ON ABSORPTION AND SCATTERING COEFFICIENT EFFECTS IN MODELLISATION SOFTWARE

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This paper presents the results provided by two simulation programs for a very simple model: a cube in which all sides have the same absorption but different global scattering coefficients. Effects on merit figures of the main acoustic parameters are shown for scattering changes for a single absorption coefficient. The results are helpful for understanding the role of absorption and scattering on the values of these parameters.

INTRODUCTION

The modelling of a room, hall, or concert hall by an acoustic simulation program involves two main processes: firstly, the development of a geometric model using a set of surfaces; and secondly, the allocation of a material for each of the surfaces. The most recent programs indicate absorption and scattering coefficients in frequency bands. The scattering coefficients are interpreted as the percentage of energy not specularly reflected. Energy conservation is given by the relationship

$$(1 - s)(1 - \alpha) + \alpha + s(1 - \alpha) = 1 \quad (1)$$

where s is a scattering coefficient (the fraction of reflected energy that is not reflected specularly); and α is an absorption coefficient (the fraction of incident energy that is not reflected). The programs that include scattering give reliable results, as was remarked in the First International Round Robin on Room Acoustical Computer Simulations [1]. The use of scattering coefficients in simulation programs is a simple way to make these programs realistic. The coefficients can also serve as a tool that enable users to adjust their model to the experimental data [2].

Two commercial programs were used in this study: CATT-Acoustic v.8 with The Universal Cone Tracer (TUCT); and Odeon v10. Although both programs are based on ray tracing, the scattering treatments differ in each program.

CATT-Acoustic uses cone-tracing algorithms [3,4]. Accordingly, scattering is frequency dependent; while direct sound and first-order specular reflection are deterministic. From the second reflection, specular and diffuse reflection is performed randomly. Thus for the coefficient $s = 0.5$ (in CATT-Acoustic a number between 0 and 100 is used, while in Odeon a number between 0 and 1 is used), half of the rays are specularly reflected and the other half are diffused [4].

Odeon uses a hybrid algorithm [5]. For early reflections it uses the mixed method of images and ray tracing. For late reflections it uses a special ray tracing method, with secondary sources that radiate energy from the wall surfaces. The parameter transition order (TO) (default 2) defines the transition from early to late reflection methods. The program also specifies the number of rays included in the early reflection method.

For reflections with an order that is lower than the transition order (TO), Odeon determines the source image and includes the corresponding reflection in the reflectogram (if visible to the source). The attenuation of that reflection is determined while taking into account distance, scattering, and air absorption. Odeon continues with the mixed method until the TO order. The late-rays are treated as secondary sources and emit a diffracted beam in accordance with the Lambert distribution. The result is the sum of the two beams with the weights '1-*s*' and '*s*' (see Figure 1).

In brief, the difference between the two programs is in the first and second order reflections (TO by default). In the CATT case (Algorithm 1) the first order reflections are treated stochastically, whereas Odeon uses the mixed method of image and ray tracing.

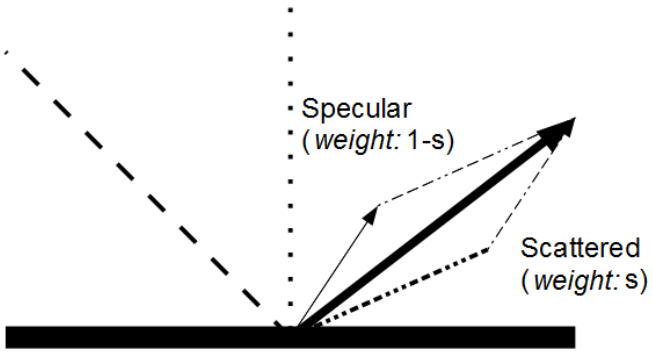


Figure 1. Energy conservation in Odeon algorithm [5]

A SIMPLE GEOMETRY: 20 M CUBE

The cube is one of the simplest geometries that can be studied. The same absorption for all walls and frequency bands was given to minimise the model complexity when comparing the results of both programs. The scattering coefficient was uniformly distributed over all the surfaces and was varied for each simulation. A similar approach was found in the literature [6,7]. A deeper study on a complex room can be found in [8]. It must be underlined that this work does not discuss how each program works. As previously mentioned, the intention is only to compare the results provided by both programs for the cube

model as this may serve as a valuable guide for program users.

