Comparison of edge diffraction simulation methods

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Introduction

Simulation methods based on Geometrical Acoustics (GA) are widely spread in the application areas of room and city acoustics, although diffraction, as a dominant wave phenomenon, cannot be directly handled by these approaches due to the underlying basic principles of GA. However, extensions for additionally computing edge diffraction exist for these methods. In this contribution, some of these methods shall be briefly described and compared with each other by the examples of a simple wedge and a scaled model of a noise barrier.

Diffraction Models

Maekawa's detour law

Maekawa published a simple approach for computing diffraction only as a *function of the detour* that the sound has to travel around an obstacle that blocks the direct line of sight between sound source and receiver. The transmission loss of sound was empirically determined at first, and later aproved by further analytical derivations. This approach was first published in [1].

Svensson's secondary source model

The approach by Svensson et al. is based on the exact Biot-Tolstoy solution, where the concept of *secondary edge sources* is used. In this extended method analytical directivity functions are derived for such edge sources that give the exact solution also for finite edges - at least for first-order diffraction. More details are given in [2].

Stephenson's uncertainty based diffraction

The basic idea of Stephenson's uncertainty-based diffraction method is to deflect energy particles around an edge as a function of the respective shortest fly-by distance, i.e., the closer the particle passes the edge, the more it gets diffracted into the wedge's shadow zone. The width of a virtual slit is computable by introducing a so-called *Edge Diffraction Strength* from which a *Deflection Angle Probability Density Function* can be derived. More details can be found in [3].

Comparison on the basis of a Single Wedge

For a first comparison of these different diffraction approaches, a simple setup of a single wedge (opening angle 10°) was chosen, where a sound source and 15 receivers were positioned as depicted in Fig. 1. Here, the edge-source angle φ_S was set to 0°, while the edge-receiver angles φ_R varied from $-84° < \varphi_R < 84°$. Source and receivers were positioned in plane with a distance of $10\,m$ to the edge and all surfaces were modeled as full absorbent to suppress any reflections. The total transmission levels T, i.e, the sound level difference in comparison to free field conditions, were computed for all 15 receivers using a numerical approximation of Maekawa's law, Svensson's *Edge Diffraction Toolbox*[4], and Stephenson's Beam Integration method[5]. In contrast to former investigations [3], absolute distances were chosen instead of wavelengths.

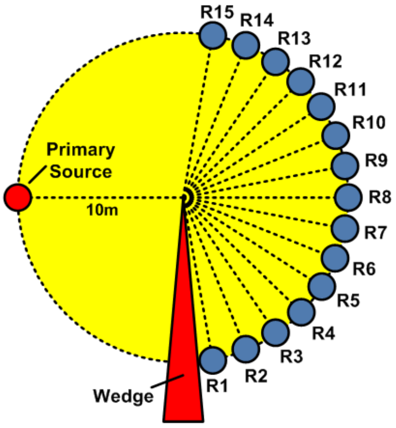

Figure 1: Simple wedge (length 100m) with an inner angle of 10°. The sound source is denoted as red sphere, while the 15 receivers are denoted as blue spheres. Both, sound source and receivers are at $10\,m$ distance to the edge.

In Fig. 2, the transmission levels after Maekawa (top, left), Svensson (top, middle) and Stephenson (top, right) are shown as a function of frequency (*x-axis*) and receiver position (*y-axis*), where the latter can be interpreted as diffraction angle (receivers 1-7 are in the shadow zone, while receivers 8 to 15 are in the view zone with $T \approx 0\,dB$). In the shadow zone, energy is diffracted especially for low frequencies. To compare the investigated simulation methods, the absolute difference values of T are compared. Here, Svensson's approach matches Maekawa (bottom, middle) quite well for low frequencies, while for higher frequencies differences up to $3\,dB$ occur. Especially receiver 7 cannot be exactly computed due to occuring singularities. Stephenson's approach, on the other hand, matches Maekawa (bottom, left) well for high frequency, while for low frequencies differences up to $2\,dB$ occur. Finally, the comparison of Svensson's and Stephenson's approaches (bottom, right) show up discrepancies up to only $3\,dB$, while for high frequencies the straight forward direction (receiver 7) is different for all methods (up to

