

## **ACOUSTIC PHENOMENA ASSOCIATED TO THE AUDIENCE**

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Ivana Rossell, Cristina Vicent  
Enginyeria i Arquitectura La Salle, Universitat Ramon Llull.  
Pg. Bonanova, 8 (08022)  
Barcelona  
Spain  
Tel: 93 290 24 27  
Fax: 93 290 24 16  
E-mail: [ivana@salleurl.edu](mailto:ivana@salleurl.edu)

### **ABSTRACT**

The audience area in theatres or auditoriums represents the most important and major absorption surface in the hall. The absorption coefficient values are established but they vary significantly from one author to another. This variability makes its qualification one of the main problems in acoustic designs. Not only the absorption coefficient value but other acoustic phenomena such as diffraction, edge effect, seat dip effect, influence on audience distribution, kind of seating... etc, must be controlled.

In this paper we will expose some of these phenomena offering a theoretical review and an experimental part with measurements in our laboratory and in a small conference hall. We will analyse the audience absorption in a reverberation chamber and the seat dip effect in the hall.

### **INTRODUCTION**

The reverberation time in a room depends on the absorption materials used to cover its surfaces but almost the total acoustic absorption is related to audience area.

Audience absorption is due to people's clothing, it acts as a porous absorber. At low frequencies, the absorption coefficient is lower than at mid and high frequencies. Clothes vary with time and season, so we can only work with weighted absorption values, and we usually find a lot of different data from one author to another.

### AUDIENCE AND SEATS ABSORPTION

When people are dispersed in a room the absorption is calculated on the basis of the number of seats. So we find the absorption per person ( $A_{pp}$ ), and we calculate the absorption (in  $m^2$  or *Sabines*) with the equation  $A_p = N \cdot A_{pp}$  ( $N$ =number of persons).

For a seated audience, quantification depends on the area they occupy. Beranek found that more accurate results were produced when audience was treated like other materials, on the basis of absorption per unit area (using the absorption coefficient), making the results insensitive to seating density.

One person seated in the last row absorbs less than people seated in the middle or in the first rows because they are exposed to the direct sound field. For this reason it's usual to find important differences in absorption data given from measurements in laboratory test (small test area) and from measurements made in auditorium, in real situation.

We present now some absorption values (in Sabines) calculated by Kath and Kuhl for "dispersed people" case:

$f(\text{Hz})$	125	250	500	1K	2K	4K
<i>Standing person with coat</i>	0.17	0.41	0.91	1.30	1.43	1.47
<i>Standing person without coat</i>	0.12	0.24	0.59	0.98	1.13	1.12
<i>Seated musician with instrument</i>	0.60	0.95	1.06	1.08	1.08	1.08

### ABSORPTION CALCULATION FOR SEATED AUDIENCE

If we consider the typical audience situation in conference rooms, theatres or auditoriums, it is better to use the absorption coefficient values in the following two situations: occupied and unoccupied seats. Depending on the degree of upholstery, values vary sensitively. Kosten and Beranek showed that seat absorption (occupied or unoccupied) augments with the occupied area, independent from the number of seats. This assumption is valid when the area per seat is between  $0.45 m^2$  and  $0.79 m^2$ .

The total audience absorption is calculated by the formula:  $A_s = S_A \alpha_s$ .  $S_A$  is the effective acoustic area, this area includes the edge effect (a perimeter strip round the seating zone in

plan). This perimeter strip 0.5 metre wide is added to the true seating area, except where it abuts wall and along balcony fronts.

