Analysis of an Air Transparent Soundproof Window System & Comparisons to Physical Test Data

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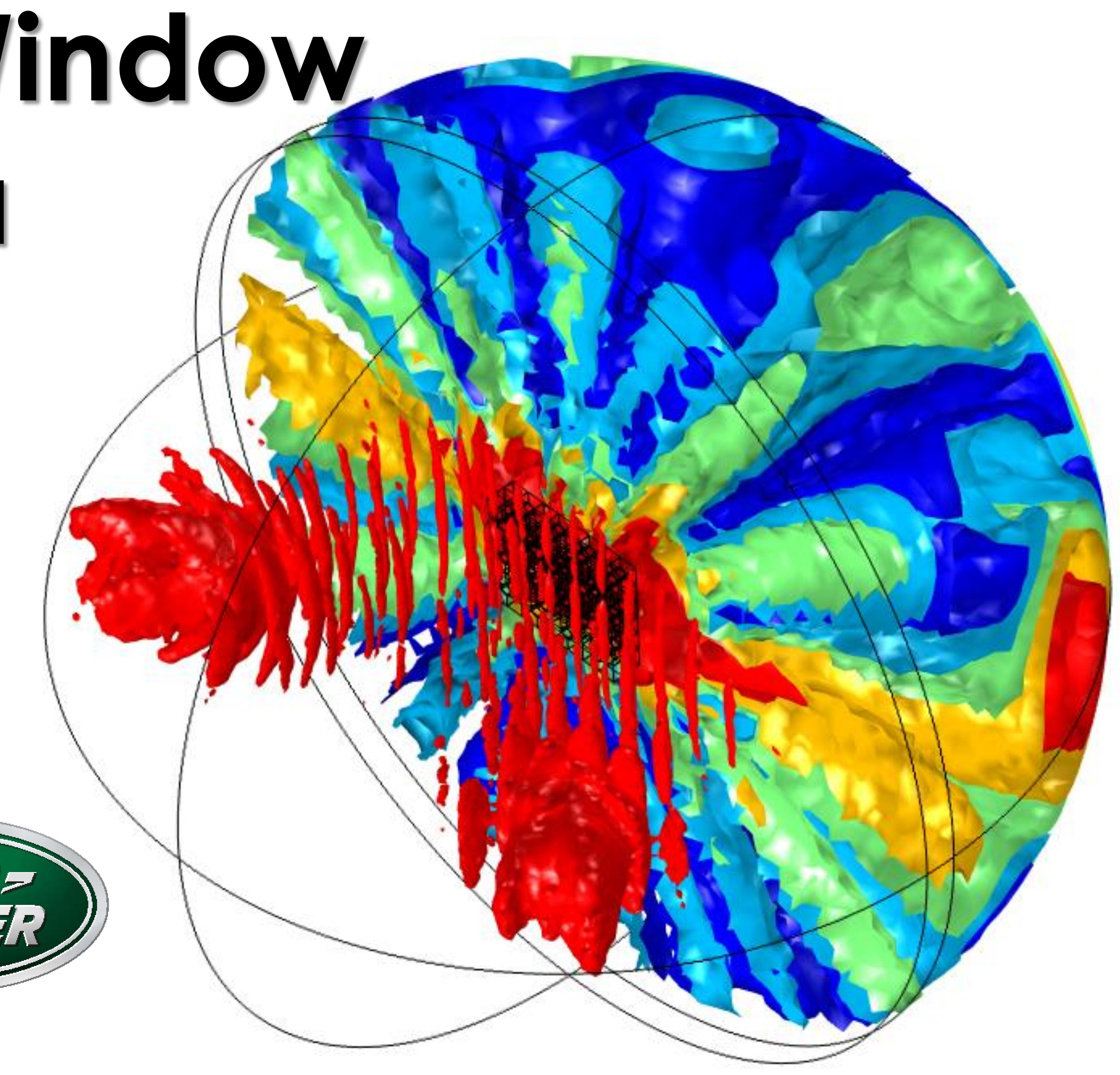

INTRODUCTION

Sound, unlike light, is a longitudinal wave and therefore it requires a medium to propagate. This, makes it difficult to separate the acoustic response from the travelling medium. With the need to continuously provide clean fresh air into buildings and other enclosed spaces, designers are looking at new novel ways to provide this without the need of space taking & energy consuming ventilation systems. One novel method is to use natural ventilation through multi-glazed windows. The drawback to these designs, is the high acoustic transmission, making them undesirable.

