AUDIBILITY OF COINCIDENCE DIPS AND STRUCTURAL RESONANCE DIPS IN ACOUSTIC ISOLATION CURVES

Léopold Kritly[1,3], Kristian Jambrosić[2], Monika Rychtáriková[1,4], and Christ Glorieux[5]

[1] KU Leuven - Faculty of Architecture, Hoogstraat 51, 9000 Gent/ Paleizenstraat 65, 1030 Brussel, Belgium. Emails: Leopold.Kritly@kuleuven.be; Monika.Rychtarikova@kuleuven.be

[2] University of Zagreb – Faculty of Electrical Engineering and Computing, Unska 3, HR-1000 Zagreb, Croatia. Email: Kristian.Jambrosic@fer.hr

[3] EPF – Institute of Systems and Electronics, 860 Rue St-Priest, 31090 Montpellier, France.

[4] STU Bratislava - Faculty of Civil Engineering, Dep. of Architecture, Radlinského 11, 81005, Bratislava, Slovak Republic.

[5] KU Leuven - Dept. Physics and Astronomy, ZMB – Laboratory of Acoustics, Celestijnenlaan 200D, 3001, Heverlee, Belgium. Email: Christ.Glorieux@kuleuven.be

ABSTRACT

The audibility of coincidence dips and structural resonance dips in acoustic isolation curves of different types of walls is investigated. Measured and simulated wall transmission curves with varying dip magnitude and central frequency are emulated in listening tests by presenting simulated sound on the receiving side of a wall, which originates from sending realistic sound pressure level pink noise through a wall and by applying its transmission curve as a filter. Differences in dip magnitude of 1.5dB and more are found to be audible. Shifting the central frequency of the dip from 400Hz to 500 Hz or from 1600Hz to 2500Hz is clearly audible.

INTRODUCTION

It is known that today people spend around 87% of their time inside buildings [1], and their experience of indoor light, thermal and acoustic comfort or discomfort is therefore very relevant. Both the thermal and acoustic isolation of walls can be improved by adding layers. However, furbishing a wall with the aim of improving its thermal isolation does not necessarily have an unequivocal effect on its acoustic isolation [2]. In the here presented preliminary study, we verify to what extent applying ETICS (External Thermal Insulation Composite System) and lightweight thermal insulation linings, which are highly beneficial for the thermal isolation, affect the acoustic isolation of the wall. In particular, by analyzing people's perception via listening tests, we tackle the question to what extent changing the central frequency and depth of the dip in the acoustic isolation curve, which is evoked when a massive wall is treated with ETICS due to a mass-spring-mass resonance of the assembly of an outer layer, a thermal insulation layer and a massive wall, is audible. This question is especially relevant in the framework of assessing the utility of research and development efforts to decrease the acoustic insulation dip magnitude and shifting it to less audible frequencies [2,3,4]. We also address the audibility of changing the features of dips caused by the coincidence effect.

EXPERIMENTAL PROCEDURE

I. APPARATUS

All listening tests presented in this paper were performed with a Scarlett 2i2 (Focusrite) soundcard and semi-open headphones K240 MKII (AKG). The latter are known to have a flat frequency response over the hearing range, a good soundstage reproduction and an acceptable amount of harmonic distortion.
Internal laptop loudspeakers of the Dell XPS 15 were used as well to conduct some complementary tests.

The sound devices were set with a sampling frequency of 48 kHz and a bit resolution of 16 bits.

II. LISTENING TEST CONDITIONS

The listening tests were performed in a silent office of the University of Zagreb, with similar acoustic conditions as in many living situations. This test environment has been chosen to avoid effects on audibility that occur in settings with a very low background noise such as an anechoic chamber.

For this preliminary study, the testing panel was composed of 5 acousticians between 25 and 55 years old.

The stimuli were presented at two sound pressure levels, respectively around 50 dBA and 75 dBA. In the following, we refer to these levels as "medium" and "high" respectively.