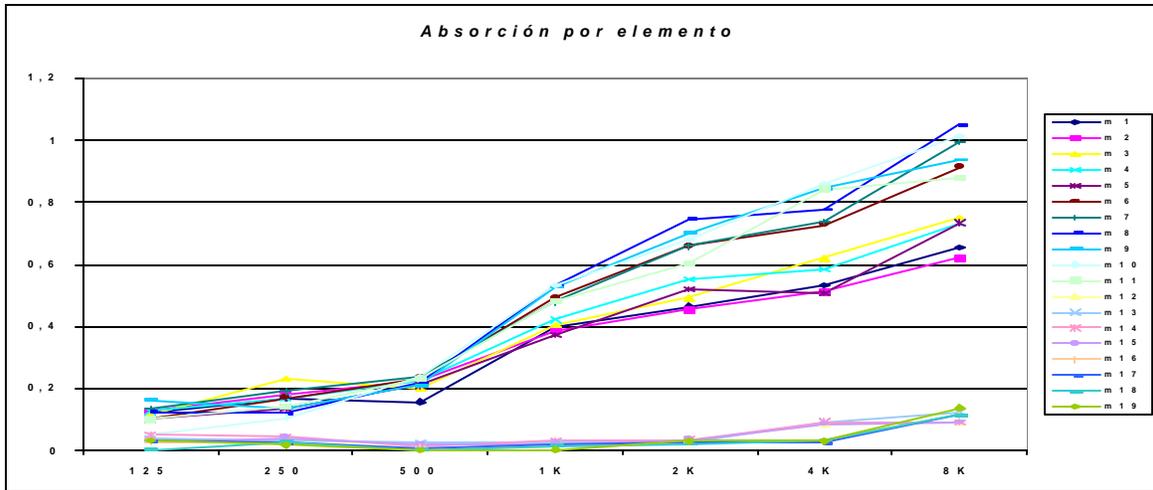
Now we show some absorption coefficients from different authors; Beranek (1996), Barron (1998) and Arau (1999).

	$f(\text{Hz})$	125	250	500	1K	2K	4K
Beranek-1996	Audience- seats heavily upholstered	0.76	0.83	0.88	0.91	0.91	0.89
	Audience- seats medium upholstered	0.68	0.75	0.82	0.85	0.86	0.86
	Audience- seats lightly upholstered	0.56	0.68	0.79	0.83	0.86	0.86
	Seats, unoccupied- heavily upholstered	0.72	0.79	0.83	0.84	0.83	0.79
	Seats, unoccupied- medium upholstered	0.56	0.64	0.70	0.72	0.68	0.62
	Seats, unoccupied- lightly upholstered	0.35	0.45	0.57	0.61	0.59	0.55
Barron-1998	Upholstered seats, unoccupied	0.32	0.50	0.73	0.87	0.85	
Arau-1999	Audience- seats heavily upholstered	0.52	0.68	0.85	0.97	0.93	0.85
	Seats, unoccupied- heavily upholstered	0.49	0.66	0.80	0.88	0.82	0.70

### ABSORPTION COEFFICIENT MEASUREMENTS

Measurements were made in a reverberation chamber and under ISO 354 specifications.

We tested 16 wooden chairs and 16 people, covering different areas for each case of distribution. We also measured the absorption of people seated in the floor and dispersed in the chamber. Results are shown in the next graphic, each colour refers to a different distribution in three situations: wooden unoccupied chairs; occupied chairs and people freely standing in the chamber.



Variations depending on the distribution were notable at medium and high frequencies. They are important due to the low absorption coefficient of the wooden chairs.

Absorption coefficient values obtained are close to Kath and Kuhl data because the area occupied by the people was quite small.

## THE SEAT DIP EFFECT

The seat dip effect is the name given to the selective attenuation experimented by the sound when arrives with grazing incidence over the audience area (occupied or unoccupied seats). It is characterised by a great dip (between 10 and 20 dB) at low frequencies (between 100 and 300 Hz). The main cause is the interference made between the direct sound and the different reflections produced in the row-row space floor and seating. This attenuation remains constant, independent on the number of rows and begins on the first rows. Reflections in the space between rows produce destructive interference with the incoming energy from the stage causing this phenomenon.