The comparison of simulations was performed for the following absorptions: 10, 20, 25 and 30 (these figures cover the cases relevant for practice as average absorption coefficients are not usually larger than 30). For each mean absorption considered, the following scattering coefficients were used: 0, 20, 40, 60, 80 and 100.

Figure 2 shows the CATT-TUCT window that indicates the software options. The default options are used for the calculations. The auto measure is used for the ray number. Similarly, auto setting was chosen for the impulse response length. The air absorption option is also marked.

In Odeon, the default options used were provided by the 'engineering' button. The program asks the user to select the impulse response duration. It is set at 5000 ms, which represents the time used by CATT-TUCT as a default option (see Figure 3).

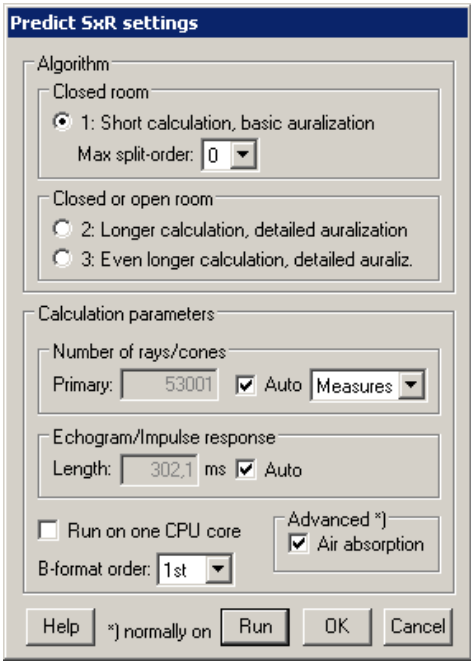


Figure 2. CATT-TUCT default options

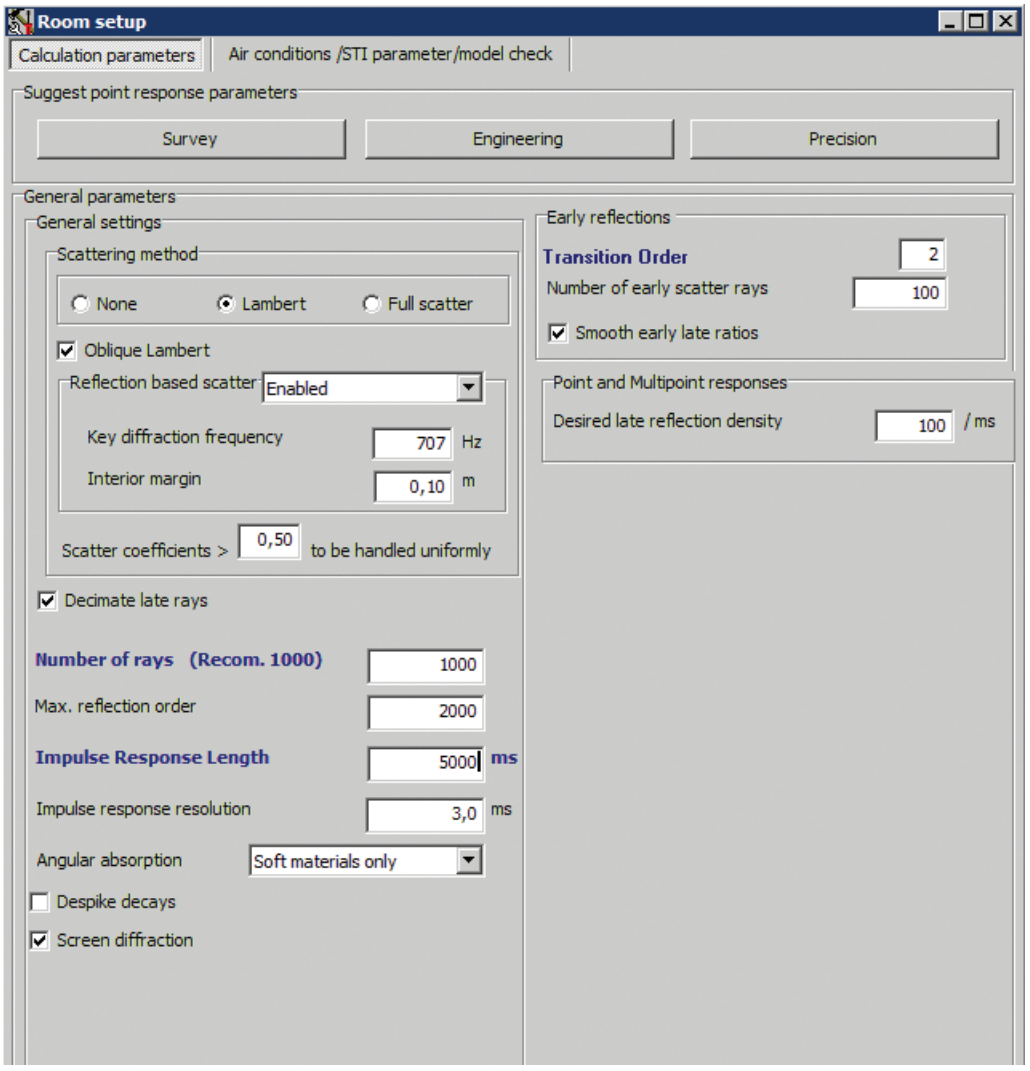


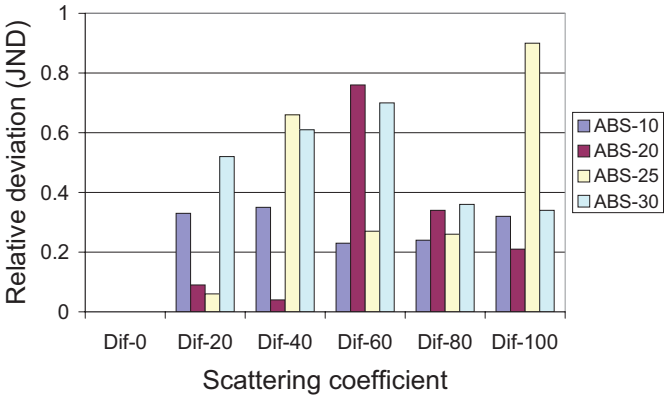
Figure 3. Odeon default options

Stability of the solutions

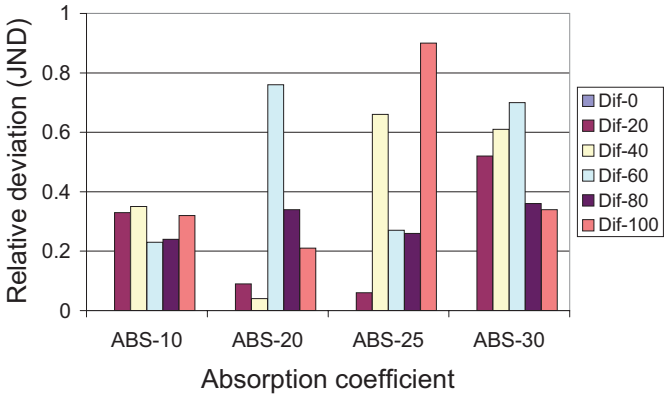
The following must be taken into account when choosing a program to calculate a prediction:

- Odeon provides a non-probabilistic solution. To repeat a calculation we have to 'trick' the program by some modification of the model. Otherwise, the program informs us that the task has already been done.
- CATT-Acoustic provides a non-deterministic solution if a non-zero scattering coefficient is entered. Therefore, it is necessary to study the stability of the solution.

