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Effect of sample area in reverberant chamber measurements of sound absorption coefficients

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Abstract

To evaluate the influence of the sample size on the experiments in a reverberant chamber to determine the sound absorption coefficient, the reasonable minimum sample area needed was analyzed, considering that the quantity of material is important for those who want to test it. Samples from 1 to 12 m^2 (by increments of 1 m^2) were used. The influence of the sample position on the room's floor has also been tested for a 10 m^2 sample arranged on the center of the reverberating chamber and scattered around the room.

Keywords: Acoustics, ISO 354, Sound Absorption, Reverberation Room.

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1. Introduction

This work analyses the consequences of the variation of sample area into the sound absorption coefficient values measured in a reverberant chamber. The area of a specific type of material was changed from 1 to 12 m^2 and also the geometric arrangement in the room was also changed for one type of area (10 m^2). The standard EN ISO 354 [1] was generically used in the laboratory tests, although the work's objective is to study what is the "minimum sample area" needed to obtain the values of sound absorption coefficient with reasonable credibility and accuracy. The standard requires a sample area 10 to 12 m^2 in the reverberant rooms with a volume less than 200 m^3 or, if having a higher volume, the volume is increased by a multiplicative factor of $(V/200)^{2/3}$, which can thus yield larger size samples. This research aims to improve the optimization of the laboratory test for determining the values of sound absorption coefficients in a reverberation chamber in order to be able to reduce the area of the sample in certain exceptional conditions without compromising accuracy.

2. Methodology

The measurements of the sound absorption coefficient values were performed in the reverberation chamber of the Laboratory of Acoustics in the College of Engineering of the University of Porto (FEUP) according to standard EN ISO 354 [1]. The reverberation room has suspended diffusers that ensure a sufficiently diffuse sound field. According to that standard, the sample area should be between 10 and 12 m^2 for a room volume equal to or less than 200 m^3, which means that in the case of FEUP's reverberation chamber ($V = 216$ m^3) the need to multiply by the factor $(V/200)^{2/3}$ which gives sample areas from 10.6 to 12.6 m^2.

The interrupted noise method was used for determining the reverberation time, with 48 measurements (100 to 5k Hz). The arrangement of the sample in the room was taken to comply with the standard (Figure 1), using omnidirectional microphones (*B&K*) spaced apart at least 1.5 to 2 m from the sound source and at least 1 m away from the surfaces of the room and sample. The equipment and software used were: Data Acquisition System *B&K PULSE 3560-D* with *B&K PULSE v. X*, two sound sources *JBL EON 15-62* and four ½" *B&K* microphones 4190.

Figure 1: Sample used in the study (*S8* = 8 m^2).

3. Sample

The sample used in the study is an 8 mm thick layer of a porous material, with dense foam that makes a sound absorbent quality (Figure 1). Since the objective of the study is to assess the effect of the sample area on the values of the sound absorption coefficient the sample was divided into equal rectangles with dimensions of 2 m^2 (1.25 x 1.6 m) and 1 m^2 (1.25 x 0.8 m). The Table 1 shows the settings used in the tests and their assigned names.

Table 1 – Data related to the samples used.

Sample name	Area (m^2)	Dimensions (m)	Perimeter (m)
S1	1	1.25 x 0.80	4.1
S2	2	1.25 x 1.60	5.7
S3	3	1.25 x 2.40	7.3
S4	4	1.25 x 3.20	8.9
S5	5	1.25 x 3.20 + 1.25 x 0.80	11.4
S6	6	1.25 x 3.20 + 1.25 x 1.60	11.4
S7	7	1.25 x 3.20 + 1.25 x 2.40	11.4
S8	8	2.50 x 3.20	11.4
S9	9	2.50 x 3.20 + 1.25 x 0.80	13.9
S10	10	2.50 x 3.20 + 1.25 x 1.60	13.9
S10 ESP (sample scattered)	10	5 x (1.25 x 1.60)	17.1
S11	11	2.50 x 3.20 + 1.25 x 2.40	13.9
S12	12	3.75 x 3.20	13.9

Figure 2: Material used in study (*S12* = 12 m^2)

Figure 3: Sample scattered (*S10 ESP* = 10 m^2).