Pink noise, i.e. broadband noise containing all hearable frequencies, similar to traffic noise, was chosen as starting signal.

III. SOUND GENERATION METHOD

Sounds were generated according to the algorithm presented in Figure 1.

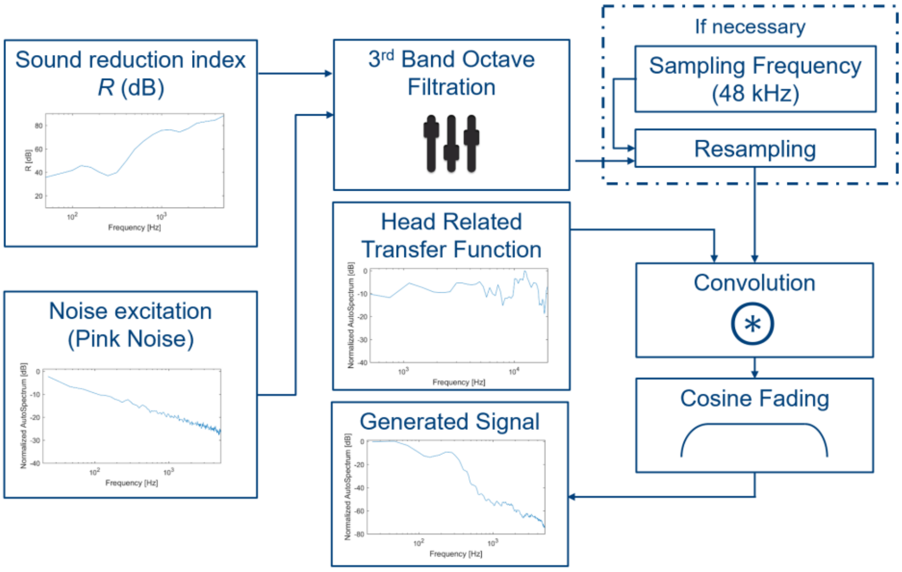


Figure 1. Block diagram algorithm of sound generation

In order to emulate the transmitted fraction of pink noise incident on a wall, we made use of third band octave wall isolation spectra of physical walls, measured according to ISO 10140-2:2010 between 100 Hz and 3150 Hz [5,6]. The lower and upper octave band were extended till respectively 20Hz and 20kHz, beyond the 50 Hz – 5000 Hz bandwidth of the sounds.

PARAMETRIC STUDY

As mentioned above, this study focused on the audibility of changes in the depth and central frequency of airborne sound insulation dips.

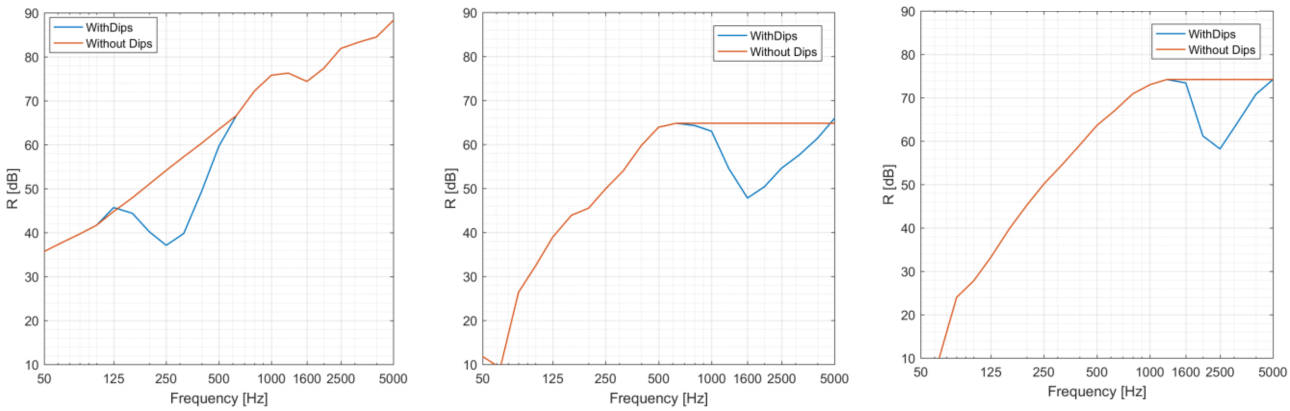
I. DIP MAGNITUDE

The investigated walls had the following specifications:

