigned to the probability of errors.

This paper introduces an attempt to answer some of the usual questions, based on "brute force" approach to calculate different scenarios using different methods and compare the results. Due to the high number of variations though, only a theoretical experiment could be arranged for this purpose.

To the best of the author's knowledge there has not been such an extensive experiment yet. The current experiment is an extension and re-evaluation of the experiment in [1]. The main goal of that study was to check if speech transmission index (STI) has any relevance over simple room acoustic parameters (EDT_{10}, T_{20}, C_{50}, G) and if not, which parameter can be used instead of STI. The scattering coefficient was set to 5%, 10%, 20% and 40%. For the two geometries and altogether 14 and 18 different absorption distribution, the results showed that except for certain cases mean T_{20}, EDT_{10} values decreased and STI increased by increasing scattering. Tendencies of G and C_{50} however were different, depending on the way absorption was distributed.

In paper [2] Shtrepi et al. focuses on how scattering settings are reflected by different simulation software in simple room acoustic parameters (EDT_{10}, T_{20}, C_{80}, G) and if these settings are audible in the simulated environment of a concert hall geometry. For the case of the selected geometry, somewhat different tendencies were observed, when overall scattering coefficients were changed from 10% to 30%, 50%, 60%, 70%, 90%. Tendencies did also depend on the selected modelling software and seemingly (including the summary of previous works) it was not possible to make any general rules on the effects if changing scattering.

In paper [3] Zhu et. al calculated reverberation times using a selected modelling software for different room shapes and changing the scattering from 1% to 10%, 30%, 50%, 70%, 90% and 99%. For a given basic shape, absorption coefficients and the room volume were kept constant, while other aspects of the shape were varied and later scaled to different multiples of the volume. The results of reverberation times were then evaluated and changes relative to the 1% scattering basis were calculated. As results show, T_{20} reverberation times were decreasing for all shapes, but T_{20} was most sensitive to change in scattering if the shape has parallel walls. In the case of other types of shapes, T_{20} seemed to stop decreasing if scattering was above 50%. We may conclude, that (as already suspected from theoretical background) rectangular geometries are the worst cases if scattering is low and therefore the best to show the effects of settings in scattering properties. We may note also, that any deviation from the plane and parallel walls introduces a macro scaled scattering by itself, even if the scattering coefficients for each surface are set to low values. That may also explain, why T_{20} stops changing after scattering coefficients are higher than a certain limit value. An interesting conclusion was also, that scaling volume did not change tendencies.

A simple derivation in [4] suggests, that a minimum of average scattering is required to make the diffuse assumptions to be valid. Figure 1 shows what is the minimum required scattering for a given average absorption to have more diffuse energy than specular energy from the -5 dB or -10 dB decay levels respectively. It is interesting to note, that [3] found a minimum of 30% of critical (minimum) scattering for the 0.50 average absorption coefficient for all geometries with planar boundaries.

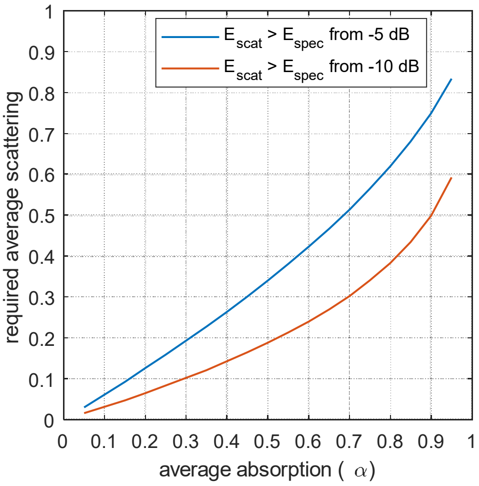

Figure 1 – Required minimum average scattering coefficient to ensure more scattered energy than specular energy from the -5 dB or -10 dB of the decay as the function of the average absorption coefficient.

According to all the above, it is seen, that all factors below together do affect validity of statistical formulas:

- average scattering in the room
- shape of the room
- average absorption in the room
- distribution of sound absorption within the room.

2 Description of the Experiment

The theoretical experiment aims the followings:

- to explore how the minimum scattering coefficient required to make statistical formulas valid;

- to explore how room acoustic parameters depend on each other and how these relationships are affected by the average scattering coefficient and the distribution of sound absorption;
- to compare different modelling software on how they interpret the average scattering coefficient.

