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Modeling Diffraction of an Edge Between Surfaces with Different Materials

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ABSTRACT

In this paper we present the measured data of the diffraction of one single edge. The data consists of cases where the surfaces, forming a diffractive edge, are covered with highly absorptive material. The measured results show that the effect of absorptive material in surfaces does not change the diffraction phenomenon prominently. This fact allows us to suggest that in several practical room acoustics design problems the effect of material absorption in edge diffraction might be neglected.

KEYWORDS: edge diffraction, room acoustics modeling

INTRODUCTION

The theory of diffraction from one single rigid edge is well understood and several analytical solutions have been derived to model diffraction. One of the computational methods for diffraction from a finite length edge has been presented by Svensson et al. [1]. This time-domain model is interesting from room acoustics modeling point of view, since it can be applied in sound field decomposition [2], in conjunction with the image-source method [3,4].

In this paper we discuss the modeling of diffraction, especially in the case when the surfaces forming a diffracting edge are covered with absorbing material. The presented ideas in this paper are due to the measurements done for a previous study [5]. First, the measurement setup is briefly reviewed and old results of the measurements are overviewed. After that, we introduce new measurement results and discuss in which cases absorption with diffraction has to be modeled.

MEASUREMENTS OF DIFFRACTION FROM A SINGLE EDGE

The measurement of diffraction from a single edge was done in the following way. A triangular shaped 20 mm thick chipboard was mounted to the corner of an anechoic room, such that two of the three edges of the plate were between the absorbing wedges, i.e. inside the walls of the anechoic room, as shown in Fig. 1. The setup allows to measure diffraction from one edge since diffractions from the other edges are attenuated almost completely. Having only one not-attenuated diffractive edge also yields that no higher-order diffractions are seen in the measured responses [5].

The measurement setup consists of a loudspeaker (Genelec 1030A) mounted above the studied edge of the plate and a microphone (B&K 4192) located to different positions. The impulse response measurements were performed by applying a swept-sine technique [6].

Figure 1: The measurement setup. A triangular chipboard covered with mineral wool is mounted between the wedges of anechoic chamber. In reported results, the microphone was positioned under the chipboard plate.

Results from measurements with the covered plate

The positions of the loudspeaker and the microphone in the measurements are illustrated in Fig. 2. The presented data is from cases where the chipboard plate was either plain, or covered with 50 mm mineral wool. In Fig. 3 we compare measured results. In addition, Fig. 3 presents results from measurement, where mineral wool was on top of the plate but installed 10 cm apart from the edge. Figures show that if the wool is more than 10 cm apart from the edge, the effect of the absorbent is negligible. However, in the case where mineral wool covers the plate totally the measured diffraction is attenuated approx. 2 dB between 1.8 and 5 kHz. At higher frequencies the attenuation is almost 5 dB.

Another comparison is made between the cases in which mineral wool is mounted both under and above of the plate. The measured responses are shown in Fig. 4. The effect of mineral wool on top of the plate is the same as in the previous case. When the absorbent is mounted under the plate, the measured absorption is higher. The material absorbs sound approximately 3 dB, starting already around 600 Hz. When absorbing wool is on both sides of the plate the cumulative absorption is seen.

The effect of mineral wool under and on top of the plate is clearly seen in Figs. 3 and 4. The absorption is obvious, but the reason why absorption starts around 1.7 kHz and around 500 Hz is unclear to us. We assume that it has to be related somehow to the wavelength of sound and how long distance sound waves travel inside the mineral wool. In addition, sound waves tend to bend around the edge of the wool and that possibly affect to the measured results.