To study the CATT-Acoustic stability, two calculations were performed for each variant of the model. Figure 4 shows the average variation in all frequencies for RT30 in units of relative deviation and taking the corresponding Just Noticeable Difference (JND) (5%) into account [9]. It can be seen that the effect of scattering does not produce significantly different results (i.e. for both calculations there is a difference of more than 1 JND in the RT30 prediction). This means that when working with the default options in CATT-Acoustic, the convergence of the solution and the number of rays and truncation time the program uses are guaranteed for the studied cases (usually averaged absorptions).



(a)



(b)

Figure 4. Variation of the CATT-Acoustic stability solution for RT30 for (a) various absorption coefficients for constant scattering coefficients and (b) various scattering coefficients for constant absorption coefficients, measured by relative deviation to JND

Effect of scattering coefficient in each program

For each program, the effect of the scattering coefficient with fixed absorption was studied when predicting different acoustic parameters. The values of each parameter were compared with the value obtained for a scattering coefficient '0' [6]. To avoid the commercial misuse of the results, we have omitted the name of the program. Programs 1 and 2 are used without identifying which is which. Average absorption coefficients are usually not larger than 30. This holds for large performance spaces, as well as for living rooms and classrooms.

Figure 5 shows the results for Program 1. To compare the differences obtained in this software, the same scale as the axis of deviation was used. Here are the comments for each parameter:

- EDT: for studied absorptions (coefficient ≤ 30), variations with the scattering coefficient do not exceed 2 JND.
- RT30: this parameter remains fairly stable with scattering variation for studied absorptions.
- SPL: remains stable in all studied cases (1 dB has been considered as JND).
- C80: remains stable in all studied cases (1 dB has been considered as JND).
- D50: shows great dependence on the scattering coefficient.
- Ts: No great variations shown.

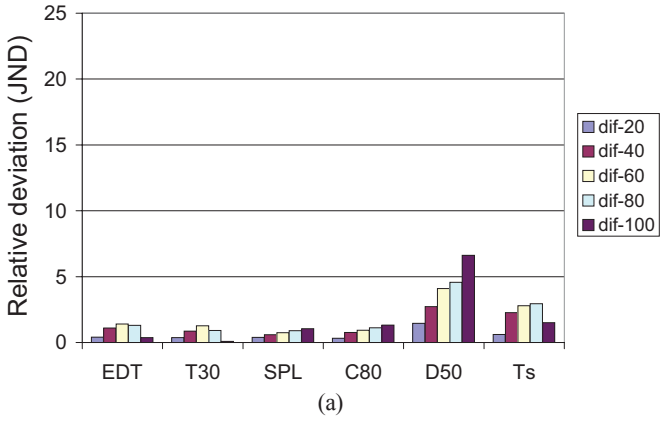
In Figure 6, the results of Program 2 are presented. The same axis of deviation scale was used to compare the differences obtained with this software. The variation in parameters is generally greater than in Program 1. The comments for each parameter are given below:

- EDT: variations are close to 5 JND.
- RT30: this parameter remains fairly stable with the variation of scattering for studied absorption.
- SPL: variations of around 5 JND were observed for the studied absorptions (1 dB is considered as 1 JND).
- C80: remains stable in all studied cases (around 2 JND).
- D50: shows large variations of around 20 JND.
- Ts: shows variations of around 5 JND.

