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Assessment of Noise Attenuation by Thin Reflecting Barriers using Dispersion Relation Preserving Scheme

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Abstract. Here, reduction in acoustic noise due to insertion of thin reflecting barriers has been estimated. Accurate simulations have been performed using numerical methods with a near spectral resolving ability, neutral stability and the physical dispersion relation preserving (DRP) nature. Use of high accuracy schemes makes present approach useful in analysis of an acoustic field consisting of acoustic waves with a large frequency band. Present investigation has been carried out for eight geometrically different acoustic barriers and for nine discrete frequencies in the one-third octave band starting from 250 Hz to 1600 Hz. Use of high accuracy DRP scheme allows one to compute the complex acoustic field by accurately capturing reflection, diffraction and interference of acoustic waves. Comparison of numerically obtained sound pressure level (SPL) distributions at different heights with the available experimental results in the literature shows a good match for the case of I-shaped barrier. In order to quantify effects of acoustic source frequencies over a large band, we have extended our analysis for a frequency range of 100 Hz to 5000 Hz for the case of I-shaped barrier. Present analysis shows that the thick T-shaped barrier and grooved barrier work efficiently in the low and mid frequency range while in the higher frequency range all the barriers are equally effective due to minimal diffraction.

AMS subject classifications: 65N06, 65N35 , 76D05, 35L05
Key words: DRP scheme, compact difference scheme, computational acoustics, barrier, insertion loss.

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1. Introduction

Identification and quantification of acoustic noise sources as well as methods to reduce acoustic noise levels in the desired region have been important research topics for many decades. Acoustic noise related problems are regularly faced by the people living inside cities as the community is constantly exposed to the road traffic noise as well as other sources of noise. Aural comfort has become an important design parameter while designing modern vehicles, residential buildings, transport stations, offices and public places.

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Researchers are focused on reducing acoustic noise by inserting barriers of different shapes and materials between the acoustic source and the receiver. Barriers prevent acoustic waves from directly reaching to the receiver and help to reduce noise by absorbing and deflecting away part of the incident acoustic energy. In the past, researchers have analyzed the effectiveness of the rigid, as well as, fully or partially noise absorbing barriers for the indoor as well as the outdoor working environments. Diffraction of acoustic waves around rigid barriers was studied in [25] by assuming the whole process to follow laws of optical diffraction while neglecting transmission of acoustic waves through the barriers. Kurze [19] pointed out limitations in the noise reduction studies performed using diffraction based methods and concluded that the choice of barrier material decides its effectiveness. Hutchins et al. [12, 13] have considered interaction of acoustic waves with the ground. Garai et al. [9] studied sound reflection, insulation and absorption properties of noise barriers while predicting the acoustic field along the street. Authors in [11] have verified the effectiveness of a single screen barrier for the indoor application by active noise control technique. Sound propagation over the rigid and the porous barriers have been investigated for various shapes in [17]. Li and Wong [23] provided a review of commonly used analytical and empirical formula for predicting sound diffracted by a thin screen barrier and explained the physical principles of sound diffraction. In the same work [23], authors reviewed some of the useful analytical and empirical formula which can be used for the calculation of sound diffracted by a barrier. Pierce and Hadden [31] also presented a theory for the diffraction of acoustic waves by barriers with finite acoustical impedance idealizing barriers as semi-infinite wedges. Sound diffraction around screens and wedges has also been studied in [15] for arbitrary point source locations. Effectiveness of the indoor barriers for low and medium frequencies has been verified in [6] using an analytical model of an acoustically coupled non-rigid room. In this work, insertion loss has been further verified by conducting laboratory experiments on the scale model. The numerical model by Hothersall [10] considered both geometrical constraints and boundary assumptions and was used to predict performance of two dimensional barriers in the outdoor environment. For the inhomogeneous boundary barriers, Wang [40] proposed a theoretical model for inhomogeneous impedance surfaces.

Researchers have used theoretical techniques in the past to quickly predict the performance of noise barriers. Such theoretical approaches are either based on the geometrical ray theory or the diffraction theory of the acoustic waves [18]. These energy based methods have limited applications as they ignore information about the phase difference. Diffusion model proposed in [28, 29] is widely used by the engineers for predicting insertion loss due to barrier. Authors in [28, 29] proposed that the acoustic barrier divides single room into two acoustically coupled rooms. Acoustic energy transfer occurs over and around the barriers and expression for sound pressure levels at various locations in the room has been derived using diffuse-field theory and energy balance approach [28, 29]. However, this approach has limitations due to implicit assumption of a uniform distribution of sound energy density [22]. Lam et al. [21] proposed a simple diffraction model based on geometrical theory of minimum diffracted path to predict the barrier insertion loss.

Authors in [2, 41] used the ray tracing method to investigate noise reduction by the