Seat dip effect was discovered in 1962 in some measurements in the New York Philharmonic Hall to improve its acoustic response. Sessler and West quantified the phenomenon and later Schultz and Watters, in 1964, also verified this attenuation at frequencies close to 150 Hz.

When the incidence angle of the sound was small (near grazing incidence) the effect was greater and the attenuation decreased for greater angles (elevating the sound source or the reception point).

Since 1964 the phenomenon it has been measured in several concert halls (Ida and Ando, 1986; Bradley 1991); in scale models (Ishida et al., 1989) and in theoretical models (Ando

et al., 1982; Kawai y Terai, 1991). The attenuation varied with the hall and the kind of seats.

Nowadays the seat dip effect is still not well understood. Not only the measured attenuation but also the subjective effect is important.

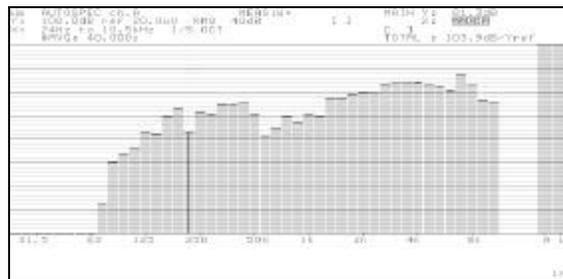
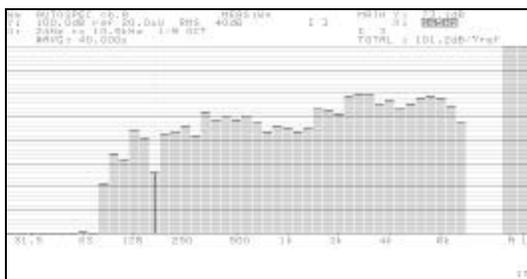
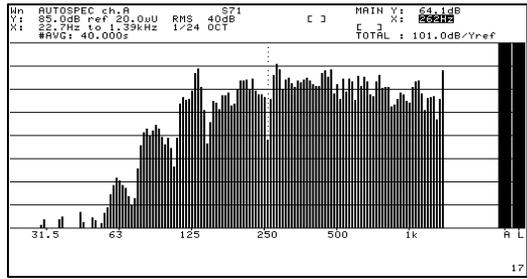
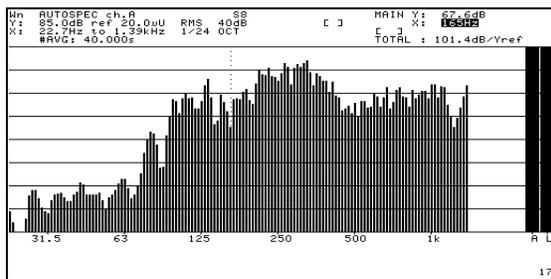
The subjective threshold obtained in a realistic simulation of the acoustic field showed that when the selective dip yielded an attenuation of  $-3.8 \pm 0.2$  dB in the frequency band of 200 Hz in the first 80 ms, the effect was perceptible. This fact does not mean to be negative for the acoustic of the auditorium.

So, the question is,

Is it necessary to eliminate this effect if it appears in all concert halls, including the best ones in the world? Is it really important?

### MEASUREMENTS

In order to obtain our own experimental results we made some measurements in a conference hall of our university. We used different positions for the sound source and reception points.



In grazing incidence (or near grazing) cases, the attenuation obtained was about 10 dB or 12 dB at frequencies of 262 Hz, 20 Hz, 165 Hz, in different situations.

## CONCLUSIONS

For acoustical designs and acoustical parameter prediction, we need correct values of absorption coefficients of every material used in the room. In this paper, we have made an overview of two important parameters: audience absorption and seat dip effect. It is not only to quantify the absorption coefficient, but we must also bear in mind many other parameters related to the audience effects. How can we represent these effects or phenomena in acoustic simulation software?

In conclusion, we can say that it is still needed much more investigation to shorten the distance between theoretical predictions and real behaviour.

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