AIM

To developed a fully parameterized numerical model of an air transparent soundproof window system & comparing the acoustic transmission losses through it to physical test data obtained from literature [1].

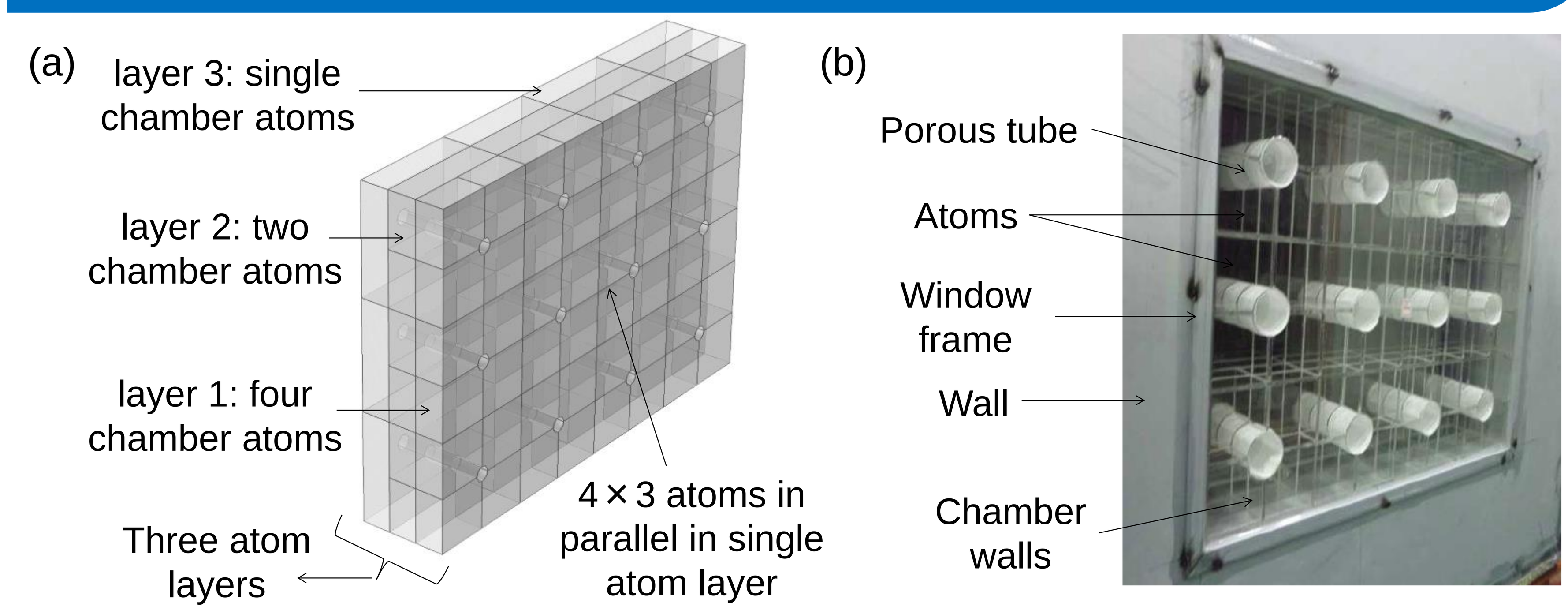

Figure1. a) Schematic of window system illustrating key features, & b) physical window from the work done by Kim & Lee[1]