- Massive wall with ETICS: R_w=55dB and mass-spring-mass resonance dip frequency f_0=250Hz.
- Lightweight wall consisting of two layers of 25mm gypsum board separated by 100mm mineral wool, R_w=54dB and dip frequency f_0=1.6kHz.
- Lightweight wall consisting of two layers of 15mm gypsum board separated by 2 x 50 mm of mineral wool, R_w=57dB and dip frequency f_0=2.5kHz.

1) REMOVING DIP

Measured sound insulation curves and their equivalents after artificial removal of the dip are shown in Figure 2 (a.b.c.).



a. Massive wall with ETICS f_0 = 250Hz

b. Light wall with Gypsum 25 mm - f_0 = 1.6kHz

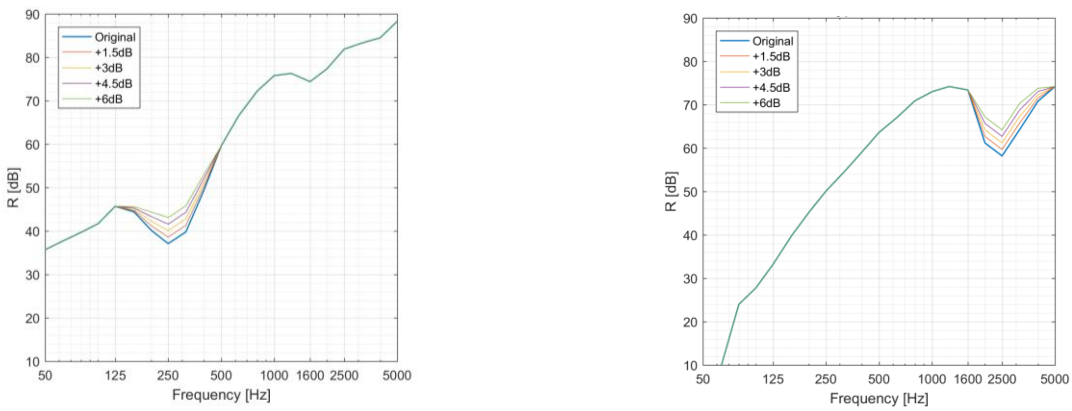
c. Light wall with Gypsum 15 mm – f_0 = 2.5kHz

Figure 2. Measured airborne sound insulation of different walls with a mass-spring-mass resonance (a) or coincidence (b,c) dip and their equivalents after artificially removing the dip

The difference between the pink noise filtered by a wall with and without its dip was found to be audible for all listeners, both at medium and high sound pressure level on the sending side of the wall, for the stimuli presented by headphones. The audibility of the sound insulation dip being evident, the sounds were also presented via the integrated speakers of a laptop. The results were consistent, highlighting the not negligible impact of mass-spring-mass and coincidence dips on the perception of outdoor sounds heard through a wall.

2) VARYING THE DIP MAGNITUDE

In order to get a more detailed view on the audibility of a dip in the isolation spectrum, additional listening tests were performed, numerically varying the dip depth in 4 steps of 1.5 dB for an ETICS treatment induced mass-spring-mass resonance dip with a central frequency of 250 Hz, and for a coincidence dip in a lightweight, gypsum board-based wall at 2.5 kHz. The corresponding sound insulation curves are shown in Figure 3 (a,b).