The samples were placed as united as possible in the central area of the reverberation chamber (Figure 2) except for sample *S10 ESP*, which was spread on the reverberation chamber by 2 m^2 blocks with the purpose to study the α variation due to the geometric arrangement of the sample in the room. This spreading consists in placing a 2 m^2 sample in the center of reverberation chamber and four 2 m^2 samples at the four corners, on the floor of the reverberation room (Figure 3).

4. Results

4.1. Effect of sample area variation

The table 2 presents the values for the sound absorption coefficients regarding samples S1 to S12. Once the visualization of the results in one graph is difficult these results were put in two figures (Figures 4 and 5) which analyzes the "low frequencies" (≤ 800 Hz) and the "high frequencies" (≥ 1 kHz).

In order to better study the sound absorption coefficient values' variability relative values were compared. The relative differences between α_i (values of sound absorption coefficient for sample with *i* m^2) with the α_{12} (value of sound absorption coefficient for sample with 12 m^2), dividing by the α_{12} (= $\Delta\alpha / \alpha_{12} = (\alpha_i - \alpha_{12}) / \alpha_{12}$). With that purpose five 1/3 octave frequency bands were used (250, 500, 1k, 2k, and 4k Hz), represented in Figure 6. It is at the 250 and 1k Hz frequency bands that there is greater relative variability in the results. From the 4 m^2 sample the values of sound absorption coefficient are in the range of less than 10% of the α_{12}.

In the remaining bands of frequency, the confidence interval of α_s values is below 10% for almost all areas, showing greater variability to the sample areas less than 4 m^2. In view of this data it can be concluded that the results for sample areas greater than 4 m^2 allow to obtain the values of sound absorption coefficient closer to the reference value (12 m^2).

The Figure 7 shows the variation of α_s for *S5* (5 m^2) with respect to the reference area *S12* (12 m^2). To obtain a reasonably reliable sound absorption coefficient value would thus be suitable to use a 5 m^2 sample area, since the α_s variation between *S5* (5 m^2) and *S12* (12 m^2) is reduced.

The behavior of α_s by frequency band was analyzed to understand the variability of the values of sound absorption coefficient by increasing the sample area. The Figure 8 illustrates that variability that allows a more concrete analysis of the behavior in five frequency bands (250, 500, 1k, 2k and 4k Hz). It is found that there is a decrease in the α_s value as the area *S* increases, and from about 5 m^2 of the value of the sound absorption coefficient has a more or less uniform behavior for all five frequency bands used.

Table 2 – Measured values for the sound absorption coefficients for samples *S1* to *S12*.

Freq. (Hz)	α_s											
	S1	***S2***	***S3***	***S4***	***S5***	***S6***	***S7***	***S8***	***S9***	***S10***	***S11***	***S12***
100	0.04	0.02	0.05	0.01	0.03	0.04	0.01	0.03	0.04	0.01	0.04	0.03
125	0.04	0.06	0.06	0.06	0.04	0.08	0.05	0.03	0.04	0.05	0.05	0.06
160	0.13	0.14	0.15	0.15	0.15	0.13	0.11	0.11	0.11	0.10	0.10	0.10
200	0.15	0.09	0.11	0.13	0.15	0.13	0.12	0.10	0.10	0.09	0.11	0.13
250	0.11	0.16	0.21	0.15	0.18	0.17	0.16	0.16	0.16	0.17	0.16	0.14
315	0.16	0.19	0.23	0.20	0.20	0.16	0.18	0.17	0.16	0.16	0.17	0.17
400	0.12	0.18	0.22	0.20	0.20	0.19	0.20	0.20	0.20	0.20	0.19	0.20
500	0.18	0.22	0.28	0.26	0.27	0.26	0.27	0.25	0.25	0.24	0.23	0.24
630	0.25	0.26	0.31	0.29	0.29	0.29	0.29	0.28	0.29	0.28	0.29	0.28
800	0.34	0.35	0.35	0.33	0.32	0.32	0.33	0.32	0.32	0.32	0.33	0.32
1000	0.35	0.40	0.45	0.40	0.39	0.38	0.38	0.38	0.37	0.38	0.38	0.38
1250	0.49	0.48	0.49	0.43	0.42	0.44	0.42	0.43	0.44	0.43	0.43	0.43
1600	0.57	0.60	0.57	0.50	0.51	0.52	0.49	0.50	0.51	0.51	0.52	0.51
2000	0.62	0.67	0.63	0.58	0.58	0.59	0.59	0.57	0.58	0.58	0.58	0.57
2500	0.72	0.72	0.68	0.64	0.66	0.64	0.64	0.64	0.65	0.65	0.64	0.63
3150	0.79	0.72	0.73	0.68	0.70	0.67	0.67	0.67	0.69	0.69	0.68	0.67
4000	0.78	0.74	0.76	0.69	0.70	0.72	0.72	0.71	0.69	0.70	0.70	0.68
5000	0.91	0.78	0.76	0.67	0.67	0.70	0.72	0.71	0.72	0.69	0.72	0.71