Comparing the programs

In Figure 7 the results obtained in both programs were compared. Average relative deviations of each value obtained in Program 1 with respect to the value obtained in Program 2 were calculated. The comments for each parameter are detailed below:

- EDT: differences do not generally exceed 4 JND for each absorption and scattering.
- RT30: differences do not generally exceed 2 JND for absorption and scattering used.
- C80: average differences obtained for each program did not exceed 4 JND.
- D50: large deviations between obtained values in each program are shown.
- Ts: differences generally do not exceed 4 JND for absorption and scattering.



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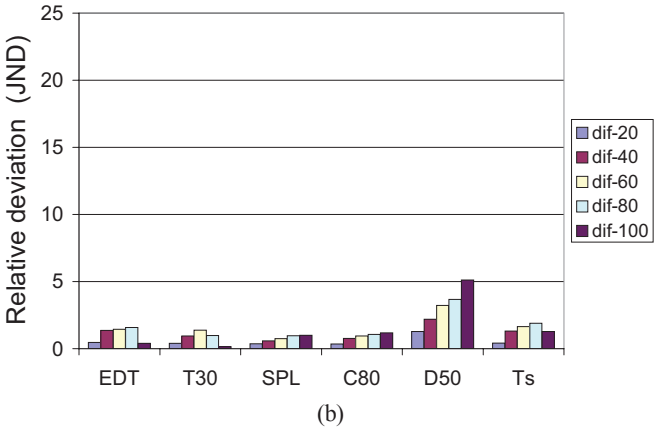

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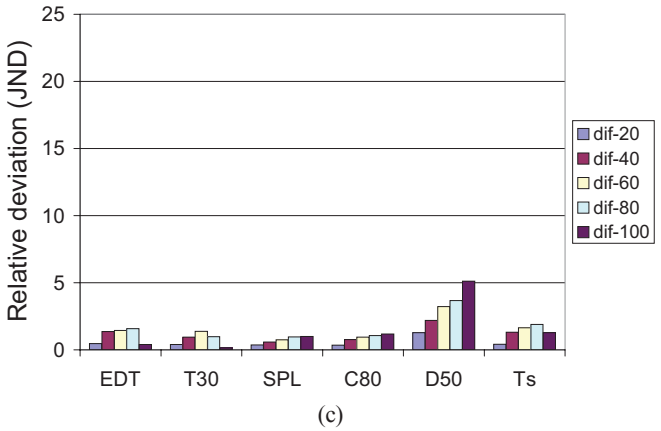

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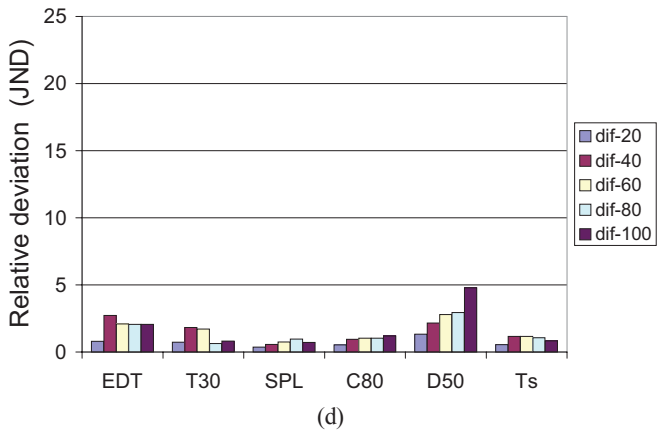
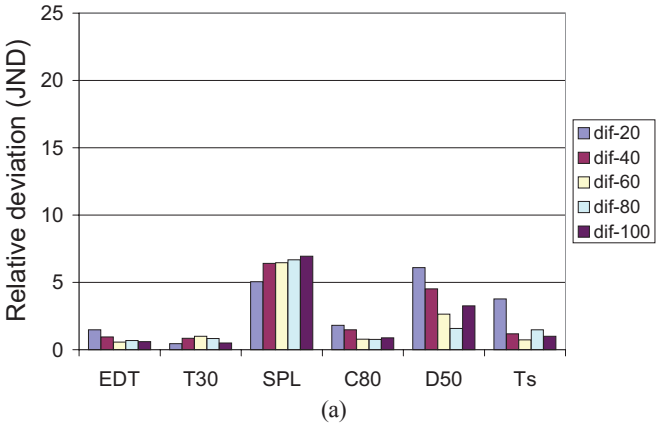
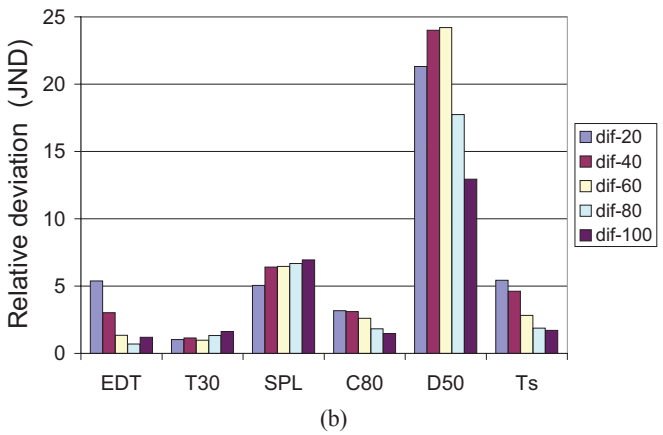