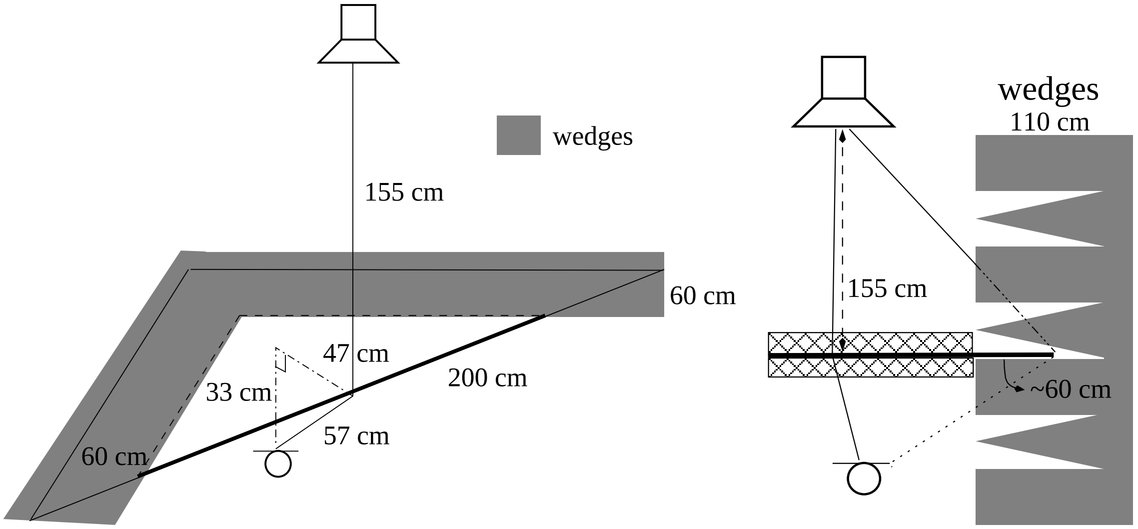

Figure 2: The schematic drawing of the setup for measuring diffraction from a single edge. Diffraction from the edge between the mineral wool wedges is attenuated since the sound has to travel through several absorptive wedges.

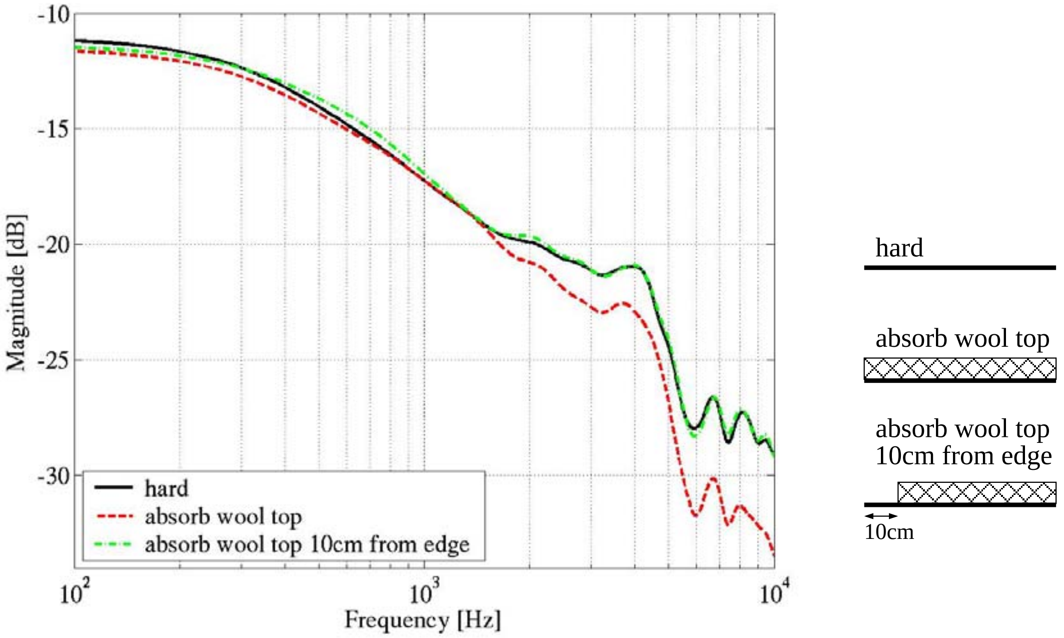

Figure 3: The measured diffraction from a single edge with and without mineral wool on top of the plate.