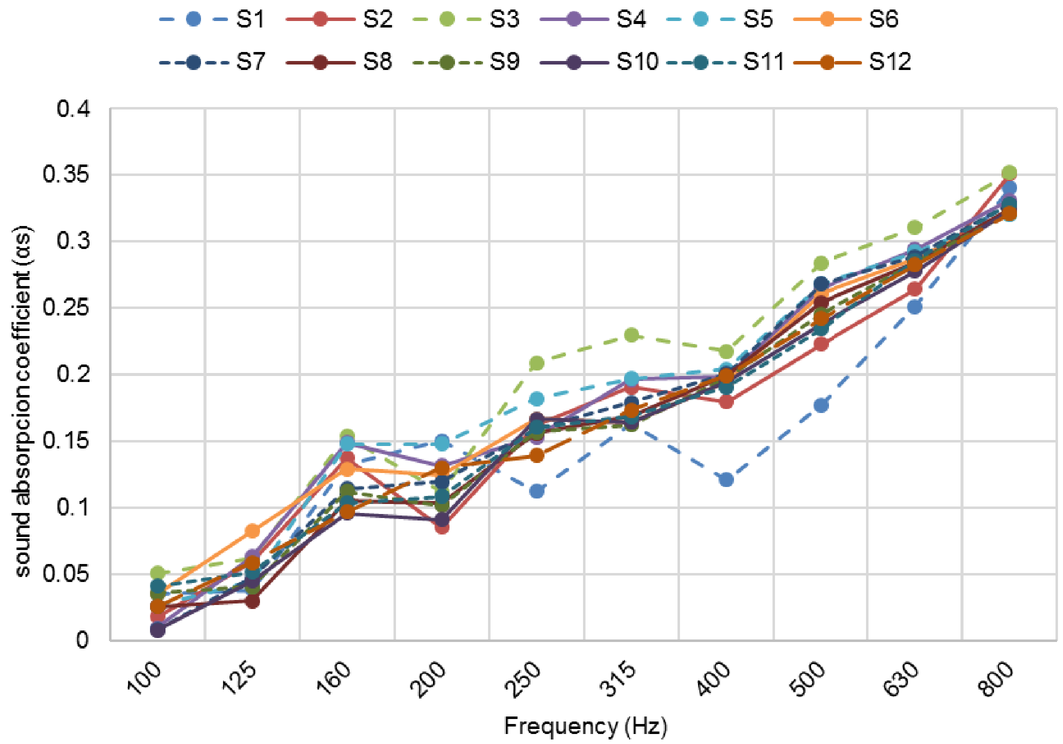

Figure 4: Sound absorption coefficient values for samples *S1* to *S12* (freq. ≤ 800 Hz).