2.1 Room Geometries

From previous works it is seen, that the effects of changing the average scattering is most obvious when the geometry is made up from parallel and planar boundaries.

Figure 2 shows geometries chosen for these calculations. All geometries have $V = 1000m^3$ volumes, but their total surface slightly differ. Main geometric descriptors are summed in Table 1, path length histograms are shown in Figure 3.

In all cases, two source positions are set: S1 (6.0 m; 6.0 m; 1.5 m) and S2 (12.0 m; 8.0 m; 1.5 m). Receiver surfaces are 1.1 m above the floor, 1 m from walls and are set to calculate parameters at a 1×1 m grid.

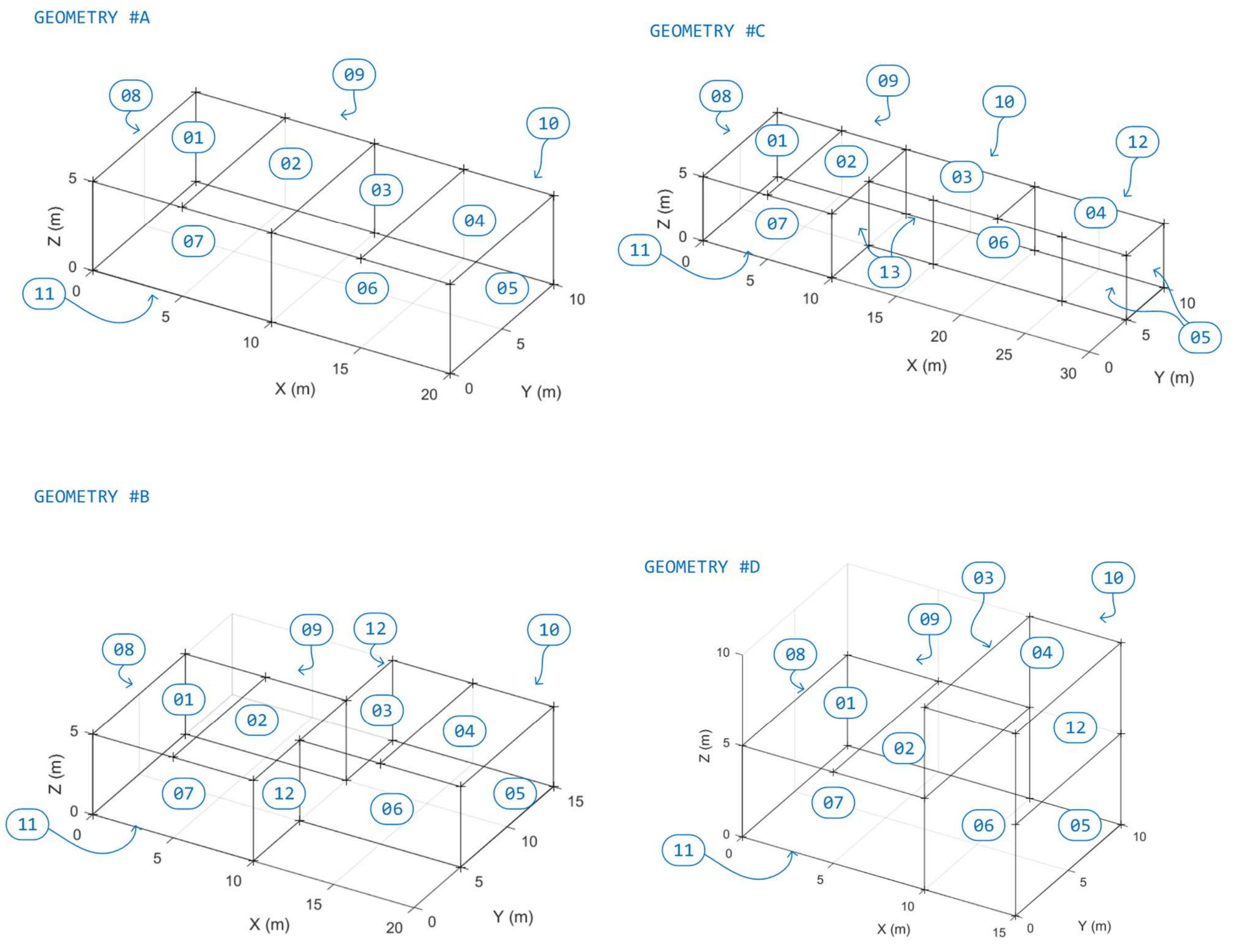

Figure 2 – Geometries used for calculations.