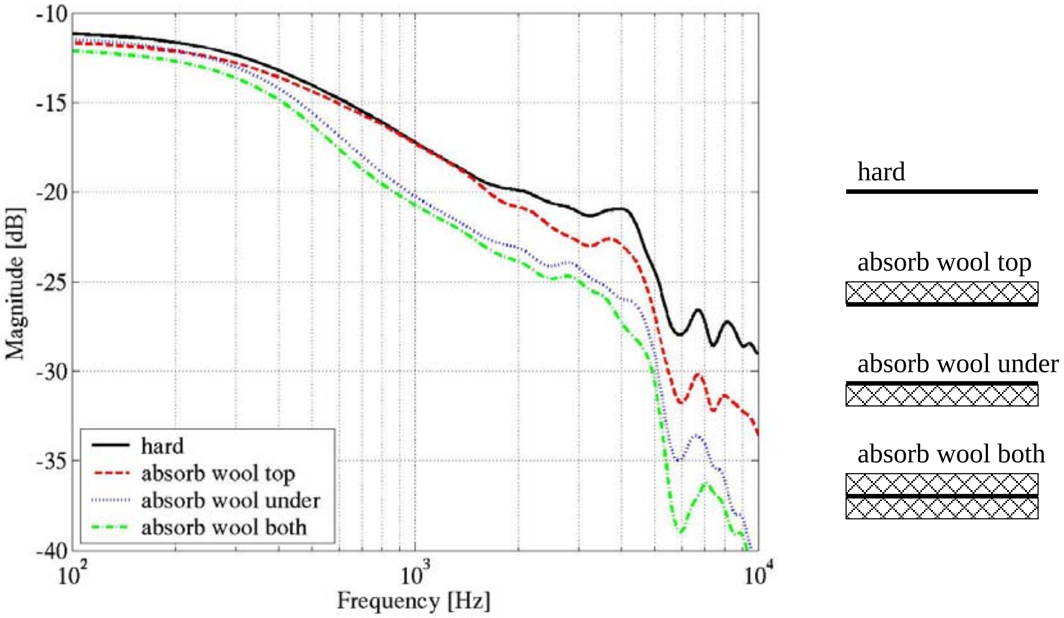

Figure 4: The measured diffraction from a single edge with and without mineral wool under and on top of the plate.

Sound pressure attenuation in mineral wool

To find out the attenuation properties of the applied mineral wool we measured the attenuation of sound pressure when sound is propagating through wool. Measurements were done in two stages in an anechoic chamber. First, we measured the system response without any material between the microphone and the loudspeaker. Then we mounted one piece of 50 mm wool between the loudspeaker and the microphone so that wool piece was about 20 cm apart from the microphone. In addition, another sound pressure attenuation measurement was done and in that case the wool piece was in 45 degrees angle between measurement equipment.

The measured results are depicted in Fig. 5. It can be seen that 50 mm thick mineral wool does not absorb any sound below 300 Hz, even in the 45 degree case where sound waves travel more than 50 mm inside the wool. However, above 300 Hz attenuation of sound pressure is quite strong being more than 10 dB above 1 kHz and more than 20 dB above 6 kHz.

If we compare these results to the results presented in Figs. 3 and 4, it can be seen that the attenuation of sound pressure is much more prominent in Fig. 5. In the case of diffraction measurements, the attenuation is only a few decibels at 1 kHz and slightly more at higher frequencies. This result suggests that the mineral wool has less effect in diffraction case than in the transmission case, at least in the measuring setup studied.

However, at least in "wool under" case the surface material affects diffraction in a similar fashion with transmission absorption. The attenuation starts at the same frequency region, and has a similar nature. The reason why the attenuation is fainter is now hypothesized. A quite natural reason would be that the sound does not only travel through the wool on both sizes of the diffraction, but bends around the wool. In "wool above" case the effect of surface material is weak, and in "wool under" case it is stronger. In "wool under" case, the bending angle around the edge of the wool is large, and it can be assumed that less sound propagate via that path. In "wool above" case, the bending angle is small, thus more sound bends around the corner of the wool. The more sound bends around the corner, the fainter is the effect of absorption.