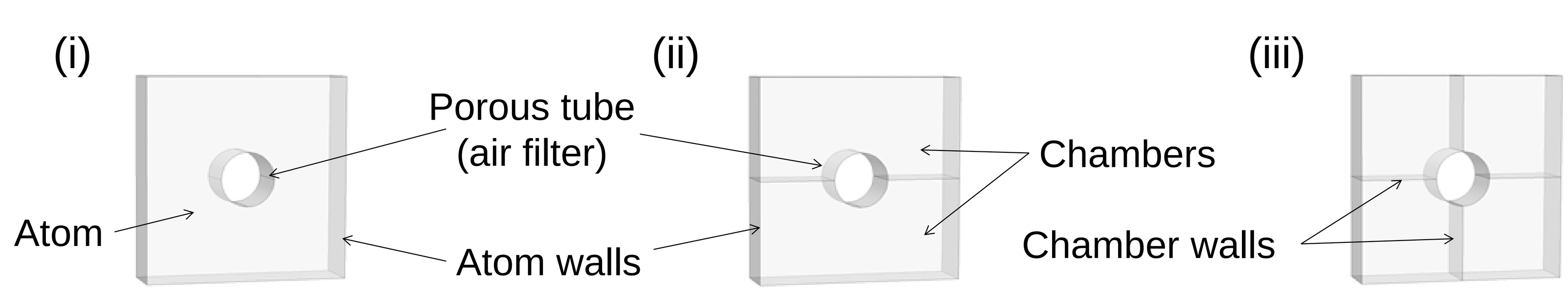

Figure 2. Window atom substructures (i) single chamber, (ii) two chambers & (iii) four chambers

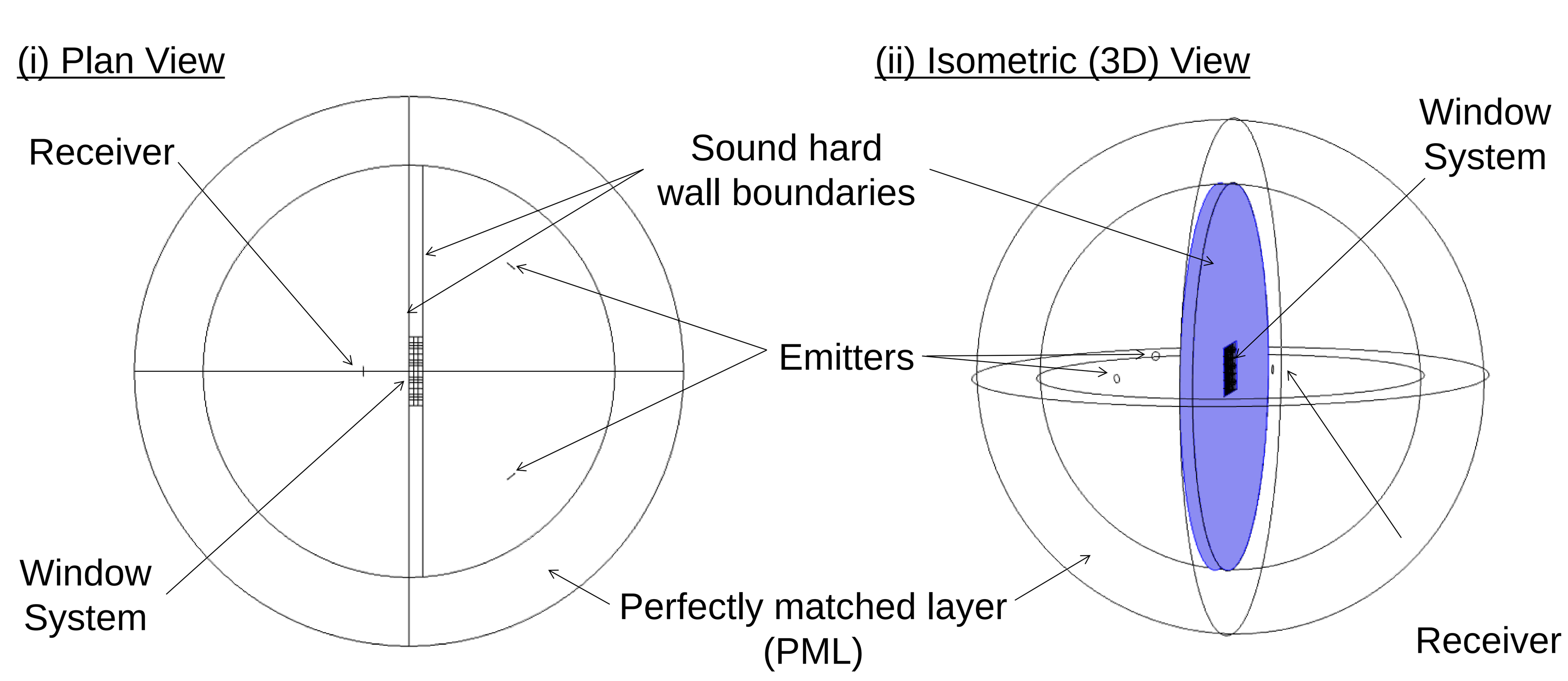

Figure 3: COMSOL model of window system and test environment

METHOD

A window design (Figure 1), based on the work by Kim & Lee [1], where they make use of three Helmholtz resonators, or atoms (Figure 2), to separate the sound from the air, was developed in COMSOL using the acoustics module (Figure 3). The model was fully parameterized & was configured to assess two variations in porous tube diameters used in the atoms; a 20mm (Type-A) & 50mm (Type-B). Two monopole sources set to emit a sound level of 80 dB were placed on one side of the window. A receiver, placed on the other side was used to measure the acoustic response & transmission loss through the window system, with the use of a surface integral probe. Sound hard boundary surfaces were used to model the physical walls of the system & to prevent sound being received directly from the emitters. A frequency sweep was performed from 1 to 5000Hz, & the acoustic transmission loss across the window assessed & compared to the physical test results from Kim & Lee [1].