a. Massive wall with ETICS – f_0 = 250 Hz

b. Light wall with Gypsum 15 mm – f_0 = 2.5 kHz

Figure 3. Airborne sound insulation curves with simulated dip depth variations

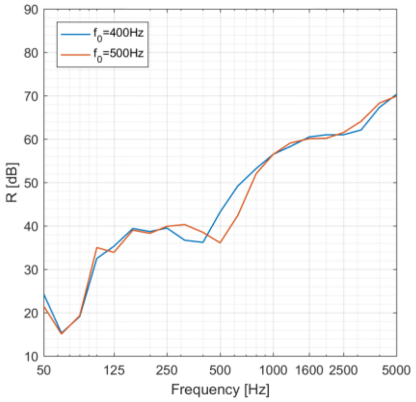
For both cases, listening tests showed that a difference of 1.5dB is clearly audible at a high sound pressure level and audible for 4 of the 5 tested people within a success rate of 90% at medium sound pressure level using headphones.

II. DIP CENTRAL FREQUENCY

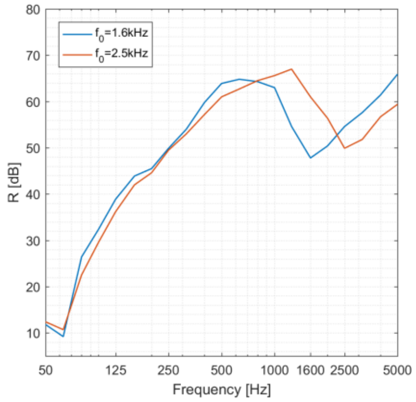
In order to check to what extent changes in the central frequency of a dip in a wall insulation curve are audible, we have performed listening tests starting from a set of measured sound insulation curves, of which a selection was made in order to obtain pairs that were as similar as possible, with only the dip frequency differing:

- Massive brick wall with ETICS furbished with 160mm of extruded polystyrene (EPS) covered by mesh reinforced thick layer of adhesive mortar, R_w=49.4dB and mass-spring-mass resonance frequency f_0=400Hz.
- Massive brick wall with ETICS furbished with 160mm of extruded polystyrene (EPS) covered by mesh reinforced thin layer of adhesive mortar, R_w=48dB and mass-spring-mass resonance frequency f_0=500Hz.
- Lightweight wall consisting of two layers of 25mm gypsum board separated by 100mm mineral wool, R_w=54dB and dip frequency f_0=1.6kHz.
- Lightweight wall consisting of two layers of respectively 12.5mm and 18mm gypsum board separated by 100mm mineral wool, R_w=55dB and dip frequency f_0=2.5kHz.

The corresponding sound insulation curves are shown in Figure 4 (a,b).



a. *Massive wall with ETICS with and without final coating – f_{01} = 400 Hz, f_{02} = 500 Hz*



b. *Light wall with 25mm and 12.5mm of Gypsum f_{01} = 1.6 kHz, f_{02} = 2.5 k Hz*

Figure 4. Airborne sound insulation of two pairs of similar walls with only the central frequency of the dip differing

The difference between the pink noise filtered by two walls with a shifted dip central frequency (400Hz - 500Hz and 1.6kHz - 2.5kHz) was found to be audible by all tested people, both at medium and high sound pressure level, both using a headphone and integrated speakers of a laptop.

DISCUSSION AND CONCLUSION

Varying the depth and central frequency of a mass-spring-mass induced (ETICS wall) and coincidence (lightweight gypsum board wall) dip in a sound insulation curve by 1.5dB and between 400Hz - 500Hz and 1.6kHz - 2.5kHz respectively, is found to be audible when listening to simulated transmitted sound for the case of pink noise on the sending side of the wall. This confirms the usefulness of research and innovative efforts that measure isolation curves and tune wall structures for optimum isolation in terms of removing or tempering dips. Further tests, with larger numbers of listeners and smaller variations, are needed to determine the just noticeable changes of dip frequency and depth. Deeper insight will also be given by adapting the psychoacoustic procedure to ABX-type listening tests and by using more realistic noises encountered at home, such as music, TV sounds or car noise. Also, differences in annoyance between transmitted sounds through walls with different colouration due to different dip features would be an interesting feature to examine.

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