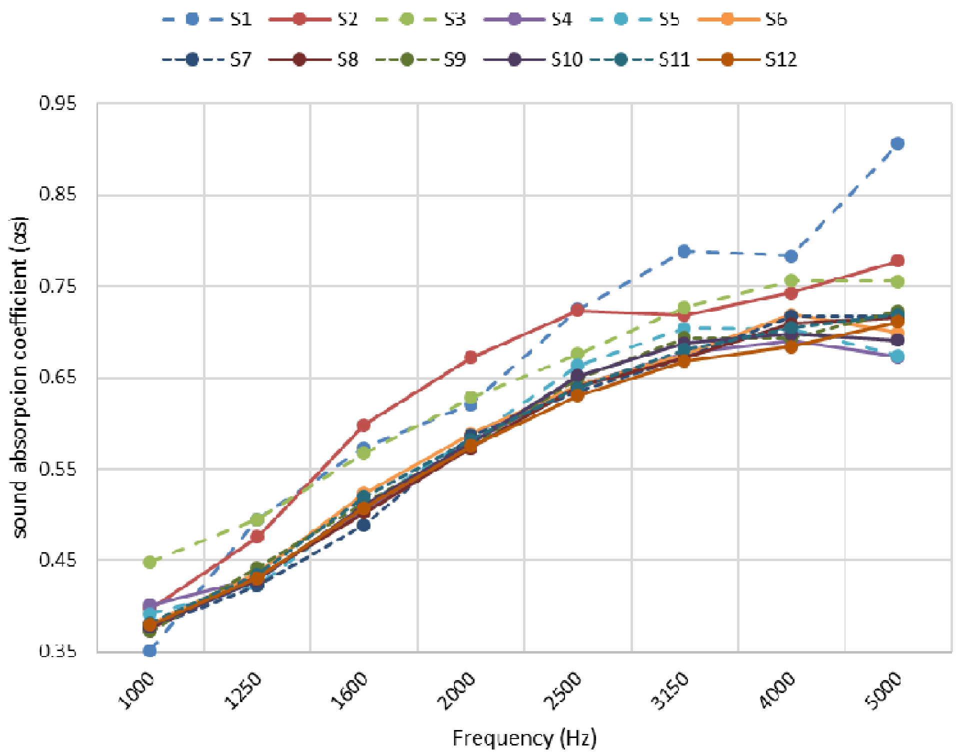

Figure 5: Sound absorption coefficient values for samples *S1* to *S12* (freq. ≥ 1 kHz).

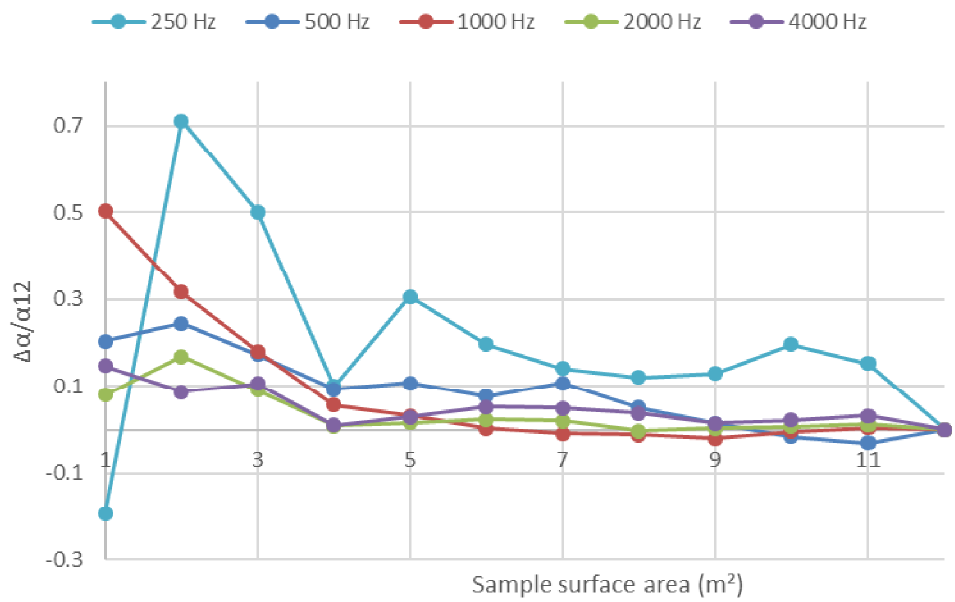

Figure 6: Relative variability of α_s regarding the reference value α_{12} (*S12* = 12 m^2) for five 1/3 frequency bands (250, 500, 1k, 2k and 4k Hz).