2.2 Surface Properties

In order to see characteristic tendencies upon the position of absorptive surfaces, all surfaces are acoustically reflective (X) and then only 2×50 m^2 of surface pieces (or boundary patches) are set to acoustically absorbing. Combinations for the four geometries are summarized in Table 2.

Actual sound absorptions set for the reflecting and absorbing boundary patches are given in Table 3.

The same scattering coefficients are set for all the surfaces: 5%, 10%, 20%, 40%, 80% for all frequencies. This makes a total of 355 models to evaluate.

shape	volume and surface		path length				
			statistic	calculated mean		shape factor (γ^2)	
	V	S	mean	specular	random	specular	random
	m^3	m^2	m	m	m	-	-
geometry #A	1000	700	5,71	6,10	5,47	0,48	0,57
geometry #B	1000	750	5,33	5,62	5,07	0,45	0,56
geometry #C	1000	800	5,00	5,52	5,04	0,48	0,61
geometry #D	1000	700	5,71	5,98	5,32	0,40	0,52

Table 1 – Geometry data of selected shapes.

variant		boundary patch												
geom.	version	01	02	03	04	05	06	07	08	09	10	11	12	13
#A, #B, #C, #D	X	-	-	-	-	-	-	-	-	-	-	-	-	-
	A	X	X	-	-	-	-	-	-	-	-	-	-	-
	B	X	-	X	-	-	-	-	-	-	-	-	-	-
	C	X	-	-	X	-	-	-	-	-	-	-	-	-
	D	X	-	-	-	X	-	-	-	-	-	-	-	-
	E	X	-	-	-	-	X	-	-	-	-	-	-	-
	F	X	-	-	-	-	-	X	-	-	-	-	-	-
	G	X	-	-	-	-	-	-	X	-	-	-	-	-
	H	-	X	X	-	-	-	-	-	-	-	-	-	-
	I	-	X	-	-	X	-	-	-	-	-	-	-	-
	J	-	X	-	-	-	-	X	-	-	-	-	-	-
	K	-	-	-	-	X	-	-	X	-	-	-	-	-
	L	-	-	-	-	-	-	X	-	X	-	-	-	-
	M	-	-	-	-	X	X	-	-	-	-	-	-	-
#B, #C, #D	N	X	-	-	-	-	-	-	-	-	-	-	X	-
	O	-	X	-	-	-	-	-	-	-	-	-	X	-
	P	-	-	-	-	X	-	-	-	-	-	-	X	-
	Q	-	-	-	-	-	-	-	X	-	-	-	X	-
#C	R	X	-	-	-	-	-	-	-	-	-	-	-	X
	S	-	X	-	-	-	-	-	-	-	-	-	-	X
	T	-	-	-	-	X	-	-	-	-	-	-	-	X

Table 2 – Summary of different combinations of the position of the sound absorbing surfaces for each geometry (room shape).

material	sound absorption coefficients for frequency bands																				
	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
absorbing	0,15	0,17	0,28	0,57	0,73	0,80	0,82	0,85	0,87	0,89	0,90	0,90	0,90	0,90	0,90	0,90	0,91	0,92	0,92	0,92	0,92
	0,20			0,70			0,85			0,90			0,90			0,91			0,92		
reflecting	0,05	0,05	0,05	0,06	0,06	0,06	0,07	0,07	0,07	0,08	0,08	0,08	0,09	0,09	0,09	0,10	0,10	0,10	0,10	0,10	0,10
	0,05			0,06			0,07			0,08			0,09			0,10			0,10		

Table 3 – Sound absorption coefficients used for the absorbing and reflecting surfaces.

