Sound Propagation over Flat Ground with an Impedance Discontinuity

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The problem of sound propagation over a flat plane with a line of impedance discontinuity is considered. The sound excitation source is assumed to be linear and set parallel to the line of impedance discontinuity. The solution to this problem is formulated by considering the plane wave spectrum decomposition of a cylindrical source, this is incorporated in the solution to the problem of plane wave diffraction by a wedge with different face impedances. The propagation over a plane surface is then taken as the special case of a wedge whose angle is equal to 180°. The present solution is, however, a high frequency asymptotic formulation, and comparisons are therefore made with two other available models, approximate also, but using instead a point-like sound source. A practical application of the present study would include the evaluation of the insertion loss of a noise barrier on a ground with different acoustical properties on either side of the barrier. The properties of the sound field above the ground may be studied prior to erecting the noise barrier at the line of impedance discontinuity.

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1. INTRODUCTION

The problem of wave propagation above a ground of uniform surface impedance has been solved by several approaches, including exact ones,[1-10] and others less exact, where approximations for the cases of far or near field, ideal boundary conditions on the surface, or for specific source and receiver positions have been developed.[2,3,6,9-17] A more complicated case to treat, and the subject of the present paper, is that of an interface with a discontinuity in the face impedances of the surface. In this case too, several attempts have been made during the last few years to determine satisfactory solutions to this problem. A well documented presentation of the various approaches used for the prediction of sound wave propagation over a ground with mixed boundary conditions may be found in the updated review paper by Boulanger et al.[18] One can also cite the model developed by Chandler-Wilde and Hothersall using a boundary integral equation for expressing the sound pressure at the receiver.[19] However, the theoretical accuracy of boundary integral techniques is usually accompanied by long running times and considerable storage requirements for computers, as discussed by Seznec.[20] Another model used by Hothersall and Harriott,[21] and others is built on the notion of Fresnel zones and where a consideration of the patch on the impedance surface contributing most to the sound pressure permits one to evaluate the pressure at the receiver. Related to this approach, Naghieh and Hayek developed a solution based on assumptions of geometrical diffraction theory through considering the total field as the sum of direct, reflected and diffracted parts emanating from the borderline between the impedance surfaces.[22] Enflo and Enflo considered instead solving the Helmholtz equation through transforming it into the Fourier domain, taking into account the boundary conditions on the two-impedance plane.[23] On the other hand, the model proposed by Rasmussen permits one to evaluate the sound field at the receiver position by means of superimposing the contributions of the two half planes, each of the fields being calculated through an integration in the vertical plane over the line of the impedance jump.[24,25] Another model based on numerical techniques has also been presented by Durnin and Bertoni, where the solution formulated as a Green function may be expressed by efficient approximations, in agreement with other approximations as well as with experiments.[26] Other models, using mostly approximations from classical diffraction theory, and therefore of a more semiempirical type, have also proven attractive because of their easy implementation in computation procedures. For not-too-specific geometrical situations or too extremely low or high frequencies, these models show good agreement with experiments or with more exact models, and they have consequently often been used successfully for practical engineering applications.[27-29]

In the field of urban traffic noise, the interest in studying the interaction of a sound field with an absorbing ground is dictated by the need of having at hand simple but accurate analytical schemes for enabling the mapping of urban traffic noise in realistic outdoor situations. To take an example of some relevance to the present study, the theoretical prediction of the noise-shielding efficiency of a simple noise barrier is often determined by means of combining one of the aforementioned models with schemes for calculating the diffraction by half planes. The insertion loss of a soundproofing element is defined as the sound pressure level difference in decibels before inserting the barrier, and after inserting it in place. Hence, in the example of the simple upright barrier, the evaluation of the sound pressure level over the ground before erecting the barrier necessitates the use of a computation model for a mixed plane. This latter is a combination of two half spaces with different impedances on the different sides of the barrier after it is erected. Other approaches with some relevance to this subject and other references to some related recent work may be found in Menounou et al.[30] and Taharzedah et al.[31]

The present study may therefore be considered as a contribution to the models used for calculating the sound field in