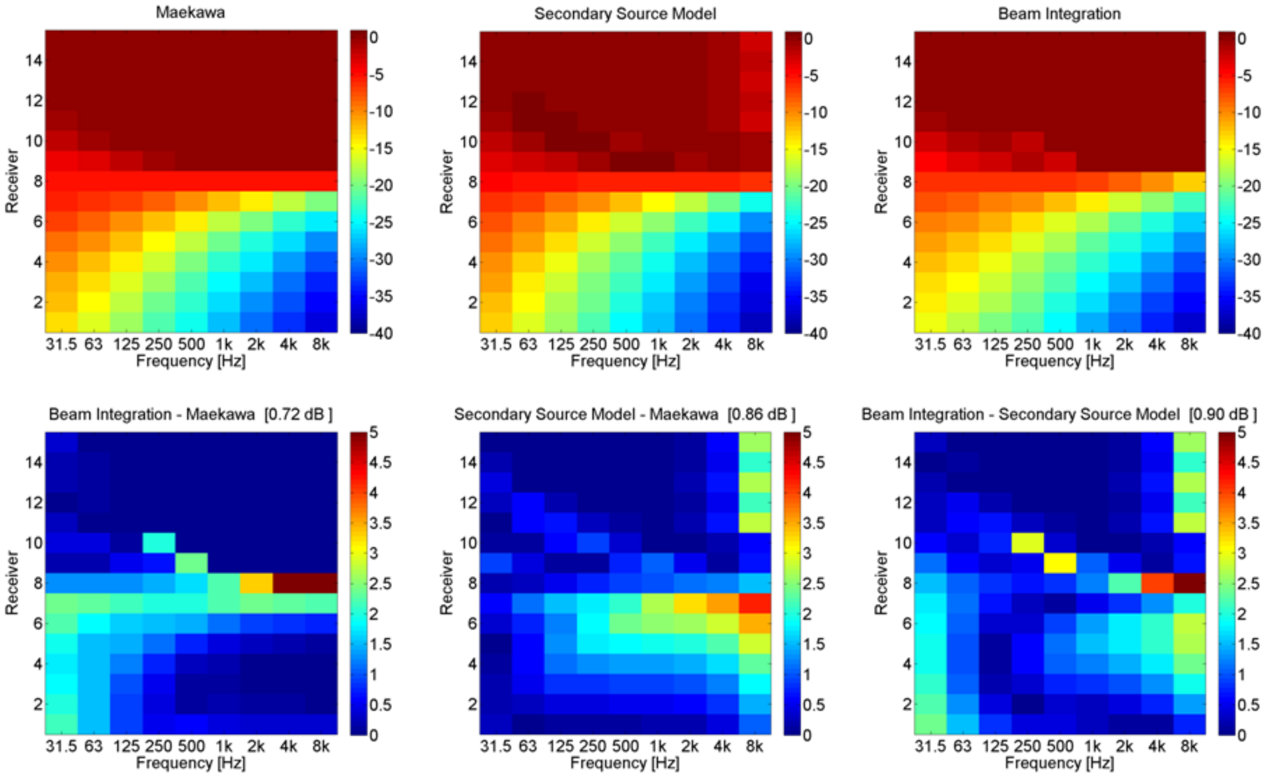

Figure 2: Computed transmission levels using different edge diffraction simulation methods.

$5\,dB$). Nevertheless, the mean difference in these comparisons is less than $1\,dB$ for all cases.

Comparison on the basis of a scaled noise barrier model

In a second series, a more practical setup of a scaled-down noise barrier (basically an L-shaped construction made from plywood featuring an additional ground layer to change the object's acoustical properties) was investigated in terms of simulation accuracy. For this setup very accurate measurements are freely available, which were performed in compliance with the openMeasurement project [6].

In a first step, simulations were performed for the all rigid-case (no additional layer) using Svensson's *Edge Diffraction Toolbox* up to third-order diffraction and results were compared to the corresponding measurements. Generally, the simulations were close to the measured responses, but a few problematic areas could be observed. Measured and simulated impulse responses were analyzed for the 1/3-octave band range of $315\,Hz$ to $6.3\,kHz$, where the frequency range of $1 - 2.5\,kHz$ reached the closest correspondence between simulations and measurements with a median level error around only $1.5\,dB$. However, the error increased significantly for the lowest frequency bands of 200 Hz and 250 Hz, which primarily came from the lack of higher orders of diffraction. A detailed description of the whole setup and the performed measurements is given in [7].

Outlook

Although very good agreements for the simple wedge case and for the all-rigid noise barrier model were achieved, the authors will take the opportunity to start more deepgoing investigations on the different diffraction methods in direct coorporation with their creators.

Literatur

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