RESULTS

Figure 4 compares the sound pressure levels for the Type-A & Type-B window systems at 1800Hz, respectively. From this, it can be see that the Type-B window, which has the larger porous tube diameter (50mm) allows more acoustic signal to be transmitted through the window, as expected. Figure 5 presents the transmission losses obtained from the model for the two window systems at various frequencies compared to the physical test data from Kim & Lee[1]. As can be seen from this, a close match is obtained for the Type-A window, while for the Type-B, this close match is not observed at the lower frequencies. Transmission losses of 24-43dB, compared to 25-40 dB are seen for the Type-A model & test data, respectively. While 19-35dB, compared to 10-36dB are seen for the Type-B model vs. test data.
Table 1, presents the resonance frequencies for the various atom types, obtained from the model. These values are also indicated in Figure 5, by the vertical lines for reference. As can be seen these values correlate well with the peaks in transmission loss, where each atom helps reduce the transmitted noise at their respective resonant frequencies.

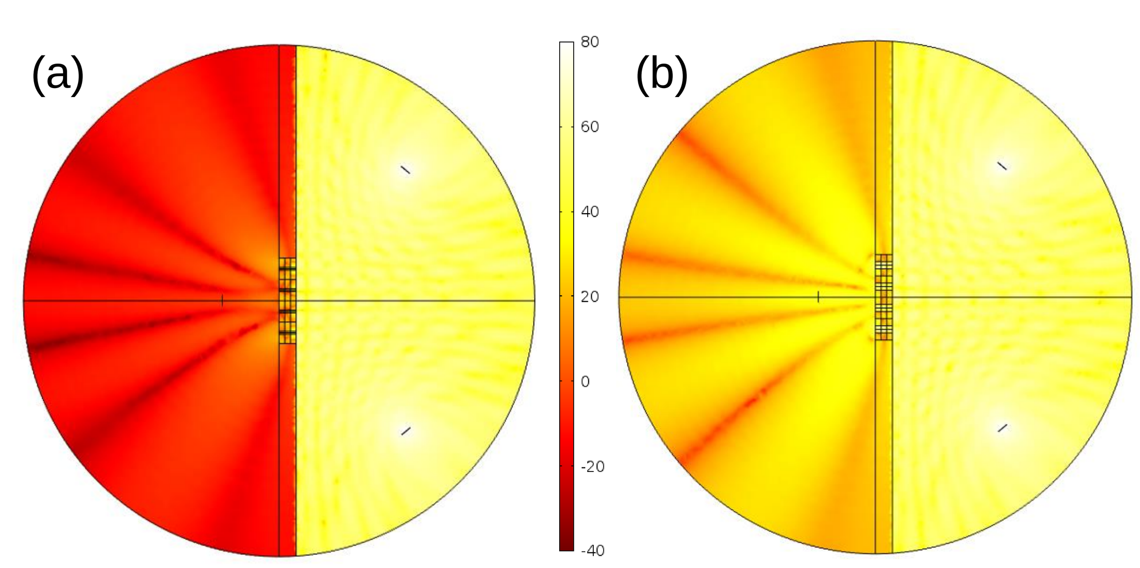

Figure 4. Comparison of sound pressure level for a) Type-A, & b) Type-B windows

Window Type	No. of Chambers	Model Resonance Frequency
A	1	500
	2	872
	4	1072
B	1	764
	2	951
	4	1600

