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THE GREEN RAY INTEGRAL METHOD APPLIED TO INDOOR AND OUTDOOR PROBLEMS

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ABSTRACT

The introduction of complex Green functions into integral representations offers a good means to combine the advantages of the geometrical methods for acoustical domains and the ability of the integral formalism to precisely couple vibrating surfaces and acoustic volumes. The method has already been validated in 3D situations. In this presentation, several examples of applications are considered. A 2D approach is chosen in order to have reference calculations up to high frequencies. The case of vibrating panels radiating inside empty or cluttered rooms, the case of acoustic surfaces (opening) between two volumes or at the periphery of a volume are considered. The case of a hole between an engine volume and the passenger compartment of a car is also treated. The method is then applied to outdoor situations and permits the coupling of long range propagation algorithms with close-range effects of complex situations (noise barriers). Finally, the full outdoor-indoor situations through window panes is considered.

1 - INTRODUCTION

The introduction of complex Green functions into integral representations offers a good means to combine the advantages of the geometrical methods for acoustical domains and the ability of the integral formalism to precisely couple vibrating surfaces and acoustic volumes.
The method presented has been named GRIM (Green Ray Integral Method) and has already been validated in 3D situations [1]. In this presentation, several 2D examples of applications are considered. A 2D approach is chosen in order to have reference calculations up to high frequencies.

2 - NUMERICAL APPLICATIONS

The underlying theory is described in [1]. Let P be the acoustical pressure in a domain with boundary $S = \mathrm{S_V} \cup \mathrm{S_A}$. The velocity V on S_V is known and on $\mathrm{S_A}$ impedance-like acoustical conditions are assumed. P can be expressed as a simple integral of the product $G_V.\ V$ over S_V, where G_V is the complex Green function when S_V is assumed rigid. If the exact (coupled) velocity is employed, then this approach is exact provided that exact G_V values can be obtained. In practice, V is obtained for an isolated and therefore decoupled problem. This is the key approximation in most cases. In [1], S_V is a glass panel or a concrete wall. But it may be also a fictitious surface and V is then an acoustical velocity. In [2], many 2D situations are considered. We shall consider here the case of a car, of a noise barrier and finally of noise from an elevated source figuring an aircraft. In practice, good results require a meshing of S_V at a minimum of 3 elements per wave-length. Several integration techniques are possible.

3 - CASE OF A CAR

The noise transmitted between the engine compartment (Figure 1) and the driver's ear propagates through the separating partition but also through the holes such as the opening around the steering. A small 5 cm-wide hole (surface S_V) in a rigid panel has thus been modelled. A unit source is placed in the engine's volume, above a rigid rectangular engine. The full problem has first been computed with the BEM-program MICADO [3]. As a second step, the car compartment has been omitted and the velocity level is computed at S_V. Finally, G_V is computed between S_V and the driver's ear by means of

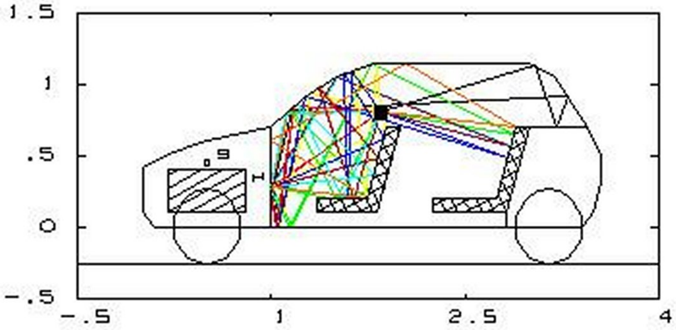

Figure 1: Geometry of a car.

a combined source-image method which includes diffraction. Figure 2a shows a comparison of the BEM and the GRIM pressure levels at the driver's ear. The agreement is quite good.