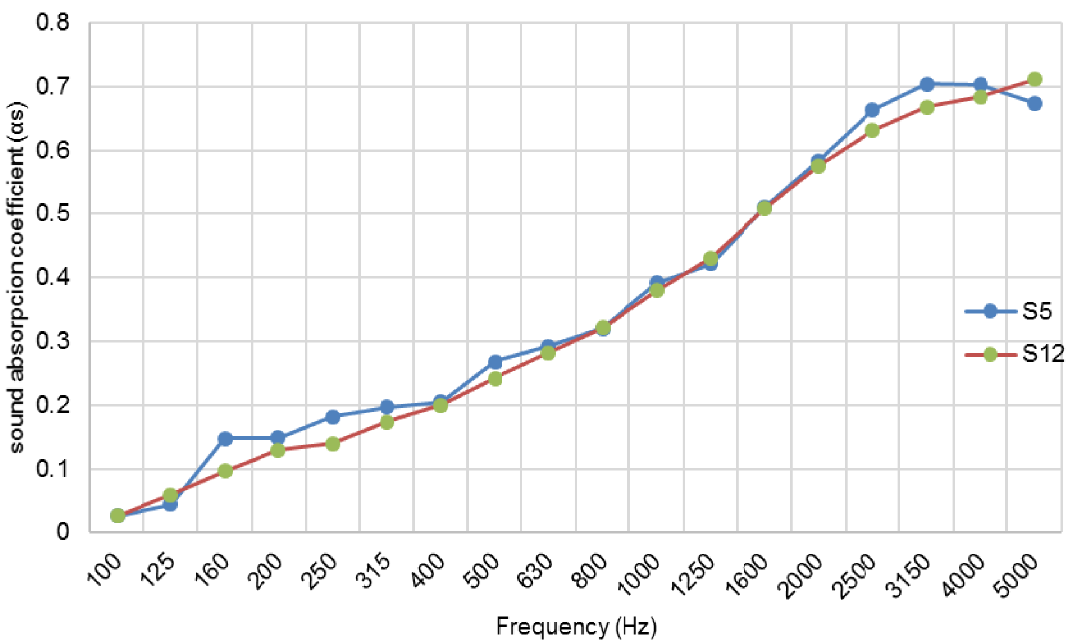

Figure 7: Evolution of α_s values for *S5* and *S12* at all frequencies.

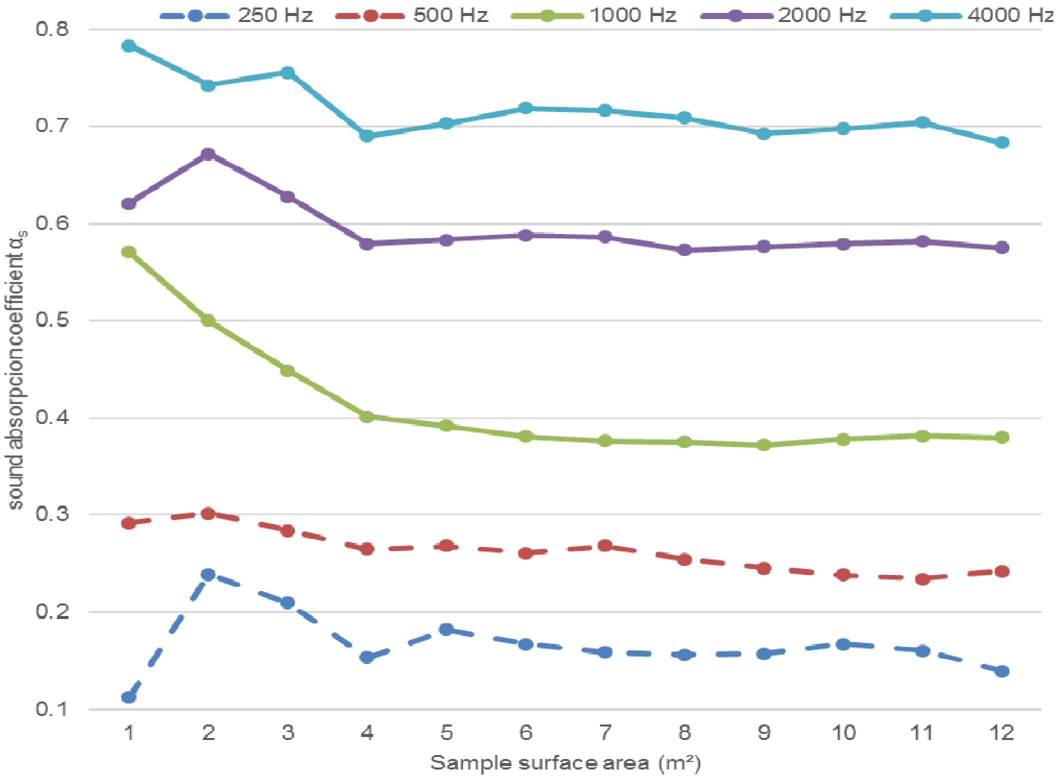

Figure 8: Variation of α_s values by frequency band with the increasing of sample area (*Si*).