Table 1: Resonant frequencies of atoms

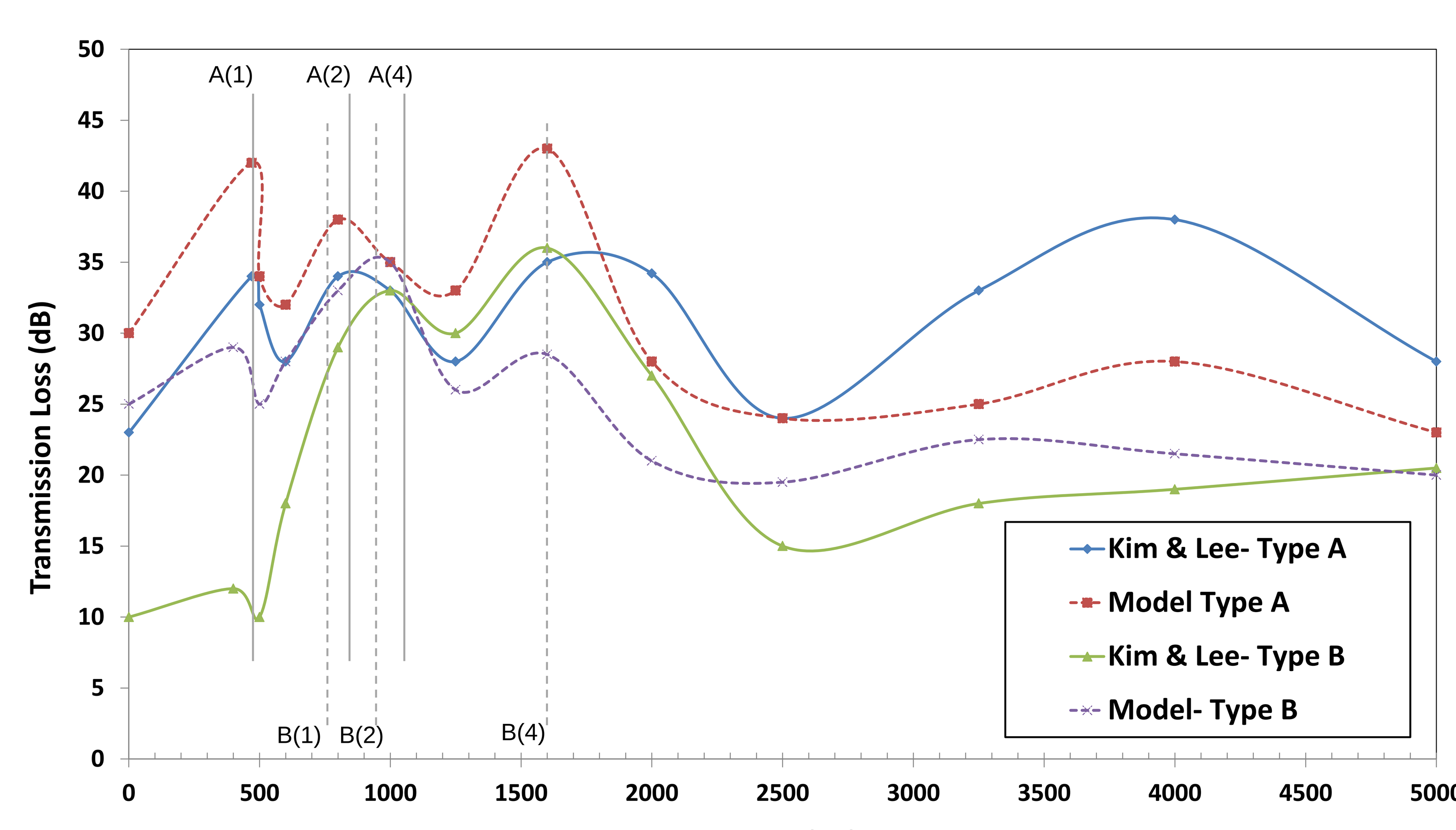

Figure 5. Transmission losses from models compared to physical test data from Kim & Lee[1]

CONCLUSION

An air transparent soundproof window system was developed & modelled in COMSOL based on the work by Kim & Lee[1]. The acoustic transmission losses obtained from the models, for two window systems (Type-A & Type-B), compared well with physical test data from Kim & Lee[1], except for frequencies below 800Hz for the Type-B window. However, the overall acoustic trends for both window types were consistent with the observed physical test data. The model also demonstrates how the atoms help to reduce the transmitted noise at their respective resonant frequencies.

References:
1. Sang-Hoon Kim and Seong-Hyun Lee, arXiv:1307.0301 [cond-mat.mtrl-sci] (2013)
2. COMSOL Multiphysics®, Acoustic Module Physics Interface Guide Version 4.4, COMSOL AB (2013)