(d)

Figure 5. Parameter variation with the scattering coefficient for a given absorption (Program 1): (a) ABS-10, (b) ABS-20, (c) ABS-25, (d) ABS-30



(a)



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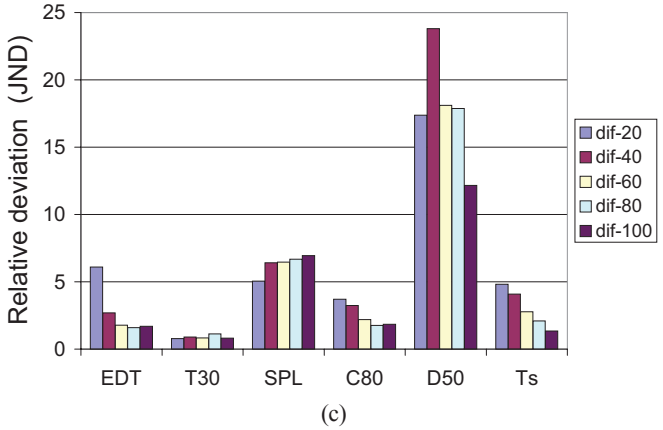

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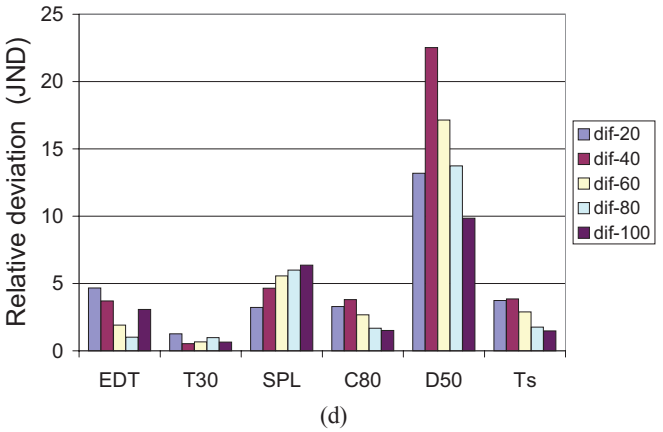

(d)

Figure 6. Parameter variation with the scattering coefficient for a given absorption (Program 2): (a) ABS-10, (b) ABS-20, (c) ABS-25, (d) ABS-30