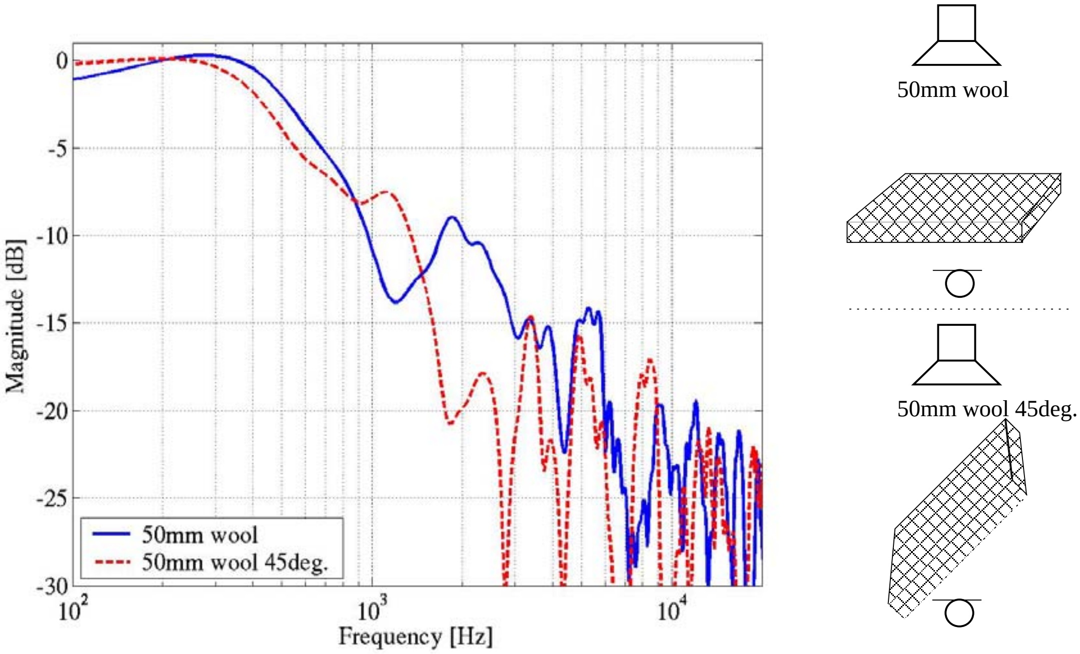

Figure 5: Absorption of sound pressure when sound travels through the 50mm thick mineral wool.

DISCUSSION: MODELING OF EDGE DIFFRACTION IN ROOM ACOUSTICS DESIGN

It has been shown earlier [5] that the measured diffraction from the rigid edge, without any covering material on the surfaces, matches well to the theoretical response presented by Svensson et al. [1]. This theoretical model does not include the effect of material in the vicinity of the edge. The modeling of material absorption together with edge diffraction is still an unsolved problem.

In this paper we have showed measured data related to above-mentioned problem. The presented data shows that even with highly absorptive material, such as 50 mm mineral wool, the effect of surface material to the diffraction is faint. The attenuation appears at the frequencies where transmission absorption is prominent, which are in most cases high frequencies.

In some cases the modeling of edge diffraction is important and the diffraction cannot be neglected in room acoustics design. Such cases are, e.g., diffraction from orchestra pit edges in opera halls and diffraction from long rigid edges in all auditoriums. However, such long edges produce diffraction, which can be characterized as low-pass effect in the frequency domain. The attenuation of surface material in diffraction was found to appear at high frequencies, thus it can be concluded that the material has generally no prominent effect to diffraction with long edges, and can be often neglected in acoustical modeling.

Other important edges from modeling point of view are those, which are close to source and receiver positions. In practice these edges contain also absorptive materials. In the future, some way to predict the effect of material in these cases should be found.

In room acoustics design, the design goal is often the optimization of room acoustical parameters. These parameters, such as reverberation time or clarity, are based on sound energy attenuation in a space and they are indeed quite coarse estimates of the acoustics of the space under study. Therefore, we suggest that the material absorption together with edge diffraction can be neglected when the design is only based on room acoustics parameters. However, when the design goal is very accurate impulse response to a certain receiver position the absorption phenomenon should be included to the modeling.

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