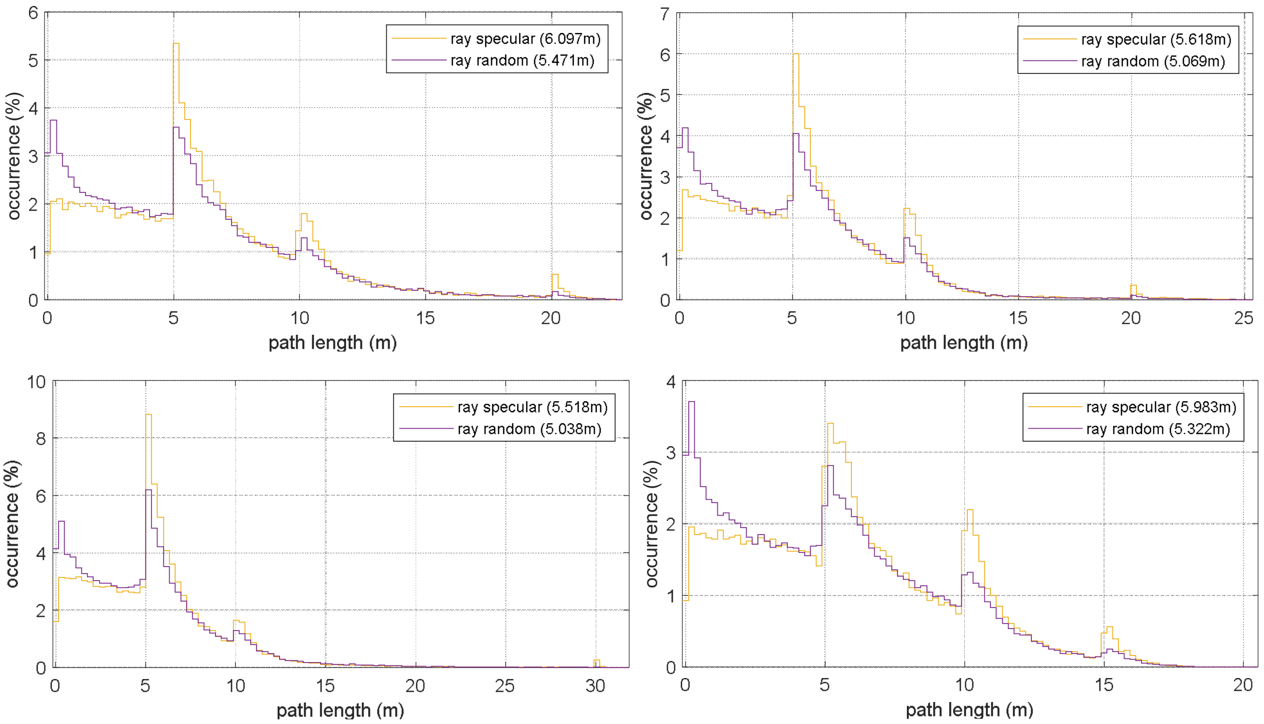

Figure 3 – Path length histograms from S1 and S2, using specular and random relfected ray-tracing (top left: geometry #A, top right: geometry #B, bottom left: geometry #C, bottom right: geometry #D).

2.3 Selected Room Acoustic Parameters

For these calculations, parameters defined in ISO 3382-1 standard were evaluated:

- reverberation time: T_{20}
- early decay time: EDT_{10}
- strength: G
- clarity: C_{50} and C_{80}
- lateral efficiency: LF_{80}.

Parameters were calculated in 1/3rd or 1/1 octave frequency bands and then the mean values in 250 Hz, 500 Hz, 1 kHz and 2 kHz bands were calculated ((denoted by m4, for example $T_{20,m4}$) for comparison.

2.4 Statistical Formulas

In the case of reverberation time, Sabine, Eyring statistical formulas were evaluated. Other formulas assume characteristic properties along x, y and z axes, which could have been used only Geometry #A (shoebox). Since statistical formulas are unable to consider the position of absorbing and reflecting surfaces in general (non-shoebox) shapes, but all assume a diffuse sound field, they might be considered as the reference values when comparing modelled results.

Other room acoustic measures (e.g. G) were calculated using formulae given [5] for example.

2.5 Computer Models

The models were run using three different computer modelling software:

E EASE (Enhanced Acoustic Simulator for Engineers) version 4.4.67.26, Aura module 3.0

C CATT Acoustic v9.1d

P PETRA Acoustics beta.

Software E and C may not need detailed introduction, because they are already established and referred in numerous papers.

Software P is a new development, its algorithms are a mixture of phased beam tracing, radiosity and boundary element methods. The software and its algorithms are currently in the testing and validation phase. Its role in this experiment is important, because all calculation details are known to the author (see Fig. 3 for example), which makes it possible to rely on data otherwise hidden from the user. In these experiments simple beam tracing and radiosity methods are used only for better comparison.

3 Results and Conclusions

Results and conclusion will be presented in the final paper.

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