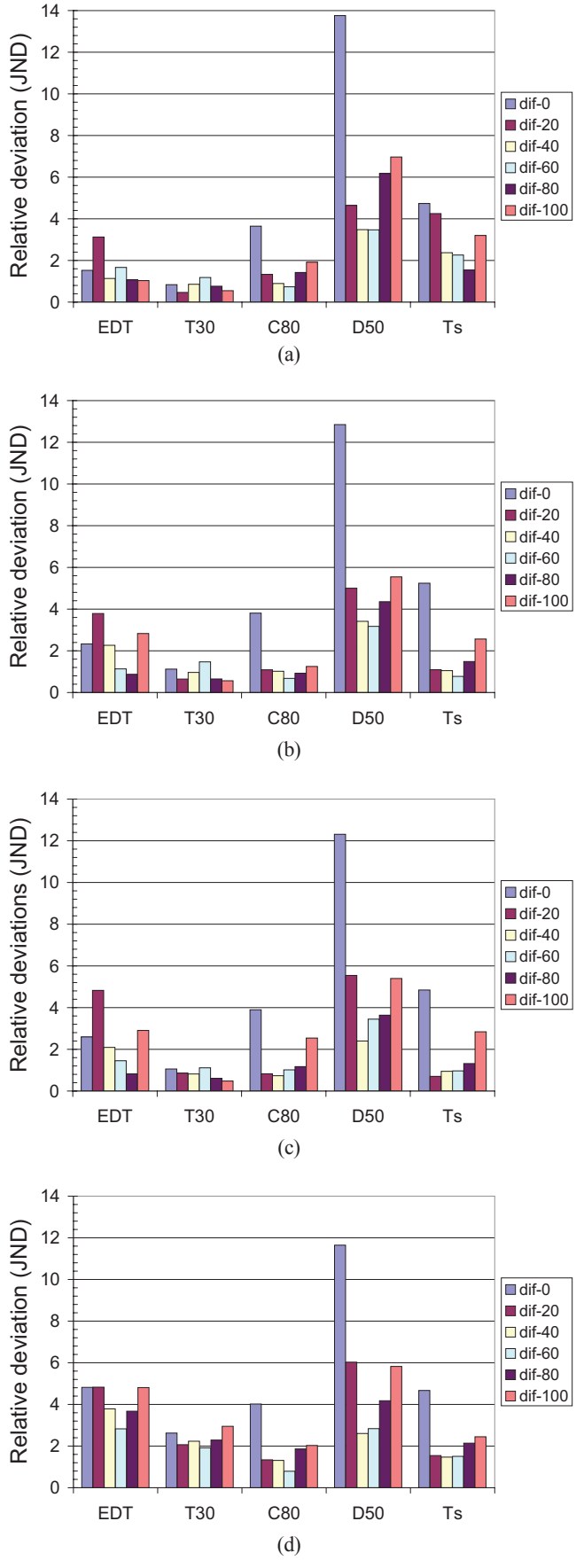

Figure 7. Relative deviation of JND between Programs 1 and 2: (a) ABS-10, (b) ABS-20, (c) ABS-25, (d) ABS-30

SUMMARY

Studying the simplest geometry (with special acoustic characteristics) revealed differences in the simulation programs (Odeon and CATT-Acoustic) when working with the default options. In a simple approach these differences seem to be justified due to the different algorithms used by the programs. The authors' intention is not to discuss the causes of these differences, nor to discuss if one of the programs is better than the other. Future research should analyse these differences more deeply in real predictions. This case study, without being generalised to other models, leads to the following conclusions:

- When working with the default options both programs guarantee the convergence of the RT solution with the number of rays and truncation time that the program uses by default.
- Program 1 shows fewer variations than Program 2 with scattering coefficient changes. D50 is the most sensitive parameter to scatter variations.
- Although in general, the parameters obtained do not show great variations between programs, results show that D50 values are program dependent. Moreover, Ts and EDT sometimes show variation near 4 JND. These facts show that the differing algorithms and scattering treatments in each program produce considerable differences in early reflections.

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