4.2. Effect of the sample geometric disposition on the reverberation room' floor

The arrangement of the test sample in a reverberation room is made according to standard EN ISO 354 [1]. The sample ought to be placed in the center of the room's floor. The following analysis sought to test the effect in the α_s values with the sample scattered in the room's floor. The sample used was the 10 m^2 (S10) and it is referred as an especial sample or "scattered" (*ESP S10*).

Table 3 shows the values variability in the NRC and α_w parameters for the two geometric dispositions on the rooms' floor (*S10* and *S10 ESP*). It is found that there is a significant gain with respect to these two parameters for a scattered sample, which demonstrates the importance of the sample's "useful" perimeter on measuring the sound absorption coefficient values in a reverberation room.

The Table 4 shows the values in all frequency bands where it shown an increase in the α_s value (from 4% to 100%) when the sample is scattered on the room's floor. As the area is the same, the only parameter which can influence this raised value is the increase in perimeter (the "edge effect"). This phenomenon was explained by Sauro *et al*. [2] when they observed the importance of the sample's perimeter into the measurement of the sound absorption coefficient. By spreading the sample across the room, there is an increase of the sound absorption coefficient values that may be due to the increase of the sample's perimeter, to the fact that the sample becomes closer to the walls.

Table 3 – Variation in the values of parameters NRC and α_w for *S10* and *S10 ESP*.

Type of sample	NRC	α_w	Class (α_w)
S10	0.35	0.25 (M)	E
S10 ESP	0.40	0.30 (M)	D

Table 4 – Sound absorption coefficient values (α_s) for *S10* and *S10 ESP* (S=10 m²).

Frequency band (Hz)	αs (*S10*)	αs (*S10 ESP*)	Δα	Δα/α10 (%)
100	0.01	0.02	0.02	100
125	0.05	0.06	0.01	42
160	0.10	0.13	0.03	35
200	0.09	0.15	0.06	69
250	0.17	0.20	0.03	18
315	0.16	0.20	0.04	24
400	0.20	0.21	0.01	9
500	0.24	0.26	0.02	10
630	0.28	0.32	0.04	14
800	0.32	0.36	0.04	11
1000	0.38	0.42	0.04	12
1250	0.43	0.49	0.06	15
1600	0.51	0.58	0.07	14
2000	0.58	0.64	0.06	10
2500	0.65	0.69	0.04	6
3150	0.69	0.71	0.02	4
4000	0.70	0.73	0.03	5
5000	0.69	0.73	0.04	6

5. Conclusion

Sometimes obtain large samples of materials (10 to 12 m²) or more) to determine the sound absorption coefficient in a reverberation room can be an obstacle, but it is required by the EN ISO 354 [1]. This work confirms that such a large sample may not be needed for reliable results in the test. For that the α_s was measured for samples from 1 to 12 m², with additions of 1 m².

The results obtained for α_s indicate that there is more variability up to the sample *S5* (5 m²) and, as the area of the sample increases, the sound absorption coefficient values tend to stabilize. So, it follows that a 5 m² sample would be sufficient for a reliable determination of the sound absorption coefficient in a reverberation room if a larger sample is not available.

The effect of sample layout in the room was also briefly studied regarding its effect in the measured α. The sample *S10* was used (10 m²), and the variability of results was checked for the αs, α_w and NRC. Higher values were obtained in all those parameters for the scattered sample (*S10 ESP*). It may concluded that with the same area of the sample, but a greater perimeter, there is a gain on the sound absorption coefficient values, demonstrating that the "edge effect" may have a great importance in determining α in a reverberation room.

References

[1] CEN, European Standard EN ISO 354: *Acoustics*. *Measurement of sound absorption in a reverberant room*, 2003.

[2] Sauro, R.; Vargas, M.; Mange, G. Absorption coefficients Part 1: Is square area enough? *Proceedings INTER-NOISE 2009*, Ottawa, Canada, paper 091.