4 - CASE OF A NOISE BARRIER

The computation of noise barriers can be done with ray tracing models or by BEM approaches. The first approach may include complex 3D ground or urban configurations but can not deal with complex barriers and close range effects whereas the BEM approach has exactly the reverse characteristics. Therefore the use of GRIM offers a means to combine the advantages of both approaches. For a given barrier the 2D velocity levels are computed on a fictitious S_V surface around the barrier, with only the barrier and a flat ground. S_V is then made rigid and G_V is computed between the receiver position and S_V. The GRIM process will then give the desired pressure at the receiver. 3D results can be considered by extending the velocity along a 3D S_V surface and for an incoherent line source by using a 2D to 3D post treatment [4,5]. As an example, a noise source is placed before a straight 3-m high noise barrier. 8 meters behind the barrier a pyramidal hill, 10 m-wide and 8 m high is also introduced. The pressure 10 m behind the hill is first computed with the full BEM approach and then by the GRIM process. S_V is then a pyramidal shape 4 m-high so that G_V must be computed between the receiver and S_V and takes into account both the hill and S_V as rigid diffracting obstacles. Figure 2b compares the reference BEM and the approximated GRIM results and shows a very good agreement.

5 - CASE OF THE TRANSMISSION OF AIRCRAFT NOISE INSIDE A BUILDING

Last, the case of outdoor sound propagation and transmission inside buildings can also be addressed by means of the GRIM approach. For a given source position E and a receiver position M inside a building, the reciprocate problem is studied. The source now being inside the building, the velocity is computed on the window pane or outside a balcony for an isolated room or room+balcony situation. In 3D, a modal model of a room has been employed. In the present case a coupled 2D BEM/FEM program called MONACO [6] has been used. The G_V functions are then computed between S_V and the outdoor source (receiver in the reciprocate problem) position, by using a ray tracing model with diffraction effects computed by GTD (Geometrical Theory of Diffraction). As an example a four-storey building with balconies is considered. A far off and high source is placed 500 m before the building and 300 m high. The pressure level at the top front room is computed for a 1 cm thick window pane. S_V is placed on the balcony opening. Figure 2c shows a good comparison between MONACO and GRIM.

6 - CONCLUSION

The Grim Ray Integral Method can be applied successfully to different situations. 2D applications have been here considered in order to show some potential applications. Other and corresponding 3D numerical and experimental validations are under study.

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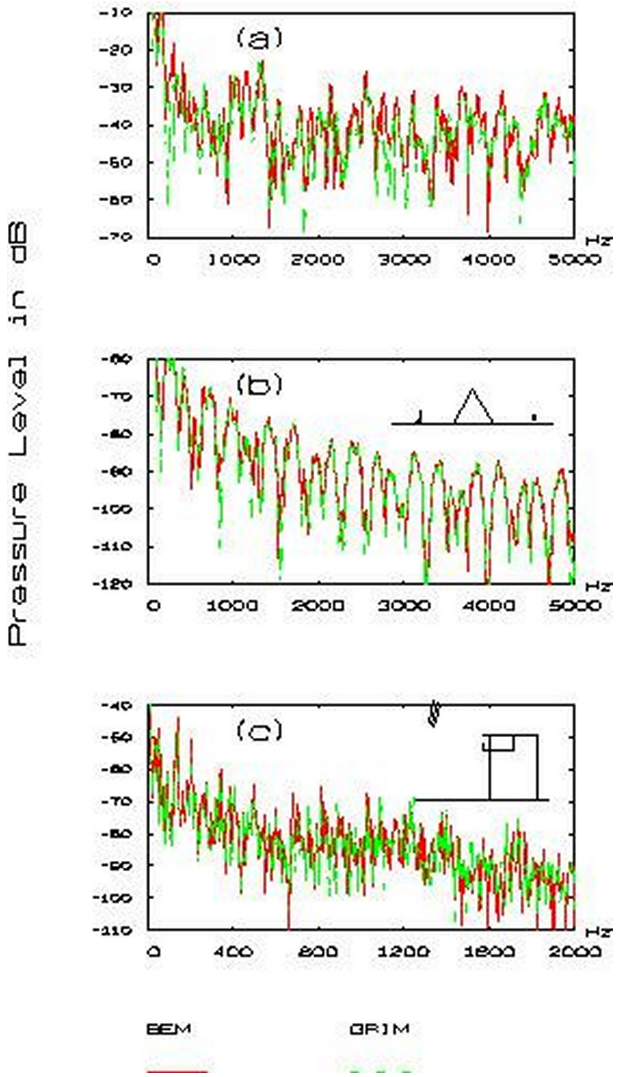

Figure 2: Comparison exact / GRIM; a) case of a car – b) case of a barrier + hill – c) case of an aircraft + building.

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